# NRHP Multiple Property Listing

## Historic Road Infrastructure of Texas, 1866-1965

This is a copy of the National Register of Historic Places (NRHP) Multiple Property Documentation Form approved by the National Register in April 2015.

*TxDOT Environmental Affairs Division*
*Effective Date: April 2015*
*420.13.GUI*
*Version 1*

COVER
64501240

NPS Form 10-900-b
OMB No. 1024-0018

**United States Department of the Interior**
National Park Service
**National Register of Historic Places Registration Form**

RECEIVED 2280
FEB 27 2015
NAT. REGISTER OF HISTORIC PLACES
NATIONAL PARK SERVICE

## Multiple Property Documentation Form

This form is used for documenting multiple property groups relating to one or several historic contexts. See instructions in How to Complete the Multiple Property Documentation Form (National Register Bulletin 16B). Complete each item by entering the requested information. For additional space, use continuation sheets (Form 10-900-a). Use a typewriter, word processor, or computer to complete all items.

New Submission  Amended Submission

**A. Name of Multiple Property Listing**

Historic Road Infrastructure of Texas, 1866-1965

**B. Associated Historic Contexts**

Development of Texas Road Networks, 1866-1965

Historic Bridges of Texas, 1866-1965

**C. Form Prepared by**


**NAME/TITLE:** Bruce Jensen, Historical Studies Supervisor
Texas Department of Transportation, Environmental Affairs Division

**STREET & NUMBER:** 125 East 11th Street  **TELEPHONE:** (512) 416-2628

**CITY/TOWN:** Austin  **STATE:** Texas  **ZIP CODE:** 78757


**D. Certification**

As the designated authority under the National Historic Preservation Act of 1966, as amended, I hereby certify that this documentation form meets the National Register documentation standards and sets forth requirements for the listing of related properties consistent with the National Register criteria. This submission meets the procedural and professional requirements set forth in 36 CFR Part 60 and the Secretary of the Interior's Standards and Guidelines for Archeology and Historic Preservation. (__ See continuation sheet for additional comments.)

Mark Wolfe
**Signature and title of certifying official** (SHPO, Texas Historical Commission)  2/18/15
Date

I hereby certify that this multiple property documentation form has been approved by the National Register as a basis for evaluating related properties for listing in the National Register.

**Signature of the Keeper**  4/14/2015
Date

**Table of Contents for Written Narrative**

**E. Statement of Historic Contexts** (Document historic contexts on one or more continuation sheets. If more than one historic context is documented, present them in sequential order.)

See Continuation Sheets 3 through 192

| | |
|---|---|
| Introduction: | Page 3 |
| Development of Texas Road Networks: | Pages 4 through 86 |
| Historic Bridges of Texas: | Pages 87 through 192 |

**F. Associated Property Types** (Provide description, significance, and registration requirements on one or more continuation sheets.)

See Continuation Sheets 193 through 264

**G. Geographical Data**

The geographic boundaries for this nomination are the State of Texas.

**H. Summary of Identification and Evaluation Methods**
(Discuss the methods used in developing the multiple property listing on one or more continuation sheets..)

See Continuation Sheets 265 through 269

**I. Major Bibliographical References**
(List major written works and primary location of additional documentation: State Historic Preservation Office, other State agency, Federal agency, local government, university, or other, specifying repository.)

See Continuation Sheets 270 through 299

**Additional Items**
See Figures, pages 300 through 341

## Section E: Statement of Historic Contexts

*Introductory Note*

Produced under the auspices of the Historical Studies Branch of the Texas Department of Transportation (TxDOT), this document is intended primarily to facilitate compliance by the agency with Section 110 regulations of the National Historic Preservation Act. As a result, the document focuses on historic elements found in roadway rights-of-way throughout the state. It is intended as a management tool to facilitate evaluation of the historic infrastructure elements most commonly impacted by roadway projects: roads, bridges, culverts, roadside parks and other landscaping installations. It is not intended as the exclusive mechanism for evaluation, documentation and nomination standards of transportation infrastructure elements, as many paths to the justification of significance may be found that were not anticipated by this study. It also is not intended as the mechanism appropriate to consideration of traditional roadside service elements such as gas stations, motels and eateries associated with the development of historic road corridors. Finally, it is not intended as a static document, in anticipation that supplemental documentation of additional property types and eras of construction may be amended to it upon completion of subsequent investigations.

Substantial portions of Section E are adapted from previous TxDOT bridge inventories and studies, including: the Historic Bridges of Texas Multiple Property Documentation Form prepared in conjunction with TxDOT's metal truss inventory (NRHP 1996; authored by planner Barbara Stocklin and historian Regina Lauderdale); the Depression Era inventory (1999; prepared by planner Daniel Harris, planner Rick Mitchell, historian John Murphey and historian Diane Gray); the non-truss inventory (2001; prepared by historian John Murphey, historian Amy Arnold and planner Daniel Harris); the roadside park context (2005; prepared for TxDOT by consulting historians Hardy-Heck-Moore, Inc.); and the inventory of post-1945 bridges (2009; prepared for TxDOT by consulting historians Mead & Hunt, Inc.). Please also note that the previous inventories provided varying levels of source documentation and reference citations. When available, these citations are included as footnotes; however, in many cases the sources were not independently examined or analyzed during the preparation of this document.

The team responsible for this document served under the direction of Bruce Jensen, historian and manager of TxDOT's Historical Studies Branch. Engineering historian Dr. Mark Brown served as the project manager for the effort and provided much of the new content regarding the evaluation of engineering significance for metal truss bridges. Historian Renée Benn conducted the fieldwork and developed evaluation methods for historic roads as outlined in this document. Historian Rebekah Dobrasko developed historic bridge evaluation methods for Criterion A associations, based on research conducted by consulting architectural historian Lila Knight. Planner Rick Mitchell with consulting historians Mead & Hunt led the team responsible for the truss-related field assessments, development of the contextual framework for this document and its final compilation. Insightful commentary and guidance were provided by historians Gregory Smith and Linda Henderson of the Texas Historical Commission (THC), historian Paul Loether of the National Park Service (NPS)'s NRHP staff and architectural historian Kate Holliday of the University of Texas at Arlington.

## Development of Texas Road Networks Through 1965

The history of Texas' road development is characterized by settlement patterns, ethnic history, economic development, and the interaction between county, state, and federal funding and jurisdiction over roads. Early American Indian trails and Spanish colonial routes, while primitive, linked Mexico with San Antonio, Goliad, and East Texas, allowing Spanish missionaries access to the developing line of presidios and missions in the region. As the Anglo-American settlement of Texas began in 1821, following Mexico's independence from Spain, new routes through the region were established, although primarily consisting of simple trails and wagon ruts. With Texas gaining independence from Mexico in 1836, the Republic of Texas approved a Central National Road through the state and called for the establishment of roads between county seats. However, road improvement during the Republic's nine-year history was minimal. Although Texas gained statehood in 1845, linking Texas to the United States via road and railroad took time. It was not until 1873 that Texas was connected to the national railroad.

Nineteenth century roads through Texas most often consisted of unimproved earthen trails and were under the jurisdiction of the counties. It was not until the turn of the century (and the advent of the automobile) that citizen involvement to "get the farmer out of the mud" provided statewide and national impetus to improve roadway networks. Booster groups across the country and in Texas developed, constructed, maintained, and promoted transcontinental and regional named highways, including the Meridian Highway, Old Spanish Trail, and Dixie Overland Highway. In compliance with the Federal Aid Road Act of 1916, the Texas Highway Department (THD) was formed in 1917 to designate a system of state highways and grant financial aid to counties for highway construction and maintenance. By the mid-1920s, the THD had assumed responsibility for maintaining and constructing state highways. Contemporaneously, the American Association of State Highway Officials (AASHO) adopted a national system of uniformly designated highways (US Highways) in an effort to tame the proliferation of named highway routes and provide consistency across the country.

The 1930s was marked by the Great Depression and work relief efforts to provide employment through road construction. Road crews worked on straightening routes, eliminating at-grade hazards, providing drainage, and beautifying the roadway landscape. By 1940 the state highway system comprised more than 22,000 miles of roads. Following the depression, World War II considerably limited the state's road construction efforts due to the labor and material shortages. Road construction during the war years was focused primarily on defense and military highways designated as part of the Defense Highway Act of 1941.

The postwar years between 1945 and 1965 were marked by an intense road-and bridge-building campaign to transform the nation's roads into a sophisticated modern transportation network. The passage of a number of Federal-Aid Highway Acts in the 1940s and 1950s dramatically increased federal funding for roads. These included not only the interstate highway system (designated in 1944), but also secondary roads (called farm-to-market roads in Texas) and urban highways. Due to extensive planning for future projects and state legislation and funding initiatives during World War II, Texas was one of the first states to begin postwar road and bridge construction. Because of this early commitment to the state's transportation needs, state funds were readily available to match federal funding after the war. The THD began an aggressive rebuilding and expansion effort in response to the state's need for improved transportation facilities. In 1949 the state bolstered its commitment to its farm-to-market roads with the passage of the Colson-Briscoe Act. This act provided significant funding to improve miles of secondary roads across the state. Between 1945 and 1965, especially, the THD made great strides in improving the state's transportation network by building interstate highways, expressways in major metropolitan areas, and a cohesive network of farm-to-market roads. The interstate system and the urban expressways that were constructed in this period greatly transformed the statewide transportation system.

The following sections present historical background on the development of transportation networks in Texas from its settlement during the Spanish Colonial period through the post-World War II era. Historical themes considered include settlement and economic development as influences to road development; local, county, state, and federal legislation and funding that stimulated road and bridge-building efforts; the THD's prioritization, planning efforts, and influence; and resulting road and bridge construction. To help illustrate these themes, Appendix A includes ten case studies. Each case study traces the historical development of a specific highway segment over time with examples taken from various regions of the state.

**Texas Roads and Trails before 1866**[1]

The development and evolution of Texas is reflected and shaped by efforts to improve transportation, with rivers, streams, and other bodies of water playing a critical and prominent role in this history. The earliest transportation routes in the state were American Indian paths that were subsequently followed by Spanish explorers, which generally marked the easiest route of travel: avoiding natural obstacles, staying near sources of food and water, and crossing streams at narrow shallow points.

In the early eighteenth century, the Spanish consolidated their claims to Texas, establishing a line of missions and presidios along the same basic routes followed in earlier explorations. Roads connecting missions and presidios generally extended in a northeasterly direction from New Spain, passing through Laredo and Presidio del Rio Grande, connecting early settlements such as San Antonio de Béxar, Nacogdoches, La Bahía (Goliad), and Victoria, and continuing into Louisiana. The roads never evolved beyond primitive paths serving as seasonal trails for travel by explorers, pioneers, and traders.[2] Because of American Indian depredations and extreme weather conditions, the Spanish settlements stagnated and in some cases declined. By the nineteenth century, transportation routes remained limited, and served two main towns in Texas: San Antonio in the southwest and Nacogdoches in the northeast.

With Mexico gaining independence from Spain in 1821, Anglo-American land promoters began surveying and mapping major settlement routes into the province of Texas, and immigrants began rushing over the Sabine and Red Rivers from Louisiana and Arkansas. Settlement and development was located primarily in the southeastern portion of Texas. Between 1821 and 1835, Stephen F. Austin and others received land grants from the Mexican government, permitting some 13,500 families to come to Texas. Many of these pioneers settled near rivers, expecting that they would facilitate trade and transportation. However, many rivers were suitable for navigation only after heavy rains and were typically shallow enough to ford. These conditions hindered large-scale navigation for commerce but allowed limited seasonal travel in certain regions of the state near the coast.[3] From 1821 to 1836, the population of Texas (excluding American Indians) grew from about 2,240 to about 39,470, an increase of more than 700 percent. Despite the growth in population, overland travel conditions remained wretched, consisting of many types of poorly kept roads and trails, including former American Indian trails, Spanish and Mexican roads, and newer trails and paths informally maintained by settlers.

---

[1] Portions of the following section regarding development of early Texas roads and trails are taken verbatim or with minimal modification from the National Register Multiple Property Documentation Form *Historic Bridges of Texas 1866-1945*, prepared in 1996 by Barbara Stocklin.
[2] Joseph E. King, "A Historical Overview of Texas Transportation, Emphasizing Roads and Bridges" report prepared for Texas State Department of Highway and Public Transportation, 1988, 2-5; John D. Huddleston, "Good Roads for Texas: A History of the Texas Highway Department, 1917-1947" (Ph.D. dissertation, Texas A&M University, 1981), 1-7.
[3] S.G. Reed, *A History of Texas Railroads* (Houston, Texas: St. Clair Publishing Co., 1941), 5-6 and 26.

Following Texas independence in 1836, few road or transportation improvements were undertaken during the years of the Texas Republic (1836-1845). The financially strapped government was unable to subsidize roadwork, instead relying primarily on counties and settled communities. The counties in most cases had insufficient funds and manpower that prevented any substantial road improvements, and routes remained functional only in dry weather.[4] Nonetheless, immigration continued at a steady pace, bringing the state's settled population to nearly 142,000 by 1847. Despite this growth, the Republic remained a thinly populated frontier with most occupants continuing to live in primitive and isolated conditions. The self-sufficient population had little need to travel, relying primarily on freighters and the infrequent stagecoaches to deliver mail and to furnish needed goods and supplies.[5]

By the time Texas obtained statehood in 1845, it was crisscrossed by a system of primitive roads. Because of the state's limited railroad mileage and navigational deficiencies, the population remained heavily dependent on overland travel. In 1848, the state passed legislation that strengthened county powers with regard to roads. This legislation provided two classes of road for Texas, a first class and second class. A first class road was cleared of trees for a width of at least 30 feet, with the stumps cut down to within six inches of the ground, and causeways were to be at least 15 feet wide. The second class roads required a cleared width of at least 20 feet, the same requirement for tree stumps, and causeways were to be 12 feet wide.[6] The law also allowed county courts to layout new public roads, discontinue old ones, and classify roads. However, without adequate drainage, the soft roads were frequently muddy, stalling traffic and slowing trade between the interior and the Gulf ports. These deplorable conditions slowed trade and prevented substantial growth in agricultural commerce and agribusiness.[7]

Immigrants continued to flood into Texas at an unprecedented rate following statehood, with the settled population exceeding 600,000 by 1860. The agriculturally rich soils and abundant supply of rivers and streams in east, central, and north Texas were major attractions to farmers and other immigrants arriving in Texas. The rise of the railroad, as the primary means for passenger and freight traffic through the state influenced the placement and role of roads within the transportation system, and the establishment of stage lines and mail routes, which connected the military forts at the fringes of Texas settlement, helped spur the population in the 1850s.

The expense and technical expertise required to erect large bridges continued to hinder road progress in the state during the mid-nineteenth century. The people of Texas still forded streams and rivers, although in some places a ferry, raft, canoe, or crudely built toll bridge, perhaps consisting only of timbers laid in the streambed, assisted the traveler. Most of the more primitive structures were built by county draftees with little or no knowledge of bridge engineering or construction. These bridges were usually short-lived, collapsing under heavy loads or falling victim to flood waters. By the 1850s, a growing number of communities were clamoring for bridges, particularly at major waterways where ferries and fording were impractical. With minimal public funding for bridge and road improvements, many counties relied on private initiatives to span major crossings. Local civic and business leaders created and funded private bridge corporations in an effort to promote regional trade and boost a community's

---

[4] B. McDaniel, "Highway Administration in Grayson County, Texas" (Master's thesis, University of Texas at Austin, 1929), 2-3; Rupert N. Richardson, Ernest Wallace and Adrian N. Anderson, *Texas: The Lone Star State* (Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1970), 115-116; Reed, 23.
[5] Richardson, Wallace and Anderson, 115-116; Calvert and DeLeon, 79-82.
[6] Canion, 53.
[7] T. R. Fehrenbach, *Lone Star: A History of Texas and the Texans* (New York: Macmillan Publishing Co., 1968), 318-320; King, "A Historical Overview of Texas Transportation," 8-11; Calvert and De Leon, 103-104 and 154-156; McDaniel, 17-18.

economic standing. Between 1850 and 1870, the Texas Legislature granted charters to more than 100 toll-bridge corporations. Without railroad connections to eastern U.S. bridge fabricators, most of these early structures were built using local materials such as timber and stone. Once completed, these privately owned structures operated as toll bridges, with each county setting the charges and regulations for their use. The monies accrued from tolls repaid the shareholders and covered maintenance expenses. Frequently, when a county's financial status improved, perhaps several years or more after the toll bridge was completed, the county commissioners' court would purchase the bridge from the corporation and open it for free passage.[8]

By the eve of the Civil War, Texas' transportation corridors included a web of railroads, railroads under development, roads, stage routes, and trails, in addition to waterways. All these routes were used to move people, mail, and supplies around the state, the largest in the Union. Roads began to be laid near railroad lines, taking advantage of the routes and any grading that the railroad companies had completed for the railroad line itself.

***County and Local Roads in the Late Nineteenth and Early Twentieth Centuries***

After the Civil War and during Reconstruction, Texas had less rebuilding to complete than other states since little fighting occurred in the state, and was more fully able to restart road development begun before the war. The U.S. military once again inhabited the forts along the frontier and began to establish new ones. Control of road development was removed from the county courts and given to a new police court through state legislation, passed in 1866 during Reconstruction. This court took over all work formerly completed by the county court having to do with roads, as well as taxes and education. This legislation also took into account the fact that there were no longer slaves in Texas to work on road construction and established the use of convict labor to construct roads and bridges.

Reconstruction also brought about more organized cattle trails. Lasting into the 1880s, these trails took millions of Texas cattle from Texas to Kansas, where they were easily shipped via rail to Chicago and the meat packing industry. The most important trail was the Chisholm Trail, named for Jesse Chisholm who traveled from Texas to Kansas, leaving a trail of wagon ruts for other travelers to follow.[9] This became the primary route cattle drivers followed to bring cattle to Kansas. The primary routes of the trails, including Chisholm Trail, the Western Trail, and the Goodnight-Loving Trail, brought cattle from south and central Texas north to American Indian Territory (present-day Oklahoma) via Fort Worth and Dallas or the western panhandle of Texas, and then to railheads in Kansas or Missouri, and by the 1870s, Nebraska. The termini of these trails were railroad stops where cattle were loaded and shipped to eastern markets. Because these trails were used to move cattle, there was no road to speak of, and no bridges were built along the routes; however, later roads followed some of the same routes as these earlier trails. The establishment of these trails helped restart the economy of Texas after the Civil War. Because of the lack of consistent rail lines, it was cheaper to ship cattle from Kansas than from Texas. This opportunity provided work for cattle drivers and profit for ranchers, both of which were needed in the wake of the Civil War.[10] This economic boom helped give Texas a firm footing for economic prosperity in the late nineteenth and early twentieth century.

---

[8] H. P. N. Gammel, *The Laws of Texas* (Houston, 1874), VIII, 141.
[9] Canion, 72; Donald E. Worcester, "Chisholm Trail," *Handbook of Texas Online*, http://www.tshaonline.org/handbook/online/articles/ayc02 (accessed 14 December 2010).
[10] Jimmy M. Skaggs, *The Cattle Trailing Industry: Between Supply and Demand, 1866-1890* (Lawrence, Kans.: The University Press of Kansas, 1973), 2-3.

One of the primary improvements after the Civil War was an increase in railroad lines across Texas. Railroads became the primary way to move people and goods around the state, and became the building blocks for settlement. In 1873, Texas was first connected to a nationwide railroad network when the Missouri, Kansas and Texas Railway Company and the Houston and Texas Central lines reached Denison.[11] The railroads overshadowed and, to some extent, replaced previous modes of transportation in Texas. A location on the railroad was suddenly critical to a community's livelihood, superseding any previous reliance on overland routes or inland ports. While roads were no longer the predominant form of travel in the state, they gained new importance as the primary means to access shipping points and accommodate travel between farms, agricultural processing centers, and major towns.[12]

Railroads also provided the means to transport materials for better road and bridge construction. Because there was little state oversight of bridge construction, and county governments had little funds to spend on roads and bridges, toll bridges were still common in this period. While most of the early toll bridges were simple, timber structures, a few more substantial bridges were built in the late 1860s and 1870s. One such example was the Waco Suspension Bridge completed in 1869 over the Brazos River in Waco (TxDOT Structure No. 09-161-0-B004-31-001, no longer in vehicular service). The bridge was a venture of the Waco Bridge Company, a corporation made up of local civic and business leaders, which in 1866 obtained a charter from the Texas Legislature to erect and operate a toll bridge on the Brazos River for 25 years. Lacking railroad connections to Waco, the company paid to have the wire cables and manufactured bridge materials hauled overland to the bridge site. The bridge was built using local labor and simple construction methods. The completed structure featured a massive 473-foot suspension span with castellated brick towers, wire cables, and a wooden plank deck. The bridge served heavy traffic volumes, carrying everything from immigrants and wagons to cattle heading to northern markets, and was critical to Waco's rise as a major crossroads and trading center. As the first bridge completed over the Brazos River and the earliest example of permanent bridge construction in Texas, the Waco Suspension Bridge was a major technological feat that influenced Texas bridge building for decades to follow.[13]

As railroads continued their expansion, the technology for the building of railroad lines and bridges evolved together, allowing them to be able to carry more weight. While the metal truss bridge was in use in the U.S. before the Civil War, no known examples were constructed in Texas. Based on timber structures of the same form, these metal truss bridges could carry more weight and span greater lengths. However, Texas had no system for metal manufacturing, and so all of the materials had to be brought to the state by train or overland. While the Waco Suspension Bridge's parts were brought overland for its construction, this was uncommon at this time. One example of a toll bridge built with trusses is the 1872 Commerce Street crossing of the Trinity River in Dallas (TxDOT Structure No. 18-057-0-9F73-25-005, see Figure 1). Although plans for the structure began in 1860, they were delayed by the Civil War and were not renewed until the spring of 1868. A two-span wrought iron bowstring truss, the spans were fabricated in the Midwest and shipped to the bridge site where they were then erected on the newly completed masonry piers. The bridge was built at a cost of $65,000, which included the construction of a wooden tollhouse. Completed in March of 1872, the new bridge (including approaches) stretched approximately 300 feet across the river. Ten years after its completion, the bridge was sold to Dallas County, which then opened it to the public as a free bridge. The Commerce Street Bridge was a prominent landmark and one of few truss bridges in the state at the time. Willard Richardson of the *Galveston News* claimed that the bridge was "one of the

[11] George C. Werner, "Railroads," *Handbook of Texas Online*, http://www.tshaonline.org/handbook/online/articles/eqr01 (accessed 14 December 2010).
[12] Richardson, Wallace and Anderson, 272-276; Calvert and DeLeon, 79-82.
[13] T. Lindsay Baker, *Building the Lone Star: An Illustrated Guide to Historic Sites* (College Station, Texas: Texas A & M University Press, 1986), 260-262; "Suspended in Time," *Waco Tribune-Herald*, 7 January 1995.

handsomest iron bridges we have ever seen." As an early example of metal truss bridge construction in Texas, the Commerce Street Bridge set a precedent for future metal truss work in the state.[14]

The Waco Suspension Bridge and the Commerce Street Bridge are examples of private toll bridges, both of which became free bridges later on in their use. Toll roads and bridges were common in the decades after the Civil War, as private companies sought to make money on bridge construction via tolls. In 1870, control of road and bridge building was returned to the county court system under the 1869 constitution and authorized the county court to appoint a "road overseer." The act authorized all counties to levy a road tax to improve roads and bridges; however, the levy could not exceed one-eighth of one percent.[15] Under this new road tax, Grayson County authorized the building of a toll bridge in 1872, the first in the county, across Choctaw Creek on the Bonham to Preston Road. Travelers had a choice of the free ford crossing or the toll bridge, with tolls ranging from "three cents for a hog or sheep to seventy-five cents for a wagon drawn by six horses or by six oxen."[16] However, tolls did not necessitate a *good* road or bridge. A bulletin from the University of Texas in 1890 commented on toll roads in general during this period, saying: "The history of toll roads has demonstrated the fact that they are suitable only to a newly developed country where any other road is out of the question."[17] The argument was also made that "on a good broken stone road a horse can draw three to four times as much as he can on a common dirt road" if both were in good condition.[18] It explained that Texans were not getting the most bang for their buck, were unaware of the advantages that good, paved roads could provide to them (few paved roads being in Texas by that point), and states that "'According to the best authorities, it costs the farmer more to carry a bushel of wheat one mile than it costs a railway to transport a ton the same distance.'"[19] Using that calculation, to ignore the requirement for good roads was folly.

Despite the monumental achievement of the Waco Suspension Bridge, the Commerce Street Bridge, and a few other iron bridges in the 1870s, the vast majority of communities continued to rely on timber bridges and ferries for at least another decade. In the Piney Woods region of East Texas, timber bridges were still prevalent into the twentieth century and, while less common, timber bridges are still used to a limited extent on some low-volume roadways in the twenty-first century. Although timber bridges had short life spans and often had to be rebuilt and replaced every so often, their simplicity and ease of construction made them a popular type in Texas. In San Antonio, for example, a series of at least six timber bridges were used at the Commerce Street crossing of the San Antonio River between 1803 and 1870. A more permanent structure, an iron truss bridge, was not built at this site until 1880. In Houston, many timber bridges and ferries existed in the late nineteenth century, but few if any permanent bridges were constructed until the twentieth century. In Austin, a bridge crossing the Colorado River was not built until 1876, requiring citizens to use a timber pontoon bridge or a ford to cross the large river (see Figure 2), though bridges crossing smaller creeks were in use within the city limits. Figure 3 illustrates the wide range of small bridges used on Austin city streets by the 1870s.[20]

---

[14] Quoted in Darwin Payne, *Dallas: An Illustrated History* (Woodland Hills, Cal.: Windson Publications, 1982), 62; Dallas County Heritage Society and the Dallas Historical Society, "A Transportation Time Line," *Legacies: A History Journal for Dallas and North Central Texas* (Spring 1995), 4; Cockrell, 66-69.
[15] Bernice McDaniel, "Highway Administration in Grayson County, Texas" (Thesis for the Degree of Master of Arts at the University of Texas, Austin, 1929), 76-77.
[16] McDaniel, 77-78.
[17] T. U. Taylor, "County Roads," *Bulletin of the University of Texas* (March 1890), 7.
[18] Taylor, 2.
[19] Taylor, 5.
[20] Augustus Koch, *Bird's Eye View of the City of Austin Travis County Texas 1873*. (Madison, Wis.: J. J. Stoner, 1873).

The reluctance to use new bridge technology went hand-in-hand with the flaws of road designation and funding processes. Throughout the 1870s, the Texas Legislature frequently examined the question of funds for roads and bridges, changes to taxes, and how to authorize road and bridge construction. In 1873 the legislature abolished the county road overseer and put roads back into the hands of the county court, made up of justices of the peace. The legislature authorized a direct tax on taxable property (five cents for each one hundred dollars) and a poll tax, both for the construction of roads and bridges. Because of the inconsistency among counties in terms of their taxable wealth, their policies on implementation of their taxing authority, and their use of funds, bridge and road building were inconsistent and limited. In 1875, the state legislature divided road construction into classes of roads: first, second, and third. A first class road was to be 60 feet wide, a second class road 40 feet wide, and a third class road 20 feet wide. However, the focus was still on removing stumps "to within six inches of the ground" for dirt roads to ensure efficient horseback travel rather than the construction of any sort of paved road.[21] A primary use for roads remained the transportation of mail. By 1874, post roads had been divided into categories of those traveled three times a week, twice a week, and once a week, and then a separate category of roads that did not carry the mail at all.[22] Figure 4 shows the development of railroad and road networks in parts of Texas by 1874.

*New Constitution and County-built Roads*

Claiming that the Radical Republicans had placed an extreme financial burden on the state, the writers of the 1876 Constitution placed all responsibility for road and bridge improvements on the shoulders of local governments. Prior to this, the state government could authorize construction of individual roads; there was still no state-wide road administrator. The 1876 Constitution reorganized the county governments and established the commissioners' court as the governing body for each county. The commissioners' courts controlled road construction and were composed of the county judge and four commissioners. Paradoxically, the constitution also included provisions that severely restricted the ability of local governments to raise funds for road and bridge projects. The local governments were placed in a difficult predicament. While, on the one hand, they were encumbered with the responsibility to build and maintain the state's roads and bridges, they were also refused access to mechanisms such as taxation and bonding that would allow them to fund these improvements. In the decades following 1876, good roads advocates undertook considerable efforts to overcome these constitutional limitations and to promote greater state involvement in road and bridge improvements.[23]

The years between 1870 and 1900 saw major changes in Texas's population and its distribution, as well as in road and bridge building. By 1880, the state stood at the brink of a major economic revolution. Railroads from the Midwest and Northeast had penetrated Texas, and these railroad connections provided thousands of farmers and communities in Texas with easy access to large U.S. markets for cotton and other agricultural goods. By this point, the cattle trails that had been an integral part of the Texas economy after the Civil War had mostly been replaced by the railroad to ship cattle to northern markets. Immigration increased rapidly in both rural and urban areas, bringing the settled population to 1.5 million by 1880. The rise in population increased the need for public services and increased demand for goods to the populations not just in urban settings but also on farms and in small towns. As the population increased and the state's economy developed, residents began accelerating their demands for improved bridge and road conditions, setting the stage for a more dynamic era of bridge-building activity.[24]

---

[21] McDaniel, 12; Canion, 80.
[22] M. Y. Mittendorfer, *A. R. Roessler's Latest Map of the State of Texas* (New York City: A. R. Roessler, 1874).
[23] McDaniel, 18-19; Huddleston, 23-24.
[24] Calvert and DeLeon, 154-156 and 180-184.

Railroad expansion also influenced population distribution and settlement patterns, prompting rapid growth in the state's eastern, central, and southern regions, with more limited growth in the Panhandle and the state's far western area. Overall, however, the population of late-nineteenth-century Texas still remained heavily concentrated in the southeast, central, and northeast portions of the state.

Major overland transportation routes across the state generally followed the same path as the railroad lines, and local traffic used these major transportation routes as jumping off points to smaller communities and rural areas situated away from railroad lines. Railway lines reached San Antonio in 1877 and El Paso in 1881, and these cities began to grow at a rapid pace. Though a late addition, El Paso's location on multiple railroad lines in the 1880s made it rise as an important location for transcontinental commerce, between the east and west coasts and with Mexico. El Paso, however, was an exception rather than the rule in West Texas's growth. Much of the area remained sparsely populated into the twentieth century. The rise of the railroads is evident in the illustrations of the state on maps from the period, all of which show railroad lines. Many of these maps were distributed by the railroad companies, and rarely are roads illustrated. Without a statewide road network, railroads were the easiest form of transportation in Texas.

In 1872, Texas's railroad mileage ranked 28th compared with other states. By 1890 the state had 8,710 miles of railroad track, ranking it third among other states, and by 1904 Texas had more than 10,000 miles, the most in the nation. According to Texas historians Robert A. Calvert and Arnoldo De Leon, "Commercial agriculture followed the tracks as cotton replaced grain and cattle as the dominant factor in economic growth. New industries grafted themselves onto commercial agriculture, turning the state from a preindustrial, rural economy into one with improved transportation facilities."[25] Generally, the most technologically advanced bridges in Texas prior to the 1900s were on early railroad lines. By the early 1870s, the railroad routes included several large truss spans, perhaps constructed of iron or a combination of iron and timber. With minimal local resources and no state or federal participation, bridge improvements on Texas roadways continued to lag behind the railroads for another three decades or more.[26]

In the years leading up to the twentieth century, counties were given additional authority to finance road and bridge improvements, opening the door for future road and bridge bonding legislation. The state bridge-bonding acts of 1884 and 1887 facilitated modest bridge improvements, allowing many counties to build their first metal truss spans. Typically, bridge bonds could fund several metal truss bridges in a county, but often were insufficient to cover large monumental crossings. Counties would usually bridge the more important crossings first, replacing timber bridges at secondary crossings as additional funds became available. A county's earliest metal truss bridges were often built on stagecoach and post routes, and on important roads linking farms with county seats and other regional centers. One county that took advantage of the new bridge bonding legislation was Grayson County, which issued $10,000 in bridge bonds during 1885 and used the monies to build a number of permanent-type bridges, including a 90-foot Pratt through truss span near Pilot Grove. Because of the legislative limitations placed on county indebtedness, however, most counties could only afford to issue bridge bonds periodically, perhaps once every five to 10 years.[27]

---

[25] Quoted in Calvert and De Leon, 179.
[26] Colorado County Historical Commission, comp., *Colorado County Chronicles* (Austin, Texas: Nortex Press, 1986), 140-144.
[27] Historic Bridge Files, Texas Department of Transportation, Environmental Affairs Division, located at TxDOT headquarters in Austin; McDaniel, 82-83.

Despite the 1884 and 1887 bridge bonding legislation, most counties still could not afford to fund bridge improvements on a large scale. During the next decade, significant progress was made to broaden county bridge-bonding powers. An 1889 act resolved questions over the authority of counties to build bridges on streams serving as county boundary lines. The law clearly affirmed that in these cases, either county on the dividing line had the authority to issue bonds for bridge improvements. Similarly, an 1895 law extended counties' bridge building authority to sites located inside the incorporated limits of cities and towns. The most consequential piece of legislation passed during this period was the 1893 bonds law, which significantly expanded the bridge bonding powers of the counties. Among its various provisions, the act extended the bonding period from 20 to 40 years, raised county bridge-bonding levels to one percent of taxable property values and loosened previous limitations on a county's overall indebtedness. These provisions allowed counties to issue six times or more the amount of bridge bonds than previously allowed, stimulating an intensive period of bridge construction in the years to follow.[28]

While county and local governments were initially slow to accept new bridge technologies, the metal truss nonetheless became a predominant bridge type in Texas in the late nineteenth and early twentieth centuries. Timber remained a prominent construction material, particularly in areas with little settlement and little access to railroad lines, as well as for short crossings of less than 30 feet. However, longer, permanent crossings required other types of bridge construction. The rise of the railroad made access to the manufactured metal trusses more available to county governments. Metal trusses were originally executed in iron and then steel later in the nineteenth century. As county governments had more money to use for building roads and constructing bridges, it became important that the cost and labor-intensity be kept down. The easiest way to limit these attributes of road and bridge construction was to purchased metal truss bridges from the manufacturing companies located in the eastern parts of the U.S. and have them shipped by rail as close to their required location as possible, then moved overland. Masonry bridge construction was never a large portion of Texas bridge building, as it was expensive and had a large labor requirement. By the end of the 1890s, some railroad lines were using masonry construction for large crossings that required extra support, but masonry was not used on a regular basis to construct road bridges until the Depression period in the twentieth century. Another metal bridge type, the plate girder, was also primarily in use by the railroads before the twentieth century, as railroad bridges required the ability to carry larger loads.

The most popular truss types were the Pratt truss and the Warren truss. By the end of the 1880s and to about 1910, the Pratt truss design became the standard truss type for short to intermediate spans (30 feet to 150 feet) and was being manufactured in a wide variety of sizes and details. The straightforward design, considerable strength, and ease of erection made the Pratt the predominant truss type for American roadways during the late nineteenth and early twentieth centuries. It quickly gained acceptance throughout Texas as the preferred type for spans under 150 feet, reaching its heyday of popularity from 1895 to 1910. Most of the earliest examples were built in central and north Texas, including the 1884 Hickory Creek bridge near Denton (TxDOT Structure No. 18-061-0-AA06-19-001, now in use as a pedestrian bridge) and the 1885 bridge over the Clear Fork of the Brazos near Albany (TxDOT Structure No. 08-209-0-AA01-88-001, now bypassed by a low water crossing and closed to traffic).[29] Both bridges are listed in the National Register of Historic Places. The Warren Truss was patented by English engineer James C. Warren in 1848. While the Warren was initially introduced in America as a pinned truss, this configuration did not fare well against the Pratt.[30] A few pin-connected Warren pony trusses survive in Texas, including the 60-foot span

[28] Gammel, IX, 1050 and X, 112-113 and 164-165.
[29] T. Allan Comp and Donald Jackson, "Bridge Truss Types: A Guide to Dating and Identifying." *History News* 32 (May 1977); Historic bridge files, Texas Department of Transportation, Environmental Affairs Division, located at TxDOT headquarters in Austin.
[30] David Guise, "The Evolution of the Warren, or Triangular, Truss," *Industrial Archeology* 32:2 (2006), 23-40.

built in 1898 over the Old River in rural Burleson County (TxDOT Structure No. 17-026-0-AA02-00-001, not in vehicular service). Once the connection technology moved from pins to rivets, the Warren's simple configuration and lightweight members provided many advantages, and by the early 1900s, it had superseded the Pratt as the preferred type for short spans (usually 30 to 90 feet). By the 1910s, some bridge builders were also designing Warren trusses with polygonal top chords and through configurations, enabling the construction of spans up to 125 feet or more.[31]

Some rare truss types are found in Texas, such as the lenticular truss.[32] This truss configuration features curved upper and lower chords that form the shape of a lens, and originated in Europe in the mid-1800s. An American version of the lenticular truss was patented in 1878, producing hundreds of small to intermediate size lenticular spans during the next 15 years. An 1889 bridge catalogue of the Berlin Iron Bridge Company lists a William Payson from Edna, Texas, as the company's only bridge salesman outside of the New England or New York area. Through William Payson's association with this company, Texas acquired at least a dozen lenticular trusses from 1889 to 1895. Payson moved his office to San Antonio in 1890, and the relocation to the region's leading city proved beneficial to his sales, as at least five of the lenticular spans were built in San Antonio.[33] The most prominent of these was a 93-foot truss originally constructed in 1890 over the St. Mary's Street crossing of the San Antonio River (TxDOT Structure No. 15-015-B038-25-002, in vehicular service). Currently, this bridge serves vehicular traffic at a river crossing in the city's Breckenridge Park. Victorian flourishes such as elaborate cast-and wrought-iron railings with rosette motifs, decorative portal cresting and urn finials help to provide relief for this large utilitarian structure. A survey of other states' bridge inventories reveals that Texas has the only known lenticular trusses remaining west of the Mississippi River.[34]

By the turn of the century, steel replaced wrought iron as the universal material for truss construction.[35] In addition, the rolling mills also began to make steel I-beams for use in place of timber stringers at smaller crossings where a truss was not required. The steel beam bridge thus supplemented the types of bridges that county governments could commission, and appears to have been in use in Texas in the late nineteenth century.[36] The expansion of railroads throughout the state allowed bridge manufacturers located in the East or in the Midwest to ship their iron or steel bridge components to Texas where they could then be transferred to the local crossing. However, the transition from timber to metal stringers was relatively slow in Texas due to the abundance of timber and its easy adaptability to stringer bridge construction, as well as the cost of shipping steel stringers from out-of-state mills to

---

[31] Jackson, 27-30.
[32] In "Designing American Lenticular Truss Bridges 1878-1900," *Journal of the Society for Industrial Archeology* 30(1):5-18, 2004, Thomas Boothby demonstrates that lenticular bridges designed by the Berlin Bridge Iron Company, including those in Texas, are actually Pauli trusses. Lenticular, however, is used through this nomination out of custom and familiarity.
[33] Historic American Engineering Record, National Park Service, U.S. Department of the Interior, "Kelley Crossing Bridge." No. TX 31, addendum.
[34] Victor Darnell to Tom Eisenhour, 5 April 1987, 12 June 1987 and 30 December 1987, Environmental Affairs Division, Texas Department of Transportation, located at TxDOT headquarters in Austin; Berlin Iron Bridge Company, *The Berlin Iron Bridge Co.: Engineers, Architects and Builders in Iron and Steel* (Hartford, Conn.: Press of Plimpton Manufacturing Co., n.d.) from Victor Darnell personal collection; Bruce Clouette and Matthew Roth, *Connecticut's Historic Highway Bridges* (Hartford, Conn.: Connecticut Department of Transportation, 1991), 7-10.
[35] Victor S. Clark, *History of Manufactures in the United States, 1860-1914* (Washington, D.C.: Carnegie Institution of Washington, 1928) 19-345; Richard Shelton Kirby et al., *Engineering in History* (New York: Dover Publications, Inc., 1990), 291-298; Edwards, *A Record of Early American Bridges*, 103.
[36] Stocklin, E-15, E-16.

Texas. It was not until the 1910s, when steel fabricators began operating in the state, that steel I-beams were used more extensively in Texas bridge construction.[37]

*Urban Innovations and Their Impacts*

By 1900, urban areas had separate and specific requirements that differed from the slower-growing rural areas. Large cities such as Dallas, Austin, Fort Worth, El Paso, and Houston experienced explosive growth in their urban populations. These cities spent money on paved roads and inter-urban electric railways to serve their citizens. The bicycle became a trend in urban areas in the 1890s, and smooth paved roads were a requirement. Smooth paved roads were only found in cities, and were a perfect route for bicycle rides.[38] Even El Paso had the McGinty Club, a booster organization that organized programs such as "bicycle races made famous by the appearance of Miss Annie Londonderry, who had just completed a world tour by bicycle."[39]

A second innovation was that of the interurban electric railways. By 1891 Dallas had 42 miles of primarily electric "street and suburban railway" to serve its citizens and surrounding suburbs.[40] Austin had an urban railway system as early as 1887, illustrated on a birds' eye map published that year. In 1891, the Austin Rapid Transit Railway Company had formed, and, by 1895, had published its own map of the city of Austin illustrating the railway lines. Streetcar lines ran on the roads (Austin's railway ran up Congress Avenue), and thus the roads had a new and different purpose of supporting the streetcar lines and bringing people from suburban locations to downtowns and became primary routes through cities. The first automobile came to Texas in 1899, shipped to Terrell and driven into Dallas. The new conveyances, while initially of secondary importance to bicycles and streetcars, soon came to dominate the push for additional road legislation and new road and bridge building technologies.

The disparity between counties with money and those without came to a head between 1890 and 1915. Road legislation in the 1890s had favored counties with larger revenue streams by giving those counties greater power over their road networks in both funding and legislation.[41] Urban counties and densely populated rural counties (usually those with widespread cotton production) typically had higher taxable property values and therefore greater potential for revenue. These laws were "to create a more efficient road system" for these counties.[42] These counties could employ a county-wide road commissioner, purchase road equipment, employ labor for construction of roads and bridges as was necessary, and condemn land for new roads. Further amendments to this law gave these counties a deputy road commissioner, gave the county court the power to lay out the road system and contract out the improvements for the roads, made all overseers in the precinct subject to the road commissioner, and

[37] Stocklin, E-15, E-16; Ralph K. Banks, "Short Spans, About Bridges, Part III," *County Progress Magazine*, November 1994, 16-17; Ralph K. Banks, "Short Spans About Bridges, Part IV," *County Progress Magazine*, January 1995, 26-27.
[38] Kaszynski, 19-20.
[39] Conrey Bryson, "McGinty Club," *Handbook of Texas Online* http://www.tshaonline.org/handbook/online/articles/vqm01 (accessed 10 December 2010).
[40] J. P. Murphy and Charles Bolanz, Revised Edition of Murphy and Bolanz Official Map of the City of Dallas and Suburbs (Dallas: N.p., 1891).
[41] McDaniel, 20-21; H. P. N. Gammel, *The Laws of Texas, 1822-1897, Volume X* (Austin, Texas: The Gammel Book Company, 1898), 71-75. These counties included Grayson, Dallas, Galveston, Brown, Comanche, Mills, Fannin, Travis, Hunt, Hill, Kaufmann, and Fayette.
[42] Gammel, 71.

provided citizens a way to be exempt from road work by paying the road fund three dollars a year.[43] Other counties did not have nearly as much freedom to building their road systems.

But road and bridge monies furnished by any of the counties could not keep pace with rising technologies or needs of the populace. Well used and kept up roads could receive mail up to six times a week; poor quality roads had only once a week service or required special delivery service, particularly in West Texas.[44] Reluctant to pass measures that would centralize road decision-making, the state legislature instead broadened local funding mechanisms for road and bridge improvements. A 1903 act permitted county commissioners' courts to issue bonds for road improvement and maintenance in addition to bridge construction. A 1904 amendment to the Texas constitution allowed for "any county or political subdivisions of a county to vote road bonds" to be used for the construction of roads and bridges. Despite this, three years passed before the Legislature passed an act to enable the issuance of such bonds.[45] Under this provision, residents of a smaller political subdivision of a county, such as a commissioners' precinct, could vote for bonds to improve roads and bridges, rather than requiring the entire county to vote on the bonds. The state still refused to fund road and bridge building.

By 1909, a second act allowed counties to define "road districts" that did not have to coincide with any other subdivision of the county.[46] This law also lifted the limit on the amount of taxes that could be levied to pay for bonds for road building, though the limit on the dollar amount of the bonds themselves was not lifted.[47] This allowed smaller areas of each county to designate and build roads and the required bridges. This could make for uneven and inconsistent roads throughout one county, as well as between counties. In addition, cities and municipalities had to work with county governments to connect city streets with county roads, a process that could be time consuming and inconsistent.[48]

Besides the inconsistency of the roads in the state, the lack of money meant that Texas was behind other states in the country when it came to fixing its roads.[49] In 1893, the federal government formally became involved in roads with the formation of the Office of Road Inquiry within the United States Department of Agriculture, and that same year the nation's first state highway department was formed in Massachusetts; other states soon followed.[50] The Office of Road Inquiry, which was renamed the Office of Public Road Inquiry in 1899, evolved into a central source of technical road-related information that collected data and released bulletins and circulars addressing road construction and administration issues.[51] While both the federal and state governments were beginning to focus more on roads, the Texas Legislature refused to establish a statewide road system and statewide department of roads, putting Texas even further behind other states in the condition of its roads.

The conditions of Texas's roads had not kept pace with the new conveyances. With Texas's roads still in the state of considering "good" roads those that had the tree stumps less than six inches from the ground, automobile enthusiasts and truck farmers quickly became disgruntled with the state of Texas's roads. As previously discussed,

---

[43] McDaniel, 20-22.
[44] Post Route Map of the State of Texas (N.p., 1907).
[45] McDaniel, 28.
[46] McDaniel, 31-32.
[47] McDaniel, 32-33.
[48] Jeff Dunn, "The Development of Automobile Roads in Dallas County, 1905-1926," *Legacies* (spring 2000), 13.
[49] Dunn, 13.
[50] Bruce Seely, *Building the American Highway System* (Philadelphia: Temple University Press, 1987), 12-13 and 22.
[51] Seely, 9.

the rise in urbanization made cities the first to upgrade streets and bridges. As the population began to spread, having roads and bridges in good condition became a requirement further from the downtowns of the cities. In addition, the cities' population required more food to be brought in from the country. The poor roads leading into cities did not facilitate this, and became part of the general outcry for better roads in the state. Cities were concerned with the roads within their boundaries, counties were concerned with their road and bridge building, and little cooperation occurred between them. No large-scale planning was instituted for road and bridge design: "Texas roads bore no semblance to an integrated highway system. Roads had been amateurishly routed without any thought of continuity. Drainage remained inadequate and bridges non-existent in the rural areas of the state. Travel remained, therefore, virtually impossible in rainy or cold weather."[52]

However, new road and bridge technologies were occurring around the country. While Texas continued to use metal trusses and timber beams for bridge crossings, concrete was introduced nationwide in the 1890s, with the first concrete bridges in Texas built c.1900.[53] As Texas's bridges were constructed by county governments, concrete was an unlikely choice of bridge material at first. Bridges were much more likely to be of well-known materials such as metal and wood. By the 1910s, counties were constructing bridges using the new concrete technology, but combined it with the well-known bridge type of steel I-beams, called the "arch floor system," where the concrete acted as a fire retardant and protection from corrosion.[54] Counties used this technology for all types of crossings, including the "low-water crossing." A low-water crossing is a crossing that is usually dry (unlike a ford, which is usually wet), but can flood in times of high water. It requires less time, money, and building materials to construct a low-water crossing. In contrast to other concrete bridges, low-water crossings were constructed of concrete slabs or concrete box culverts.

Innovations to the commonly-used bridge types continued into the twentieth century. In Texas, Parker and camelback truss types were common from about 1905 onward. Both of these truss types utilized the common Pratt truss and modified its form in particular ways to allow for longer crossings. The Parker found extensive use in twentieth century Texas.[55] Examples of these trusses with longer spans include the 235-foot Parker span built by E. P. Alsbury and Son in 1906 over the Little River near Gause (TxDOT Structure No. 17-166-AA05-25-001, bypassed and in pedestrian use), and the 200-foot camelback span, built by the Chicago Bridge and Iron Company in 1909, over the Little River at the Bryant Station Crossing (TxDOT Structure No.17-166-AA02-75-001, bypassed and in pedestrian use).

Fortunately, by the 1910s, truss bridges had become much less costly for the commissioners' courts and city councils. While road building was still expensive, and new bridge technologies were costly, truss bridge prices had dropped significantly. In January 1908, the Corsicana City Council gave the power to buy a bridge to the Oakwood Cemetery Committee, and in April 1908, the Cemetery Committee reported that the bridge over Pin Oak Creek (TxDOT Structure No. 18-175-0-B010-45-001, in vehicular service) was completed: the cost for the 30-foot Pratt bedstead span was $217.17. In comparison, in 1883 Navarro County paid more than $1,500 for an iron bridge of unknown length, and in 1903 the county paid approximately $633 each for three bridges that were 60 feet and 75

[52] Huddleston, 25.
[53] Texas Department of Transportation, Historic Bridge Database, 2008.
[54] Knight & Associates, Inc., *Historic Documentation of the Gruene Bridge, Gruene, Comal County, Texas,* Prepared for the Texas Department of Transportation, 2004.
[55] Carl W. Condit, *American Building Art: The Nineteenth Century* (New York: Oxford University Press, 1960), 153.

feet in length.[56] Some county commissioners' courts erected small truss spans using local men or convict labor in an effort to be economical. In addition, as roads were upgraded or changed, counties were reusing bridges. While some bridges would serve at their original location for many years, often the counties would salvage washed-out or obsolete spans and move them to new locations. If the county commissioners could not find a new use for an old truss, they would often sell the bridge to other nearby communities and counties.[57] In Ellis County, the Commissioners' Court authorized the purchase of a bridge for the Bluff Springs Road crossing over Bear Creek in 1913 (TxDOT Structure No. 18-071-0-AA05-97-001, in vehicular service). The bridge that was erected at that location was actually moved from another point in Ellis County, as the bridge itself bears a date of 1890.[58]

Even into the early twentieth century road conditions in Texas were still very primitive. While a few towns boasted hard-surfaced roads, most counties were comprised entirely of dirt roads. Without sufficient funding or guidance, most counties laid out roads following the path of least resistance. As a result, most of the narrow pathways snaked around and along property lines and natural barriers and did not connect with roads in neighboring counties. With load capacities of seven tons or less, the light bridges on these routes were also very prone to washouts and substructure failures. In 1895, Roy Stone, head of the Department of Agriculture's Office of Road Inquiry, declared that Texas had made "less headway" in road improvements than any other state in the country.[59] Nonetheless, as early as 1890, there had been calls in Texas to "get farmers out of the mud." This sentiment echoed the national movement for better roads, including rural mail delivery routes and improved connections between farms and markets. This movement also coincided, in urban areas, with the rise of the bicycle and the automobile, creating a movement that transcended conveyance as well as economic circumstance.

**Named Auto Trails/Private Road Associations**

*Good Roads Movement*

The popularity of the bicycle and the introduction of the automobile in the 1890s raised national public awareness of the need for adequate road networks. In response to the poor condition of the nation's road system, the "Good Roads Movement" emerged. By the 1880s, interest groups began pressuring the federal government to reevaluate its role in the development of roads. A group of bicyclists organized the League of American Wheelmen, founding the first of many organizations to promote road improvements as part of the Good Roads Movement. With the motto "lifting our people out of the mud," the League of American Wheelmen and other advocates of the Good Roads Movement lobbied the federal and state governments for better roads and financial resources for road building and maintenance activities.[60] However, as discussed in the previous section, the rise of the bicycle was an urban movement, and had little impact on rural road improvements.

---

[56] Mead & Hunt, Inc., *Historic Context and Comparative Analysis Report: Statewide Study of Bedstead Truss Bridges*, Appendix E: Navarro County – North 15th Street at Pin Oak Creek, Prepared for the Texas Department of Transportation, July 2009, E-3.
[57] King, "A Historical Overview of Texas Transportation," 30-31; Historic Bridge Files, Texas Department of Transportation, Environmental Affairs Division, located at TxDOT headquarters in Austin.
[58] Mead & Hunt, Inc., *Historic Context and Comparative Analysis Report: Statewide Study of Bedstead Truss Bridges*, Appendix B: Ellis County – Bluff Springs Road at Bear Creek, Prepared for the Texas Department of Transportation, July 2009, B-3.
[59] King, "A Historical Overview of Texas Transportation," 23-24.
[60] George E. Koster, *A Story of Highway Development in Nebraska* (Lincoln, Nebr.: Department of Roads, 1997), 7 and 11.

With the formation of the Office of Road Inquiry in 1893, the federal government created a central source of technical road-related information.[61] When it was renamed to the Office of Public Road Inquiry in 1899, it continued with technical and promotional efforts to improve roads and assist the Good Roads Movement.[62]

Rural Free Delivery Service (postal delivery), begun in 1896, further increased public awareness for an adequate road system and broadened the support for good roads, especially among those in rural areas who did not previously see the need. Mail delivery was required in all climatic conditions and poor road conditions could prohibit this. Additionally, local applications for Rural Free Delivery Service were sometimes denied because of poor road conditions.[63] Rural free delivery was especially important to those communities in west Texas not served by railroad lines (see Figure 5).

From 1880 to 1900, the population of Texas doubled, reaching three million by the turn of the century. Agitation for good roads grew as the population desperately needed to move animals and wagons more efficiently. The introduction of the automobile to the state in 1899 provided further impetus for good roads. Within a decade, automobile statistics from 180 counties showed a total of 14,286 motor vehicles operating in the state.[64] As a result of this agitation, numerous national, state, and local groups became involved in road promotion through the National Good Roads Association, chapters of which sprang up in numerous locations across the country, including Texas. The Texas Good Roads Association (TGRA) was established in 1903, with 126 local Good Roads chapters formed in Texas by 1915. The TGRA and other groups, including the Associated Secretaries of Commercial Clubs and the Texas Farmer's Congress, carried out educational programs related to road development and pressured state and local politicians for road improvements. Additionally, the Agricultural and Mechanical College of Texas (now Texas A&M) and the University of Texas played significant roles in the state's Good Roads Movement by speaking out for a state highway department and a state highway system and providing technological advice and assistance, including testing on road materials.[65]

In 1902, the Texas Farmers' Congress called for state control of roads, and soon the Texas Democratic Party added the development of a state road system to its convention platform. A year later, Texas auto owners formed the Texas Good Roads Association to press lawmakers for road improvements and a statewide road system.[66]

Still reluctant to pass measures that would centralize road decision-making, the state legislature again broadened local funding mechanisms for road and bridge improvements. A 1903 act, modeled after the bridge bonding legislation of 1884 and 1887 (discussed previously), finally gave counties the authority to issue bonds for road work. Laws enacted in 1907 and 1909 under authority of a 1904 constitutional amendment went one step further, empowering subdivisions of counties, such as special road districts, to vote bonds for road construction and maintenance. The road-related legislation of the early 1900s temporarily resolved the issue of good roads, clearly establishing the counties and their road districts as the custodians for the state's roads and bridges. Many local road

---

[61] Seely, 9.
[62] Seely, 16-17.
[63] Seely, 27.
[64] Rupert N. Richardson, *Texas: the Lone Star State* (Englewood Cliffs, N.J., Prentice-Hall, Inc., 1958), 353.
[65] John David Huddleston, *Good Roads for Texas: A History of the Texas Highway Department, 1917-1945* (College Station, Texas: Doctoral Dissertation at the Graduate College of Texas A&M University, 1981), 27-30; HHM, Inc. *Preliminary Guidelines for Assessing NRHP Eligibility for Texas Roadside Parks.* Prepared for the Texas Department of Transportation, 2005, 7.
[66] Huddleston, 25-26.

districts formed in the years that followed, approving numerous bonds for road and bridge improvements in rural and urban areas.[67] Texas's roads remained under the control of city and county governments until 1917, at which time the THD was formed.

In Texas and across the country, the cooperative efforts of good roads associations, private organizations, and government agencies resulted in marking a system of automobile roads throughout the nation and Texas. "A highly important activity of the Good Roads Association," notes engineering historian Joseph King, "was determining the routes followed by long distance roads." Relying largely on existing roadways and following established railroad corridors, the private highway associations pieced together the state's first long distance roadway system. In return for the promise of booming business and tourism, communities paid subscriptions to the road associations and agreed to make road and bridge improvements along the routes.[68]

In 1905, the Office of Public Roads (OPR) was created by the passage of the Agriculture Appropriations Act, which terminated the Office of Public Road Inquiry and established a permanent federal road agency with an annual budget of $50,000.[69] Based on continued testing, the OPR issued typical material specifications and testing procedures, as well as construction guidelines in 1911 and bridge specifications shortly after. The OPR was renamed again in 1915, when it became the Bureau of Public Roads (BPR) in the U.S. Department of Agriculture. Highway standards were also developed by professional trade organizations, a few states, and even the Lincoln Highway Association, which developed an ideal pavement section.[70]

The Good Roads Movement's goal was to improve roads to a level of hard surfacing, either through the use of macadam, bituminous macadam, or concrete. Despite the early efforts of the Good Roads groups and early highway agencies, including the National Good Roads Association, 32 affiliates of the Automobile Club of America, and 18 state and 14 local road associations, only 154,000 of the country's more than two million miles of road were improved (hard surfaced) by 1904. The groups' efforts continued across the country, and by 1916 that total stood at 257,000 miles.[71]

A road reflective of this era in Texas is the 1915 constructed Austin to San Antonio Post Road (A-SAPR). Congress passed the Post Office Appropriations Act on August 24, 1912. Through this Act, $500,000 was appropriated in 1913 "for improvement of roads used in rural free delivery, in order to ascertain how such improvement would affect the amount of territory served by rural carriers, the increase in the number of delivery days, etc." This statement implied that the overreaching goals were to determine the financial savings earned by improving rural mail delivery and what might be the economic gain to farmers taking products to market.

By October 1912, Governor Colquitt initiated communication with the Postmaster General L.H. Hitchcock. Hitchcock offered Texas $10,000 to aid in the building of a post road in Texas as an experiment with the provision that the state and local governments double the amount of the expenditure. The offer continued with the provision that the road was to be used by Star or RFD carriers. Governor Colquitt selected a stretch of road beginning in Fort

---

[67] Richardson, 353; H. P. N. Gammel, *The Laws of Texas*, vol. XII (Houston: Gammel Publishing Co.), 313; Von Boeckmann-Jones Co., *General Laws of the State of Texas* (Austin, Texas, 1907), 249-251.
[68] Quoted in Joseph E. King, "A Historical Overview of Texas Transportation," 41; Historic Bridge Files, Texas Department of Transportation, Environmental Affairs Division, located at TxDOT headquarters in Austin.
[69] Kaszynski, 30.
[70] Seely, 29.
[71] Seely, 9 and 24.

Worth that continued to Weatherford and Mineral Wells, about fifty miles. While the Governor debated with his advisors which road to select, the new US Postmaster General A.S. Burleson withdrew the offer. The Texas delegation prevailed and the new amount offered from the federal government was $40,000.[72]

In December 1913, State Representative Somers V. Pfeuffer of New Braunfels requested from Governor Colquitt part of the funds allocated to Texas to construct a "Post Road" from Austin to San Antonio. This route that had existed in a rudimentary form since the early nineteenth century as a trail deserved attention as one of the most traveled stretches of road in the state. Pfeuffer's request fell in line with three other applications. As the Governor negotiated with the Postmaster General, the latter preferred that the allocation be spent on one experimental road. Again, the state selected the Fort Worth to Mineral Wells route, but differences led all to abandon the project and the state allocation was reduced to $10,000.[73]

After repeated requests from Governor Colquitt, the US Secretary of Agriculture (between 1905 and 1915 the Department of Agriculture oversaw the Office of Public Roads) granted $25,000 to $50,000 in aid to be used on a post road in Texas selected by the governor. Colquitt, responding to Representative Pfeuffer, offered the aid to Comal County and then later to Comal and Bexar counties. The final award reached $40,000 but Travis and Hays counties became interested and the federal aid grew to $80,000. The selected route followed the old post road from Austin to San Marcos, then New Braunfels and on into San Antonio. By the beginning of 1914, all the local, state, and federal partners' agreement on the project doubled the federal aid to $160,000 with the money deposited in banks by May 1914.[74]

Built in 1915-16, the A-SAPR roadway began in downtown Austin and continued to downtown San Antonio, stretching north to south across five counties: Travis, Hays, Comal, Guadalupe, and Bexar. The road followed earlier routes established during the period of Spanish exploration, the Republic of Texas, and early statehood. The entire alignment has been surveyed by TxDOT with portions of the 71-mile roadway containing integrity and determined eligible for listing using the evaluation methods in Section G.

*Development of Auto Trail Associations*

As previously discussed, beginning in the 1890s private organizations and governmental groups worked cooperatively to build and promote a comprehensive and integrated transportation system throughout the country. Until the 1920s, when the establishment of the US Highway System rendered them virtually obsolete, road promoters such as the National Good Roads Association heavily influenced this work.[75]

During the late nineteenth and early twentieth century, road designation, promotion, and improvement of cross-country routes were primarily the result of private interests and cooperative efforts. Citizen organizations, such as the Meridian Road Association and Dixie Overland Highway Association, were formed to designate, promote, and improve regional and cross-country highways. These groups also lobbied state, federal, and local governments to cooperatively plan and construct roads. Local commercial clubs, business associations, automobile clubs, and merchants often contributed labor and funds to bring major roads through their towns and improve local roads.

---

[72] Pevehouse, 7-8
[73] Pevehouse, 8-9
[74] Pevehouse, 9
[75] Richard F. Weingroff, "From Names to Numbers: The Origins of the U.S. Numbered Highway System," http://www.fhwa.dot.gov/infrastructure/numbers.cfm (accessed 15 November 2010).

These interest groups were critical to the ultimate development of a national highway system. As in other states across the nation, local automobile clubs such as the San Antonio Auto Club supported road development efforts and offered members opportunities to travel along regional roads and trails, race vehicles, campaign for improved roads, and create maps for existing routes.[76]

Road-specific organizations promoted their routes through published guidebooks. These guidebooks advertised the group's highway by offering route directions and identifying locations of tourist services and sites of interest. In addition to the published road and route guides, gasoline, oil, and tire companies often published state maps identifying early named highways. These state maps provided information on a variety of highways, but also served as a marketing piece and included the location of the sponsoring company's service stations. Within Texas, organizations such as the Texas Good Roads Association, Austin Automobile Club, and Bexar County Highway League also published log books providing maps and textual route guidance for roads in the state, with routes organized by names and termini.[77] While private associations handled promotion and marking of the named routes, the responsibility for the construction and upkeep of the roads and bridges remained under public control.

Among the transcontinental trails and highways that crossed Texas were the well-known Meridian Highway, Dixie Overland Highway, Bankhead Highway, and Old Spanish Trail. Other named highways included the Jefferson Highway, Jefferson Davis Memorial Highway, King of Trails, Hug-the-Coast Highway, and Ozark Trail. As the automobile gained popularity and travelers made their way across the state and the country, these routes became well-traveled thoroughfares. A 1918 Transcontinental Highway map illustrates the proliferation of named highways across the country, including 49 inter-state highways, more than 10 of which traversed through Texas (see Figure 6).

Additionally, this map provided a table regarding the mileage of national highways through each state. Texas contained the most national highway mileage by far, with 8,690 miles on 13 national highways; Montana and California followed with 6,250 miles and 5,500 miles, respectively.[78]

*Texas's Named Highways*

According to the 1918 Transcontinental Highway Map (see Figure 6), Texas had 128,971 miles of public roads, of which 8,690 miles (or 6.74 percent) were national or transcontinental routes. Among the well-known transcontinental routes were the Meridian Highway, Old Spanish Trail, Dixie Overland Highway, Bankhead Highway, Jefferson Highway, and King of Trails. Other more regionally recognized named trails included the Golden Belt, Southwest Highway, Lone Star Route, Colorado-to-Gulf Highway, Atlantic-Pacific Highway, Dallas-Canadian-Denver Highway, Ozark Trail, and Hug-the-Coast Highway (see Figure 7). Prior to 1917 and the designation of Texas state highways, many of the transcontinental routes through Texas followed existing county roads in rural areas, often paralleling major railroad lines, and city streets in urban areas. Many of these named

[76] Hugh Hempill, "Early Automobiles in San Antonio: 1899-1916," Texas Transportation Museum, http://www.txtransportationmuseum.org/ECH.htm (accessed 28 January 2011).
[77] Texas Good Roads Association and Austin Automobile Club, *Texas State Highway Guide*, (Austin, Texas: Forum Printing Co., 1918); Bexar County Highway League, *Bexar County Highway League's Official Log Book For Texas: 1914-1915*, (San Antonio, Texas: D. E. Colp, 1914).
[78] Transcontinental Highways of the United States in Auto Trails and Commercial Survey of the United States (New York: George F. Cram Co., 1918).

highways were also later encompassed by the enumerated state highway system and US Highway System. For example, the initial 1917 designation of Texas state highways included:

- State Highway (SH) 2, along the Meridian Highway route
- SH 6, on the King of Trails
- SH 11, on the Jefferson Highway
- SH 12, on the Jefferson Davis Memorial Highway
- SH 13, on a branch of the Ozark Trail

The 1926 designation of highway routes also incorporated vestiges of these former named highways into the national system. For example, the Meridian Highway became U.S. Highway (US) 81 and the Old Spanish Trail and Dixie Overland Highway became US 80 and portions of US 90. Ultimately, many of these routes paralleled or overlaid the Interstate Highway System in the post-World War II era. In an effort to highlight the development of named highways in the early twentieth century and their promotion by private organizations, brief histories are given below of several of the many named trails running through Texas.[79]

*Texas's Named Highways: Meridian Highway*

The Meridian Road, renamed the Meridian Highway in 1919, was developed in the early twentieth century to become the primary north-south route through the central US. Extending from Winnipeg, Canada, to Mexico City, Mexico, the Meridian Highway passed through six states, including Texas (see Figure 8). The road's initial route followed the survey of the Sixth Principal Meridian line through the central Great Plains, hence the name Meridian Road.

The Meridian Road, promoted by one of the earliest road associations, was organized in Kansas at a meeting of supporters on June 1911 to establish a direct, north-south automobile route. The objective of its promoters, led by John C. Nicholson of Newton, Kansas, included the adoption of a sign, mapping of a route through Kansas, and instructions for the association to promote the road south to the Gulf of Mexico and north to Canada.[80]

After the Meridian Road Association was formed in Kansas, the group solicited support from other states. In Oklahoma and Texas, various other highway organizational efforts were already underway; however, most of these organizations had failed to establish a road passable for automobiles. The Meridian Highway Association was formed in Texas in 1911, and the association was divided into three divisions: the North Texas division from Burkburnett to Waco; the San Antonio division from Waco to Laredo; and the Gulf division from Waco to Galveston.[81]

---

[79] Transcontinental Highways of the United States in Auto Trails and Commercial Survey of the United States; John D. Miller, Map Showing Proposed System of State Highways as Adopted June 1917, (Austin, Texas: Texas State Highway Department, 1917); AASHO, Map of United States System of Highways Adopted November 11, 1926, (N.p., 1926).
[80] "Meridian Highway History," *Texas Oil News* (N.p., c.1920). Available at Nebraska State Historical Society, Nebraska State Historic Preservation Office, Lincoln, Nebr.
[81] "Meridian Highway History," *Texas Oil News.*

In January 1912, the International Meridian Road Association was formed, representing Canada, North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, and Texas. The constitution and bylaws of the association specified that:

The Meridian Highway shall be well graded, well drained Highway with permanent bridges, substantial culverts and kept in a condition to facilitate travel, and it shall be the aim and object of the Association to secure the construction and maintenance of a hard surfaced road as soon as conditions will warrant the same and is justified.[82]

The International Meridian Road Association adopted official signs for the road consisting of 12-inch-wide bands on poles indicating to travel straight ahead (see Figure 9). Turns were indicated by a 6-inch white band with 6-inch red band above painted with the letters "M.R." on three poles before and three poles after each turn. The association was also involved in advertising, promotional tours, and general improvements to the road and was the body responsible for solving any disputes over route location at the state borders.[83]

Each state division of the organization was responsible for activities within the state including the location of the road, maintenance, and signage. In the spring and summer of 1912, the state divisions were assigned to lay out the road, post signage, and get the road in the best condition for travel and advertising.[84] In 1917, the Meridian Highway became SH 2 along its route through Texas, although it also continued to be marketed as the Meridian Road. SH 2 and the Meridian Road traveled through Wichita Falls, Henrietta, Fort Worth, Cleburne, Meridian, Waco, Austin, San Antonio, and Laredo.[85] In 1919, the Meridian Road was renamed the Meridian Highway by the association. Improvements along the national route continued in various stages over the years. The International Meridian Highway Association's brochure in 1927 boasted, "By the end of 1928 the Meridian Highway will be practically surfaced from Winnipeg to Laredo and will be an all-weather road – perhaps the second all-weather road across the U.S. – the Pacific Highway being the first."[86]

In 1926, the BPR designated the prospective primary US Highway System and the Meridian Highway was designated as US 81. This was the only named highway given the same US route number across the entire US[87] Designation as a state and then a federal highway ensured funding and continued maintenance. This designation also led the route to be improved and alignments adjusted to meet state and federal standards.

*Texas's Named Highways: Dixie Overland Highway*[88]

The Dixie Overland Highway (see Figure 10 for highway marker and Figure 11 for map) was conceived by the Automobile Club of Savannah, Georgia, in July 1914 as a route that would connect the Atlantic and Pacific coasts through the states of Georgia, Alabama, Mississippi, Louisiana, Texas, New Mexico, Arizona, and California. In

---

[82] Meridian Highway Constitution and by-laws (F. A. Long Papers, Manuscript Collection, Nebraska State Historical Society, Lincoln, Nebr.).
[83] "Meridian Highway History."
[84] "Meridian Highway History."
[85] Map Showing Proposed System of State Highways as Adopted June 1917.
[86] "The International Meridian Highway – U.S. Highway No. 81 Bulletin, June 9, 1927," (F. A. Long Papers, Manuscript Collection, Nebraska State Historical Society, Lincoln, Nebr.).
[87] "The International Meridian Highway – U.S. Highway No. 81 Bulletin, June 9, 1927."
[88] Text derived from Richard Weingroff, "U.S. Route 80 The Dixie Overland Highway," *FHWA Highway History*, http://wwwcf.fhwa.dot.gov/infrastructure/us80.cfm (accessed 22 December 2010).

1914, the club determined the location of the highway would connect Savannah, Georgia, to Los Angeles, California. Within Texas, the route would connect Dallas, Fort Worth, Alamogordo, and El Paso. The club asserted that the Dixie Overland Highway, when constructed, would be the "shortest, straightest, and only year round ocean to ocean highway in the United States."[89] By July 1915, during the Automobile Club of Savannah's second annual meeting, it received reports from the states involved that "an ocean-to-ocean all-weather highway was practical and was then about 50 percent constructed."[90] By 1919, the western terminus of the route was revised to San Diego. Through Texas, the route of the Dixie Overland Highway largely corresponded to SH 15 from Longview to Dallas, and SH 1 from Dallas to El Paso. The portion of the route west of Dallas was also shared with the Bankhead Highway. Other portions of the transcontinental route also corresponded with the Old Spanish Trail, the Lee Highway, and the Jefferson Davis National Highway.

In his memoirs, Colonel Ed Fletcher describes his account of his record-breaking trip across the country on the Dixie Overland Highway in 1926, which was the fastest trip across the country at that time: a distance of 2,535 miles in 71 hours and 15 minutes. At this time, only about five percent of the highway was hard surfaced, with most of the road containing dirt and clay surfaces. The U.S. Highway System was also created in 1926, and much of the Dixie Overland Highway became US 80 (see Figure 12) and US 90. The only portions of the route that were not incorporated into US 80 were three sections in Georgia, two short sections in Alabama, and one section across western Texas. The sections not included as part of US 80 in Texas were the route between Roscoe and El Paso (US 84, 380, 70, and 54).[91]

*Texas's Named Highways: Old Spanish Trail*[92]

The Old Spanish Trail (see Figure 13 for highway marker and Figure 14 for map) was conceived in 1915 as the shortest route between the Atlantic and Pacific Oceans, connecting St. Augustine, Florida, and San Diego, California. The route took nearly 15 years to construct at a cost of more than $80,000.[93] The route opened for travel in 1929, after the designation of an enumerated U.S. Highway System, and was billed by the Old Spanish Trail Association as the most expensive and highly engineered of all the transcontinental trails.

Although the Old Spanish Trail Association began its efforts in Mobile, Alabama, by 1919 it had reorganized and moved to San Antonio, Texas. Prior to its reorganization, the Association struggled to implement the highway, which faced numerous physical obstacles, including two-thirds of the drainage waters in the U.S. and 125 miles of delta on the east and west banks of the Mississippi River. Moreover, the Association struggled to fund the highway, which it originally hoped would be partially funded by the federal government as a military road. Nonetheless, with the Association's reorganization and relocation to San Antonio in 1919, the highway began to take shape.

---

[89] Weingroff, "U.S. Route 80 The Dixie Overland Highway."
[90] Weingroff, "U.S. Route 80 The Dixie Overland Highway."
[91] "Dixie Overland Highway," *American Roads*, http://www.americanroads.us/autotrails/dixieoverland.html (accessed 22 December 2010).
[92] Much of this text is derived from "The Old Spanish Trail: Building the Shortest Highway in the Longest Amount of Time," *Drive the OST*, http://www.drivetheost.com/history.html (accessed 22 December 2010).
[93] It is unclear whether constructing the Old Spanish Trail included upgrading existing roads or implementing new roads, or a combination of both.

Under the name of the Old Spanish Trail, the Association began to market the route as a romantic link to the region's Spanish colonial history with historical information readily presented in the Trail's travelogs, which were issued from the mid-1920s through 1931. When the route was eventually opened for travel in its entirety in 1929, it provided a link across a previously inaccessible west Texas and eliminated 35 ferry crossings along the Gulf of Mexico. Through Texas, the route connected Orange at the Louisiana border with Beaumont, Houston, San Antonio, and El Paso.[94] In the March 1929 *Old Spanish Trail Travelog*, the eastern section of the highway (from St. Augustine, Florida, to San Antonio, Texas) was identified as 65 percent paved, with the remainder of gravel, sand-clay, or otherwise improved surface. The western section of the route (from San Antonio, Texas, to San Diego, California) was 31 percent paved at the time, with the remainder of gravel or otherwise improved surface.[95] The western segment of the Old Spanish Trail, from Van Horn, Texas, to San Diego, California, shared much of its route with the Dixie Overland Highway. With the designation of the U.S. Highway System in 1926, the Old Spanish Trail also became US 90 from Jacksonville to Van Horn, Texas, and US 80 along the western segment to San Diego.[96]

*Roadside Features*

Like the roads themselves, the many necessary bridges, culverts, and engineering structures associated with constructing and surfacing transcontinental and regional highways were often the result of lobbying by private associations. However, the direct responsibility for construction and maintenance of these structures still lay with public bodies. Many counties and local road districts issued bonds for road and bridge work on named highway routes during the 1910s. One of the most impressive structures built on a private highway route was the 1916 bridge over the Canadian River located just north of the community of Canadian, Texas, on the Dallas-Canadian-Denver Highway (now listed in TxDOT Historic Bridge Database as TxDOT Structure No. 041070XXXXXX001, now in pedestrian use only). The bridge was originally built with 17 Parker through truss spans and stretched more than 2,500 feet across the river. In 1924, the THD added four additional Parker through truss spans to the structure, bringing its total length to nearly 3,300 feet.[97]

Other structures associated with named auto trails from this period of time include marker posts and historical markers. For instance, on March 24, 1927, the Old Spanish Trail Association erected a zero milestone marker (a large Texas granite boulder with a plaque) in Military Plaza, the site of the old courthouse, in San Antonio, Texas. This was one of three zero milestones erected along the Old Spanish Trail.[98] Numerous concrete obelisks were erected at critical junctures of the Ozark Trail between Missouri and New Mexico, including several across the Texas Panhandle (see Figure 15). Among the extant Ozark Trail obelisks in Texas are concrete pillars in Tampico and Dimmitt.[99]

---

[94] Will Fossey, "Old Spanish Trail," *Handbook of Texas Online*, http://www.tshaonline.org/handbook/online/articles/ero01 (accessed 28 January 2011).
[95] *Old Spanish Trail Travelog, March 1929, The National Trunk Line through the Southern Borderlands*, http://www.oldspanishtrailcentennial.com/Travel%20logs/1929-1/1929-1%20Travel%20log%20index.htm (accessed 22 December 2010).
[96] Maps do not indicate whether the Old Spanish Trail was designated with a state highway number prior to its U.S. Highway designation.
[97] Historic Bridge Files, Texas Department of Transportation, Environmental Affairs Division, located at TxDOT headquarters in Austin.
[98] "The Old Spanish Trail: Building the Shortest Highway in the Longest Amount of Time."
[99] Arthur Krim, "Ozark Trails – Mother Road," *SCA Journal* (spring 1996), 24.

In 1915-1916, the Texas Society of the Daughters of the American Revolution, with financial support from the Texas legislature, commissioned surveyor V.N. Zivley to resurvey the path of the old El Camino Real through Texas and identify locations for marker placement at five-mile intervals along the route, from the Sabine River along the Louisiana border southwestward to the Rio Grande. The pink granite markers, 123 in total, were dedicated in 1918, each with the inscription "Kings Highway, Camino Real, Old San Antonio Road, marked by the Daughters of the American Revolution and the State of Texas, A.D. 1918." Most of the Zivley markers are still intact, though some have been moved due to road construction or are now located on private property.[100]

Soon after plans for the transcontinental Lincoln Highway (which became one of the most successful auto trails) were announced in 1912, the southern ladies of the United Daughters of the Confederacy countered with a plan of their own for a southern coast-to-coast rock highway to honor Confederate President Jefferson Davis. The women started out slow but fought hard for the legitimacy of their road. One lasting legacy of their work was the placement of stone markers for the Jefferson Davis Highway along its numerous routes. After 1926 promoting their trail was a tougher battle. Once highways were brought under the umbrella of state and federal governments and were given their numbers, it was more difficult to hang onto the names, especially in foreign territory so far from the source of the inspiration. The backers of the Jefferson Davis Highway had petitioned, as had other trail organizations, to be given just a single highway number for their route so that it would not be divided up between several of the new US highways. They were unsuccessful. The Jefferson Davis Highway promoters were also hampered in their quest for official recognition by a confusing route that included assorted loops and spurs and changing termini. Markers for the Jefferson Davis Highway are rarely found today. [101]

*Automobile Popularity and Alternatives to the Named Trail Movement*

By the mid-1920s more than 250 named routes existed across the country, many of which overlapped, especially in the less populated west. Rivalries among trail boosters, route duplications, and the often questionable intention of promoters led the public and the BPR to consider alternatives to the named trail movement. With the swelling number of national automobile registrations, which had increased from less than 500,000 in 1910 to nearly 10 million in 1920, "the time when highway transportation could be left to private entrepreneurs was quickly passing."[102] Nonetheless, the popularity of some named auto trails continued, even after being supplanted by the U.S. highway system in 1926, and the names of the highways continued to be used along with state and U.S. designations.

**Early Development of the Texas Highway Department and U.S. Highway System**

As a result of private organizations and regional interests, named highways crisscrossed the nation prior to the 1920s. As the number of named highways grew, however, so did confusion among automobile users, whose numbers were also greatly increasing. By 1930, the country boasted more than 26 million registered motor vehicles.[103] Problems stemming from the nationwide maze of named highways included the fact that named trails

---

[100] Claire Williams, "Commemorating Texas History: The Historical Marker Program", unpublished manuscript. N.p., 1986, 2.
[101] Richard F. Weingroff, "Jefferson Davis Memorial Highway." *FHWA Highway History*. http://www.fhwa.dot.gov/infrastructure/jdavis.cfm (accessed 7 August 2012).
[102] Richard F. Weingroff, "From Names to Numbers: The Origins of the U.S. Numbered Highway System."
[103] Weingroff, "From Names to Numbers: The Origins of the U.S. Numbered Highway System."

did not always provide travelers with the shortest or most direct route between cities, and in some locations named trails overlapped each other. Private promoters of the named trails were also concerned that if they invested in roadway improvements, the federal government, due to the new emphasis on the role of highways in national defense that followed World War I, would then "take over and complete their trail as a defense measure."[104]

The Federal Aid Road Act of 1916 provided the opportunity to improve and construct roads, and was the impetus for the creation of the THD in 1917; Texas was one of the last states to create a highway department. Agitation for good roads caused many states to establish highway departments at the turn of the century. By the end of 1910, 30 states were appropriating monies for road and bridge improvements and 19 had state offices to oversee state road funds. By 1913, all states except Florida, Indiana, Mississippi, Tennessee, South Carolina, and Texas had adopted provisions for state action in highway construction.[105]

The Federal Aid Road Act provided $75 million over five years to states for building rural roads and an additional $10 million ($1 million per year for 10 years) for roads and trails in the national forests.[106] The federal aid was not to exceed 50 percent of the cost of construction.[107] Allotment of money was based on, among other factors, population and existing road networks. The bill's passage shifted the focus from county and local government control of road development to national oversight and allocation of transportation funding through established state highway agencies. Although the states gained the ability to design and supervise road improvements, all federal-aid projects were still subject to federal standards and reviews. While private local and national organizations continued to promote long distance roads and transcontinental auto trails, states began concentrating on creating local, regional, and state road networks.

Under a complicated apportionment formula, the bill gave the largest single appropriation to Texas, but also required formation of a state highway department before federal monies could be received. Not wanting to forfeit the opportunity to receive federal monies, the 1917 35th Legislature, after lengthy deliberations, passed House Bill 2, which finally established a state highway agency for Texas. In addition to allowing the federal funds to be spent, the bill also authorized the THD to raise state highway monies by assessing automobile registration fees.[108]

*THD Creation, Organization, and Goals*

Established in 1917, the THD operated under two main divisions: registration and engineering. The registration section dealt primarily with licensing, fees, and aid allotment while the engineering section handled road and bridge design, construction, and maintenance. The Texas Highway Commission, which governed the THD, approved the position of State Bridge Engineer in a January 24, 1918, resolution. In the agency's initial inception, the administrative control of the department was vested in a three-member State Highway Commission and a State Highway Engineer, under which the registration and engineering divisions operated.

Under the direction of the State Highway Engineer, the agency was to distribute state and federal road aid to counties, establish standards for the construction and maintenance of highways, ferries and bridges, and supervise the construction of state and federal aid projects.

---

[104] Weingroff, "From Names to Numbers: The Origins of the U.S. Numbered Highway System."
[105] Ralph K. Banks, "Road to Creation of the Department Not a Smooth One," *Transportation News*, September 1986.
[106] Weingroff, "Federal Road Act of 1916: Building a Foundation" in *Public Roads* 60, no. 1.
[107] State Highway Department of Texas, *First Biennial Report*, 13.
[108] Huddleston, 31; King, "A Historical Overview of Texas Transportation," 35-36.

The organization of the THD changed throughout the 1920s and early 1930s to include more specialized divisions, including Maintenance, Administrative, Engineering, and Federal Equipment, among others. The THD also divided the state geographically into divisions, locating field offices in each of these areas. Renamed districts in the 1930s, the number of division offices reached nine by 1923, nearly doubling to 16 in 1925, and reaching the current 25 offices in 1932 (see Figure 16).[109]

*THD project Development, Review, and Approval*

Despite the THD's quick action to designate a state highway system and the guarantee of federal and state matching funds, the new agency initially wielded very little power over road and bridge building in Texas. Recognizing the substantial investment that counties had already made in roads and their interest in maintaining local control over highway routes, the legislature had established a weak highway department that gave the counties primary jurisdiction over the highway system. Counties initiated all applications for state and federal aid and were awarded state and federal monies on a first-come, first-served basis.[110]

Typically, when a county wished to receive state or federal aid for a project, it would raise bonds to match state or federal monies and hire a county engineer to draft the necessary surveys, plans, and estimates in accordance with THD requirements. The county submitted its application for state or federal aid to one of the department's division engineer offices. After reviewing an application, the division engineer would forward the materials to the THD's Engineering Division in Austin for design approval. The Engineering Division processed applications for state and federal aid, forwarding projects with federal aid requests to the BPR for compliance with federal guidelines and standards. The county advertised for bids and awarded contracts, and its engineer supervised the construction process. The division offices inspected and monitored the construction work, employing a resident engineer to perform this work when a project was exceptionally large or complicated. Federal and state aid apportioned to the counties were paid only after the work was completed and inspected by THD engineers, with additional BPR inspections required for federal aid projects.[111] Roadways receiving federal aid were distinguished by the placement of concrete posts, three to four feet in height, at the limits of every federal-aid project. Affixed to federal-aid posts were metal shields or rectangular plaques indicating the federal-aid project number and year of construction. Placement of federal-aid project markers began by the late 1910s and continued into the post-World War II era.[112]

Highway maintenance was also a responsibility of the counties. The counties signed maintenance agreements on all federal and state aid highway projects. They also continued to maintain the older unimproved sections of the state highway system. In accordance with an amendment passed by the 1917 35th Legislature, the counties collected automobile registration fees on an annual basis, retaining half of the monies for local highway maintenance and remitting the other half to the state highway department for highway construction funding.[113]

---

[109] State Highway Department of Texas, Third Biennial Report, 8; Fifth Biennial Report, 7; Eighth Biennial Report, 146.
[110] Huddleston, 40-41; State Highway Department of Texas, *Second Biennial Report*, 7-8 and 42-45.
[111] Huddleston, 40-41; State Highway Department of Texas, *Second Biennial Report*, 7-8 and 42-45.
[112] "Black Milestones for Neglected Federal-Aid Roads." *Municipal Journal* 44, no. 11 (March 16, 1918), 230; Bygone Byways, http://home.comcast.net/~bygonebyways/.
[113] Huddleston; *First Biennial Report* (Austin: Von Boeckmann-Jones Co., 1919), 8.

*THD Early Highway Networks and Initial Projects*

In its first eight years the THD concentrated on state highway designation, development of road and bridge design standards, and building a funding foundation for the department, particularly in light of the newly designated state highway system.

In the Texas Highway Commission's first public hearing on June 21, 1917, it designated a tentative network of 22 state highways, which were identified as numbered state routes. When funds became available again in 1919, the number of designated state highways increased to 38.[114] Working with the counties, the commission chose roads that followed existing county roads and consisted largely of the same system of routes that had already been designated by named highway associations such as Meridian Highway and King of Trails. State highway routes were intended as trans-Texas routes extending across the state and connecting commercial centers. Examples include SH 2 and SH 9, among others. SH 2 was previously designated the Southern National Highway. It began in Orange and ended in Del Rio, following present-day IH 10 and US 90. SH 9 was originally the Puget Sound to Gulf Highway and began in Corpus Christi, extending north to Amarillo. It roughly followed present-day IH 37 and US 83. However, World War I interrupted the implementation of the state highway network.

By 1919, the number of designated state highways had increased to 38, stretched 12,000 miles, and ran from state line to state line, connecting commercial centers. In 1921, there were 46 numbered routes covering 15,000 miles.[115] The 1921 Second Biennial Report Designated Highways Map illustrates the routes of the designated highways, showing a concentration of the highways primarily east of the Fort Worth-San Antonio line to the Louisiana border and north of the San Antonio-Houston line (see Figure 17). Highways and road networks were slower to develop in the southern, western, and panhandle portions of Texas, likely due to the smaller populations, remote geographic locations, disparity in wealth between the counties, lighter road traffic, and smaller amount of fund appropriations (see Figure 18).[116]

*Early Design Standards and THD Projects*

In the THD's *First Biennial Report* in 1919, the State Highway Engineer recommended that the state highways be divided into three separate classes: first class (trunk system), second class, and third class. These were different than the existing county road designations that varied widely from county to county. Although counties still maintained control of these highways, there was now a uniform designation system throughout the state. The main distinguishing factors between the state highway classes were the width and composition of the road as defined by the type of traffic. Heavy truck traffic was to be relegated mostly to first class roads with 24-foot paved width and not to exceed 2,500 miles of total road. Roads with lighter traffic were primarily the second and third class designations, with 16-foot gravel and 12-foot sand-clay roads, respectively.[117] The State Highway Engineer also recommended that the state highway system have standard designs and markers and not exceed a maximum 15,000 miles. The 1922 Highway Map of the State of Texas (see Figure 25) illustrates all three types of roads. At this time, first and second class roads comprised only seven percent of the system.

---

[114] First Biennial Report, 52.
[115] First Biennial Report, 11; Second Biennial Report, 7.
[116] Huddleston, 38.
[117] State Highway Department of Texas, *First Biennial Report*, 23.

The road classifications and designation process helped guide the THD in selecting routes, but other issues hindered consistent road funding and design processes. Counties still controlled the majority of road design projects in Texas until 1923, and the available federal monies to the state came with additional stipulations. The lack of state control over the highway system caused inconsistencies, particularly in bridge construction along the various state highway routes. Counties could initiate locally funded bridge projects at will. A highway route in one county could include a new 15-ton THD bridge, while in an adjacent county the same route could have county bridges with carrying capacities of seven tons or less. As noted in the third biennial report, "The heaviest load that could be carried over the highway is controlled by the weakest bridge."[118]

Biennial reports and THD histories indicate that early THD activities remained largely focused on expanding the state highway network through designating state highways, extending existing roads, and constructing new roads.[119] Between 1917 and 1927, the design of the roads on the state highway system did not change significantly (see Figure 19 for a typical section of highway in 1926). Many of the early highway designers were former railroad engineers, and their experience was reflected in early roadway design. Steep curves and grades were modified for traffic purposes and volumes changed, but little attention was given to the high roadway profile, deep side ditches, narrow pavement, and inadequate shoulders of most early highways, as seen in Figure 26.[120] These early roadway designs often proved to be unsafe for motorists, whose automobiles were not guided by rails and had a much higher center of gravity than heavy locomotives.[121]

Road surfaces throughout the state depended on the available resources and funds within the area and "varied from region to region: shell along the coast, gravel in central and northern areas, iron ore gravel in the northeast, rock asphalt and caliche in the south and southwest, and earth in the Panhandle."[122]

During the first few years of its existence, the THD also developed standard bridge and culvert designs, as well as general roadway width standards for bridge and culvert projects. By 1920, standard plans were available for timber trestle, concrete slab, concrete girder, steel beam, pony truss, and through truss bridges. Early culvert standards included those for concrete box culverts, concrete and cast iron pipe culverts, concrete slab culverts with masonry substructure, and stone slab culverts with masonry substructure (see Figure 20).[123] Most of the early THD standard designs and specifications corresponded closely with federal circulars and bulletins promulgated by the BPR. Most of the Bridge Section's early designs were for short to medium spans, reflecting the THD's early emphasis on road surfacing projects and small drainage improvements on state highway routes. Warren and Parker trusses were the most common truss bridge types and large bridge construction was deferred until the 1930s with increased federal aid stemming from Depression-era aid and work programs. "Low water" concrete slab and culvert structures were frequently used in areas that had light traffic volumes and infrequent flooding problems, such as West and Northwest Texas. These structures were simple in design and eschewed engineering significance in favor of low-cost construction. Standards on state highways required a minimum 16-foot roadway width for bridges (although

---

[118] State Highway Department of Texas, *Third Biennial Report*, 51.
[119] State Highway Department of Texas, First through Sixth Biennial Reports; Joseph E. King, *A Historical Overview of Texas Transportation, Emphasizing Roads and Bridges* (Austin, Texas: Texas State Department of Highways and Public Transportation).
[120] Gibb Gilchrist, Texas Highway Department 1927-1937 (N.p., 1937), 42.
[121] HHM, 7.
[122] King, 55.
[123] Texas Department of Transportation, Historic bridge standard plan files, Available at Texas Department of Transportation Environmental Affairs Division, Austin, Texas.

most roadways were 20 feet) and a 24-foot clear roadway for culverts.[124] Additionally, the THD began advocating for elimination of railroad grade crossings as early as 1919.

Of the 384 completed and active projects between 1918 and 1920, only six percent were bridge projects in varying stages of completion. Although grading and bridge projects were grouped together and quantified by mileage in the biennial reports, the reports also recorded the separate number of solely bridge construction projects. By the end of 1924, there were 65 bridge projects totaling 10 percent of the total projects, and by September 1927 the number decreased to 51 bridge projects, only nine percent of the total projects.[125]

*Impact of 1921 Federal-Aid Highway Act*

An important shift took place as a result of the 1921 Federal-Aid Highway Act: control of road and bridge projects changed from county and local governments to the THD. Unlike the 1916 federal act that only provided funding for developing rural road networks, the Federal-Aid Highway Act of 1921 created a national highway system and charged each state with creating a system of state highways that would later become the national highway system. Federal and state funding was allocated at a 50/50 match, and each state's system was not to exceed seven percent of the state's total highway mileage.[126] With this federal assistance and later highway acts and relief funding, THD expenditures increased in 1921 and into the early 1930s (see Table 1).

**Table 1. Total THD Expenditures, All Purposes (1918-1932)**

| Fiscal Year | Expenditures |
|---|---|
| 1918 | $1,268,284.82 |
| 1919 | $1,498,356.38 |
| 1920 | $2,411,285.26 |
| 1921 | $6,904,973.27 |
| 1922 | $8,876,381.76 |
| 1923 | $8,593,947.54 |
| 1924 | $12,144,393.36 |
| 1925 | $20,602,264.66 |
| 1926 | $19,988,350.79 |
| 1927 | $19,992,960.96 |
| 1928 | $28,710,176.32 |
| 1929 | $34,529,881.27 |
| 1930 | $47,331,977.54 |
| 1931 | $42,163,806.33 |
| 1932 | $42,795,910.64 |

[124] State Highway Department of Texas, *Second Biennial Report*, 47.
[125] State Highway Department of Texas, First Biennial Report, 28; Fourth Biennial Report, 75; Fifth Biennial Report, 79.
[126] Wisconsin Historical Society, "Federal Aid Highway Act of 1921," http://www.wisconsinhistory.org/archstories/late_roads/fed_hwy_act.asp (accessed 8 December 2010).

*Source: Texas Almanac and State Industrial Guide 1970-1971 (Dallas, Texas: A.H. Belo Corporation, 1969).*

As part of this legislation, Congress also created the Federal-Aid Primary System that included two types of roads: principal and inter-county.[127] Principal roads served through traffic and connected cities, and inter-county roads were rural routes that connected the principal roads and included local and county roads.[128]

With the Federal-Aid Highway Act of 1921, the state of Texas saw the inherent difficulty in allowing county control over these federal projects. Consequently, another important shift took place after the Federal-Aid Highway Act of 1921. In January 1923 the 38th Texas Legislature moved quickly to give the THD administrative control over the state highway system. It passed one act to raise motor vehicle registration fees and a second act to institute a one-cent-per-gallon occupation tax on gasoline (with three-fourths of revenues going to the state highway fund and the remainder to the state's permanent school fund).

While the Federal-Aid Highway Act of 1921 laid the groundwork for a federally-assisted road network, it did not directly create a nationally designated system of highways. Instead, the movement for a nationwide system of highway routes and road signs was proposed at an AASHO annual meeting in 1922. AASHO, an organization of senior state and federal highway officials formed in 1914, served as a link between road booster groups, state governments, and the federal government. The organization had a role in shaping many aspects of road policy, including building, financing, and maintenance. Following the 1922 AASHO annual meeting and AASHO's subsequent recommendations on how to identify the system's routes, the Secretary of Agriculture appointed the Joint Board on Interstate Highways to undertake the endeavor of designating the system of highway routes and establishing a standard system of signing the routes.[129]

The Joint Board on Interstate Highways held meetings across the country throughout 1925 to receive input on the new system of highway routes. Early on, Joint Board of Interstate Highways members agreed the system would be numbered rather than named, and would be designated as the "U.S. Highway" system rather than as the "interstate system" or "numbered Federal system of interstate highways."[130] The remainder of their work focused on identifying the routes to be designated as U.S. highways and developing standardized signage.

By the end of 1925 a national numbering system plan was adopted for the U.S. highways and included the standard design for signs to mark roads carrying the same name or number between states. When this plan took effect in 1926, the new numbering system affected 145 roads, or 76,000 miles of road, across the U.S. The uniform white shield sign had bold black text and the only variation was the name of the state. The state's name was included in the top portion of the sign, and the highway number appeared in large bold text in the lower portion. Odd numbers were used for north-south routes with numbers that ended in 1 and 5 designated for principal routes, while even numbers were assigned to east-west roads with principal routes designated using multiples of 10.[131]

---

[127] Federal Highway Administration, "Highway Statistics Summary, Section IV: Highway Finance," http://www.fhwa.dot.gov/ohim/summary95/text/hf.html (accessed 1 February 2011).
[128] Huddleston, 44.
[129] Weingroff, "From Names to Numbers: The Origins of the U.S. Numbered Highway System."
[130] Weingroff, "From Names to Numbers: The Origins of the U.S. Numbered Highway System."
[131] Kaszynski, 60.

In most cases the designated U.S. highways followed existing named highway routes. For example, the Dixie Overland Highway, including dual routes through the South, became US 27, 25, 41, 80, 90, and 441. The Old Spanish Trail, which traversed the southern half of the country between St. Augustine, Florida, and San Diego, California, became US 80 and portions of US 90 (see Figure 21).[132]

In Texas's case, many of the U.S. highways followed the enumerated state highways. Upon close examination of two maps showing the proposed system of state highways from 1917 (see Figure 22) and the approved U.S. Highway System from 1926 (see Figure 23), similarities between the major routes and the incorporation of a number of state highways into U.S. highways can be gleaned. For instance, SH 1 and SH 15 were subsumed by US 80, which extended from Savannah, Georgia, to San Diego, California, and which ultimately became part of IH 20 through Texas. Additionally, SH 2 was incorporated into US 81, which extended north-south from the Canadian border near Pembina, North Dakota to Laredo, Texas. This route ultimately was superseded by IH 35 in Texas.

*1925 State Highway Act and THD Reorganization*

In 1925, another shift in state highway control resulted in the beginning of massive changes for the THD, including increased control over state highways, a substantial overhaul of THD administration, and implementing professional road and bridge design and construction standards.

A 1925 ruling of the State Court of Civil Appeals (Robbins vs. Limestone County) resolved the issue of state highway control. In considering the case of a county that would not give the THD its share of registration fees, the judge determined that the state could assume authority over public roads and that the legislature could administer these roads through its designated agencies.

Following the ruling, the 1925 39th Legislature immediately passed the necessary laws to bring Texas into compliance with the 1921 Federal Aid Amendment. The 1925 State Highway Act gave the THD total control over state highway construction and maintenance. This control resulted in increased application of design and review standards that directly impacted the condition and quality of existing and proposed state highways and bridges. However, it did not completely exclude counties from participation in highway road matters. The inadequacy of state funding and the increased statewide demand for roads meant that Texas would have to continue to accept county assistance until 1932.

After the 1925 State Highway Act, the THD's funding mechanisms and project types dramatically changed. The department seized upon increased funding opportunities in the late 1920s and early 1930s, increasing the size of the agency to include 25 district offices by 1932 (see Table 1 showing THD expenditures during this period). However, in 1926 and 1927, the department was embroiled in a misappropriation of funds scandal that slowed some projects. The Texas Highway Commission neglected needed maintenance on highways in the state and instead redirected funds to highways whose condition did not indicate a need for maintenance work. Consequently, the BPR was reluctant to provide federal funds for new road construction when the state was not maintaining its existing roads. The BPR suspended federal aid funds to Texas in January 1927. After a series of meetings internally with the Texas Highway Commission and THD and externally with the BPR, federal funds were reinstated in April 1927.

---

[132] Howard Lawrence Preston, *Dirt Roads to Dixie*: *Accessibility and modernization in the south, 1885-1935* (Knoxville: University of Tennessee Press, 1991), 130 and 132.

Following the funding scandal and temporary loss of federal funds, the THD and the Texas Highway Commission underwent massive changes beginning in 1927.[133] Newly elected Governor Dan Moody appointed a new Texas Highway Commission in 1927, which moved quickly to normalize THD operations. In 1927 and 1928, the commission cleansed the THD and reorganized the department to take on increased construction and maintenance responsibilities. The majority of the administrative officials were replaced and Gibb Gilchrist was appointed as the new state highway engineer. Additionally, the 1927 40th Legislature authorized an increase in the gasoline tax to boost the department's almost depleted highway fund, raising the tax from one to three cents for a six-month period from March 1927 to September 1927, after which time the tax was fixed at a rate of two cents per gallon.

Recognizing that a complete system of highways would require an aggressive program to improve the state's bridges and culverts, the new highway commission established the separate Bridge Division in 1928 to oversee the state's bridge program. Bridge engineers were paying special attention to traffic and safety factors, and designing bridges with straighter roadway alignments and greater roadway widths and bridge loading capacities. In order to accommodate pedestrian concerns, the THD also began installing sidewalks on bridges located in or near communities.[134]

With the increase in agency responsibilities and establishment of additional districts (still known as divisions at the time), the THD also began a spate of building construction in the late 1920s. Prior to the late 1920s, the THD headquarters had been located in the second floor of the State Office Building in Austin. In 1931, the THD received authorization to begin work on a new State Highway Building on the southwest corner of Eleventh and Brazos Streets in Austin. The nine-story Art Deco building was completed in 1933 (and listed in the National Register in 1998).[135] Until Gibb Gilchrist's administration as State Highway Engineer, districts (then still known as divisions) used rooms in a county courthouse or rented commercial building for offices, with warehouses located off-site. Beginning in 1929, the THD began a concerted program to build "office plants" for all 25 divisions. Each plant included a dedicated office building, warehouse, various shop buildings, and yard space. The first division office was built in late 1929 in Tyler, and the process continued for several years. The last office for this building effort was completed in San Angelo in 1936. At the same time, the THD also began a process of building warehouses for resident engineers, county section foremen, and maintenance equipment. By the late 1930s, the department had built 222 warehouses of this type. [136]

*Professional Design Standards and THD Projects*

The Texas Highway Commission began to plan and prioritize highway improvements, giving preference to projects that would "fill in the gaps" on the designated state highway system. Resident THD engineers assumed the project planning responsibilities previously conducted by county engineers. The commission also set up a stringent bidding process that awarded highway contracts to the lowest responsible bidder. Even though the state authorized additional funding opportunities, state highway construction costs were still mostly funded by the state, with the

---

[133] Huddleston, 82-83.
[134] Gilchrist, 75-95.
[135] 1918 State Office Building and 1933 State Highway Building, National Register nomination, 1998, National Register of Historic Places database search, http://nrhp.focus.nps.gov/natreghome.do?searchtype=natreghome (accessed September 19, 2012)
[136] Gilchrist, 200-205; "Golden Anniversary, Texas Highway Department, 1917-1967." *Texas Highways* 14, no. 9 (September 1967): 22-24, 32, 48.

county contributing anywhere between a quarter to a third of the cost, and federal allocations usually remaining less than a third of the total cost.[137]

By 1928, Texas had approximately 18,000 miles of state highways.[138] With the THD's control over highway projects, the use of standardized plans, and more equal distribution of projects across the state, additions to the state road network and improvements to existing roads were occurring at an increasing rate in the previously underserved areas of the south, west, and panhandle portions of the state.

Additionally, the THD undertook revisions to highway design and construction standards. Unlike the first decade of the THD in which the agency focused mostly on highway designation and construction, the late 1920s and early 1930s showed vast road design improvements (see Figure 24 for a typical highway in 1937). The revised design standards included straightening alignment and curvature, reducing grade, and utilizing shallow ditches and flat slopes.[139]

With the increased speed on roads and increase in automobile traffic (estimated at one million autos in the state in 1929),[140] the right-of-way was increased on all roads to a minimum of 80 feet in 1926. By 1930, the minimum was increased to 100 feet on "lesser important Highways" and 120 feet on "main traffic arteries." Right-of-way maps were also first developed in 1929 and were required for any project to be constructed. [141]

Until the late 1930s, the THD continued to use the unit, or stage, construction approach to implement road designs (see Figure 25). Under this design method, projects were broken into two or more distinct units of improvements. The first unit would typically include clearing the right-of-way, grading, and construction of adequate drainage structures, and could also involve placement of subgrade base and application of a light bituminous treatment to protect the riding surface. After a period between several months up to a few years, a second unit would typically add gravel base materials and a more permanent paved surface to the roadway. The unit construction method was thought by THD engineers to satisfy both design and cost efficiency considerations. The vehicular traffic and natural weathering on the earthen road or initial base course provided compaction of roadway material at no cost, and the agency was able to quickly expand the state highway system by constructing at least minimal improvements in Unit I construction.[142]

In 1927 the Texas Highway Commission also initiated a series of feasibility studies on interstate bridge construction across the Oklahoma and Louisiana boundaries. The THD's first three interstate highway bridges, none of which remain in place, were completed jointly with Oklahoma by 1931 (see Figure 26). A bridge on SH 3 between Orange, Texas, and St. Charles, Louisiana, across the Sabine River followed the next year but is no longer extant.

At the end of the 1920s, the Texas Highway Commission and THD also focused on a new aspect of highway projects: designed landscapes and increased aesthetics in design. In 1927, commercial and political advertisements

---

[137] State Highway Department of Texas, Sixth Biennial Report, 74; Seventh Biennial Report, 222-224; Eighth Biennial Report, 113-116.
[138] State Highway Department of Texas, *Eighth Biennial Report*, 11.
[139] Gilchrist, 43.
[140] Huddleston, 120.
[141] Gilchrist, 30 and 47.
[142] Gilchrist, 44.

were removed from rights-of-way.[143] A priority was placed on providing bridge designs that blended with the natural environment. Special efforts were made to provide architectural treatment for bridges that were readily visible to the public.[144] In 1929, the THD began concerted efforts to protect and preserve existing trees, as well as plant new trees, during construction projects. These efforts were championed at the highest levels of the agency, by State Highway Engineer Gibb Gilchrist and State Highway Commissioner Walter Ely.[145] Set standards and designs were not official until the creation of the Landscape Division in 1933, but the beginnings of aesthetically pleasing road and bridge designs were occurring.

By the beginning of 1929, the THD oversaw approximately 19,000 miles of state highways with 25 district offices in place by 1932. The design, construction, and maintenance of these highways in Texas had shifted. What began in the late 1910s and early 1920s as a disjointed collection of rural, county-maintained roads and poorly designed and maintained state routes became a professionally designed and constructed system of state highways traversing the entire state by the close of the 1920s, also including establishment of new design standards for bridges and culverts

***Texas Roads in the Great Depression and World War II***

By the early 1930s the THD, under the leadership of State Highway Engineer Gibb Gilchrist, had largely developed its primary trunk system (see Figure 27), assumed responsibility for construction and maintenance on the state highway system, and steadied the overall administrative and organizational direction of the agency. However, even as the THD was gaining organizational stability and professionalism, the agency faced stark challenges with the coming of the Great Depression. County and municipal governments also dealt with financial difficulties and increased needs. While the Depression years were often marked by hardship and thrift, they also represented a time of change and improvement for Texas road development. The period was marked by increased federal road funding and establishment of a host of federal work-relief agencies, redirecting highway spending and ushering in greater direction on the part of federal policymakers and road officials. At the same time, Texas also benefited from a number of state programs designed to boost pride and beautify the roadside while also helping revive the state's economy.

The U.S. stock market crash of October 1929 marked the outset of the Depression, with continued drops in stock values and frequent bank shutdowns through the early 1930s. While economic downturn arrived more slowly and less severely in Texas than in the industrial states of the northeast U.S., a cotton price bust struck Texas farmers. From 1929 to 1932, the commodity price of this vital cash crop declined from around 17 cents per bale in 1929 to less than five cents per bale in 1932.[146] This drop was particularly devastating, causing widespread unemployment in rural areas of the state. The extended drought that created the Dust Bowl in the Texas Panhandle made farming conditions across the state even worse. Bank closings, depressed oil prices, and rapidly falling agricultural prices all produced a tremendous strain on the Texas economy. These problems were magnified by the state's rapidly growing population, which had reached 5.8 million by 1930. The state had also become increasingly more

[143] Gilchrist, 127 and 130.
[144] State Highway Department of Texas, *Twelfth Annual Report*, 17-19.
[145] HHM, 10.
[146] George Brown Tindall, *The Emergence of the New South, 1913-1945* (Baton Rouge: Louisiana State University Press, 1967), 354-5.

urbanized since the turn of the century. The 1930 census revealed that more than 40 percent of the population of Texas resided in urban areas.[147]

On November 15, 1929, President Herbert Hoover, sometimes called "the Great Engineer" for his advocacy of huge public works projects, summoned his Cabinet secretaries and sent a message to state governors to accelerate their spending on construction projects and make new spending proposals to stop economic decline.[148] Similar requests were made by Hoover to local governments as well.[149] On a national level, federal-aid highway spending increased from $75 million to $125 million yearly for fiscal years 1931, 1932, and 1933, in addition to emergency matching-fund loans provided to the states. Employment on federal-aid road construction increased from 200,000 in March 1931 to 365,000 in June 1931, and to 500,000 in June 1932.[150] Texas fared particularly well under this reoriented federal-aid program. Between 1930 and 1933, regular federal-aid road spending on the Texas state highway system ranged from $6.8 million to $7.6 million annually, a marked increase from the $4.5 million per year spent from 1928 to 1930.[151]

In 1930 and 1932, Congress also passed a series of emergency appropriation measures allocating additional federal aid for state road programs. These measures provided the THD with more than $12.5 million to serve as a "temporary advance" (subsequently made a grant) to help match regular federal aid monies. These grants allowed the THD to continue road projects that would have otherwise been abandoned due to insufficient matching state funds. In a small way, these provisions helped stabilize construction employment in Texas. In January 1933, outgoing Governor Ross Sterling noted that the emergency federal aid allotments had helped the THD "to accomplish even more than usual progress in the midst of the depression, and to give employment to more than the ordinary number of persons."[152] In fact, Texas would hardly have been able to maintain a viable road-building program during the early years of the Depression if the federal government had not stepped in to replace the funds once provided by the financially strapped state and county governments.

The emergency federal-aid program came with special provisions designed to maximize employment. The emergency funding legislation banned convict labor on federally funded projects, which had been common during the early years of southern road construction. It also encouraged use of hand labor where "reasonably economical" and temporarily altered the requirement that all states match federal-aid funds dollar-for-dollar.[153] Later BPR regulations for federal-aid projects set up local employment committees, established a short 30-hour work week, favored veterans with dependents, allocated funds according to labor expended, encouraged "restrictive hand labor methods," and allowed day-labor construction, all to provide "unemployment relief."[154]

---

[147] Dallas Morning News, *Texas Almanac and State Industrial Guide, 1943-1944*, Dallas, 1944, p. 63; Robert A. Calvert and Arnoldo De León, *The History of Texas*, Arlington Heights, Ill.: Harlan Davidson, Inc., 1990, 291-324.
[148] James J. Flink, *The Car Culture* (Cambridge, MA: MIT Press, 1975), 32-41, 155.
[149] Jim Steely, "Public Works of the Depression Era", *Texas Architect*, (May-June, 1986), 100.
[150] Bruce E. Seely, *Building the American Highway System: Engineers as Policy Makers* (Philadelphia: Temple University Press, 1987), 6.
[151] "Federal Aid: Fiscal Years 1928-1944." Unpublished notes. Located in Depression-era Files, Texas Department of Transportation, Environmental Affairs Division.
[152] Quoted from Texas Legislature, *House Journal: Forty-Third Legislature, Regular Session*, Austin, Texas, 1933, 30; Huddleston, 173; Texas State Highway Department, *Texas State Highway Department 1927-1937*, 30-37.
[153] G.G. Edwards, "To All Resident and Division Engineers", Texas Highway Department Administrative Circular, 12 Feb. 1931.
[154] Gibb Gilchrist, "Method of Handling Employment on Emergency Construction Highway Projects", Texas State Highway Department Administrative Circular, 27 Sept. 1932; Gibb Gilchrist, "Contractors' Payrolls on Emergency Construction

At the same time, the Texas Legislature also began to address the state's worsening economic situation, contributing some work-relief highway construction policies of its own. In a series of resolutions and acts, the legislature requested that the THD play a lead role in combatting the effects of the Depression. In 1931, the 42nd Legislature authorized a 30-cent-per-hour minimum wage for labor expended on state and road projects, and passed another act requiring contractors to purchase Texas-manufactured products whenever possible. The legislature also requested the THD to conduct its operations in such a way as to provide the greatest possible opportunity of employment for Texas citizens. It was also suggested that all future road contracts be granted exclusively to Texas contractors (defined as persons building highways in Texas on or before six months prior to April 12, 1932). The Texas Highway Commission adopted all of the recommended resolutions and made them departmental policy. Subsequent legislation in 1933 and 1935 required THD contractors to hire workers at the prevailing wage rates in a locality, to keep records of all workers employed, and to limit the work day to no more than eight hours a day per employee.[155] With federal and state labor-making provisions in place, some THD projects incorporated materials and construction methods that required extensive handwork. For example, a 1931-32 federal-aid project on US 290 in West Texas built 13 concrete-arch culverts with masonry headwalls, dual masonry guard walls, and rubble fill along a spectacular four-mile stretch of mountainous roadway near Ozona and the Pecos River.[156]

Even with these measures, Texas state and local governments could not meet the massive demand for relief. The Texas Legislature cut its budget by one-fourth in 1932 and asked for additional help from the federal government. The growing relief burden, accumulated debt from road construction, and declining tax income forced many county governments into default.[157] With the financial situation deteriorating in many counties, the 1932 Texas Legislature passed House Bill 2, mandating that the state assume all county bonds for highway improvements and eliminating all county contributions for state highway projects with the exception of county right-of-way contributions. The law also set aside one-fourth of the THD's portion of the state's gasoline tax for reimbursement of county indebtedness. The diversion of one-fourth of the gasoline fund financially impaired the state road agency's ability to fund construction or buy new heavy equipment and made even more pressing the need for emergency federal funding.[158] Nonetheless, after this early crisis, dynamic leadership from the Texas governor's mansion and a powerful Texas delegation to the U.S. Congress pushed for federal activity that led to major growth for several areas of state government. World oil prices, which had tumbled following overproduction in the new East Texas

---

Projects", Texas State Highway Department Administrative Circular, 27 Sept. 1932; F.P. Sexton, "Emergency Construction 1933", Texas State Highway Department Administrative Circular, 4 Jan. 1933; G.G. Edwards, "Emergency Federal Aid Projects", Texas State Highway Department Administrative Circular, 12 Jan. 1933; Texas State Highway Department, :N.R.W.R. Projects: Introduction and General Plan", Texas State Highway Department Administrative Circular document 8-35-1050, Sept. 1935, 1. Administrative Circulars available through Texas Department of Transportation, General Services Division, Records Management Section and Texas Department of Transportation Crossroads intranet.

[155] John D. Huddleston, "Good Roads for Texas: A History of the Texas Highway Department, 1917-1947" (Ph.D. dissertation, Texas A&M University, 1981), 146 and 170-74; Texas Legislature, *General Laws of Texas: Forty-Third Legislature, Regular Session*, Austin, Texas, 1933, 91-94; Texas Legislature, *General Laws of Texas: Forty-Fourth Legislature, Regular Session*, Austin, Texas, 1935, 644-45.

[156] Texas State Highway Department, *Plan and Profile of Proposed State Highway, Crockett County, State Highway 27*, Federal Aid Project 619-C, 1931. Plans available through Texas Department of Transportation, General Services Division, Records Management Section and Texas Department of Transportation Crossroads intranet.

[157] James T. Patterson, *The New Deal and the States: Federalism in Transition* (Princeton: Princeton University Press, 1969), ch.2; Works Projects Administration, *Final Report on the WPA Program 1935-43* (Washington, D.C.: U.S. Government Printing Office, 1943), 1-2; Huddleston, 170.

[158] Huddleston, 170-172 and 174-176; Texas State Highway Department, *Texas State Highway Department, 1927-1937*,32-5.

field in the early 1930s, stabilized following the Texas Railroad Commission's proration of production. Petroleum production throughout the state boomed as never before during the rush for "black gold" in the state's oil fields.[159] Nevertheless, the Texas economy, like the rest of the country, failed to recover until the wartime expansion of the 1940s.

After a long political battle in 1932, Hoover signed the Emergency Relief and Construction Act, which created the Reconstruction Finance Corporation (RFC) to lend $300 million to states for bank and business loans. This bill also provided $322 million for federal public works, $5.5 million of which went to Texas.[160] It also provided loans to states to operate relief programs. In Texas, chambers of commerce distributed some of this federal relief in 1932 and early 1933. Then, in March 1933, Texas established the Texas Relief Commission (TRC) to administer money allocated by the RFC to help "destitute unemployed persons."[161] While the RFC had negligible direct impact on Texas road construction, it was notable as the earliest of the Depression-era federal relief agencies, representing a major expansion of federal involvement in combatting unemployment.

*Programs of the "First New Deal"*

Following his March 1933 inauguration, President Franklin Roosevelt quickly instituted the first of his New Deal programs and policies, intended to stabilize the nation's economy and increase employment through greater federal spending. Texas became a major recipient of relief funding from the federal government during this era, and it nearly led the nation in several areas of New Deal work-relief spending. Texas clearly benefited from Roosevelt's early decision to support massive road construction as a "convenient and noncontroversial way to provide jobs for the unemployed and stimulate the economy."[162] Road development, in Texas and elsewhere in the U.S., was spurred through a host of new federal agencies that directly constructed or funded public works projects. In addition, "national recovery" legislation greatly increased federal funding for road construction and maintenance beyond the usual federal-aid program. In Texas, the federal dollars helped to replace monies previously contributed by counties towards road construction, and represented an increased proportion of overall highway construction funding in the 1930s (see Table 2). By the late 1930s and early 1940s, the state's proportion of funding rebounded as the economy stabilized and federal relief spending declined.

---

[159] Richard Lowitt, *The New Deal and the West* (Bloomington: Indiana University Press, 1984), ch. 7; "Oil and Gas Industry", *The Handbook of Texas Online* http://www.tshaonline.org/handbook/online/articles/doogz.
[160] William J. Barber, From New Era to New Deal: Herbert Hoover, the Economists, and American Economic Policy, 1921-1933 (New York: Cambridge University Press, 1985), 80-82, 147-155, 178-179, 184; Lester V. Chandler, America's Greatest Depression, 1929-1941 (New York: Harper & Row, 1970), 32, 50-51; Tindall, 373-374.
[161] Texas Relief Commission, *Guide for Administering of and Accounting for Relief Funds* (Austin: Texas Relief Commission, 21 March 1933), section III; Texas Relief Commission agency history summary, Relief Commission Division, Texas State Board of Control records. Archives and Information Services Division, Texas State Library and Archives Commission. Summary available at <http://www.lib.utexas.edu/taro/tslac/20172/tsl-20172.html#series9>.
[162] James J. Flink, *The Car Culture* (Cambridge, MA: MIT Press, 1975), 175, 187.

**Table 2. Funding By Source, 1928-1945 (as a percentage of total funds)**

| Fiscal Year | Federal Funds | State Funds | County Funds | Other Funds |
|---|---|---|---|---|
| 1928* | 33% | 32% | 35% | not reported |
| 1929* | 30% | 34% | 36% | not reported |
| 1930* | 18% | 48% | 34% | not reported |
| 1931* | 29% | 38% | 33% | not reported |
| 1932* | 27% | 44% | 29% | not reported |
| 1933* | 47% | 47% | 6% | not reported |
| 1934* | 69% | 31% | 0% | not reported |
| 1935* | 56% | 44% | 0% | not reported |
| 1936* | 64% | 36% | 0% | not reported |
| 1937* | 54% | 44% | 2% | not reported |
| 1938** | 38% | 58% | 0% | 4% |
| 1939** | 36% | 59% | 0% | 5% |
| 1940** | 38% | 52% | 2% | 8% |
| 1941** | 30% | 60% | 2% | 8% |
| 1942** | 33% | 57% | 5% | 6% |
| 1943** | 36% | 51% | 5% | 9% |
| 1944** | 29% | 67% | 1% | 3% |
| 1945** | 28% | 69% | 2% | 1% |

** Figures from fiscal years 1928 to 1937 are based on actual payouts on construction projects during each year.*

*** Figures from fiscal years 1938 to 1945 are based on cost of construction projects completed during each year.*

*Source: Gibb Gilchrist, Texas Highway Department 1927-1937, p. 168; Texas Highway Department, Biennial Reports, September 1, 1936 to August 31, 1946.*

### *Federal Emergency Relief Administration (1933-1935)*

Created by the Federal Emergency Relief Act of May 12, 1933, the Federal Emergency Relief Administration (FERA) acted as the first comprehensive attempt to provide unemployment relief through large federal grants rather than state loans. During its fairly brief operation, FERA spent over $3 billion to provide relief for 20 million Americans, 16 percent of the U.S. population at the time.[163] In addition to providing direct relief payments, FERA funded a variety of public works. For roadway projects, the agency paid up to 70 percent of roadway project cost for labor, transport, and materials. Nationwide, FERA spent a total of $1.3 billion for work programs, including $1 billion of federal funds, to employ up to 2.5 million workers at one time. Out of this, $353 million went for highway, road, and street construction, and $148 million went for rural roads alone. In Texas, FERA spent $36 million on public works, including $23 million of federal funds. Of this, $12 million ($7 million of federal funds) was spent for roadway construction. FERA road projects in Texas were mostly focused on county and local road systems. THD records suggest that FERA involvement with state road projects was limited to providing funds for labor on some drought and flood relief projects in 1934 and early 1935.[164]

---

[163] Work Projects Administration (WPA), *Final Statistical Report of the Federal Emergency Relief Administration* (Washington, D.C.: U.S. Government Printing Office, 1942), iii, 2, 5-7, 53, 58, 165.
[164] Gilchrist, *Texas Highway Department 1927-1937*, 33-35, 65-67; State Highway Department of Texas, *Ninth Biennial Report*, 5; State Highway Department of Texas, *Tenth Biennial Report*, 9, 44-45.

In a typical Texas county, a local sponsor applied to either a local relief office or the TRC for funds to hire available laborers for a small public improvement project. These projects were then placed into a larger block request to the federal FERA administrator. Typical road projects were repair or replacement of drainage structures or surfacing a stretch of county road. FERA and other work relief programs quickly approved far more projects than they could possibly man in order to maximize available labor; as a consequence, many approved projects were never completed, and some projects did nothing more than simple touch-up work on a stretch of road.[165] FERA projects improved 274,000 total miles of roadway across the U.S., including improvement of 30,000 miles of paved roadway, before the Works Progress Administration (WPA) replaced FERA in late 1935. FERA roadwork was substantial in its own right and served as a stepping stone to grander work-relief programs.[166]

*Civil Works Administration (1933-34)*

While waiting for other relief programs to get underway, the Roosevelt administration issued a November 9, 1933, executive order to create the Civil Works Administration (CWA). The agency was designed as a simpler program that could rapidly mobilize millions of unemployed workers and bolster existing relief programs during the 1933-34 winter, the season of highest unemployment. During its five months of operation, the CWA spent over $950 million ($860 million of federal money, with the remainder state matching funds) to employ up to 4.3 million workers at one time. Of this money, 75 percent went to labor, and the largest proportion of CWA spending (33.8 percent) paid for the construction, improvement, and repair of 255,000 miles of highways, roads, and streets.[167] CWA work projects were managed much like FERA projects. In fact, while the CWA operated, FERA almost completely shut down its work programs and contributed substantial funds and personnel to the CWA.[168] Similar to FERA, CWA road projects in Texas were almost exclusively sponsored by counties or municipalities rather than the THD, with the exception of a few drought and flood relief projects during the winter of 1933-34.[169]

Together, FERA and the CWA employed far more workers than any other Depression-era program. Yet their roadway projects are rather difficult to identify since they were often small in scale, sometimes ephemeral in nature, and usually poorly documented. Nonetheless, they likely played an integral role in improvements to county road systems in Texas during the Depression

*National Industrial Recovery Act (1933-40)*

The National Industrial Recovery Act (NIRA), enacted on May 15, 1933, created a series of federal agencies to regulate and stimulate the national economy. In addition, under Section 204 of the act, the BPR replaced its regular

---

[165] Work Projects Administration, *Final Report on the WPA Program 1935-43* (Washington, D.C.: U.S. Government Printing Office, 1943), 4, 5.
[166] WPA, Final Statistical Report of the Federal Emergency Relief Administration [FERA], iii, 2, 5-7, 53, 58; WPA, Final Report on the WPA Program, 2, 3.; James T. Patterson, The New Deal and the States: Federalism in Transition (Princeton, N.J.: Princeton University Press, 1969), 52, 73.
[167] WPA, *Final Report on the WPA Program*, 3-5; Bonnie Fox Schwartz, The *Civil Works Administration, 1933-1934: The Business of Emergency Employment in the New Deal* (Princeton, N.J.: Princeton University Press, 1984), vii-x, Chandler, 199-202.
[168] WPA, Final Statistical Report of the FERA, 8-9.
[169] Gilchrist, *Texas Highway Department 1927-1937*, 33-35, 65-67; State Highway Department of Texas, *Ninth Biennial Report*, 5; State Highway Department of Texas, *Tenth Biennial Report*, 9, 44-45.

federal-aid program in Texas with an expanded National Recovery highway program. During the 1933-34 fiscal year, the National Recovery highway program brought federal funding as a proportion of total highway spending to its greatest peak since the THD's 1917 establishment (see Table 1). As part of NIRA, the THD established the National Recovery Work Relief (NRWR) program to aid sufferers of flood and drought. Randall and Potter counties received the first THD-administered NRWR projects in September 1933, and 242 Texas counties were eventually declared eligible for NRWR or Emergency Relief Program (ERP) bridge funds (the exceptions being some Gulf Coast counties: Brazoria, Chambers, Galveston, Jefferson, Kenedy, and Kleberg).[170] Over the next four fiscal years, these programs spent almost $33 million on the Texas state highway system without requiring state or local matching funds.

NIRA extended the federal government's role in Texas highway construction in other ways. NIRA provided the first federal grants for urban highway and rural secondary road construction. An important provision in the act authorized federal aid for highway routes located in incorporated towns, which was the first time federal-aid spending was allowed in these areas. Since only 50 percent of National Recovery highway funds could benefit state or U.S. highways on the federal-aid system, at least 25 percent was allocated to extend funding to federal-aid highways through municipalities, and up to 25 percent was allowed for other state and county roads not on the primary federal-aid system. This provision allowed the THD to initiate a number of important bridge projects in urban areas (see Figure 28). This trend continued with the 1934 federal Emergency Appropriation Act, which extended the National Recovery highway funding program. It retained the requirement for funding of federal-aid highways through municipalities and strengthened the funding commitment to secondary roads, mandating allocation of a minimum of 25 percent for state highways or county roads that were not on the federal-aid system. The Emergency Appropriation Act granted $12 million to Texas, more than any other state, out of $195 million apportioned for roads nationwide.[171]

In order to meet the act's intent regarding employment generation, the BPR instituted various labor-related stipulations for NIRA-funded projects. These stipulations required THD contractors to hire laborers from local unemployment lists, to follow strict guidelines regarding wages and hours of work for day laborers and to use hand labor construction methods during construction. For bridge work, the hand labor provisions applied to the painting of structural steel, the erection of form work, the use of boring holes in piles and forms, and various other aspects of bridge construction.[172] Under NIRA, the BPR also allowed highway departments to administer force-account labor instead of working through contractors, and it sometimes allowed work to proceed without detailed plans as long as an engineer was in charge.[173]

The THD administered 534 National Recovery projects, including a number of large bridge projects. While National Recovery funds were initially appropriated between 1933 and 1935, the THD was financing projects with

---

[170] Gilchrist, Texas Highway Department, 1927-1937, 65-66.
[171] Gilchrist, Texas Highway Department, 1927-1937, 65-66.
[172] The Statutes at Large of the United States of America from March 1933 to June 1934 (Washington, D.C., U.S. Government Printing Office, 1934), 195-211.
[173] T.J. Kelly, "Required Special Provisions for National Recovery Project Approved by the Acting Chief, Bureau of Public Roads, September 27th, 1933," To All Division and District Resident Engineers, July 19, 1933, Texas Highway Department Administrative Circular; T.J. Kelly, "Important Notice to All Contractors, Materialmen, Bondsmen, and Division Engineers, October 5, 1933, Texas Highway Department Administrative Circular.

the funds as late as 1940.[174] Two important National Recovery projects included the SH 34 Bridge at the Trinity River over the Ellis and Kaufman county line, completed in 1934 (no longer extant), and the Red River bridge on SH 78 north of Bonham, completed in 1938 (NRHP 1996, TxDOT Structure No. 01-075-0-0279-02-024).[175]

*Public Works Administration (1933-39)*

Section 202 of NIRA established the Public Works Administration (PWA) to fund or assist the construction of large-scale public works.[176] Federal PWA funds were matched by state or local monies. Projects funded under this program were subject to almost identical labor provisions as Section 204 projects, as discussed above.[177] By April 1935, the PWA had allocated $2.56 billion nationally for some 19,000 construction projects to employ over two million workers, and $600 million went directly to roadway construction.[178] Yet implementation of many PWA projects was delayed markedly by the complex process for technical planning and administrative approval.
On the Texas highway system, the PWA helped to fund the construction of the $2.7 million Port Arthur-Orange Bridge, now commonly known as the Rainbow Bridge (NRHP 1996, TxDOT Structure No. 20-124-0-0306-03-015), a massive cantilever and continuous steel truss over the Neches River. The PWA also spent $675,000 for construction of a new 2.5-mile-long Galveston Island causeway (no longer extant) to parallel the existing congested two-lane structure.[179]

In some cases, PWA funding was used in conjunction with other relief programs to fully fund road projects. During the 1934 fiscal year, the PWA granted $2.7 million for supervision and equipment on the THD's NRWR road projects. These funds could pay up to 30 percent of individual project cost and were balanced by a 70 percent per-project payment for labor provided by the FERA, CWA, or WPA. This original allocation, however, took over four years to spend because projects were often discontinued when the TRC failed to assign sufficient day labor.

*Additional Relief Funding (1934-35)*

The Hayden-Cartwright Act of 1934 extended NIRA and gave Texas another $12 million in emergency grants. Section 3 of the act also set aside federal monies for emergency construction and repair work for bridges "which have been damaged or destroyed by floods, hurricanes, earthquakes or landslides." While the special labor provisions of NIRA pertained to projects funded under the NIRA extension program, they did not apply to emergency construction work authorized under Section 3 of the act. Severe flooding in 1935 and 1936 made the THD eligible to receive funding under the emergency provisions of the Hayden-Cartwright Act. The THD received emergency funding to construct and repair a number of important bridges, including the Llano River bridge on US 87 (former SH 9) near Mason, constructed in 1936 (NRHP 1996, TxDOT Structure No. 14-157-0-0071-04-018),

---

[174] From "Federal Aid: Fiscal Years 1928-1944." Unpublished notes. Located in Depression-era Files, Texas Department of Transportation, Environmental Affairs Division, Austin, Texas.
[175] Historic Bridge Files, Texas Department of Transportation, Environmental Affairs Division.
[176] T.H. Watkins, *The Great Depression: America in the 1930s* (Boston: Little, Brown, 1993), 142 and 148.
[177] The Statutes at Large of the United States of America from March 1933 to June 1934 (Washington, D.C., U.S. Government Printing Office, 1934), 195-211.
[178] Harold L. Ickes, *Back to Work: The Story of PWA* (New York: Macmillan, 1935), 149, 256.
[179] Ickes, 82-83, 91; Bruce Boone, "Traffic Unshackled: Galveston's New Causeway Is Mighty Monument to Engineering Achievement," *Texas Parade* January 1939, 4-5, 24.

and the US 190 Bridge over the Colorado River at the Lampasas-San Saba county line, completed in 1940 (NRHP 1996, TxDOT Structure No. 23-141-0-0272-05-023).[180]

The federal Emergency Relief Appropriation Act of 1935 gave Texas $11 million for state highway construction and $12 million for grade separation projects. Similar to the NIRA provisions, ERA monies did not need to be matched with state funds. In order to get these projects under way in time to provide employment during the winter of 1937, all project plans had to be approved by July 1, 1936. This act included labor stipulations that were almost identical to NIRA. Numerous THD bridge projects were funded by this program, including the Burr's Ferry Bridge on SH 63 across the Sabine River at the Texas and Louisiana state line (NRHP 1996, TxDOT Structure No. 20-176-0-0214-04-005).[181]

While federal relief programs and enhanced funding greatly increased THD funding levels during the Depression, agency officials still tried to conserve resources as much as possible in an effort to maximize the effect of federal relief funds and to provide as much employment as possible. THD records of the 1930s evidence that THD bridge engineers often salvaged old trusses and reused them at locations with lesser traffic requirements. In an effort to conserve resources, bridge engineers also relied heavily on available materials, such as stone and timber, for bridge construction during this period.[182]

*Civilian Conservation Corps (1933-42)*

In an attempt to bring employment to unskilled and uneducated young persons, Roosevelt issued an executive order on April 5, 1933, to establish the Civilian Conservation Corps (CCC) to employ unmarried, physically fit male youth aged 18 to 25 years from families on relief. This wildly popular New Deal agency fell under the unwieldy jurisdiction of the U.S. Forest Service, Soil Conservation Service, and NPS, although the U.S. Army organized the operation of individual group camps. At its peak around 1935, the CCC employed over half-a-million young men nationally, and 2.5 million went through this program before it shut down in 1942. In Texas, the TRC and then the Department of Public Welfare directed the selection of enrollees and first instituted what became a national policy that officially segregated blacks from regular CCC camps. In 1935, Texas had up to 31,935 CCC enrollees, trailing only Pennsylvania in number of enrolled youth. Ninety-seven companies (most with 200 men each) worked throughout the state in that year, and local newspapers faithfully followed their exploits.[183]

Besides providing employment, education, and work experience for underprivileged youth, the CCC operated projects for erosion control, reforestation and timber management, fire control, range rehabilitation, wildlife habitat

---

[180] The Statutes at Large of the United States of America from March 1933 to June 1934 (Washington, D.C., U.S. Government Printing Office, 1934), 993-996.
[181] State Highway Department of Texas, *Tenth Biennial Report*, 9-11; Historic Bridge Files, Texas Department of Transportation, Environmental Affairs Division, Austin.
[182] Historic Bridge Files, Texas Department of Transportation, Environmental Affairs Division, Austin.
[183] Chandler, 202-203; John A. Salmond, *The Civilian Conservation Corps, 1933-1942: A New Deal Case Study* (Durham, N.C.: Duke University Press, 1967), ch. 1 and 6; Kenneth E. Henderson, Jr. "The Civilian Conservation Corps in the Southwestern States," in *The Depression in the Southwest*, ed. Donald W. Whisenhunt (Port Washington, N.Y.: Kennikat Press, 1980), 3-8, 17-21; William J. Brophy, "Black Texans and the New Deal," in *The Depression in the Southwest*, p. 121; Works Progress Administration, *Report on the Works Program* (Washington, D.C.: U.S. Government Printing Office, 16 March 1936), 85-87; James Wright Steely with Joseph Monticone, *The Civilian Conservation Corps in Texas State Parks* (n.p.: Texas Parks and Wildlife Department, 1986), 7.

reconstruction, flood control, and historic site preservation and restoration.[184] Even more popular were the facilities it built for outdoor recreation and nature tourism. In national parks, national forests, and state parks, the CCC built hundreds of fine buildings, winter sports facilities, swimming areas, and uncounted miles of trails. In Texas, the CCC suddenly gave the struggling Texas State Parks Board and its leader, D. E. Colp, the power and means to select, design, and plan a host of CCC projects under the supervision of the NPS. Besides developing what became Big Bend National Park, the CCC built 56 parks in Texas, 31 of which make up the core of today's Texas State Park system. CCC refectories, cabins, pools, and shelters in these parks display some of the finest rustic masonry architecture in the U.S.[185]

Road construction was central to park development policy during this era. The spate of spending for this purpose, in fact, began with a $13 million appropriation in 1931, and the NPS spent most of the $220 million it received between 1933 and 1940 on "massive" road improvement projects. The policy to build "one well-built, low-speed, scenic through road per park" dates from this period.[186] The CCC contributed substantively to this trend. In Texas, the CCC built long scenic drives in Bastrop, Buescher, Lake Brownwood, Garner, and Big Spring state parks, and it built roads in other existing parks, including a stretch over the 6,000-foot Green Gulch divide in Big Bend. These roads were meticulously built by hand to follow the contours of a picturesque landscape and usually incorporated a diverse set of hand-built, stone masonry drainage structures to match the rustic styling of other park buildings.[187] The 17-mile Bastrop-to-Buescher road today, for example, incorporates 35 masonry culverts, two masonry diversion dikes, and two monumental stone gates, as it winds among the "Lost Pines of Texas."[188] Bastrop State Park is now a National Historic Landmark, and intact CCC-associated resources in the park are contributing resources to the historic property.

Outside the confines of state and national parks, the CCC was not involved in road construction or improvements on the Texas state or county road systems. While the state and national park roads and their associated structures represent the aesthetic and recreational values, development philosophy, and attention to labor-intensive handwork typical of Depression-era work-relief road construction, their significance is best understood and evaluated within the context of state and national park development in Texas, rather than road system development.

*Programs of the "Second New Deal"*

In the mid-1930s, the U.S. Supreme Court found many of the Roosevelt administration's anti-Depression tactics to be unconstitutional extensions of federal government power. In 1935 it declared many parts of NIRA to be illegal. This led to a reorganization of federal work relief, which affected Depression-era road construction in several ways. The National Recovery highway program shut down, although projects continued to operate using allocated funds until 1940. In its stead, the U.S. Congress brought back the federal-aid highway program, initially funded at pre-Depression levels. The federal government also stopped making direct grants to states and localities for relief

---

[184] Salmond, ch. 7.
[185] Steely, 2-17; Phoebe Cutler, *The Public Landscape of the New Deal* (New Haven: Yale University Press, 1985), 67-69, 99, 101.
[186] James J. Flink, *The Automobile Age* (Cambridge, MA: MIT Press, 1988), 171-182.
[187] Steely, 14, 15.
[188] Gregory T. Cushman, "Depression-Era, Work-Relief Road Projects in Bastrop County, Texas," Texas Department of Transportation, Environmental Affairs Division, Cultural Resources Management Section, Report to the Texas Historical Commission (Aug. 1996), 6-13; Depression-Era Inventory Files, housed at Texas Department of Transportation, Environmental Affairs Division, Austin.

payments when it dissolved FERA on July 1, 1935. Meanwhile, state highway spending gradually crept back towards pre-Depression levels, as automobile ownership and gas tax revenue increased rapidly during the late 1930s. As the Roosevelt administration organized the "Second" New Deal to replace these programs, it established the most comprehensive program of the Depression Era to provide unemployment relief through public work projects: the Works Progress Administration (WPA).[189]

*Works Progress Administration / Work Projects Administration – 1935-1943*

The April 8, 1935, Emergency Relief Appropriation Act granted an unprecedented $4.88 billion for the works program, and Executive Order 7034 issued on May 6, 1935, created an entirely new work-relief organization intended to meld the duties and procedures tested by the CCC, FERA, PWA, and CWA.[190] In its scope, longevity, and effect on Texas and the nation, the WPA should be viewed as the most influential New Deal program in terms of work-relief road construction and improvement.

During the WPA's early years of operation, project proposals were submitted by local government sponsors for review and approval, with proposals progressing through one of 20 district WPA offices in Texas, the state WPA office in San Antonio, and WPA headquarters in Washington, D.C., prior to approval.[191] Texas benefited immediately from the vast array of projects supported by the WPA.[192] During the first year of WPA operation, Texas only trailed five states in number of projects.[193]

Work on roads, streets, and highways immediately became the single most significant part of WPA activity. During its first months of operation, 32 percent of total projects and 40 percent of total spending met the "constant pressure from the public for construction of roads," as local officials jumped at the opportunity to build roads with federal money.[194] Nationwide, the WPA built 572,353 miles of rural roads and highways, 67,141 miles of urban streets, and 11,593 miles of park and other roads, and improved landscaping along 58,209 miles of roadside.[195]

In Texas, the WPA did road work on all classes of roadways, from major state and U.S. highways to county lateral roads and urban streets. It built 31,836 miles of new and improved roadway, 7,686 new and improved bridges and viaducts, and 34,431 new and improved culverts, and also installed sidewalks, curbs, gutters, guardrails and guardwalls, street lighting, and traffic signs; painted traffic control lines; landscaped roadsides; removed railroad track; and eliminated hundreds of dangerous railroad grade crossings. The WPA only built more road miles in three states, more bridges in four states, and more culverts in 11 states than it did in Texas. WPA projects accounted for $401.1 million of spending in Texas, of which $286.9 million were federal funds, with the remainder representing local-sponsor matching funds. Only eight states spent more than the $159.6 million that Texas spent on WPA road projects. Many other states, however, also viewed WPA dollars as a bonanza to improve their road

---

[189] See Arthur Schlesinger, *The Age of Roosevelt: The Politics of Upheaval* (Boston: Houghton Mifflin, 1960), part II.
[190] Works Progress Administration, *Report on the Works Program* (Washington, D.C.: U.S. Government Printing Office, 16 March 1936), 2, 25.
[191] Works Progress Administration, *Report on the Works Program* (Washington, D.C.: U.S. Government Printing Office, 16 March 1936), 17, 26; Works Projects Administration, *Final Report on the WPA Program 1935-43* (Washington, D.C.: U.S. Government Printing Office, 1943), 7-15.
[192] Works Projects Administration, *Final Report on the WPA Program 1935-43*, 47-71.
[193] Works Projects Administration, Final Report on the WPA Program 1935-43, 36
[194] Works Progress Administration, *Report on the Works Program*, 26.
[195] Works Projects Administration, *Final Report on the WPA Program 1935-43*, 131.

systems: 20 states spent a greater percentage of their WPA funding on road construction than Texas's 39.8 percent.[196]

Depression-era road policy in general, and the WPA in particular, gave the THD an opportunity to expand its authority over urban and rural Texas roads both outside and inside the existing state system. As noted earlier, the THD gained administrative control over primary highways in Texas in the 1920s, and in 1932 it took on the county burden for state highway construction, as the state assumed county road indebtedness.[197] Since many towns and small communities had lost the ability to afford road maintenance, in 1937 the THD took over maintenance of state-system highways in all rural towns with a population under 2,500. Previously, these small towns were responsible for maintenance of state highways within their limits. The THD also assumed maintenance responsibility for some municipal roads in areas where little development had occurred along the roadway.[198]
The Roosevelt administration reorganized the WPA as the U.S. economy improved. In 1937, it cut the national WPA workforce by half and decreased the number of Texas WPA districts from 20 to 12. In this climate, the THD organized a takeover of much of WPA funding for Texas road construction. After 1938, the THD directly received and approved district road construction proposals or made a complete plan itself before making a statewide proposal to the WPA. In effect, the THD took over administration of rural-road construction during the last years of the Depression as a transition to designation and construction of a state Farm to Market (FM) road system after World War II.[199] This trend represented a major centralization of road construction and maintenance authority in rural Texas. Texas counties never regained their former importance in the Texas road network, and only recovered some of their ability to fund the state highway system during the economic upturn of the 1940s and 1950s. As a result, the Texas road system came closer to THD state highway engineer Gibb Gilchrist's ideal, where a "line of authority and line of instruction" extended "through *one person*, an engineer, located at the central [state] office…Any other policy must result in chaos," [his italics].[200]

*Projects and Construction*

To maximize the use of labor, WPA road projects usually involved extensive hand workmanship using local materials. One manifestation of this emphasis on labor-intensive handcraft was the use of stone masonry to construct or decorate roadway structures, such as bridges, culverts, drainage channels, and guardwalls (see Figure 29). Nationally, the WPA used masonry construction to build 15,754 of 77,965 new bridges and viaducts and 4,689 of 46,046 reconstructed or improved bridges and viaducts.[201]

In a particularly large and noteworthy (but not atypical) example, the THD sponsored a WPA project to construct and improve 27.75 miles of SH 16 and SH 254 in Palo Pinto County below Possum Kingdom Dam west of Fort Worth. This force-account labor project employed 317 federal and five local-sponsor workers (approximately 250 unskilled, 41 semi-skilled, eight skilled stone masons, 13 other skilled workers, and 12 superintendents) for 497,071 man-hours between September 16, 1940, and October 28, 1942, for a total labor cost of $181,065 and total project cost of $311,089. These workers excavated almost 100,000 cubic yards of earth, applied 75,000 cubic yards

[196] Works Projects Administration, *Final Report on the WPA Program 1935-43*, 124, 126-127, 131, 155.
[197] Seely, 72; Gilchrist, Texas Highway Department, 1927-1937, 3, 176.
[198] T.H. Webb, "Circular Letter: National Recovery Municipal Projects," To All Division Engineers, September 28, 1937, Texas Highway Department Administrative Circular.
[199] Texas Highway Department Administrative Circular.
[200] Gilchrist, Texas Highway Department, 1927-1937, p. 14.
[201] Gilchrist, Texas Highway Department, 1927-1937, p. 131.

of sledged-caliche flexible base, and laid a high-type, all-weather asphalt surface. The project's centerpiece was the construction of the spectacular 433-foot-long, 18-span, Roman-arch Possum Kingdom Bridge over the Brazos River (TxDOT Structure No. 02-182-0-0362-02-003, in vehicular service, see Figure 30). The Possum Kingdom Bridge was one of the few bridges built during the Depression to feature true masonry arch construction and is considered the largest masonry bridge construction project undertaken in Texas. The project also included construction of several culverts and one guard wall, using stone masonry as a primary material. The project used over 5,000 cubic yards of locally obtained limestone and sandstone during a structural steel shortage.[202]

Unfortunately, there are no statistics to count the number of masonry structures built from native stone by the WPA on Texas roads. Yet the frequency with which they were itemized in WPA project inventories and the number of structures which remain on Texas roads makes it logical to conclude that these simple, rustic, labor-intensive structures played a substantial role in efforts to construct an all-weather road system using work-relief labor. WPA road construction represents the final time this traditional construction technique was used to any great extent on public roads in Texas.

As noted previously, while the WPA constructed bridges using stone masonry, other small stone masonry drainage structures were often included in WPA projects, particularly on rural county road improvement projects. These structures included box culverts with masonry abutments and wingwalls, pipe culverts with masonry headwalls, retaining walls, guard walls, lined drainage channels, retards and check dams to slow and direct water runoff, drop inlets to catch and convey water from higher to lower elevation, and tree rings. In some cases, numerous masonry bridges and smaller structures of various types were constructed along a roadway. These small structures are of little importance when viewed individually; however, their significance as a product of work-relief road construction is better conveyed when part of a larger, intact road segment that contains a great number and variety of these resource types.

WPA construction on secondary lateral or "feeder" roads was particularly important to the economy and Iifeways of rural areas. Before the 1930s lateral roads were always the responsibility of local property owners or local governments, even though the original good roads movement had emphasized the construction of FM roads. In Texas these secondary roads, off the state highway system and serving local traffic, remained under the purview of counties and municipalities even after the creation of the THD in 1917 and its administrative expansion in the 1920s. Throughout the U.S., county governments typically funded local road improvements by going into bonded debt, and they rarely planned or maintained them systematically. With the onset of the Depression, most county governments in Texas found themselves in dire financial difficulties and unable to fund local road construction. Consequently, the federal government made FM road construction a major priority of its work-relief programs. Fourteen percent of national WPA expenditures during its first year of operation went to fund 10,000 FM projects, and the 1936 Federal-Aid Highways Act allowed federal-aid funds to fund for the first time a system of secondary highways linking local roads to primary highways.[203]

Texas used the WPA to improve local and county road systems throughout the state, presaging the foundations of its FM road system. The Texas WPA spent more than any other state to construct local "feeder" roads during its

---

[202] National Archives, Works Projects Administration, Texas, Project Folders, Project 16344, Microfilm Roll C-299. Microfilm available at Texas Department of Transportation, Environmental Affairs Division, Austin.
[203] Ellis L. Armstrong, ed. *History of Public Works in the United States, 1776-1976* (Chicago: American Public Works Association, 1976, p. 75; Tindall, 256-257; Seely, 145-146, 159; Huddleston, iii, 222; Works Progress Administration, *Report on the Works Program*, 29; Gilchrist, *Texas Highway Department, 1927-1937*, 31-32.

first years of operation. Forty-six percent of total WPA spending in Texas in 1935 and 1936 went to build these roads, including 9,507 of the first 9,957 miles of WPA road construction in Texas.[204] Although these roads were not made to the "high standards of construction" of regular state highways, they were a huge improvement over the "impassable bogs" that rural travelers encountered on unimproved roads after heavy rains.[205] Lateral road construction regularized transport of farm and ranch produce to market, and it ensured regular access to mail, school, medical service, church, and social gatherings in town, with the intention that isolated farming families would be "better off both socially and economically and their standard of living…more nearly approach that of their brethren on the state highway system.[206]

The scope of the county-sponsored WPA road projects could be immense. As an example, Tarrant County received WPA funding for a county-wide road improvement project that lasted from 1938 to 1940. Through this project, WPA laborers constructed 52 concrete bridges and 987 concrete culverts to replace wooden drainage structures. Project accomplishment reports indicate that most of the structures were also classified as "masonry," likely meaning the bridges and culverts were faced with stone masonry headwalls.[207] More typically, a county-sponsored WPA project would include addition of graded gravel or caliche base to the roadway, sometimes accompanied by construction of proper drainage ditches and drainage structures. Bridges, culverts, and other drainage structures constructed by the WPA, including some featuring stone masonry construction, are still found today on many county roads and a limited number of state-system FM roads.

As noted earlier in this section, the THD took a much more active role in planning and development of WPA road projects beginning in 1938. During the biennial period from September 1938 to August 1940, the THD initiated 163 state-sponsored WPA highway and bridge projects, covering 883.3 miles of roadway at a total cost of $8.3 million. One feature of the THD/WPA program was the novel use of private contractors on over half of these road projects. For these projects, the THD developed plans and specifications and received bids from private contractors to provide supervisory and skilled labor, equipment, and some materials. The WPA provided unskilled and semi-skilled laborers and a portion of the materials. The THD paid contractors using state funds, as a project match. The remaining THD-sponsored WPA projects were conducted using the "day labor" method employed on most relief agency projects, with the THD directly supplying supervisory and skilled labor as the project sponsor.[208]

*National Youth Administration (1935-1943)*

A June 1935 executive order established the last important New Deal work-relief program that affected road construction in Texas. Similar to the CCC, the National Youth Administration (NYA) employed young men aged 17 to 25 who were not in school. NYA project types were almost as varied as the WPA but less elaborate than the

---

[204] Works Progress Administration, *Report on the Works Program*, p. 30; Charles E. Simons, "On Texas Highways: Activities of the State Highway Department," *Texas Parade*, Dec. 1936, p. 21.
[205] T.H. Webb, "Circular Letter: Discussion General Design for Proposed WPSO Projects," To All Division Engineers, October 23, 1935, Texas Highway Department Administrative Circular; Charles E. Simons, "On Texas Highways: Activities of the State Highway Department," *Texas Parade*, Aug. 1936, p. 21.
[206] Simons, *Texas Parade*, Aug. 1936, p. 21.
[207] National Archives, Works Progress Administration, Texas, Project Folders, Project 10273. Microfilm rolls of WPA projects available at Texas Department of Transportation, Environmental Affairs Division, Austin.
[208] State Highway Department of Texas, *Twelfth Biennial Report*, 8, 9.

CCC. During its peak years of service, the NYA employed more than 1.2 million youth in its out-of-school work program, in addition to 2 million high-school and college students employed by its student work program.[209]

The NYA program in Texas was celebrated as one of the most successful in the nation, with rising political star Lyndon B. Johnson serving as the state's first NYA director. Johnson was an ardent New Dealer and Roosevelt supporter, who in 1935 sought the NYA job following his removal as legislative aide to Congressman Richard Kleberg. Johnson, only 26 years old at the time, proved to be a tireless manager who actively pushed to forward the agenda of the NYA and other New Deal relief agencies in the state. Johnson and his staff were responsible for initiating the idea of having NYA youth work on beautification projects along THD highways. Johnson soon left his role as NYA director to successfully run for the U.S. House of Representatives in spring 1937, following Rep. Buck Buchanan's death. As a Congressman, Johnson was noted for his strong efforts to bring Federal relief money and other public works funding, for projects such as the Lower Colorado River dams and rural electrification, to his Hill Country district.

In accord with the Depression-era spirit, NYA workers performed a number of beautification and small construction projects along Texas highways (see Figure 31). The initial agreement between the NYA and the THD called for employment of 15,000 youth on beautification projects. Projects were organized and supervised by THD district staff, who trained the NYA youth in necessary skills such as landscaping and masonry work.[210] Crews of 12 to 15 male youth graveled mail-box turnouts, side road approaches, and school bus walks; sloped and sodded banks; shaped and sodded ditches; installed grass retards to prevent erosion; planted trees; and landscaped miles of road.[211] The NYA also built masonry school bus shelters and pedestrian bridges.

Roadside parks represented the most distinctive NYA contribution to the Texas highway system. The Depression-era marked the beginning of large-scale roadside park construction in Texas, as the THD focused on highway beautification and other responses to auto-tourism and the Texas Centennial celebrations. During its first year of operation in Texas, the NYA provided labor in 200 roadside parks out of 400 completed or under construction and 1,000 parks planned.[212] These parks fulfilled the THD plan to install inexpensive rest parks of the "utmost simplicity" at regular intervals between towns on land donated by locals. These parks would create "natural outdoor niches" with "panoramic vistas, good trees, protection from sun and wind, proximity [to] streams, and other advantages" that would improve the "mental attitude of the motorist."[213] Although NYA workers primarily cleared, landscaped, and sodded roadside parks, the typical site also had several distinctive structures: wood or masonry picnic tables and benches, fireplaces, rubbish burners, fences, rails, posts, and parking areas. In fact, THD plans promoted masonry construction over timber and concrete because it was inexpensive to build, long-lasting, and "natural" in appearance so that the parks stood in harmony with their natural surroundings.[214] As a representative monument of NYA labor and THD planning, these parks met several central concerns of the Depression-era: the desire for conservation and recreation, the taste for rustic architecture, the need to provide work

---

[209] Chandler, 206, 207.
[210] HHM, 17.
[211] "Discussions on Roadside Development," 31; J. Rex Ritter, "Worthy Public Works," *Texas Parade*, October 1937, 19.
[212] Charles E. Simons, "Traveler's Oasis: The Story of Texas' Roadside Parks," *Texas Parade*, September 1936, 3-5, 24-25.
[213] State Highway Department of Texas, Landscape Division, "Suggested Plantings, Preservations & Arrangements for Highway and Roadside Improvements," *Suggestions for Roadside Development* 3 (1 February 1937), p. 22; Simons, "Traveler's Oasis", p. 3.
[214] State Highway Department of Texas, Landscape Division, "Suggested Plantings, Preservations & Arrangements for Highway and Roadside Improvements," 22-29.

relief for youth, and the drive to create a progressive road system while providing relaxation for the modem automobile traveler and tourist. Additional information on the THD's roadside park program and its relation to broader beautification initiatives is found in the discussion of roadside features, found later in this section.

*Trends in THD Road Design and System Development*

At the same time as work-relief agency funds were constructing bridges, culverts, and roadside park elements using stone masonry for a rustic appearance, the THD was also moving forward with continued emphasis on roads and bridges that would allow for greater traffic volumes, higher speeds of travel, and a safer driving experience. The 1930s and early 1940s saw a continuation of the THD's emphasis on more stringent design standards, allowing for greater traffic volumes and higher speeds of travel on the state highway system. Gilchrist left the THD in 1937, and was replaced by Julian Montgomery, and then by Gilchrist protégé Dewitt C. Greer in 1940. Gilchrist's successors continued his push towards professional and efficient design. Greer in particular was known for pushing economical and cost-effective methods in design.[215]

*Design Standards*

To guide changes in design standards and specifications, greater attention was given to research and testing. Gaining a better understanding of soil and base material properties was particularly emphasized by the THD throughout the period.[216] For bridge design, the THD stressed greater use of hydraulic analyses, soil borings, and other studies to guide selection of superstructure and foundation type.[217] THD engineers noted that many "features of early road construction…are recognized as distinct hazards to the present-day high speed traffic." Safety-based design features included more stringent soil and base selection for smoother riding surfaces, reduced grades and side slopes, gentler curves, adequate pavement and shoulder width for faster and wider vehicles, use of non-skid pavement, and greater use of erosion control devices to preserve the roadway's integrity.[218] The THD's 1940 biennial report touted "new principles of highway design," with three principal design features: alignment, grade, and section; and three divisions of traffic: type, speed, and density.

The trend towards wider right-of-way also continued through this period. While a 100-foot minimum right-of-way was used for highways on the THD's system during the early and mid-1930s, many heavy-traffic roadways featured right-of-way widths between 120 and 200 feet. By 1940, the THD's recommended minimum right-of-way width for state-system roadways was 160 feet, with provision for later construction of a divided facility along heavily traveled highways.[219] The THD's aggressive grade separation program, as noted above, was also considered as an integral feature of the department's emphasis on safer highways.

Traffic circles were constructed in major cities during the period to handle increasing amounts of intersecting traffic. Traffic circles were touted as a way to avoid dangerous head-on collisions and facilitate greater traffic volumes by keeping traffic flowing in a single direction. The concept of traffic circles was not new in the state. Fort Worth's 1927 city plan called for widespread use of traffic circles on city streets, although only one,

---

[215] Hilton Hagan, *An Informal History of the Texas Department of Transportation* (Austin, Texas: Texas Department of Transportation, 1991), 25-27.
[216] State Highway Department, Eighth Biennial Report, 4; Ninth Biennial Report, 11-12; Twelfth Biennial Report, 13.
[217] State Highway Department of Texas, *Eleventh Biennial Report*, 11.
[218] State Highway Department of Texas, *Tenth Biennial Report*, 5.
[219] State Highway Department of Texas, Ninth Biennial Report, 8; Tenth Biennial Report, 7; Twelfth Biennial Report, 7.

Bluebonnet Circle (still extant), is known to have been constructed.[220] During the 1930s, the THD began to construct traffic circles to handle the traffic from multiple major highways; the most well-known was the Waco Traffic Circle. The Waco Circle was built as a National Recovery highway project in the 1930s at the intersection of US 77, US 81, and SH 6, with landscaping that formed a star-in-circle design.[221] The Waco Circle served as a prominent landmark and stopping point for motorists for several decades, and is still in use although most through traffic now travels on nearby interstate Highway (IH) 35.

*Road System Development*

Much of the state's trunk highway system, connecting major intrastate points, was developed by the 1930s. In terms of system development, the THD worked on filling gaps in the highway system and connecting major trunk highways. The agency also improved existing roadways, with placement of all-weather paved road surfacing, and alignment changes to eliminate hazards such as sharp curves, dangerous intersections, and undesirable stream crossings. Maps from the period illustrate typical system improvements during the period.

A comparison of a 1931 Federal-Aid highway map (Figure 32) and the 1941 state highway map (Figure 33) shows system expansion in the Texoma region of north Texas. The 1931 map clearly illustrates a skeleton trunk highway system with one or two primary highways in each county. Sharp right-angle curves are indicated on several highways, and much of the system is earth-or gravel-surfaced (indicated on the map by the letters E and G next to the highways). In contrast, the 1941 map displays more north-south routes, a predominately paved network, and establishment of connecting routes in Montague and Grayson counties to link previously existing major through highways.

Similar trends are found in the rural areas of the Texas Panhandle. A 1933 THD map (see Figure 34) shows that nearly all state highways in the region are graded earth-or gravel-surfaced, even along the former Ozark Trail route on SH 86 through Briscoe and Swisher counties. By 1945, (see Figure 35) nearly all of these roads were paved, with SH 207 serving as a connecting north-south route, and alignment changes on US 70 and US 385 that reduce sharp turns and more efficiently link the region's communities. Figure 36 shows the installation of brick pavement on US 180.

Table 3 illustrates the emphasis that THD placed on paving the state highway system. Between 1929 and 1945, the total system mileage rose around 42 percent, increasing from 18,034 miles to 25,705 miles. Over the same period, the proportion of paved mileage dramatically increased, from 33.6 percent in 1929 to 91.7 percent in 1945.

[220] "Bluebonnet Circle Village," City of Fort Worth, Texas website. www.fortworthgov.org/planninganddevelopment/urbanvillages/default.aspx?id=12444
[221] Gilchrist, 135.

**Table 3. THD System Mileage and Total Expenditures, 1929-1945**

| Fiscal Year | Paved Roads Mileage -State Highway System | Total Maintained Mileage -State Highway System | Percentage of Paved Mileage on State System | Yearly Percentage Increase in Total System Mileage | Total THD Expenditures - All Purposes |
|---|---|---|---|---|---|
| 1929 | 6,061 | 18,034 | 33.6% | NA | $ 34,529,884.27 |
| 1930 | 7,317 | 18,528 | 39.5% | 2.74% | $ 47,331,977.54 |
| 1931 | 8,602 | 18,788 | 45.8% | 1.40% | $ 42,163,806.93 |
| 1932 | 9,865 | 19,148 | 51.5% | 1.92% | $ 42,795,910.64 |
| 1933 | 10,692 | 19,349 | 55.3% | 1.05% | $ 40,650,348.20 |
| 1934 | 12,338 | 19,914 | 62.0% | 2.92% | $ 36,035,108.59 |
| 1935 | 13,285 | 20,359 | 65.3% | 2.23% | $ 35,796,704.45 |
| 1936 | 13,979 | 20,798 | 67.2% | 2.16% | $ 45,424,987.83 |
| 1937 | 15,369 | 21,109 | 72.8% | 1.50% | $ 44,923,105.64 |
| 1938 | 16,617 | 21,466 | 77.4% | 1.69% | $ 39,912,418.54 |
| 1939 | 18,363 | 22,868 | 80.3% | 6.53% | $ 47,569,591.46 |
| 1940 | 19,440 | 23,434 | 83.0% | 2.48% | $ 40,210,347.86 |
| 1941 | 20,557 | 23,833 | 86.3% | 1.70% | $ 36,170,214.93 |
| 1942 | 21,785 | 24,598 | 88.6% | 3.21% | $ 49,557,251.56 |
| 1943 | 22,668 | 25,172 | 90.1% | 2.33% | $ 31,628,520.65 |
| 1944 | 23,018 | 25,214 | 91.3% | 0.17% | $ 27,440,069.57 |
| 1945 | 23,562 | 25,705 | 91.7% | 1.95% | $ 26,955,618.80 |

*Note: Fiscal year 1929 was the first year that total system and paved mileage figures were reported definitely.*
*Source: Texas Almanac 1956-1957 (Dallas: A.H. Belo Corporation, 1955), 348.*

*Roadside Parks and Highway Beautification*

Concern to conserve the natural environment and stimulate tourism inspired the THD to implement some changes on the state road system that went beyond providing work relief or building functional roads. As noted previously, the THD started to save existing trees within highway rights-of-way in 1929. In April 1933, the THD hired landscape engineer Jac Gubbels to implement a highway beautification program centered in a newly created Landscape Division.[222] The THD's departmental focus on highway beautification was soon bolstered by federal legislative mandate. NIRA and other federal highway aid during the Depression required that a minimum 0.5 to 1 percent, depending on the funding type, be set aside for landscaping and beautification.[223]

[222] Gilchrist, Texas Highway Department, 1927-1937, 17-18, 127.
[223] American Association of State Highway Officials, *Historic American Highways* (Washington, D.C.: American Association of State Highway Officials, 1953), 125; Gilchrist, 131.

Gubbels' duties grew with the landscape profession during the Depression, as he promoted a road-building philosophy "to build more attractive, safer and convenient highways for less money by taking advantage of natural forces and native materials.[224] In his view, a completed highway should be "in harmony with the surrounding landscape" by avoiding artificial "angular, stiff...shar[p] lines and corners" and monotonous straight sections. These defects posed a "mental hazard" to the driver, besides inscribing "a separate bleeding scar" across the landscape.[225] Gubbels' practical approach was thus not limited to beautification, but actually incorporated landscape elements into essential design features. Accordingly, groups of shrubs or trees could be used to enhance drivers' safety by highlighting warning signs, the beginning of a narrow bridge, or the start of a sharp curve in the roadway.

With vocal support from the highest administrative levels and the help of a citizens' beautification group led by Mrs. Frank W. Sorell, Gubbels organized district personnel throughout the THD to propose and implement new standards wherever possible during the Depression. By 1940, with the added impetus of a 1934 federal mandate to spend on roadside improvement, the THD had installed 9,600 planted miles, 13,995 erosion-controlled miles, 15,260 miles with "good or moderate cross-section," 119 miles of additional right-of-way for tree preservation, 478 roadside parks larger than one-half acre, and 277 parks and turnouts smaller than one-half acre.[226]

Roadside parks represent the most enduring manifestation of the THD's Depression-era beautification and landscaping efforts.[227] In the spirit of Gilchrist and Ely's mandate to preserve and plant trees, a few THD maintenance foremen constructed unofficial roadside parks in the early 1930s on their own initiative. It remained for Gubbels to extend this spirit across the agency in the mid and late 1930s. For roadside park design, he emphasized the use of native materials and designing around existing topography to achieve a "rustic" design aesthetic that blended with its surroundings. A typical roadside park from this period included a service road departing from the main highway right-of-way and forming a semicircular path through the park area. Often a low masonry wall separated the park from the highway. Picnic units, including a bench with seats, a rubbish burner or bin, and a barbecue pit, were scattered throughout the park. In some cases, picnic units were shaded by arbors. Larger roadside parks sometimes featured winding roads, unusual natural features, or more intricate plantings, while smaller picnic areas were placed at regular intervals along the highway. Gubbels described the typical picnic area as "a half acre or acre of ground, often in the form of a square or rectangle…spaced more or less regularly at intervals of five to ten miles. They are equipped with substantial tables of rustic design, and benches of similar construction."[228] Native stone masonry was the dominant material used in construction of tables, benches, and other furnishings in Texas roadside parks during this period, as at most national parks and the developing Texas state park system. Exceptions were made in heavily forested areas like east Texas, where pine logs were often used for benches and arbors.

The detailed handcraft of the best roadside park work was well-suited to the requirements of work-relief programs, which needed to keep enrollees busy for months at a time. By the mid-1930s, many Texas state parks were being

---

[224] Texas Highway Department, Landscape Division, *Discussions on Roadside Development*, (n.p.: n.d., 1940), 43. Available in Depression-Era Files, Texas Department of Transportation, Environmental Affairs Division, Austin.
[225] Texas Highway Department, Landscape Division, *Discussions on Roadside Development*, 43.
[226] Texas Highway Department, *Twelfth Biennial Report*, p. 57; Gilchrist, *Tex Highway Department, 1927-1937*, 17, 18, 129-131.
[227] Information on roadside parks in this section is condensed from HHM's study of Texas roadside parks, prepared for the Texas Department of Transportation in 2005. Information on Depression-era parks is found on pages 10-21 of the 2005 study.
[228] Jac Gubbels, State Highway Department of Texas, Landscape Division: Suggested Plantings, Preservations & Arrangements for Highway and Roadside Improvements (Austin: State Highway Department of Texas, 1937) in HHM, 16.

developed using CCC labor and hand-craftsmanship to construct improvements following rustic design principles. In similar fashion, the NYA, under the direction of Lyndon B. Johnson, proved instrumental in advancing the THD's roadside beautification program, including construction of roadside parks. Additional details of NYA involvement in roadside park construction are found in the work-relief agency discussion above.

The THD accomplished other forms of "roadside improvement" during this era. Inside rights-of-way, it installed school bus shelters, rural school turnouts, and more secure stock underpasses. Maintenance crews removed large roadkill and metal objects with a special "magnetic nail picker." Outside rights-of-way, the THD landscaped its own property, provided suggestions for the beautification of private homes and businesses, and encouraged the voluntary elimination of urban signs and billboards within 300 feet of a state roadway. Meanwhile, the Texas Legislature in 1935 banned free livestock from fenced highways, prohibited the "vandalism" of roadway wildflowers, and criminalized dumping and littering within 300 feet of a public highway.[229]

*The 1936 Texas Centennial and Historical Markers*

The beautification spirit fit perfectly with state plans to promote the natural beauty of Texas and encourage automobile tourism as part of the 1936 Centennial of Texas Independence celebration. The official Centennial Exposition was held at Fair Park in Dallas with 6,345,385 visitors during its five-month run. An unofficial Texas Frontier Centennial was celebrated throughout the year in Fort Worth, and other major celebratory events took place in San Antonio, Houston, El Paso, and other cities around the state. A primary goal of the Centennial celebrations was to encourage automobile tourism to visit the celebrations for out-of-state visitors as well as residents. A May 8, 1935, law organized and funded the Commission of Control for Texas Centennial Celebrations to coordinate statewide plans, which involved work relief funding from the PWA, WPA, and THD. As part of this program, the THD erected one of the most visible and lasting relics of the Centennial celebration. To commemorate Texas history, regular highway crews placed 264 markers throughout the state for a total cost of $53,157.60. These markers can be recognized by their pink granite base, bronze tablet, and a bronze state seal, and they were often placed with turnouts or plantings meant to create "small beauty spots along the highway." Most markers celebrated county history, with smaller numbers commemorating battlefields, towns, stage or trail crossings, forts, and other historical sites.[230]

The THD also installed 23 stone-masonry boundary markers in the shape of the state of Texas on important highways crossing the state border. These were often associated with roadside parks and 13 entrance stations built in early 1936 to serve as tourist information centers for the Centennial celebration.[231] In a mid-1990s inventory of Depression Era resources, 18 of these markers were documented as extant, although several have been moved or

[229] Gilchrist, *Texas Highway Department, 1927-1937*, 129-131; Texas Highway Department, *Eleventh Biennial Report*, xx-xxii, 23-24.
[230] Gilchrist, Texas Highway Department, 1927-1937, 18, 214; Harold Schoen, ed. Monuments Erected by the State of Texas to Commemorate the Centenary of Texas Independence (Austin: Commission of Control for Texas Centennial Celebrations, 1938).
[231] "First Thing Traveler Sees in Texas," 1938 newspaper clipping from Ben Lednicky, "Early-Starting Days with the Highway Department, Paris District, 1937-1942," scrapbook located at Texas Department of Transportation, Travel and Information Division Photo Library, Austin.

repaired.[232] Some municipalities also constructed town boundary markers during this era to provide local work relief.[233]

The Commission of Control also worked with county advisory boards to erect over 450 historical markers at or near historical sites. Over 250 additional markers were placed at the graves of well-known Texans. These markers were constructed of gray granite slabs, with marker text inscribed in the stone or cast on an attached bronze plate. Many of these markers also featured a small bronze star and wreath affixed to the marker front. While not directly associated with the THD marker initiative, many of these historical markers were placed adjacent to state highways to inform visitors and the traveling public.[234]

*Bridge Types of the Period*

THD biennial reports repeatedly stressed the importance of the department's bridge program during the 1930s and into the early 1940s. In 1934, the THD report noted that more funds had been spent on bridges and large culverts during the 1932-34 biennium than during any other period in the department's history to date.[235] The push for new bridge construction continued through the 1930s, before tapering off with the shift to war production and material shortages in the early 1940s. The THD also worked to widen and strengthen older bridges to meet new roadway width and loading requirements.[236] As early as 1934, bridge design standards called for 24-foot roadway width on most structures, increasing to 40-foot or 44-foot roadway width for bridges in heavily urbanized areas, well beyond the widths of most bridges constructed in the early THD years.[237]

During the early and mid-1930s, the most used bridge types were: bridge-class multiple concrete box culverts (those over 20 feet in length), concrete girder bridges, steel I-beam bridges, and timber trestle bridges with a timber or concrete floor. Concrete slabs were rarely employed, even for short-span crossings. Steel trusses, while limited in number, continued to be used for most long-span crossings throughout the decade, and were the bridges most likely to be featured in the biennial reports as the most celebrated accomplishments of the THD bridge program.[238] To a lesser extent, the THD and local agencies constructed concrete arch and masonry arch bridges, discussed in greater detail below. The THD continued to use concrete box and pipe culverts for minor crossings and drainages. Cast iron culverts used in the late 1910s and early 1920s had been supplanted by corrugated metal pipe culverts by the 1930s. During this period, the agency also developed standard plans for stone masonry culvert headwalls.[239]

By 1938, the THD had begun to employ new bridge types and designs that "afforded distinct advantages" to the department. Continuous and cantilever steel I-beam designs allowed for a shallower deck and lower grade line, and replaced metal truss spans for some short-and medium-span crossings. The department began to use reinforced concrete rigid frame bridges at grade-separated roadway intersections, as a way to minimize differences in grade

---

[232] Depression-era Database, Texas Department of Transportation, Environmental Affairs Division, Austin, Texas.
[233] Texas Highway Department, *Suggestions for Roadside Development*, 1 (1 April 1935)/2 (1 August 1935), p. 21.
[234] Williams, 3-4; Commission of Control for Texas Centennial Celebrations. *Monuments Erected by the State of Texas to Commemorate the Centenary of Texas Independence* (Austin: The Steck Company, 1939).
[235] State Highway Department of Texas, *Ninth Biennial Report*, 6.
[236] State Highway Department of Texas, *Twelfth Biennial Report*, 19-20.
[237] State Highway Department of Texas, *Ninth Biennial Report*, 7.
[238] State Highway Department of Texas, *Ninth Biennial Report*, 6 and 7; *Tenth Biennial Report*, 11-13.
[239] Texas Department of Transportation. Historic bridge standard plan files, Available at Texas Department of Transportation Environmental Affairs Division, Austin, Texas.

while providing a pleasing appearance in urban areas. Continuous reinforced concrete slabs came into use as a specialized type for short spans, as an "economical and permanent" type of structure that offset the difficulty in its construction.[240]

*Bridge Aesthetics*

The THD's focus on "roadside improvement" extended beyond the landscaped plantings and designs of Jac Gubbels and the THD Landscape Division in roadside parks, at bridge ends, and along road rights-of-way. THD bridge designs of the period also showed a growing appreciation and awareness of bridge aesthetics. During this period, bridge engineers began emphasizing overall simplicity and the need to provide harmonious treatment of railings, bridge ends, and substructure. In a 1936 report, THD Chief Bridge Engineer George G. Wickline echoed the aesthetic theories of the City Beautiful Movement when he noted, "the growing interest in highway beautification has made it necessary that structures be designed to blend harmoniously with the surroundings, and, in the cases of structures in or near cities,…that the structure…add to rather than detract from the general architectural beauty of the city's improvements."[241]

Bridges in communities and urban areas, and structures located adjacent to parks and railroad lines received particular aesthetic emphasis. In these cases, THD bridge engineers provided a visually pleasing design and applied decorative details and ornamentation to a bridge's piers, railings, and approaches.[242]

THD engineers occasionally employed the open-spandrel concrete arch design to create gateway bridges along highways entering cities. The THD achieved its highest artistic expression using this type with the 1935 Guadalupe River Bridge on the original alignment of SH 2 (now BU 35) in New Braunfels (TxDOT Structure No. 15-046-0-0016-11-016). This 818-foot-long bridge is composed of five open-spandrel arches with classically detailed spandrel columns and Art Deco pilasters. The open-spandrel arch was constructed up until the 1940s, when the last bridge of this type, the Lamar Boulevard Bridge over the Colorado River (TxDOT Structure No. 14-227-0-0113-12-065) in Austin opened for traffic in 1943. While few closed-spandrel concrete-arch bridges appeared after the 1920s, one notable exception is the bridge on State Spur 536 over the San Antonio River (TxDOT Structure No. 15-015-0-0253-06-029) in San Antonio. The State Highway Department designed this three-span arch, known as the Roosevelt Street Bridge, with embellished Mission style accents in 1935 for a scenic highway along the Old Mission Trail.

While stone masonry construction was most widespread on work-relief projects, some cities also used the material for aesthetic effect during the early part of the twentieth century into the Depression period. The most notable use of stone as a construction material for non-work-relief municipal projects was as a component of Austin's city beautification program. Considered the most "artistic" choice for small or medium spans, a number of stone arches were constructed on principal streets crossing Shoal Creek and Waller Creek. One of the last surviving examples of one of these arches is the Waller Creek Bridge on East 6th Street (TxDOT Structure No. 14-227-0-B000-17-005). Erected c.1930, the 37-foot-long structure presents a single arch composed of rough-cut limestone blocks and features masonry parapet railing on the south side of the structure.

---

[240] State Highway Department of Texas, *Eleventh Biennial Report*, 11.
[241] State Highway Department of Texas, *Tenth Biennial Report*, p.11; also Gilchrist, *Texas Highway Department, 1927-1937*, 75-95. For more on the City Beautiful and bridge design see below and: James L Cooper, *Artistry and Ingenuity in Artificial Stone: Indiana's Concrete Bridges, 1900-1942* (Greencastle, IN: J.L. Cooper, 1997), 7-35.
[242] State Highway Department of Texas, *Twelfth Biennial Report*, 17-19.

*Railroad Grade Crossing Elimination*

As noted earlier, elimination of dangerous at-grade railroad crossings had been a focus of THD officials since 1919 (see Figure 37). This concern was shared by highway administrators throughout the nation, as the number of automobiles and the annual mileage per vehicle continued to rise through the 1920s. By the 1930s, the elimination of the state's most dangerous grade crossings had taken on a higher priority for the THD. The June 1934 National Recovery highway funding included appropriations specifically earmarked for grade separations. This funding was dramatically increased with the passing of the federal Emergency Relief Appropriation Act of 1935.[243] Railroad companies were no longer expected to fund grade crossing projects, as federal funds were made available under this program specifically for this purpose. These funds did not have to be matched with state money, which greatly relieved the THD from the cost of construction. As part of the 1935 relief act, approximately $10,800,000 was allotted to Texas for hazardous grade crossings eliminations. Funds from the National Recovery Program financed a number of substantial highway railroad grade crossings and underpasses during the 1930s.[244]

These projects typically replaced dilapidated timber crossings with modem concrete overpasses designed with wide roadways, sidewalks and ornamental railing, and architectural treatment given to the concrete supports. Not only did the program replace dangerous structures, but also utilized WPA labor to relieve unemployment during the Depression. The Oakland-Merlin Overpass, carrying present-day Malcolm X Boulevard over the Dallas Area Rapid Transit railroad and Hickory Street in Dallas (TxDOT Structure No. 18-057-0-9021-70-001) in Dallas is representative of an overpass constructed under this program. Erected in 1937, the 1,759-foot-long overpass is composed of 25 spans of steel I-beam units, and is the longest example of its type in the state. The 1937 South Main Overpass (TxDOT Structure No. 02-220-0-ZM06-70-001) in Fort Worth is another good example of an overpass constructed under a National Recovery Program. This 1,335-foot-long overpass utilized a 232-foot through-plate girder main span to limit the different elevations between the two roadways. Another significant overpass financed under the National Recovery Program includes the 18th Street Viaduct (TxDOT Structure No. 09-161-0-0209-01-034) in Waco. These overpasses still carry the main highway traffic over the railroad, symbolizing the lasting benefit of the National Recovery Program's cooperative state and federal grade crossing elimination program. The late-1930s push for grade separations was largely halted with the onset of World War II, due to the restriction of materials needed for the war effort.

*The Onset of World War II*

By 1940 the focus of the THD system development quickly shifted towards preparing the state's road network for national defense and transport of war materials. The February 1940 national Good Roads Congress in Chicago declared "Roads Rule the World" as it used the motorized German blitzkrieg in Europe and vehicle transport problems during recent military maneuvers in East Texas and Louisiana as evidence for the need for increased military road expenditure.[245] Congress responded by allowing the federal government to assume the entire cost of strategic highways built under the 1940 Federal Highways Act.[246] After June 1940, the WPA directed its work toward "roads, streets, bridges, and highways forming a part of the national strategic highway network or providing

[243] American Association of State Highway Officials, *Historic American Highways*, 123 and 124.
[244] Note: The discussion of Depression-era grade separations is largely taken from: Texas Department of Transportation, *Texas Historic Bridge Inventory, Survey of Non-Truss Structures*, 2001, available at Texas Department of Transportation Environmental Affairs Division. The inventory report has only limited use of citations for its source material.
[245] Charles E. Simons, "Roads and War," *Texas Parade* June 1940, p. 23.
[246] Huddleston, 225-226.

access to military or naval establishments...or industrial plants engaged in war work," and it allowed certified projects to ignore hourly and monthly spending limits.[247] By 1943 the expanding wartime economy, declining unemployment, and war-related spending led to the discontinuation of the federal work-relief programs.[248] The THD's roadside park and beautification program also quickly subsided after 1940. During the war years, beautification activities were limited to basic maintenance of existing parks.

*National Defense Highways*

At the onset of U.S. involvement in World War II, the Defense Highway Act of 1941 designated a national road system of defense or military highways. The act allocated $50 million for a strategic network of highways and $150 million for access roads.[249] These funds were divided among, and matched by, the states for survey and planning of the strategic network of highways in or through municipalities and urban areas.[250] This military network of highways was designated to expedite the transportation of goods, services, and raw materials between military installations, suppliers, major defense plants, and coastal shipping ports. Military roads were given high priority for improvements during the war.

The Defense Highway Act of 1941 authorized a large system of defense highways in Texas, including 6,375 miles of the Strategic Military Network, a national transportation network of 75,000 miles.[251] The Texas Strategic Military Network included three road classification levels based on priority: 4,154 miles of first priority roads, 1,566 miles of second priority roads, and 655 miles of third priority roads. Moreover, Texas's long international border with Mexico and exposed coastline on the Gulf of Mexico necessitated national defense attention. As a major producer of wartime commodities such as petroleum, and as a hub for military facilities, Texas was critical to national defense. The state maintained 43 forts, air fields, naval bases, and military training facilities within its borders by 1940.[252] Such a strong presence of military personnel and wartime supplies influenced the development of roads and bridges during World War II. The designation of the Strategic Military Network resulted in Texas maintaining one-twelfth of the network's total national mileage.

These roads connected the military with border points and coastlines in order to link the flow of military personnel and supplies. However, at the time of designation, many of Texas's roads and bridges did not meet recommended standards to withstand the weight and width of heavy military machinery. Further, only 44 percent of bridges on the strategic network in Texas had the required horizontal clearance of 26 feet or more. As a result, the majority of

---

[247] Work Projects Administration, *Final Report on the WPA Program*, 84-89.
[248] Huddleston, 227-235; Armstrong, p. 84; D.C. Greer, "Administrative Order No. 32-42, State Sponsored W.P.A. Highway Projects," To All District Engineers, June 9, 1942.
[249] Seely, 176.
[250] American Association of State Highway Officials, The History and Accomplishment of Twenty-Five Years of Federal Aid for Highways: An Examination of Policies from State and National Viewpoints ([Washington, D.C.]: American Association of State Highway Officials, [1944]), 15.
[251] Kirk Kite, "A History of the Texas State Department of Highways and Public Transportation 1917-1980" (PhD dissertation, University of New Mexico, 1981), 120; Joseph E. King, *A Historical Overview of Texas Transportation, Emphasizing Roads and Bridges* (Austin, Texas: Texas State Department of Highways and Public Transportation, n.d.), 65.
[252] Texas Highway Department, *The Texas Highway System as Related to National Defense Transportation* ([Austin, Texas]: [Texas Highway Department], December 1940), 2-3.

bridge and road improvements undertaken in Texas during the war were completed to improve this Strategic Military Network.[253]

*Wartime Transportation Needs*

During World War II, Texas's economy was strengthened by the defense industry and increased construction business associated with a wartime economy. Texas attracted the military and defense industry with its temperate climate and available petroleum. During the war, a large number of people migrated to Texas's urban areas for industrial jobs that met wartime demands. By 1945, it was estimated that 500,000 Texans had moved from the state's rural counties to its urban counties.[254] Texas's wartime economic boom doubled the income per capita in the state.[255]

Despite the state's industrial growth, road and bridge construction was limited during the war. Federal funding for highway and bridge projects was drastically cut, and a shortage of materials and equipment delayed many road and bridge projects. The THD employed creative measures for bridge construction in response to material shortages. By the early 1940s, the War Department severely restricted the use of steel, causing a rapid decline in steel I-beam, girder, and truss construction. For example, the THD used metal "sucker" rods used on oil wells for bridge reinforcement when regular reinforcing bars were scarce. The agency also began to use salvaged bridge members as reinforcing in concrete structures. The THD used temporary crossings, such as the Bailey truss, to address immediate bridge needs. The military developed the Bailey truss during World War II to serve as a temporary crossing that could be erected quickly. In April 1945, the THD installed a Bailey truss on US Highway 271 over the Sabine River near Gladewater to replace a flood-damaged structure. A quick solution was needed to restore traffic across this waterway because the bridge carried heavy military traffic between the oil towns of Gladewater, Kilgore, Tyler, and Longview. Within a matter of days, 150-and 120-foot spans were erected as a temporary crossing while repairs were made to the permanent structure.[256] No known examples of Bailey trusses remain extant in Texas. Texas's road network, including bridges, suffered due to the limited number of projects that could be completed during World War II. New projects were not undertaken and existing roads were not maintained, except those on designated defense highways. By 1944, bridge construction likewise was largely confined to routes serving military and essential civilian traffic.

*Planning for postwar Construction*

State transportation needs continued to mount during the war; thus, planning for a postwar construction program became one of the THD's major wartime activities. A nationwide survey, conducted by AASHO in 1943, found that 17,000 miles of roads in Texas needed to be rebuilt, widened, or relocated. Similarly, 600 bridges on the

---

[253] Texas Highway Department, *The Texas Highway System as Related to National Defense Transportation*, 2-3.
[254] "World War II," Handbook of Texas Online, http://www.tsha.utexas.edu/handbook/online/articles/WW/npwnj.html (accessed 11 July 2005).
[255] "Texas Since World War II," Handbook of Texas Online, http://www.tsha.utexas.edu/handbook/online/articles/TT/npt2.html (accessed 12 July 2005).
[256] A. C. Gentry and I. H. Cructcher, Jr., "Bailey Truss Spans to the Rescue!," *Better Roads* 15, no. 9 (September 1945): 31-32.

state's main highways required to be widened or rebuilt. The resulting transportation improvement effort to address these inadequacies was estimated to cost $830 million.[257]

In an effort to anticipate postwar road-and bridge-building construction needs, the THD completed a large number of surveys and plans during World War II for future projects that would be constructed after the war. In addition to having planned postwar projects, Texas also had state funds available after the war to begin projects immediately. Texas placed a high priority on road building, which was necessary to obtain matching funds, and is exemplified by state legislation passed during this period. As a result of the THD's superlative planning efforts, the state was prepared at the end of the war to resume its road and bridge building with the aid of federal funds.

**Post-World War II Road Network Developments**

Economic prosperity, industrial expansion, and population growth certainly impacted Texas's creation of a post-World War II highway system that could serve the state's expanding economy, with particular emphasis placed on urban networks. Significant milestones in Texas's technological and industrial postwar economy include Jack Kilby's and Robert Noyce's invention of the microchip at Texas Instruments and Fairchild Semiconductor Corporation, respectively, in Dallas, and the creation of Johnson Space Center in the 1960s in Houston. In particular, the Texas economy witnessed a shift to high-tech industry, particularly in North Texas, Houston, and Austin during the postwar era. Transportation networks in Texas, including a growing system of urban freeway loops that linked interstate highways and improved farm-to-market or secondary roads, enabled manufacturers to deliver products easily and cheaply.[258]

In addition to the influence of industry on the transportation system, traffic in Texas boomed in the immediate postwar years. Between 1945 and 1950, motor vehicle registrations increased from 1.7 to 3.1 million; by 1955, the number of licensed vehicles exceeded four million. Population growth was also significantly strong in Texas in the postwar decades. According to the U.S. census records, the population of Texas numbered 6,424,824 people in 1940; 7,711,194 people in 1950, representing a 20.2 percent growth; and 9,579,677 people in 1960, representing a 24.2 percent growth. Interestingly, much of the postwar population surge was located in urban areas. By 1957, the 15 most populous counties of Texas included populations numbering approximately five million people. While containing less than six percent of the land area of the state, these counties contained 55 percent of the state's population.[259]

With particular foresight, State Highway Engineer Dewitt C. Greer addressed the state's urban traffic and transportation system problems beginning in 1945. At this time, Greer created distinct expressway offices, separate from district offices, in San Antonio, Houston, Dallas, and Fort Worth. This enabled these cities to develop limited-access freeways beginning in the late 1940s, many of which would be incorporated into the interstate system with few changes.[260] As a result, the THD expanded its urban highway network fourfold between World War II and the mid-1950s, and by 1957 nearly 10 percent of the 30,000 miles of city streets in Texas were part of

---

[257] American Association of State Highway Officials, The History and Accomplishment of Twenty-Five Years of Federal Aid for Highways: An Examination of Policies from State and National Viewpoints (Washington, D.C.: American Association of State Highway Officials, 1944), n.p.
[258] Beaumont, Penny, et.al., Anywhere to Everywhere: The Development of the Interstate Highway System in Texas, (August 2006), 3.
[259] Texas Research League, "A Program for Texas Highways," 1957, 6-7.
[260] Beaumont, 11.

the state highway system.[261] In addition to the rapidly expanding urban highway network in the postwar period, Texas's secondary road network, known as the farm-to-market (FM) system, increased by 33,000 miles between 1951 and 1961.[262] This system, which is discussed below, was widely recognized as the most developed rural highway network in the nation. The state's profound economic and demographic changes, combined with rising vehicle use, led to rapid expansion of the state's highway system. New road types developed during the postwar period included controlled-access highways, such as the Interstate Highway System, and rural FM roads. Table 4 shows the dramatic increase of total mileage in the state as new roads of various types were rapidly being developed between 1945 and 1965.

**Table 4. THD System Mileage, 1945-1965**

| Fiscal Year | Total Mileage |
|---|---|
| 1945 | 25705 |
| 1946 | 26327 |
| 1947 | 27626 |
| 1948 | 30146 |
| 1949 | 32555 |
| 1950 | 34929 |
| 1951 | 36157 |
| 1952 | 38389 |
| 1953 | 44179 |
| 1954 | 46676 |
| 1955 | 48840 |
| 1956 | 50839 |
| 1957 | 52977 |
| 1958 | 54367 |
| 1959 | 55932 |
| 1960 | 57015 |
| 1961 | 58286 |
| 1962 | 59434 |
| 1963 | 60520 |
| 1964 | 61604 |
| 1965 | 62618 |

*Source: Texas Almanac and State Industrial Guide 1970-1971 (Dallas, Texas: A.H. Belo Corporation, 1969).*

*State and Federal Funding and Legislation in the Postwar Period*

While federal legislation of the period was responsible for a new focus on, and national funding apparatus for, transportation development, Texas also relied on transportation funding that the state presciently established during the war. Texas also passed its own legislation to accelerate construction and improvement of transportation networks, especially the state's FM roads. In particular, revenue from state gasoline taxes and vehicle registration

[261] Texas Research League, "A Program for Texas Highways," 1957, 7.
[262] Goode, The Texas Farm to Market Road Program in Perspective, 1945-1970, n.p.

fees, investments in war bonds, and federal programs funded Texas highway and bridge construction, as well as maintenance, during the post-World War II period.

The Texas Legislature first imposed a gasoline tax in 1923 at a rate of one cent per gallon on motor fuels dispensed; three-fourths of the receipts of this tax went to the State Highway Fund and one-fourth to education. During World War II, shortages of labor and materials slowed THD construction work, but "the gasoline tax revenue, which held up well during the war, built up a sizable balance in the treasury."[263] By 1946, the gasoline tax was at four cents per gallon; half of which was allocated to highways.[264]

In 1941, a variant on the gasoline tax was initiated when the Texas Legislature passed the Omnibus Tax Law. Among its provisions, this law provided for an occupation tax on oil, natural and casing-head gas, and sulfur produced within the state, and an occupational or excise tax on the first sale, distribution, or use of motor fuel in the state. This excise tax was essentially a gasoline sales tax, paid by the consumer to the gasoline distributor, who then paid the tax to the state.[265] While most highway construction funding was distributed through the State Highway Fund, the Omnibus Tax Clearance Fund, authorized by the Omnibus Tax Law, was used to fund the Colson-Briscoe Act of 1949 and continued to partially fund FM road construction through the postwar period.[266]

Additionally, state legislation enacted in 1943 enabled the THD to invest approximately $30 million in short-term maturity U.S. Treasury Certificates, also known as war bonds. These treasury certificates produced approximately $250,000 in interest annually, which was available for construction after the war.[267] The THD expected revenues totaling at least $49 million in the first three postwar years, allowing them to take full advantage of available federal aid, which amounted to $167.4 million.[268]

New postwar legislation and funding, combined with accumulated revenue from the war years, also influenced the acceleration of highway and bridge construction. The Texas Highway Commission, which governed the THD, designated the first state-designated FM road program in 1941. However, few miles were initially constructed due to restrictions imposed by World War II.

In order to address nationwide road deficiencies, a national postwar highway program was implemented through the enactment of the 1944 Federal Aid Highway Act, which expanded federal funding available for the nation's road system. The federal aid road system included three types of roads: 1) federal-aid primary system, including U.S. Highways and State Highways, roads designated by the states as primary transportation routes; 2) secondary system, known as feeder roads, including FM roads, rural postal delivery routes, and public school bus routes; and

---

[263] State Highway Department of Texas, *Fifteenth Biennial Report, 1944-1946*, 2.
[264] Shannon Miller, *The First 50 Years, 1918-1968: Austin Bridge Company and Associated Companies* (Dallas, Texas: Taylor Publishing Company, 1974), n.p.
[265] "Omnibus Tax Law H. B. No. 8," in *General and Special Laws of the State of Texas Passed by the Regular Session of the Forty-Seventh Legislature* ([Austin, Texas]: Secretary of State, 1941), 269-275.
[266] "Highway Development," *Handbook of Texas Online*, http://www.tsha.utexas.edu/handbook/online/articles/view/HH/erh2.html (accessed 28 April 2004); Kirk Kite, "A History of the Texas State Department of Highways and Public Transportation 1917-1980," Abstract of Dissertation" (PhD dissertation, University of New Mexico, 1981), 130.
[267] Kite, "A History of the Texas State Department of Highways and Public Transportation 1917-1980," 123-124.
[268] Dewitt C. Greer, Administrative Circular No. 32-44, 8 July 1944. Administrative Circulars – Texas Highway Department Correspondence.

3) highways in urban areas. The 1944 Federal Aid Highway Act increased funds for primary roads and also provided new funding for construction of urban highways and expressways and secondary roads. Previous federal aid had been focused largely on rural roads and had limited the number of miles of secondary roads that could be improved with federal funds. This was the first time federal funding was provided for urban and secondary highways without mileage limitations.

The 1944 Federal Aid Highway Act provided $500 million in nationwide funding over a three-year period, including $150 million for secondary roads. Yet, this funding, for which the states were responsible to match at a 50/50 ratio, proved to be somewhat limited when distributed among all the states. The Act provided a program of $174 million for Texas's roads, of which it was required to match with $87 million of state funds. The federal appropriation contributed approximately $43.5 million for primary highways, $30 million for FM (secondary) roads, and $13.5 million for urban routes through metropolitan areas.[269] Prior to the establishment of federal aid funds, the THD had prepared a postwar program with projects totaling over $107 million for road and bridge improvement on the primary road system alone. However, the established federal aid enabled the THD to invest $30 million in its existing FM road program over a three-year period. Thus, the additional distribution of federal aid monies, especially for secondary roads, influenced the THD's ability to expend money on FM road and bridge building.[270]

The 1944 Federal Aid Highway Act allowed states to use 10 percent of appropriated federal funds to eliminate highway-railway at-grade crossing hazards on the federal aid system.[271] Grade separation structures, constructed to elevate either the roadway or the railroad, were completed under this program to eliminate crossing hazards. In addition, the Federal Aid Highway Act of 1944 authorized designation of the National System of Interstate Highways. The interstate system was intended to connect principal metropolitan areas, cities, and industrial centers, and to serve national defense and connect border points with routes of continental importance in Canada and Mexico.

The period immediately after passage of the 1944 Act accounts for one of the largest increases in the THD's annual expenditures; spending increased sevenfold from $11.7 million in fiscal year 1944-45 to $71 million in fiscal year 1947-48.[272] Because Texas had completed construction plans during the war and had healthy financial reserves that allowed the state to match federal funding, the Texas Highway Commission was able to act immediately to begin construction and improvement of the state's road network.

In 1945, an anti-deficit amendment to the Texas state constitution was adopted that prevented the state government from spending money until the revenue was available. While many states incurred debt during the execution of their highway-building program, Texas only spent available monies.[273] Additionally, anti-diversion legislation in the form of a constitutional amendment was passed by the state legislature in 1945, which voters approved in 1946.

---

[269] State Highway Department of Texas, *Fifteenth Biennial Report, 1944-1946* (Austin, Texas: State Highway Department of Texas, 1947), 3-4.
[270] Kite, "A History of the Texas State Department of Highways and Public Transportation 1917-1980," 127; Greer, Administrative Circular No. 32-44.
[271] A. E. Johnson, ed., *Published on the Occasion of the Golden Anniversary American Association of State Highway Officials: A Story of the Beginning, Purposes, Growth, Activities and Achievements of AASHO* (Washington, D.C.: The American Association of State Highway Officials, 1965), 153.
[272] State Highway Department of Texas, Biennial Reports, 1944-1966.
[273] Morehead, *Dewitt C. Greer: King of the Highway Builders*, 53.

This Good Roads Amendment, which was actively supported by Governor Coke Stevenson, the Texas Good Roads Association, and other road organizations, prevented road funds from being redirected to other governmental agencies.[274] Three-quarters of these revenues were reserved for highway construction, maintenance, and administration of highway laws, while the remaining one-quarter was allocated to the Available School Fund (money set aside by the state from current or annual revenues to support the public school system).[275]

In 1947, further legislation was enacted that changed the 1941 bond assumption law so that any surplus over $2 million in the county and district road indebtedness fund would be allocated to the state highway fund. Moreover, the legislature enabled local and county governmental units to contribute funds to the THD, if they chose, in order to accelerate road construction during the postwar period.[276] This commission policy was commonly referred to as the 75-25 program, outlined in Minute Order 23476 and passed by the legislature on June 2, 1947. This program accepted funds from counties for 75 percent of the construction cost for FM roads, up to a maximum of $100,000 per year. The state then provided the remaining 25 percent of the costs. Under the 75-25 program, 2,788 miles of FM roads were constructed in 93 counties at a cost of approximately $32.5 million. The 75-25 program proved to be a short-term solution for new road construction. It was discontinued in 1949 with passage of the Colson-Briscoe Act.[277]

With available funds, Texas was in a good position to act quickly in their postwar building efforts, while other states in the country found it difficult to raise the matching funds required by the Federal-Aid Highway Acts. By mid-1947 Texas accounted for one-quarter of all highway work under contract in the country, due in part to its head start in planning and reserve of available funds.[278]

By 1948, revenue from the gasoline sales tax and enforcement of license fees had reached its highest point in department history, and it was estimated that there would be enough funds to match federal aid and a small amount left for the betterment of roads with 100 percent state funds.[279] Annual spending on Texas roads and bridges continued to rise during the postwar period, equaling more than $100 million in 1952, topping $200 million beginning in 1957, and exceeding $300 million after 1963. In addition to the funding mechanisms described above, a portion of funding for roads was also generated through vehicle registrations. The state's vehicle registrations nearly doubled in the years after the war, providing increased transportation funds. In 1945, 1.7 million vehicles were registered, a total that increased to 3.1 million in 1950.[280]

Federal funding provided by the Federal-Aid Highway Act of 1956 quickened the pace of Texas road construction on primary, secondary, and urban roads, as well as interstate highways. In 1955 the federal government appropriated $35 million for the state. This appropriation accounted for 25 percent of the total $142 million spent

---

[274] John D. Huddleston, "Good Roads for Texas: A History of the Texas Highway Department, 1917-1947" (PhD dissertation, Texas A&M University, 1981), 234-235.
[275] "Highway Development," Handbook of Texas Online; *Texas Almanac and State Industrial Guide*, 1947-1948 ed. (Dallas, Texas: A. H. Belo Corporation, 1947), 310.
[276] Huddleston, "Good Roads for Texas: A History of the Texas Highway Department, 1917-1947," 234.
[277] Preston C. Goode, *The Texas Farm to Market Road Program in Perspective, 1945-1970* (Austin, Texas: N.p., April 1971), 2.
[278] Hagan, *An Informal History of the Texas Department of Transportation*, 31.
[279] State Highway Department of Texas, *Sixteenth Biennial Report, 1946-1948* (Austin, Texas: State Highway Department of Texas, 1949), 3.
[280] "Texas Department of Transportation," *Handbook of Texas Online*.

that year on highway improvements in Texas. By 1958, the federal appropriation for Texas had more than quadrupled to $149 million, accounting for 55 percent of the total $269 million annual state expenditure.[281] The increased percentage of federal funding demonstrates the federal government's larger share of construction of the interstate system. Rather than the 50/50 match for other roads, federal appropriation for interstate construction was 90 percent with a 10 percent match by the states. Following passage of the Federal Aid Highway Act of 1956, the THD's annual expenditures show a significant increase, rising from $143 million in 1956-57 to $269 million in 1958-59.

[281] Alonzo C. Taylor, "The Expanded Federal Highway Plan as it Relates to Texas," *The Texas Engineer* 28, no. 1 (January 1958): 8.

Table 5 shows annual expenditures the THD made with federal and state funds for construction of highways and structures for the period from 1945 to 1965.

**Table 5. THD Annual Expenditures from 1945 to 1965***
(amounts have been rounded to the nearest dollar and include funds from federal and state sources)

| Years | Highways | Farm-to-Market Structures | All Structures | Total – Highways and Structures |
|---|---|---|---|---|
| 1944 to 1945 | Not available | Not available | $903,461 | $11,792,455 |
| 1945 to 1946 | Not available | Not available | $983,290 | $17,351,483 |
| 1946 to 1947 | Not available | Not available | $2,663,143 | $42,763,679 |
| 1947 to 1948 | Not available | Not available | $5,841,474 | $71,665,858 |
| 1948 to 1949 | Not available | Not available | $12,627,388 | $77,431,275 |
| 1949 to 1950 | Not available | Not available | $11,423,525 | $76,505,902 |
| 1950 to 1951 | $83,280,078 | $728,372 | $11,650,506 | $95,658,956 |
| 1951 to 1952 | $83,892,990 | $946,629 | $11,748,866 | $96,588,485 |
| 1952 to 1953 | $90,830,579 | $1,701,789 | $9,517,356 | $102,049,724 |
| 1953 to 1954 | $98,682,804 | $1,776,302 | $16,497,695 | $116,956,801 |
| 1954 to 1955 | $86,979,867 | $3,340,534 | $24,305,598 | $114,625,999 |
| 1955 to 1956 | $125,073,745 | $1,565,997 | $15,408,212 | $142,047,954 |
| 1956 to 1957 | $130,401,271 | $2,306,729 | $10,714,431 | $143,422,431 |
| 1957 to 1958 | Not provided in biennial report | Not provided in biennial report | $31,641,522 | $210,251,946 |
| 1958 to 1959 | $251,912,042 | $2,970,666 | $14,295,676 | $269,178,384 |
| 1959 to 1960 | $243,977,703 | $4,320,610 | $20,555,733 | $268,854,046 |
| 1960 to 1961 | $206,963,920 | $1,404,084 | $23,071,131 | $231,439,135 |
| 1961 to 1962 | $230,371,219 | $1,989,108 | $18,796,463 | $251,156,790 |
| 1962 to 1963 | $215,919,764 | $1,245,882 | $15,432,488 | $232,598,134 |
| 1963 to 1964 | $274,992,114 | $1,880,925 | $20,282,397 | $297,155,436 |
| 1964 to 1965 | $279,109,136 | $3,247,750 | $32,072,472 | $314,429,358 |
| 1965 to 1966 | $300,168,191 | $4,643,682 | $16,751,822 | $321,563,695 |

** Based on the state of Texas's September 1 to August 31 fiscal year cycle.*
*Source: State Highway Department of Texas, Biennial Reports, 1944-1966.*

*Farm to Market System*

Since its inception, the FM (or secondary) road system was a significant component of the Texas transportation network. Within Texas, the term "farm-to-market" was used interchangeably with "ranch-to-market;" the road designation was dependent on who lived along the route. If residents considered themselves farmers, the roads were designated FM roads. If residents considered themselves ranchers, the roads were designated ranch-to-market

roads.[282] Although many FM roads were constructed in rural areas that have since been suburbanized, they continue to be designated as FM roads. The FM roads are numbered routes preceded by the abbreviation "FM."

From 1917 through the 1940s, the state highway system had focused on primary trunk routes for inter-city trade and travel. Secondary, or lateral, routes that connected rural areas with nearby market towns or county seats remained under local purview at the county level. Many of these FM roads received federal funding for improvements through the WPA and other Depression-era relief programs. At the same time, regular federal highway aid increasingly included funding for secondary roads as well as the primary highway system. By the late 1930s, the THD was ready to begin designating a state FM road system.

FM roads were defined as roads in rural areas, including feeder roads, secondary roads, school bus routes, rural mail routes, and milk routes that were not part of the state highway system of primary roads. In consultation with county commissioners, the THD selected the system of FM roads based on each county's needs for improved rural routes and the following criteria:[283]

- They could not be potential additions to the state highway system of the designated Primary Federal Aid Highway System.
- They had to serve primarily rural areas and connect farms, ranches, rural homes, sources of natural resources, and points of public congregation, including developed communities.
- They had to be capable of assisting in the creation of economic values in the areas served.
- They should serve as public school bus routes or rural free delivery routes, or both.
- They should be capable of integration with the existing Texas road system, with at least one end connected to a previously improved road in the system.

Development of the FM program brought benefits to the state's rural and urban populations. As a result of road improvements, farmers in rural areas were no longer isolated but had improved roads allowing access to markets and medical and educational facilities in nearby cities. Rural mail service improved as a result of the FM roads, and school buses were able to travel more safely. Within urban areas, FM roads meant that fresh crops were available at city markets. The roads also aided in suburban development by allowing access to areas outside the city center and facilitated recreational travel within the state.[284]

*Legislation and Funding*

The Texas Highway Commission designated the first FM road program in 1941; although, few miles were initially constructed due to restrictions imposed by World War II. The 1944 Federal Aid Highway Act, as described above, enabled the state to construct secondary roads at a much quicker pace in the postwar period. In 1945, the commission authorized construction of 7,500 miles of FM roads to be financed with 50-percent federal and 50-percent state funds.[285] Within only three years, Texas led the nation in total number of FM or secondary roads constructed or under contract.

---

[282] Hagan, *An Informal History of the Texas Department of Transportation*, 30.
[283] Kite, "A History of the Texas State Department of Highways and Public Transportation 1917-1980," 180-181.
[284] "The FM Program for 1965," *Texas Highways* 12, no. 7 (July 1965): 11; Arthur G. Bruce and John Clarkeson, *Highway Design and Construction*, 3rd ed. (Scranton, Penn.: International Textbook Company, 2004), 4-5.
[285] Kirk Kite, "A History of the Texas State Department of Highways and Public Transportation 1917-1980, 128.

Despite this progress, several Texas legislators, including Neveille H. Colson, Dolph Briscoe, Jr., George A. Moffitt, and Ray Kirkpatrick, introduced FM road appropriation bills in the legislature in January 1949. An expected surplus of $100 million in the state's general revenue fund stimulated the introduction of these bills.[286] The resulting Colson-Briscoe Act was the most important Texas law influencing road and bridge construction between 1945 and 1965. The Texas Legislature passed the Colson-Briscoe Act, which was introduced by two "champions of road legislation," Senator Neveille H. Colson and Representative Dolph Briscoe, Jr., on March 24, 1949. The legislation read that the funded "roads shall serve rural areas primarily and shall connect farms, ranches, rural homes and sources of natural resources such as oil, mines, timber, etc., and/or water loading points, schools, churches, and points of public congregation, including community developments and villages."[287] The Act appropriated $15 million in annual funding from the Omnibus Tax Clearance Fund for FM roads. The THD used this money to match federal funds provided under the Federal Aid Highway Act of 1944. Additional funding allowed the state's program to expand by nearly 3,000 miles per year beyond the original 7,500-mile network that had been authorized in 1945. Under the program, the state was responsible for funding construction and maintenance of FM roads, while affected cities and counties were responsible for providing right-of-way.[288]

However, conflict over how to fund the $15 million yearly appropriation plagued the bill after its first two years in effect. Legislative debates in 1951 focused on who to tax for more money and how much to spend on rural roads. The annual $15 million appropriation authorized by the Colson-Briscoe Act was funded by the state's general fund, to which the oil and natural gas industry contributed considerably through royalties and other taxes. While many legislators supported taxing the oil and natural gas industry for road-building programs, Dewitt C. Greer and the THD preferred highway-user taxes, including taxes on gasoline and tires. Initially, in 1951, legislators voted for increasing the gathering tax on natural gas pipelines to support the state's spending needs, and in 1955, the gasoline tax was raised to five cents per gallon.[289] In 1962, the Colson-Briscoe Act was modified to supplement the annual $15 million with additional funds already available to the THD, so that at least $23 million would be available annually.[290] The Texas Highway Commission also expanded the designated size of the FM road system from 35,000 to 50,000 miles, allowing future FM road construction to take place.[291]

Between 1951 and 1961, Texas constructed 33,000 miles of FM roads at an average cost of $15,500 per mile.[292] By 1956 there were 2,358 FM roads in Texas, and by the end of 1965 the Texas FM system included more than 36,000 miles of roadway.[293] The state's FM system was so extensive that it was 150 percent larger than the state-maintained highway networks of six states combined: Maine, New Hampshire, Vermont, Massachusetts,

---

[286] "Bills Due This Week to Spend 30 Million of State Surplus," *The Dallas Morning News*, 12 January 1949, 3.
[287] Kite, "A History of the Texas State Department of Highways and Public Transportation 1917-1980," 180-181.
[288] Kite, "A History of the Texas State Department of Highways and Public Transportation 1917-1980, 130.
[289] Richard M. Morehead, "New Plan to Block More Taxes Drafted in State Legislature," *The Dallas Morning News*, 4 February 1951, 10; Richard M. Morehead, "Gas Tax Bill Passes House," *The Dallas Morning News*, 11 April 1951, 6; "Compromise Sought on State Tax Bill," *The Dallas Morning News*, 13 May 1951, n.p; Richard M. Morehead, "Legislative Conferees Break Taxes Deadlock," *The Dallas Morning News*, 5 June 1951, n.p; Francis Raffetto, "Taxes Go up Today," *The Dallas Morning News*, 6 September 1955, n.p; Morehead, *Dewitt C. Greer: King of the Highway Builders*, 52.
[290] Kite, "A History of the Texas State Department of Highways and Public Transportation 1917-1980, Abstract of Dissertation," 130.
[291] "Highway Development," Handbook of Texas Online.
[292] Goode, *The Texas Farm to Market Road Program in Perspective, 1945-1970*, n.p.
[293] Erlichman, 207; Goode, The Texas Farm to Market Road Program in Perspective, 1945-1970, n.p.; "Greer Addresses Road Federation," Texas Highways, 12; Greer, "The Future of Highways and Highway Transportation," Texas Highways, 17.

Connecticut, and Rhode Island.[294] By 1971, the FM road system, which included 41,053 miles of roadway, carried 17.6 million vehicle miles daily for an average of 464 vehicles. This compared to 7.1 million vehicle miles daily for an average daily traffic of 55 vehicles along the existing county road and street system.[295]

*Design of FM Roads and Associated Structures*

All roads under the FM program were designed and constructed under supervision of the THD's Land Service Road Division, which was established on April 1, 1945. Determining design standards for the initial 7,500-mile FM system posed a problem at the inception of the program. Due to the large number of miles and lighter traffic volumes, it would not have been practical to construct FM roads to the same standards as primary roads.[296] FM roads often followed the alignments of existing county routes, were two-lane, asphalt-surfaced, and designed to carry an average daily traffic of 330 vehicles. Plans and construction efforts were directed by the THD and counties were responsible for furnishing right-of-way. Preparation of road and bridge plans by the THD, rather than by local engineers, also sped the process by eliminating the time it would have taken the THD to review locally developed plans. Construction efforts were also simplified and accelerated under this centralized system.[297]

In 1957, a Texas Research League study of 300 miles of FM roadway along 35 distinct projects established a general assessment of the system's construction characteristics. The study noted that the system is "remarkably homogenous," with 92 percent of the roads being constructed in the last 10 years; 94 percent of the roads featuring an asphaltic surface less than one inch thick on a flexible base; and 88 percent of the roads featuring a width of 18 to 22 feet. The majority of the roads were built along the alignment of an existing county road, which was often unimproved. Over half of the Texas Research League's case study FM roads were built where only a dirt road existed before.[298]

The THD periodically updated their design standards for FM roads to reflect AASHO standards of design for rural highways carrying a low volume of traffic as well as the department's growing understanding of best practice rural road design. For example, a 1962 administrative circular documenting FM design standard updates noted several differences including the base width, which was reduced up to four feet for economy. Other economy measures included eliminating pipe headwalls and using pipe culverts rather than small box culverts. For most improved FM roads, the overall roadway width measured 28 feet with the shoulder widths measuring four feet and the asphaltic surface width measuring 20 feet. Bridges along improved FM roads featured a width of 14 to 18 feet with an H-10 design loading, or gross truckloads of 20,000 pounds.[299] These FM load values are less than the load standards for state highways of the period. FM 155 in Fayette County was one such FM road improved by the THD (see Figure 38 and Figure 39 for before and after photographs).

---

[294] "The FM Program for 1965," *Texas Highways*, 11.
[295] Texas Highway Department, *The Texas Farm to Market Road Program in Perspective*, (Austin, Texas: Texas Highway Department, April 1971), 4.
[296] "Texas 1946 Secondary Road Program Established New Construction Record," *Engineering News-Record* 138, no. 4 (23 January 1947): 100.
[297] "Texas 1946 Secondary Road Program Established New Construction Record," *Engineering News-Record*, n.p.
[298] Texas Research League, "The Texas Farm to Market Road Program," 1957, 10-11.
[299] Dewitt C. Greer, "Subject: Design Standards for Farm to Market Roads," *Administrative Circular No. 23-62*, 7 February 1962.

The FM road system spanned many streams and rivers; therefore, bridges provided critical crossings. Many of the existing structures on FM routes were in poor condition and unable to meet current transportation needs. Thousands of structures were planned for replacement with modern facilities that could accommodate two-way traffic and larger vehicles with heavier weight loads.

The THD's commitment to the FM system is demonstrated by the state's expenditures in the 1950s on structures. During the 1950-51 fiscal year, just over $728,000 was spent on construction of bridges on FM roads, accounting for six percent of the total amount spent on bridges statewide. By the 1954-55 fiscal year, the amount had grown to $3.3 million, or 13.7 percent of the state's $24.3 million annual expenditure for bridges.[300]

In order to economically construct the thousands of bridges needed for the FM system, the THD developed standard plans to reduce design and construction costs.[301] During the 1940s, the reinforced concrete slab bridge type was heavily used for structures on the FM network.[302] Concrete slab bridges had been used extensively on THD roads prior to 1945 and were redesigned in the mid-1940s for specific use on the FM road system.[303] This design, modeled after research conducted at the University of Illinois, was called the FS Slab. Although extensive research did not reveal what "FS" signified, it may have stood for flat slab.

In the late 1940s, concrete pan-formed girder bridges, which were specifically designed for FM roads, became popular economical additions to the FM system. These structures were economical to construct because, in a time of high-priced labor, the pan-formed concrete bridges could be constructed utilizing reusable steel forms, reducing the amount of hours of skilled labor needed.[304] Reinforced concrete box culverts were also designed by the THD for smaller crossings on FM roads.[305]

THD continued to employ simple box and pipe culvert designs to span short crossings, similar to previous periods. By 1964, the department had a wide-ranging series of standards for single and multiple concrete box culverts, concrete culvert headwalls, and cement stabilized headwalls for metal and concrete pipe culverts.[306]

*Impacts of the FM System*

The intended purpose of the FM road system was to improve road service to farm families and enable farmers to enjoy better access to markets, medical services, and educational services. Additionally, rural mail service and access to recreational activities would improve. Many hoped that the FM road program would also deter farmers

---

[300] State Highway Department of Texas, *Eighteenth Biennial Report, 1950-1952* (Austin, Texas: State Highway Department of Texas, 1953), n.p; State Highway Department of Texas, *Twentieth Biennial Report, 1954-1956* (Austin, Texas: State Highway Department of Texas, 1957), n.p.
[301] "Texas 1946 Secondary Road Program Established New Construction Record," *Engineering News-Record*, n.p.
[302] Texas Department of Transportation, "Texas Historic Bridge Inventory: Survey of Non-Truss Structures," 32.
[303] Texas Department of Transportation, *Bridge Design Manual* ([Austin, Texas]: [Texas Department of Transportation], December 2001), Section 7-16.
[304] "Texas 1946 Secondary Road Program Established New Construction Record," *Engineering News-Record*, n.p; Frank W. Perrin, "Low Cost Bridge: Design Capitalized in a Texas County Road Program," *Roads and Streets* 93, no. 6 (June 1950): 39.
[305] "Texas 1946 Secondary Road Program Established New Construction Record," *Engineering News-Record*, 101-102.
[306] Dewitt C. Greer, "Subject: Culvert Standards," Administrative Circular No. 123-64, 17 November 1964; Texas Highway Department, F.M. Highway No. 1582, Frio, La Salle & McMullen Counties, Project Nos. R1500-1-4, R-1500-2-1, R1500-3-1, Plans of Proposed Grading, Structures, Base & Surfacing, 6 December 1961.

from abandoning their farms and ranches and moving into urban and suburban areas. However, in their 1957 report, the Texas Research League acknowledged that "the FM program has not halted the steady migration of farm population to the cities, and it has not stopped the process of farm consolidation which is shown by the rapid decrease in the gross number of farms while the acreage under cultivation remains static."[307] Despite the attrition of approximately 10,200 Texas farms between 1945 and 1954, the Texas Research League reported that County Commissioners agreed that rural land values increased along FM routes, social and religious activities increased substantially because of these paved roads, and the ease of transporting goods resulting from these roads benefitted both farmers and consumers.[308] An additional impact of the FM program was the shift from county oversight of rural roads to state administration. In 1937 the state administered only 11 percent of the total rural road mileage, carrying 71 percent of the rural traffic; but, by 1957, the state administered 26 percent of rural road mileage, carrying 87 percent of rural traffic. This shift in administrative responsibility relieved county officials and taxpayers.[309]

*County and Municipal Road Systems*

During the postwar period, the THD assumed responsibility for many miles of highway and streets as it expanded its FM road and urban highway systems. In doing so, the THD shifted responsibility away from county and city officials. For example, county roads constituted 147,002 miles of rural road mileage in Texas in 1954, representing a 13 percent decrease from the state's 1940 county road mileage of 169,625 miles. This mileage decrease was largely the result of the state's re-designation of some county roads as FM roads. Due to the growing postwar FM system, the majority of county roads served only local needs rather than inter-community traffic. Additionally, in 1954, the majority of county roads remained either unimproved or graded and drained earthen roads.[310]

Counties and municipalities continued to be involved in the construction and maintenance of roads and structures under their jurisdiction during the postwar period. An article in *Roads and Streets* by Frank Perrin, the Burleson County Engineer in 1950, mentioned that Burleson County built THD-designed pan-formed girder bridges on its county roads.[311] However, the pan-formed girder bridge generally was not very prevalent on county roads and had been designed originally for FM roads. In general, little information regarding decision-making processes for county roads and bridges was revealed during research efforts for prior TxDOT bridge studies. In a 2006 interview, Herman Baass, a retired bridge contractor, provided some insight regarding his experience building bridges for county governments along the Gulf Coast. He stated that county governments put forth a request for bids for a particular crossing and that the most inexpensive proposal that could span the crossing was typically chosen, with counties exhibiting little preference for particular bridge types or materials. Additionally, he noted that no engineers reviewed or signed his plans and he worked directly with the county commissioners and judges when issues arose.[312]

---

[307] Texas Research League, "The Texas Farm to Market Road Program," 1957, 13; Texas Research League, "A Program for Texas Highways," 1957, 5.
[308] Texas Research League, "The Texas Farm to Market Road Program," 1957, 14.
[309] Texas Research League, "A Program for Texas Highways," 1957, 5.
[310] Samuel Amado Muller, "A Study of the Public Road System in Texas," Thesis Presented to the Faculty of the Graduate School of the University of Texas, January 1955, 54-55.
[311] Perrin, "Low Cost Bridge: Design Capitalized in a Texas County Road Program," *Roads and Streets*, 39.
[312] Herman Baass, Interview with Mead & Hunt, Inc. and TxDOT Bridge Division, Texas Department of Transportation, digital audio and video recordings, Twin Pines Nursing Home, Victoria, Texas, 23 June 2006.

By 1954, a total of 26,857 miles of city streets existed in the 765 incorporated towns and cities in Texas. This mileage represented an increase of 34 percent over the 19,961 miles documented in 1940. The increase in mileage was due primarily to the growth of incorporated cities and towns, consolidations, and urban expansions. Additions to the city street system in the postwar period included the expressway systems constructed in Houston, Dallas, San Antonio, Fort Worth, El Paso, and Austin, which are discussed in more detail below. Additionally, by 1954, the THD had rebuilt or modernized 300 miles of city streets into urban highways in an effort to alleviate traffic bottlenecks.[313] By 1957, the state's highway network included approximately 3,000 miles of city streets (approximately 10 percent of the state's city street network).[314]

Very limited information was found during research efforts regarding decision-making processes and road and bridge-type preferences in urban city governments. Examination of bridge inspection files during previous TxDOT bridge studies produced plans for some city bridges, which were often designed by consulting engineering firms for the city or other government agencies.

*Postwar Trends for U.S. and State Primary Routes*

While interstate highways were a newly conceived road system, the U.S. and State Highways were well established, mature systems at the beginning of the postwar period. First designated by AASHO and the BPR in 1925 and 1926 to form a nationwide network of highways, the system continued to be expanded until the advent of the Interstate Highway System with the passage of the Federal Aid Highway Act of 1956.

Texas state highways, including short links often called loops and spurs, are funded and maintained by the state to provide local and regional access to US and interstate highways. Essentially, the state highways provide primary route access in areas with no designated U.S. or IH highway. Both the U.S. and SH systems are considered primary roads with minimum H-20 (two axles carrying 40,000 pounds) design load requirements. Despite the rapid expansion of the state's overall road network, which doubled in the postwar period, in large part due to the FM program, the state's additional primary and secondary roads were still critical to Texas's highway needs. In 1957, primary and secondary roads (not including FM roads) numbered more than 23,000 miles, carried the bulk of rural traffic, and connected population centers throughout the state. Although the mileage of these road networks did not change much during the postwar period, the traffic volume they carried increased substantially. In 1946, these roads carried almost 23 million vehicle miles of travel daily, and by 1955, without any major mileage increases, daily travel on the state highway system increased to nearly 40 million vehicle miles.[315] As the Texas Research League reported, "the tremendous increase in traffic on the main rural state highways has made it necessary to think in terms of many miles of multi-lane highway where formerly two-lane roads would have been adequate for years to come."[316]

A number of projects in the mid-1950s addressed these issues to upgrade some U.S. and State highways to expressway standards, including interregional multi-lane "superhighways" along US 81 and US 77, which were to be completed in 1961. These expressways were soon re-designated as interstates, including IH 35. Additional information on expressways is found in the following section. Notably, much of the early work was completed in

[313] Muller, "A Study of the Public Road System in Texas," 55-58.
[314] Texas Research League, "A Program for Texas Highways, 1957, 5 and 7.
[315] Texas Research League, "A Program for Texas Highways, 1957, 7-8.
[316] Texas Research League, "A Program for Texas Highways, 1957, 9.

urban areas as part of urban expressway projects. Nonetheless, by 1955 the state's road network included 37 US Highways and 210 state highways.[317]

*Expressway and Interstate Highway Systems*

The THD was at the national forefront of designing urban expressways, also called freeways or controlled-access highways, prior to the advent of the Interstate Highway System, which is also a controlled-access freeway system. As early as 1940, San Antonio had a proposed loop expressway system.[318] By 1943, state laws had been enacted to permit the THD to build expressways in larger cities, a program that was ultimately nationally promoted and directed by the Federal Aid Highway Act of 1944. By 1945, Texas State Highway Engineer Dewitt C. Greer created special expressway project offices in Houston, Dallas, Fort Worth, and San Antonio to achieve the program goals. By 1950, the state had 1,518 miles of controlled access highways under construction in Dallas, Fort Worth, Houston, and San Antonio.[319] However, according to Greer, it was not until 1951 that the state-wide expressway program really expanded—this was the year that the Texas Legislature ratified a law permitting the state to purchase right-of-way to provide frontage roads and access control for the expressway system.[320] Prior to this, the THD was responsible for design and construction of urban expressways only, while the city was responsible for the cost of right-of-way.[321] Citizens of Dallas, Houston, San Antonio, and Fort Worth voted to provide funds to purchase right-of-way for these limited-access highways in the mid-to-late 1940s, and projects were planned to build urban routes directly through cities, utilizing elevated grade separation structures.[322] Many of the expressways, which were often originally designated as State or US Highways, would ultimately be incorporated into the interstate system beginning in the late 1950s.

Expressways, including the interstate highways of the late 1950s, were designed to provide fast and safe mass transportation within, through, and connecting metropolitan areas. The objective of the expressway was to separate through traffic from cross traffic, which included turning vehicles, parked cars, and pedestrians. These roads were able to handle three to four times the traffic volume of highways and city streets of the same width. Ingress and egress was available only at designated control points, and bridges or overpasses (grade separation structures) were required at most intersections to eliminate at-grade crossings and improve safety and traffic flow.[323] Within cities, routes were typically constructed a few blocks from the main downtown area. Such routes were favored because property values and, hence, right-of-way costs were lower and they helped move traffic away from congested urban centers. In urban areas where congestion of heavy automobile traffic could not be avoided, elevated roads were often constructed.[324]

---

[317] Erlichman, 207.
[318] Erlichman, 191-192.
[319] Erlichman, 195.
[320] Hagan, *An Informal History of the Texas Department of Transportation*, 29; Dewitt C. Greer, "Access Control One Way of Restoring Traffic Stability," *Better Roads*, October 1956, 50.
[321] "Texas Urban Expressways Being Designed from Center Out," *Roads and Streets* 88, no. 11 (November 1945): 11-12.
[322] "Texas Urban Expressways Being Designed from Center Out," *Roads and Streets*, 65.
[323] "Golden Anniversary, Texas Highway Department, 1917-1967," *Texas Highways* 108; Department of Economic Development, "State's top community development projects honored;" Dewitt C. Greer, "Expressways," *Texas Highways* (n.d.): 8-9; Laurence I. Hewes and Clarkson H. Oglesby, *Highway Engineering* (New York: John Wiley & Sons, Inc., 1954), 36.
[324] "Texas Urban Expressways Being Designed from Center Out," *Roads and Streets*, 11-12.

*Design Standards for the Expressway and Interstate Systems*

Design and construction of freeways and related structures nationwide, and in Texas, was influenced by standards created by national transportation organizations. Two such organizations played a prominent role in setting and disseminating design standards. Plans and guidance developed by the BPR and professional transportation organizations, like AASHO, were instrumental in setting federal transportation policy and disseminating information regarding new materials and technology, standard designs, and best practices to state departments of transportation. These organizations had influenced roadway and bridge design standards since the 1910s. During the postwar period, national design standards, plans, and specifications were frequently adopted by state departments of transportation, including Texas. The Federal Aid Highway Act of 1956 formalized efforts of the BPR and AASHO to work together on national design standards.

Throughout the postwar period, the BPR defined national standards and specifications for transportation facilities, approved state's proposals for road and bridge construction projects utilizing federal funds, provided guidance on road and bridge construction, and prepared and distributed standard bridge plans. This information was disseminated through publications of research studies and design manuals.[325] The BPR published its first edition of standard bridge plans in 1953 and periodically updated these plans to reflect new technologies and materials. The 1956 edition includes plans for a variety of highway superstructures of varying span lengths and roadway widths, including I-beams, plate girders, and concrete slabs. Bridge types included in the BPR standard plan set reflect established bridge types and designs commonly constructed during this period.

Like the BPR, AASHO had a long history of defining and disseminating standard practices for road and bridge building to address varying traffic needs, loads, and speeds. In 1945, AASHO first adopted specific recommended design standards for interstate highways.[326] AASHO also issued guidance and policies on grade separation structures. In 1944 AASHO published *A Policy on Grade Separations for Intersecting Highways*.[327] In 1956, AASHO adopted *A Policy on Design Standards, Interstate System*, establishing the geometric design standards for the interstate system.[328] Among the standards issued in the 1956 policy were:[329]

- Design speed of at least 70, 60, and 50 miles per hour (mph) for flat, rolling, and mountainous topography, respectively, and at least 50 mph in urban areas
- Gradients not steeper than three percent for 70 mph roadways, four percent for 60 mph roadways, and five percent for 50 mph roadways
- Traffic lanes not less than 12 feet wide
- Divided highways where the design hourly volume exceeds 700

---

[325] "Brief History of the Direct Federal Highway Construction Program," Federal Highway Administration, http://www.fhwa.dot.gov/infrastructure/blazer01.htm (accessed 3 March 2005).
[326] American Association of State Highway Officials, *Policies on Geometric Highway Design* (Washington, D.C.: American Association of State Highway Officials, 1945), 4.
[327] American Association of State Highway Officials, *A Policy on Grade Separations for Intersecting Highways* (Washington, D.C.: American Association of State Highway Officials, 1944), 43.
[328] American Association of State Highway Officials, *A Policy on Design Standards: Interstate System* (Washington, D.C.: American Association of State Highway Officials, 1959), 5-6.
[329] American Association of State Highway Officials, *A Policy on Design Standards: 1 – Interstate System, 2 – Primary System, 3 – Secondary and Feeder Roads* (Washington, D.C.: American Association of State Highway Officials, 1956), 2-6.

- Medians measuring 36 feet wide in rural areas with flat and rolling topography and measuring at least 16 feet wide in urban and mountainous areas
- Usable shoulder width of not less than 10 feet on the right of traffic
- Bridges and overpasses of deck construction with a clear height of at least 14 feet

AASHO published *A Policy for Arterial Highways in Urban Areas* in 1957, which built upon the 1954 policy for rural highways and included substantial guidance on interchange design and grade separations in metropolitan areas and took into account traffic operation and driver behavior.[330] Many of the policies, research information, and specifications developed and promoted by AASHO and the BPR were incorporated into the THD's postwar road and bridge program.

A unique design feature of Texas expressways and Texas interstate highways is the use of frontage roads paralleling the high-speed, controlled access highway. In a 1956, *Better Roads* article, Dewitt C. Greer discussed THD's long standing policy of building frontage roads, a policy that was established during World War II as a means to eliminate chance of property-damage charges. According to Greer, "in Texas, an expressway is always defined as a multi-lane divided highway with frontage roads and control of access. Traffic that originates on or is destined for the roadside has unrestricted access to the frontage roads and is fed at controlled points into the through lanes for express traffic."[331] Greer asserted that freeways with frontage roads increase property values up to five miles away, thus positively impacting the urban economy, while also addressing the concerns of the adjacent landowner by providing access to the expressway through parallel frontage roads.[332] Greer's established standards for interstate highways in Texas included a right-of-way measuring 150 feet for the interstate route and an additional 100 feet for frontage roads. As a result, the Texas interstate system features 4,500 miles of parallel frontage roads, which give the system a different feeling than similar systems throughout the country.[333]

*Expressways*

The earliest expressways, dating from the 1940s and referred to as "first generation," were typically four lanes wide and did not always include shoulders, although they did typically feature frontage roads. Many bridges constructed under the first generation were of a minimum width and unfortunately were not planned with future widening in mind. The second generation of expressways came within two decades of the first generation and in response to the need for increased traffic capacity. These facilities typically included six to 10 lanes, wider medians, shoulders, and crown-width bridges—a concept initiated by the THD that substituted guardrails for curbs.[334] Early Texas expressway projects that demonstrate the challenges of first generation expressways and evolution include the Gulf

---

[330] American Association of State Highway Officials, *A Policy on Arterial Highways in Urban Areas*, n.p; American Association of State Highway Officials, *Standard Specifications for Highway Bridges*, n.p.
[331] Greer, "Access Control One Way of Restoring Traffic Stability," *Better Roads* (October 1956), 31.
[332] Greer, 50.
[333] Beaumont, 12.
[334] Texas Department of Transportation, "Bridge Inspection Manual," Texas Department of Transportation, http://manuals.dot.state.tx.us/dynaweb/colbridg/ins/@Generic__BookTextView/3;cs=default;ts=default;pt=8 (accessed 11 July 2005), Section 5.

Freeway, located between Houston and Galveston, begun in 1948; the North Central Expressway in Dallas, begun in 1949; and the Eastex Freeway in Houston, authorized in 1945 and 1953 and begun in the early 1950s.[335]

*Case Study: Gulf Freeway – IH 45 South, Houston, Texas (see Figure 40 and Figure 41)*

Recognized as Texas' first freeway, the first section of the Gulf Freeway opened to traffic on September 30, 1948, to much fanfare. Planning efforts for this route began in the 1930s and continued through the 1940s as the City of Houston envisioned a super-highway between Houston and Galveston along the former route of the Galveston-Houston Electric Railway. Prior to the Gulf Freeway's construction, SH 3/US 75 was the main route between Houston and Galveston. The Gulf Freeway was ultimately given the US 75 designation, while SH 3 remained along its current alignment. With the advent of the interstate system, the Gulf Freeway was also designated as IH 45.

Following the passage of the Federal Aid Highway Act of 1944 and the disbursement of funds after World War II, the THD released formal plans for the Gulf Freeway featuring overpasses and frontage roads, a design feature that distinguished this Texas freeway from other emerging freeways throughout the country.[336]

The THD awarded the first construction contracts in September 1946, and two years later the first section of the freeway, extending from downtown Houston to Telephone Road, opened to traffic. Progress on the remaining mileage between Houston and Galveston moved quickly and featured a 300-foot-wide alignment bypassing the two cities. The highway featured gentle curves to combat driver monotony and a number of dog-legs to achieve the optimal alignment over stream crossings and through the most easily acquired right-of-way. On August 2, 1952, a dedication ceremony was held for the full length of the highway. Although named the "Gulf Freeway," only 8.5 miles of the route within Houston were actually of freeway design; the remaining stretch of highway, although divided, featured 32 at-grade crossings. However, the THD quickly decided to start a program to eliminate 30 at-grade crossings beginning in 1959, a program that was complicated by the fact that the THD had not purchased access rights along this stretch of highway. Ultimately, the entire highway would feature frontage roads, and in 1976, the last at grade crossing was eliminated.[337]

The Gulf Freeway became heavily congested within a decade of its completion, making obvious the deficits of first generation freeway design. These shortcomings included the absence of a median barrier; access ramps that were too short; poor sight lines from its rolling topography, especially at overpasses; and bridges that lacked shoulders. The THD would take these lessons and apply them to the second generation of Houston freeways, beginning in the late 1950s. Simultaneously, the THD began to reconstruct the Gulf Freeway to meet the traffic demands of the city. In 1960, the first widening project to expand the freeway to six lanes was completed between present-day Loop 610 southward to Sims Bayou. Segments of the first generation freeway along the Gulf Freeway continued to be visible until the early 1980s.[338]

---

[335] The source references this to be the first expressway constructed in Texas, but this could not be confirmed. Erik Slotboom, *Houston Freeways: A Historical and Visual Journey* (Cincinnati, Ohio: C. J. Krehbiel, 2003), n.p.
[336] Erik Slotboom, *Houston Freeways: A Historical and Visual Journey* (Cincinnati, Ohio: C. J. Krehbiel, 2003), 144-147.
[337] Slotbloom, 149.
[338] Slotbloom, 152-155.

*Case Study: North Central Expressway – US 75, Dallas, Texas (see Figure 42 and Figure 43)*

Like the Gulf Freeway, the North Central Expressway had its origins in a railroad corridor: the Houston and Texas Central Railroad (H&TC). Following George Kessler's City Beautiful plan for Dallas, which included the possibility of removing the H&TC tracks for a boulevard, the vision of a wide north-south thoroughfare was heavily engrained in the minds of Dallas officials and planners. However, it was not until the THD became involved in 1943 that the north-south expressway became a reality. At this time, the THD and the City of Dallas reached an agreement for the city to provide right-of-way and drainage outside of the right-of-way, and for the THD to provide engineering services and construction within the right-of-way, including overpasses, underpasses, curbs, gutters, and sidewalk. Despite this agreement, progress on the project was stalled by World War II and the resulting restrictions on materials such as steel and concrete and also by the necessary negotiations with the railroad companies who owned the track that the expressway would subsume.[339]

In February 1947, the first contract for the North Central Expressway was awarded. Two years later, on August 19, 1949, a gala celebration was held to commemorate the opening of the first segment of expressway, which measured only two miles long. By 1956, the entire length of the North Central Expressway opened, extending from the southern city limits beyond the northern city limits to McKinney. However, like the Gulf Freeway in Houston, traffic congestion quickly characterized the route and demonstrated the shortcomings of this first generation expressway.

Improvements to the expressway, including widening, continued through 1999. As an urban expressway, the North Central was critical to the high-tech industrial growth of Dallas. It is not surprising that industries, such as Texas Instruments, and suburban office buildings and retail development located along the route.[340]

*Case Study: Eastex Freeway – US 59 North, Houston, Texas (see Figure 44)*

The Eastex Freeway, authorized in 1945 and 1953, was Houston's second completed freeway and extended from Houston north to the Liberty County line (40 miles). As with other urban expressways, the City of Houston was responsible for acquiring the costly right-of-way for this heavily urbanized route; ultimately, the city sold $1.3 million in bonds to help fund the acquisition. By 1951, the first construction contract was awarded for frontage roads and the dedication of the first opened section was held on December 22, 1953. Like the Gulf Freeway and North Central Expressway, the Eastex Freeway quickly suffered from low first generation freeway standards, including the narrow width, overpasses without shoulders, and ramps with poor geometrics. However, the low capacity was not an immediate problem for this route. It was not until the Houston Intercontinental Airport (now Bush Intercontinental Airport) was opened in 1969 and Friendswood Development, a division of Exxon Corporation, implemented a 14,000-acre planned community in north Houston (Kingwood) that traffic on the Eastex Freeway reached capacity. Expansion and reconstruction efforts began in the early 1970s and continued through the 1990s.[341]

---

[339] Tom Killebrew, "The Creation of the Modern Freeway in Dallas, Texas, 1911-1949: the Story of North Central Expressway," *Legacies: A History Journal for Dallas and North Central Texas, XIV*, no 1 (Spring 2002): 39-47.
[340] Killebrew, 47-49.
[341] Slotboom, 226-231.

*Tolled Highways: The Dallas-Fort Worth Toll Road and Dallas North Tollway*

Although tolled highways of expressway standards were not as prominent in Texas as in other states across the nation, one example from the postwar period is the Dallas-Fort Worth Toll Road, commonly known as "The Turnpike." In 1953, the state legislature approved the creation of the Texas Turnpike Authority to build a turnpike toll highway between Dallas and Fort Worth. Opened in August 1957, this facility was built as a six-lane divided expressway with limited access.

The new highway replaced US 80, and its 82 stoplights, as the primary artery between the central business districts of the two cities. Arlington, near the midpoint of the toll road, soon became one of the nation's fastest-growing cities, with entertainment attractions, such as Six Flags of Texas and Arlington Stadium, and the Great Southwest Industrial Park locating adjacent to the new highway. By 1977, the toll road bonds were paid off, ahead of schedule, and the highway was transferred to the State Department of Highways and Public Transportation, the successor agency to the THD; the former Turnpike now comprises part of IH 30.[342] A second toll highway, the Dallas North Tollway, was being planned in the mid-1960s. In 1968, the first segment of the Dallas North Tollway opened between IH 35E in Dallas to IH 635. The route expanded northward to US 380 near Frisco throughout the next four decades.

Unlike Texas freeways, tollways had no frontage roads, featured very limited access, and had specific ramp and interchange designs to accommodate tollbooths (see Figure 45). On the Dallas-Fort Worth Turnpike, toll plazas were located just west of downtown Dallas and in east Fort Worth, with just a handful of interchanges along the 30-mile route. A service center located on the Turnpike at Arlington housed a restaurant and a service station for each direction of traffic, representing the only businesses accessible from the highway.[343] Figure 46 shows an example of the distinctive trumpet and double-trumpet interchanges found along the Turnpike. The Texas Turnpike Authority maintenance offices are shown in the image's foreground and the Turnpike service center in the background.

***Interstate Highway System***

As discussed above, the 1944 Federal-Aid Highway Act greatly expanded federal funding for the nation's road system. The Act also authorized designation of the National System of Interstate Highways. The interstate system was intended to connect principal metropolitan areas, cities, and industrial centers, and to serve national defense and connect border points with routes of continental importance in Canada and Mexico. The interstate system was expected to carry 20 percent of the nation's traffic and connect 90 percent of cities with a population of 50,000 or more. The 1944 Act called for the system not to exceed 40,000 miles.[344] A drawback of the act was that it did not provide funding for construction of the interstate system, but only acknowledged the designation.[345]

---

[342] Erlichman, 199-200; Texas Department of Transportation, "IH 30 Corridor," Texas Department of Transportation website, http://www.dot.state.tx.us/ftw/mis/ih30/history.htm; O.K. Carter, "The biggest reason for Arlington's decades-long boom," *Fort Worth Star-Telegram*, 30 August 2007, B-2.
[343] "Dallas – Fort Worth Turnpike." *Texas Highways* 4, no. 12 (December 1957), 22.
[344] A. E. Johnson, ed., 153.
[345] "Golden Anniversary, Texas Highway Department, 1917-1967," *Texas Highways* 14, no. 9 (September 1967): 31; Department of Economic Development, "State's top community development projects honored," http://web.archive.org/web/20040503212353/http://pio.neded.org/press/2001/01rel21.htm (accessed 4 March 2008).

Not surprisingly, the 1944 Federal Aid Highway Act did not anticipate postwar financial prosperity, which dramatically increased automobile ownership, highway usage, and commercial development. The unexpected increase in automobile usage created congestion in many urban areas and increased pressure on the overall transportation network.[346] While several other highway acts were passed in 1950, 1952, and 1954, they were overshadowed by the Federal Aid Highway Act of 1956. These acts, in the early 1950s, continued federal funding to states for road and bridge projects with only slight increases in appropriations and provided limited funding for the interstate system. The Federal Aid Highway Act of 1952 authorized the first funding for the interstate, but it was only $25 million a year nationally for fiscal years 1954 and 1955. The Federal Aid Highway Act of 1954 authorized an additional $175 million for fiscal years 1956 and 1957.[347] However, this was only token money and did not provide enough to begin large-scale construction of the interstate. In addition to continuing postwar construction efforts, these acts also provided funds for interstate planning, which had been previously authorized in the 1944 Federal-Aid Highway Act.

The Federal Aid Highway Act of 1956 not only substantially increased federal appropriations to states for primary, secondary, and urban highway construction, it made the first significant appropriations for construction of the interstate highway system. The 1956 Act expanded the interstate system to 41,000 miles and provided allocations for 90 percent of construction costs, with states only responsible for the remaining 10 percent. The entire interstate system was anticipated to cost more than $27 billion nationwide.[348] In order to finance construction, federal legislation created the Highway Trust Fund, which was supported by an increased federal tax on gas and diesel fuel.[349] The 1956 Federal-Aid Highway Act also authorized an initial 13-year construction period for interstate highways, which would eventually be extended as states faced routing and funding difficulties.

In addition to increased funding for road construction and financial backing for the interstate, the 1956 Act brought uniformity to the nationwide road-building effort. The Act included a provision requiring national organizations, such as AASHO and the BPR, to cooperate to develop design standards to accommodate traffic forecasts through 1975. The standards were meant to ensure national uniformity of design, provide full control of road access, and eliminate at-grade crossings.[350]

*Texas's Interstate System*

Starting construction on the interstate was a major focus of the THD from 1956 to 1965. Texas was allocated 2,905 miles out of the total 41,000-mile interstate system nationwide that was outlined in the Federal-Aid Highway Act of 1956. The state's mileage was to be included on seven interstate highways: three running north-south from Oklahoma through Dallas-Fort Worth to Corpus Christi, Laredo, and Galveston (IH 35, 37, and 45); and four running east-west, one across the panhandle and three from Shreveport, Texarkana, and Orange westward to El Paso (IH 10, 20, 30, and 40). There were also four urban loops within this mileage at Dallas, Fort Worth, San Antonio, and Houston. In some cases, the first generation expressways discussed above were incorporated into

---

[346] Seely, *Building the American Highway System: Engineers as Policy Makers*, 191.
[347] Federal Highway Administration, "The Dwight D. Eisenhower National System of Interstate and Defense Highways," Federal Highway Administration, http://www.fhwa.dot.gov/reports/routefinder/ (accessed 3 August 2005).
[348] A. E. Johnson, ed., 181.
[349] Tom Lewis, *Divided Highways: Building the Interstate Highways, Transforming American Life* (New York: Viking, 1997), 121.
[350] Richard F. Weingroff, "Federal-Aid Highway Act of 1956: Creating the Interstate System," Federal Highway Administration, http://www.fhwa.dot.gov/infrastructure/rw96e.htm (accessed 8 October 2004).

Texas's urban interstate system, as was the case with the Gulf Freeway (now IH 45 in Houston) and the Interregional Highway (now IH 35) in Austin.[351] Where state highway initiatives, including FM programs, had required cities and counties to be responsible for the cost of right-of-way, federal funds allocated under the 1956 Act included up to 90 percent of interstate construction costs and provided for the cost of interstate right-of-way.

The THD oversaw the design of interstate projects, and the majority of construction work was hired out to contractors.[352] Interstate highway planning and construction progressed quickly in Texas. In 1956, the first interstate contract was let for a portion of IH 45 in Navarro County near Corsicana.[353] In 1957, only one year after passage of the federal act, the Texas Highway Commission had already approved its third program of interstate projects in the state. Between the three project programs, Texas had more than 1,500 miles of its interstate system under development, including advance planning for an additional 404 miles. Interstate construction continued at a rapid pace in Texas, and by the beginning of 1959, Texas led the nation in interstate construction, with 444 miles completed, including 402 interstate bridges, and an additional 436 miles under construction.[354]

By 1962, Texas's interstate system included the following highways, which were either open, under construction, or planned:[355]

- IH 10 from the Louisiana border to the New Mexico border north of El Paso (879 miles)
- IH 20 from the Texas border east of Marshall through Dallas-Fort Worth to a point southwest of Pecos, where it joined IH-10 (634 miles)
- IH 30 from Texarkana to Dallas-Fort Worth where it joined IH 20 (240 miles)
- IH 35 from the north Texas border to Laredo, including both IH 35E and IH 35W (492 miles)
- IH 37 from San Antonio to Corpus Christi (142 miles)
- IH 40 from the Texas-New Mexico state line to the Texas-Oklahoma state line (182 miles)
- IH 45 from Dallas to Galveston, passing through Houston (286 miles)

In September 1963, Texas continued to lead the nation in interstate miles constructed, with 1,264 miles open to the public. An additional 1,163 miles were in progress, placing Texas second only to California, which had 1,346 miles in progress.[356] In November of that year the Texas Highway Commission approved the largest work program in the history of the THD, enabling it to secure all remaining right-of-way for the interstate system and to cover construction costs for additional miles.[357] In 1965 Texas continued to lead the nation in number of interstate highways constructed, with 1,623 miles open to traffic (see Figure 47). Although the state was well-positioned to initiate a strong campaign of interstate construction, it is likely that Texas led the nation in construction, in part, due to the sheer number of interstate miles that were designated to cross the state.

---

[351] Kite, "A History of the Texas State Department of Highways and Public Transportation 1917-1980," 135-136.
[352] Weingroff, "Federal-Aid Highway Act of 1956: Creating the Interstate System," Federal Highway Administration.
[353] Beaumont, 29.
[354] James W. Barr, "Interstate Progress Report," *Texas Highways* 6, no. 1 (January 1959): 2-3; "Commission Approves Third Interstate Phase," *Highway News* 11, no. 1 (February 1957): 2; Erlichman, *Camino Del Norte*, 209.
[355] Beaumont, 29.
[356] Richard Pierce, "Interstate: More Than the Sum of Its Parts," *Texas Highways* 11, no. 2 (February 1964): 1.
[357] "Giant Step in Interstate Progress," *Texas Highways* 11, no. 1 (January 1964): 10.

Texas also built its portion of the interstate more economically than other states, averaging $610,000 per mile compared to the national average of approximately $1 million per mile.[358] A 1963 article called "Bridge Building Costs Texas Less" summarizes a BPR study that found that Texas had the lowest cost per square foot for interstate bridges. In the article, Greer was quoted as saying that economy on the interstate bridges was achieved through the standardization of bridge details.[359] Additional economies were achieved because Texas had about 2,500 miles of highways that could simply be upgraded to new federal interstate standards; thus, many of Texas's interstate routes were developed along existing US and state highways. For instance, IH 45 replaced US 75 between Dallas and Houston; IH 35 replaced US 81, and IH 40 replaced US 66 across the Panhandle. Much of Texas's interstate system encompasses upgraded existing roads for which frontage roads were built during the improvement process. Additionally, in some cases, former US and SH roadbeds were used as frontage roads for the new interstate system.[360] Examples include:

- The IH 20 westbound frontage road in western Parker County, where the truss bridge originally constructed to carry US 80 over the Brazos River (TxDOT Structure No. 02-184-0-0314-01-006, in vehicular service) became the bridge for the frontage road lanes.
- The IH 10 northbound frontage road in Kimble County, where the truss bridge originally constructed to carry US 290 over Johnson Fork Creek (TxDOT Structure No. 07-134-0-0142-01-003, in vehicular service) became the bridge for the frontage road lanes.
- The IH 20 eastbound frontage road in Eastland County, where the concrete girder bridge originally constructed to carry US 80 over Bear Creek (TxDOT Structure No. 23-068-0-0314-05-020, in vehicular service) became the bridge for the frontage road lanes.

Like many other states, Texas was unable to complete its interstate system by 1972, as was stipulated in the 1956 Federal-Aid Highway Act. Additionally, two interstate routes were added to Texas's system in 1969 and 1982. IH 27, which connects Amarillo and Lubbock over a distance of 124 miles, was designated in early 1969 following the Federal-Aid Highway Act of 1968, which added 1,500 miles to the national interstate system. IH 44, from Wichita Falls to the Texas-Oklahoma state line, was designated in 1982 and links Texas to Missouri via Oklahoma. The last segment of Texas interstate, a segment of IH 27, was not completed until 1992.[361]

*Expressway and Interstate Grade Separation Structures and Interchanges*

THD constructed several large traffic circles in major cities during the late 1940s and early 1950s in an attempt to handle the growing urban traffic volumes of the postwar years. Examples include the Field Traffic Circle that connected US 77, SH 114 (now LP 12), and US 183 in Dallas; the Broadway and North Loop Traffic Circles on early freeways in Houston. Circles were also constructed in smaller cities, such as Henderson, Mexia, and San Marcos, where multiple major highways intersected. None of the above listed structures remains extant. A late example of traffic circle construction was the Benbrook Traffic Circle built in the late 1950s in southwest Fort

[358] "Texas Holds Road-Building Lead in U.S.," *Dallas Times*, 1 January 1964, n.p.
[359] "Building Bridges Costs Texas Less," *Highway News* 17, no. 9 (September 1963): 5.
[360] Beaumont, 29.
[361] Beaumont, 29.

Worth. The Benbrook Circle, over 1000 feet wide at its greatest diameter, remains in operation at the intersection of US 377 and SH 183.[362]

Expressway and interstate construction in the late 1940s through the 1960s led to construction of a number of specialized structures including overpasses, underpasses, and more complicated multi-level interchanges. Reflecting expressway design guidelines discussed above, both expressway and interstate bridges often included prestressed concrete girder, steel I-beam, and steel girder bridges. In particular, bridge types such as steel I-beam and reinforced concrete box beams were used when curved spans were needed, and often utilized in interchanges for these same reasons.

When AASHO issued design standards for the interstate system in 1956, it established a minimum design value of 14 feet for vertical clearance (the distance from the interstate roadway pavement to the bottom of the overpass). It was not until after the interstate system was under construction that the Department of Defense (DOD) informed the BPR that the 14-foot clearance was not adequate for defense purposes. In 1960, the Secretary of Commerce revised the minimum vertical clearance to 16 feet. The revised standard applied to all interstates in rural areas and to limited numbers of urban Interstate routes.[363] At the national level, previously constructed bridges represented a significant problem with the new vertical clearance standards since the cost of correcting vertical clearance could be prohibitively expensive. Corrective efforts included lowering the roadway grade, raising the superstructure using power jacks, or providing exit and entry ramps to enable easy on-and-off access of military equipment. Following a 1967 survey revealing that 2,650 bridges within the system did not meet the revised DOD standards, the Federal Highway Administration (FHWA), AASHO, and the Military Traffic Management Command decided that a priority network would be established to serve major military installations and only 350 bridges nationwide would be corrected to provide clearance.[364]

During the postwar period, established forms of interchanges included the T, Y, cloverleaf (partial or full), trumpet, diamond, directional, and rotary types.[365] In particular, the directional interchange type was utilized for the intersection of two high-volume freeways. This type of interchange, which often includes several structures or multi-level structures, results in free-flow paths with little extra travel distance. During the 1950s and 1960s, urban freeway and interchange concepts evolved and responded, in particular, to the factors of high traffic speed and high volume.[366]

The first three-level interchange in Texas was constructed in 1953 at the west end of the Baytown Tunnel, southwest of Baytown, as part of an overall highway plan to connect SH 225, SH 146, and the tunnel. Originally,

---

[362] Slotboom, 147, 228-229; Texas State Highway Department, *General Highway Map, Dallas County, Rockwall County*, 1954, revised to 1961; Texas State Highway Department, *General Highway Map, Limestone County*, 1957, revised to 1961; Texas State Highway Department, *General Highway Map, Rusk County*, 1955, revised to 1961; Texas State Highway Department, *General Highway Map, Tarrant County*, 1958, revised to 1961.
[363] FHWA, "Right of Passage: The Controversy Over Vertical Clearance on the Interstate System," Federal Highway Administration, http://www.fhwa.dot.gov/infrastructure/50vertical.cfm.
[364] FHWA, "Right of Passage: The Controversy Over Vertical Clearance on the Interstate System," Federal Highway Administration.
[365] American Association of State Highway Officials, *A Policy on Geometric Design of Rural Highways*, n.p.; American Association of State Highway Officials, *A Policy on Design Standards: 1-Interstate System, 2-Primary System, 3-Secondary and Feeder Roads*, n.p.; American Association of State Highway Officials, *A Policy on Arterial Highways in Urban Areas*, n.p.
[366] Donald W. Loutzenheiser, "New Concepts for Urban Freeway Interchanges," *Journal of the Highway Division: Proceedings of the American Society of Civil Engineers* 88, no. HW1 : 31, 36.

plans prepared by the consultant included two structures and an at-grade crossing of the Texas and New Orleans Railroad. The THD district engineer thought a better solution was possible and recommended a three-level interchange. This proposed design met some resistance due to the fact that the structure would be the first of its kind in Texas and the low traffic volume at the site may not have justified such a structure. The three-level interchange was designed using a standard continuous I-beam supported by conventional three-column bents (substructure unit made up of columns connected at the top by a cap or strut).[367] The bridges now at this location were constructed in 1999 and 2000, and original three-level interchange is no longer extant. Shortly after completion of the Baytown interchange, two more three-level interchanges were completed in 1955: the non-extant Fort Worth Expressway interchange and the US 81 (now US 77 Business) expressway interchange at Waco, which included a top-level bridge carrying US 84 (TxDOT Structure No. 09-161-0-0055-15-380, in vehicular use) and a middle-level bridge carrying northbound and southbound lanes of US 81/US 77 Business (TxDOT Structure Nos. 09-161-0-0055-15-001 and 09-161-0-0055-15-006, both in vehicular use).[368] In 1958, a three-level interchange at the intersection of US 77 Business (now also IH 35) and State Spur 484 was completed. This interchange included a continuous I-beam bridge for the middle-level roadway carrying US 77 Business Northbound (TxDOT Structure No. 09-161-0-0049-01-124, in vehicular use) and a continuous plate girder bridge for the top-level roadway carrying State Spur 484 Southbound (TxDOT Structure No. 09-161-0-0049-01-141, in vehicular use).[369]

Texas's first four-level interchange was completed in 1958 at the intersection of IH 20 and IH 35 in Fort Worth. Known locally as a "pretzel" or "mixmaster," this non-extant four-level interchange was designed before the establishment of national interstate standards. Originally planned in 1945-1947 as a cloverleaf interchange, the design was adjusted after subsequent traffic estimates identified the need for a direct-connection interchange to handle more traffic than was capable with the cloverleaf interchange. Because of restrictions on acquiring additional right-of-way due to existing railroad tracks and a government housing project, the resulting design stacked four roadways and included steep grades and curves on the ramps. Ultimately, the interchange met most of the AASHO interstate design standards with the exception of maximum grade on a small portion of IH 35. The interchange used continuous reinforced concrete haunched spans for several notable reasons, including a shortage of structural steel and slow delivery times, the necessity of vertical clearance requirements, and reinforced concrete's adaptability to horizontal and vertical curves without complex shop details.[370] This interchange was known nationally, and in a 1962 study, it was identified as an example of a compact directional interchange necessitated by site limitations. Although the geometrics of the interchange were slightly lower than the 1962 norm, the author suggested that the interchange should be viewed by other engineers and designers, citing that more attention should be paid to overall urban effects of plans than to developing the highest possible standards throughout the directional interchange.[371]

---

[367] Randle B. Alexander, "3-Level Traffic Separation at West End of Baytown Tunnel," *Texas Highways* 1, no. 3 (January 1954): n.p.
[368] "The Only Way to Go is Up...Three Level Interchanges," *Texas Highways* 2, no. 8 (June 1955): 3-4.
[369] Inspection files for Structure 091610004901124 and Structure 091610004901141, Texas Department of Transportation, Waco District Office, Waco, Texas.
[370] "The Pretzel," *Texas Highways* 5, no. 3 (March 1958): 2-8.
[371] Loutzenheiser, "New Concepts for Urban Freeway Interchanges," *Journal of the Highway Division: Proceedings of the American Society of Civil Engineers*, 36.

*Roadside Parks and Highway Beautification*

After a period of inactivity and deterioration during World War II, THD's roadside park program was reinvigorated in the postwar years.[372] In the late 1940s, the THD focused its efforts on maintaining and improving existing roadside parks, building new ones only where new state highways were established or where existing roads were rerouted. Several notable roadside parks of the late 1940s were built on the 74-mile Davis Mountains State Park Highway, commonly known as the "Scenic Loop," in Jeff Davis County. Maintaining the rustic aesthetic established by THD in the 1930s, many of these parks used natural rock formations and the mountainous terrain as a backdrop, with tables, benches, and other fixtures made of locally quarried limestone masonry.

The aesthetic of THD roadside parks began to change radically in the 1950s, turning from the rustic designs of the 1930s and 1940s to a modern appearance incorporating far more man-made materials. Brick largely replaced stone for use in fixtures and arbors incorporating corrugated metal or other substances became popular in some regions. Decreased maintenance budgets in the 1950s may have borne responsibility for the changes by limiting the design options available to district staff. By 1958, THD boasted more than 900 furnished roadside parks with designs ranging from rustic to modernistic, plus over 200 turnouts. [373] In that year, in which 30 new roadside parks were approved statewide, corrugated asbestos arbors with V-shaped steel supports were typical, illustrating the profound changes in park design. Although native stone was still sometimes used in tables, benches, arbor bases, and retaining walls, it no longer resembled the old rustic fashion. Instead, it was laid in smooth, even courses and topped with a concrete coping for a sleek, brick-like appearance. Other parks were built entirely with brick, stressing smooth horizontal lines that form a contrast with the surrounding landscape. By the 1960s, THD roadside parks on non-interstate highways followed increasingly simplistic designs, with stone, brick, or concrete table/bench sets and simple, flat-roofed arbors with steel supports.

In 1958, the THD also began planning for a new type of roadside park—the safety rest area—along the interstate system. These facilities were planned as part of the overall Interstate design, with specific requirements regarding location and placement in relation to other parks and nearby cities. The THD safety rest area design called for a park size between two and four acres, with two to four picnic units, each consisting of a table with benches, a fireplace, and a garbage facility. The new safety rest areas were to be paired, with one park on each side of the highway.[374] The first safety rest areas were completed in 1963 on IH 10, about 10 miles east of San Antonio. The interstate rest areas received more careful design treatment than other roadside parks of the period, often displaying a more modern interpretation on the traditional arbor and picnic table scheme. The IH 10 rest areas featured a "bat-wing" arbor, with an angled three-cornered steel-frame roof, supported by a brick pier on one end with tubular steel supports on the other.[375] By 1965, the THD counted more than 1,100 roadside parks, turnouts, and safety rest areas, with the latter numbering no more than 85.[376]

Another development in park design was the inclusion of "comfort stations" at safety rest areas beginning in 1966. These small buildings of sturdy steel frame and masonry construction contained male and female restrooms inside and information centers, dubbed "Infobords," outside. The comfort stations were then connected to the typical

---

[372] Information on roadside parks in this section is condensed from HHM's study of Texas roadside parks, prepared for the Texas Department of Transportation in 2005. Information on Depression-era parks is found on pages 29-42 of the 2005 study.
[373] *Texas Highways* 6. No. 4 (April 1959), 2-4.
[374] Texas Highway Department, Administrative Order 21-58, issued May 29, 1958, II-91.
[375] *Texas Highways* 10, no. 7 (July 1963), 7-9
[376] *Texas Highways* 12, no. 8 (August 1965), 6-7.

picnic units via landscaped walkways, creating a unified whole. Where rest areas and roadside parks had frequently been designed to ramble organically, comfort stations provided a visual focal point and locus of activity from which picnic areas extended.

In addition to the development of roadside parks along the state's emergent postwar highways and interstates, Lady Bird Johnson played an important role in the state's (and nation's) efforts to beautify highways. During the period Johnson increased awareness for highway beautification, decrying roadside advertising and requesting that they be replaced with green space and wild flowers. Lobbying at the federal level, Johnson was critical to the passage of the Highway Beautification Act on September 16, 1965.[377]

*Historical Markers*

The state's historical marker program, so prominent during the Texas Centennial celebrations, was relatively dormant through the 1940s and 1950s, focusing on placing markers at the graves of notable Texans and conducting repairs to the deteriorating Centennial markers. In 1962, the Texas Historical Survey Committee (THSC), predecessor agency to today's THC, initiated a new Tourist Information, or Travel Information, marker program. About 30 markers were placed at locations along major highways around the state. These early 1960s markers, made of cast aluminum, are distinguished by their larger size compared with later state historical markers and by their "ornate scrolled" borders.[378] Between 1964 and 1969, the THSC undertook a major campaign to erect 5,000 historical markers covering a wide variety of topics. These markers, also made of aluminum and usually erected on metal monopoles, were frequently located along roadways to capitalize on the relationship between historical markers and tourism.[379]

*Offices and Facilities*

The THD's need for larger and more functional office, warehouse, and garage space grew along with the size and complexity of the state's highway system. Across the state, new district office complexes (usually encompassing a headquarters office, warehouses, shops, and laboratory), urban expressway offices, and resident and maintenance engineers' offices, often incorporating basic International or New Formalist influences, had replaced many of the old 1930s-era buildings by the late 1960s (see Figure 48). For example, when the new Houston District office was completed in 1952, it was hailed as "modern" and "streamlined" in appearance. The Waco District Headquarters office retains integrity and is reflective of the standards of this time period.[380]

[377] Beaumont, 35.
[378] Williams, 1, 5.
[379] Williams, 6-9.
[380] Texas Highway Department, *Construction and Maintenance Bulletin*. No. 27 (September 1953), 1.

# Historic Context: Historic Bridges of Texas 1866-1965

## Early Bridge Design and Construction

*Early Timber Bridges*

The rugged travel conditions and primitive timber bridges of early Texas reflect common themes in American history. As settlers pushed south and west across the frontier, they depended on fording, ferrying, and simple timber structures to meet basic transportation requirements. Early bridge construction was conditioned, to a large extent, by the urgency of transportation across vast expanses of territory, and the versatility of the American settler. Travelers in Texas and elsewhere relied on practical experience, as well as the materials and tools at hand, to blaze trails and build simple timber bridges, such as pile-and-beam structures. Although these bridges were not constructed for permanence, they met the basic transportation needs of settlers.[381]

*Masonry Arches*

Populations in the more industrialized areas of the country began experimenting with more permanent bridges in the late seventeenth and early eighteenth centuries. While timber bridges had many advantages, they were limited in terms of their durability, length of individual span, and load-bearing capacity. The first permanent bridge type in America was the masonry arch, a form which the Romans had perfected and the Europeans had used for centuries. The arch construction combined with the weight of stone and its durability to produce a structure capable of sustaining heavy loads over a long period of time. As an expensive and time-consuming bridge to build, the masonry arch was usually reserved for long and important crossings. When the early American railroads began to forge their way across the country in the 1830s and 1840s, they also relied on masonry arches, primarily for crossing mountains and deep river gorges. The railroads continued to use masonry arches on a limited basis until the mid-1800s, when metal trusses proved more economical. By the late nineteenth century, masonry was still used occasionally, especially when strength and durability were major factors and stone was available near the bridge site.[382]

Large limestone deposits and other factors prompted some railroads in Texas to use masonry construction on a limited basis. The Gulf, Colorado and Santa Fe Railway, for example, built at least a dozen stone arch bridges on its line between Dallas and Paris from 1898 through 1912. While stone arch bridges were found occasionally on railroad lines in the state, they were rarely seen on Texas roadways. Masonry arches reached their peak popularity in the United States during the mid-nineteenth century, a period when travel conditions in Texas were still at a very primitive stage. The high costs and labor intensive requirements of masonry arches made them an impractical type for Texas roadways during this period. By the time Texas communities began building more permanent structures in the 1880s, metal truss bridges were the preferred type for intermediate to long crossings. The best surviving example of a late nineteenth century stone arch in Texas is the 1887 West Sixth Street Bridge over Shoal Creek, in Austin (TxDOT Structure No. 14-227-0-B000-18-085). This three-arch bridge, constructed of rusticated limestone

---

[381] Quoted in Donald C . Jackson, *Great American Bridges and Dams* (Washington, D. C.: The Preservation Press, 1988), 15; Llewellyn Nathaniel Edwards, *A Record of the History and Evolution of Early American Bridges* (Orono, Maine: University Press, 1959), 19-36.
[382] Eric DeLony, *Landmark American Bridges* (New York: American Society of Civil Engineers, 1993), 3-4; Richard J. Cook, *The Beauty of Railroad Bridges* (San Marino, Cal.: Golden West Books, 1987), 17-39.

and accented with voussoirs and rounded piers, still carries traffic. An unpopular type in early Texas history, the masonry arch is most often associated with the state's work relief programs during the Great Depression. Nevertheless, a mid-1990s inventory of the state's bridges revealed a few early examples of masonry arch construction, primarily in the north and central regions.[383]

The major impetus for greater advancement in bridge construction came with the railroad's expansion across the Northeast and Midwest during the 1830s and 1840s. The railroads provided a powerful stimulus for modifying and improving older bridge forms and for inventing new types with improved efficiency and strength.

*Evolution of Metal Truss Types*

The first important bridge type to result from the railroad's technological experiments was the metal truss bridge. This type has its origins in the timber truss bridge, which was first used in this country during the late eighteenth century. Early trusses consisted of an assemblage of small timber members that were connected together to form a rigid structural framework. Such structures usually were comprised of simple triangular shapes (king posts or queen posts) that were combined with an arch when a longer span was required. By the 1820s several American builders were designing long timber trusses made up entirely of triangular-based trusses. In cold climates such as New England, timber trusses were weatherboarded or covered as a protection against deterioration and extreme weather conditions. A few covered bridges were built in the state, primarily in the mid-1800s with and without weatherboarding. One of the better known examples was constructed in 1854 over the San Marcos River in Gonzales. Constructed with slave labor, the Gonzales Bridge, also called the "covered tunnel," extended more than 100 feet in length and was supported by large rock masonry piers.[384]

Railroad expansion created the major impetus for advances in truss design in the decades that followed. As trains became heavier and loading increased, many inventors and engineers in the United States began to search for the most practical and efficient metal truss design. Some of these designs were based on sound engineering principles and were used extensively by the railroads. The vast majority of these inventions, however, was more fantastic than practical and was employed, at best, one or two times.[385]

While many of the new truss configurations were very similar in appearance, they could usually be distinguished by the arrangement of truss members and the types of forces (compressive or tensile) carried by the vertical and diagonal web members. Each bridge was comprised of two trusses, one on each side of the roadway, with the top chord resisting compressive or squeezing forces and the bottom chord taking tensile or stretching forces. Diagonals and verticals connected the two chords, carrying either tension or compression or, in some cases, both types of forces. The basic pattern repeated in segments, called panels, across the length of a truss.[386]
Although some railroad trusses were executed only in wood, many, such as the Howe truss, were constructed as composite iron and timber structures. By the 1860s, an increasing number of trusses were completed in metal, first in cast iron and wrought iron, and later in steel. Iron and steel bridges offered many advantages over timber structures, particularly in terms of their strength, durability and resistance to fire. The conversion from timber to

[383] Cook, 17-39; Jackson, 18-19; State of Texas, Texas Parks and Wildlife Department, "Fact Sheet for the Paris to Farmersville Branch of the Chaparral Railroad Company" compiled by the Greenways Program.
[384] Condit, *American Building: Materials and Techniques,* 52-63; Carol Nation, "Covered Bridges in Texas," *Texas Highways,* May 1964, 14-17; Carroll, 80. No covered bridges are known to survive in Texas.
[385] Condit, American Building: Materials and Techniques, 93-112.
[386] Condit, American Building: Materials and Techniques, 93-112.

metal bridges occurred most rapidly in the Northeast and Midwest due to superior rail connections and the presence of an established iron and steel industry. In Texas and other remote areas of the country, shipping costs prevented widespread use of iron and steel in bridge-building until at least the late 1800s. The population was predominantly rural and an abundant supply of timber existed.[387]

Two popular railroad truss types were the Howe and the Pratt. The Howe truss (patented 1840) consisted of parallel upper and lower chords joined together by a complex system of wrought iron rods and wood diagonals that extended over one panel length. The wood diagonals of the Howe truss carried compression while its wrought iron verticals acted in tension. The Pratt truss, patented in 1844 by Thomas and Caleb Pratt, reversed the stress pattern of the Howe, making the vertical members stand in compression and the diagonals in tension. Although originally constructed in wood and iron, the Pratt was quickly modified for all iron and steel construction, becoming the predominant truss type of the nineteenth century.[388]

*Early Bridge Suppliers, Fabricators, and Builders*

The railroad's interest in stronger rails and bridges prompted significant progress in American iron and steel production during the mid-to late-nineteenth century. Bridge engineers first began to use cast iron for truss compression members in the 1840s. As a material that contains more carbon than wrought iron, as well as a number of other impurities, cast iron is a very strong but brittle material. The railroads quickly adapted cast iron to bridge construction, employing it either alone or in combination with timber. The use of cast iron in bridges was brought to a sudden end in the 1870s with the collapse of several major bridge structures, such as the Ashtabula Bridge in Ohio. Wrought iron, which has a significantly lower amount of carbon than cast iron, was first employed in trusses during the 1840s. By the mid-nineteenth century, American rolling mills were using this material to produce a wide variety of structural shapes, such as I-beams, channels, angle sections, and plates. As an extremely durable material that functions well in both tension and compression, wrought iron continued to gain popularity during the mid-nineteenth century and by 1870 had superseded cast iron and timber as the standard material for truss construction.[389]

The railroads' demand for a metal that was stronger and more durable than wrought iron brought about a growing interest in steel production after the end of the Civil War. During the next two decades, the Bessemer converter and open-hearth processes were perfected, making possible the production of large amounts of American steel at low cost. United States steel production rose from 16,000 tons in 1865 to nearly 5 million tons in 1892. During the mid-to-late 1880s many of the U.S. eastern and midwestern rolling mills began retooling their machines to produce structural shapes in steel, prompting a much greater use of steel in bridge building in the years that followed. From about 1890 to 1900 bridge fabricators used both wrought iron and steel members rather indiscriminately. By the turn of the century, steel had replaced wrought iron as the universal material for truss construction.[390]

---

[387] Condit, American Building: Materials and Techniques, 93-112.
[388] Condit, American Building: Materials and Techniques, 61 and 96-98.
[389] "The Manufacture of Structural Steel in the United Sates," *Cassier's Magazine* 17 (February 1900), 259-278; "The Developments of the Nineteenth Century in Bridge Design and Construction," *Engineering News 44* (December 13, 1900), 409-410; Jeffrey A. Hess, "Final Report of the Historic Bridges Survey: Part 2," Section on Iron and Steel Bridges, August 1988, State of Minnesota, Section E, 6.
[390] Victor S. Clark, *History of Manufactures in the United States, 1860-1914* (Washington, D.C.: Carnegie Institution of Washington, 1928), 19-345; Richard Shelton Kirby et al., *Engineering in History* (New York: Dover Publications, Inc., 1990), 291-298; Edwards, *A Record of Early American Bridges*, 103.

Until about 1850, most railroads designed and built their own bridges from timber or a combination of timber and iron. In the following decades, however, railroads became more dependent on metal truss bridges and a new industry of foundries and fabricating shops emerged. These industries formed, punched, assembled, and riveted the various truss members and prepared them for shipment and erection at the bridge site. Private bridge fabricators began opening shops in the United States during the mid-nineteenth century and by 1860, the vast majority of the railroads were relying almost exclusively on private companies to fill their demand for metal truss spans. Typically, bridge fabricators sold the bridge components unassembled, shipping them to the bridge location for on-site erection. While most bridge-building companies manufactured proven truss types, such as the Pratt, Whipple, and Warren, a few smaller companies specialized in a few unusual types of truss designs. By 1890, more than 30 bridge fabrication shops existed in Pennsylvania and Ohio alone, with most concentrated primarily in the Northeast and Midwest.[391]

Bridge manufacturing was a complicated task that involved at least three distinctive processes, including the production of iron and steel from raw materials, the rolling of iron and steel into structural shapes, and the fabrication of bridge members and connection pieces. Through the puddling, open-hearth, and Bessemer processes, integrated rolling mills converted iron ore, coke, limestone, and other substances into cast iron, wrought iron, and steel. These materials were then rolled into various structural shapes, such as I-beams, channels, angles, plates, and bars. As the industry evolved, the mills began producing metal products in standardized shapes and sizes. Most of the rolling mills were in the country's eastern and Midwestern steel belt, a region that contains the country's largest iron ore deposits. Historians working on the survey of Texas truss bridges in the late 1980s and 1990s noted the names of rolling mills imprinted on metal truss bridge members, typically on I-beams and channels. Several of the more common rolling mill names imprinted on Texas bridges were "CARNEGIE" (Pittsburgh), "CAMBRIA" (Johnstown, Pennsylvania), and "ILLINOIS" (Chicago).[392]

Bridge fabricators utilized a series of manufacturing processes to fashion standardized metal products into finished bridge members. One of the bridge fabricator's primary tasks was to create composite or built-up members using channels, angles, plates, and other metal components acquired from the rolling mills. By the late 1800s, American bridge fabrication had evolved into a complex yet highly standardized manufacturing process that was generally divided into five operating departments: the engineering shop, templet shop, riveting shop, machine shop, and forge shop.[393] Engineering historian David A. Simmons provides a concise account of a late nineteenth century bridge fabrication plant:

Following the receipt of a contract for the erection of a bridge, the first step in actually producing that structure was the preparation of detailed plans by the company engineers. These drawings were sent to the template shop where full-size wooden patterns of each component of the bridge were made. Much of the bending, cutting, drilling, and punching necessary to fabricate the various parts of the structure was done within the riveting shop, set up in a large area of the plant that allowed for the handling of long beams…The pins used to hold the main components of the truss together were produced on lathes and thread cutters in the machine shop. The…eyebars, were produced in the

[391] Victor C. Darnell, *Directory of American Bridge-Building Companies* (Washington, D.C.: the Society for Industrial Archeology, 1984); Charles Evan Fowler, "American Bridge Shop Methods," *Cassier's Magazine* 17 (January 1900), 200-215; Theodore Cooper, *American Railroad Bridges* (New York: Engineering News Publishing Company, c.1890), 35-40.
[392] Kirby, et al., 291-298.
[393] Fowler, 200-215.

forge or blacksmith shop. Here the ends of the bars were heated in special furnaces and formed into their final shape by powerful steam hammers.[394]

By the late nineteenth, century bridge manufacturing had evolved to a highly refined and efficient American industry. In 1900 a trade journal noted that American bridge shops had "reached as high a state of perfection as any other class of manufactories."[395]

As bridge shops expanded, they also began diversifying their lines to include lighter spans for roadway use. During the late nineteenth century bridge fabricators began producing wrought iron and steel roadway trusses in a variety of shapes and sizes. The demand was greatest for spans of 100 feet or more. Experience had shown that timber spans were somewhat impractical for span lengths of 30 feet or more, and that longer spans were necessary for more permanent bridge construction. Soon, fabricators were manufacturing trusses with lengths of 100 to 200 feet or more. Due to their efficient operations, bridge fabricators could fill orders very quickly, usually within a few weeks or even days. The expansion of the railroads throughout the country also served the bridge fabricators well, allowing them to ship their products to cities, towns, and rural communities in almost every part of the country.[396]

Typically, a bridge fabricator would ship a metal truss span in a package or kit consisting of an assortment of lightweight bridge members, as well as the necessary connection pieces, such as pins, eyebars, and bolts. Once the package arrived at its final destination, bridge agents or local men would haul the bridge members by wagon to the bridge site where the truss components would then be assembled and erected on piers or abutments. The addition of approach spans (usually timber or I-beam trestle) and a timber plank deck would complete the bridge. A bridge type that was lightweight, durable, and easy to erect, the metal truss was well-suited to the primitive travel conditions in Texas and the rest of the country. Metal truss bridges rode a tremendous wave of popularity in late nineteenth century Texas, representing a significant improvement over stream fording and ferrying, and primitive timber bridges of the past.[397]

Reconstruction saw the energy of war-trained engineers turned to the improvement and expansion of the country's infrastructure. Hints and flourishes of the romantic side of the Gilded and Victorian Age sensibilities could be seen in how American engineers used finials and ornamented plaques to soften the stark geometry of truss bridges or classical motifs to the grey concrete of City Beautiful bridges. In the case of the American Standard truss bridge, however, the sensibility went a bit deeper. The for-profit deployment of pin-connected, pre-fabricated, semi-mass-produced, standard-plan, wrought-iron trusses embodies much of what made the last half of the century distinctive. The scale of the infrastructure needs sparked the creation of countless bridge companies. The isolation and relative poverty of Texas meant the state was highly dependent on out-of-state companies for metal bridges. These engineers experimented with truss and connection details in an effort to gain competitive advantage. They tended to use pin connections because they 1) greatly simplified the calculations of the stresses and the required member sizes given the mathematical skills of most American engineers and 2) facilitated field erection before the wide-spread introduction of field riveting. Out of all this, and much more, emerged the American Standard truss best represented by the wrought iron Pratt through truss.

---

[394] David A. Simmons, "Bridge Building on a National Scale: The King Iron Bridge and Manufacturing Company," *The Journal of the Society for Industrial Archeology* 15 (1989), 29.
[395] Quoted in Fowler, 201.
[396] Fowler, 200-215.
[397] Historic Bridge Files, Texas Department of Transportation, Environmental Affairs Division, located at TxDOT headquarters in Austin.

By the late 1800s, there were scores of large bridge fabrication companies in the Northeast and Midwest, and a few smaller plants in western states, but none in Texas. Many of the U.S. eastern bridge fabricators built up a substantial business designing and fabricating roadway trusses for shipment to distant locations, such as Texas, Oklahoma, Arizona and New Mexico. By 1900, truss design and fabrication were rapidly becoming standardized, and competitive pressures precipitated the closing or takeover of many bridge firms. The largest consolidation occurred in 1900 when Andrew Carnegie bought out more than 25 of the largest bridge fabricators in the country and amalgamated them into the American Bridge Company of New York City, New York. By the early 1900s, the independent bridge firm was on the decline in the United States, disappearing almost entirely after World War I. In the years that followed, bridge-building activities were often divided between consulting engineers that provided bridge designs and steel-fabricating firms that manufactured and erected the spans.[398]

**Early Metal Truss Types in Texas**

*Bowstring Truss*

Many of the early truss types were adapted for highway use during the mid-to late nineteenth century. An early truss bridge found in Texas was the bowstring, a truss form employing an arched top chord as the primary compression member tied by a lower chord resisting tensile forces. Squire Whipple patented a design for a bowstring truss with all cast iron members in 1841. By the 1860s, other engineers such as Zenas King of Cleveland, Ohio, and David Hammond of the Wrought Iron Bridge Company of Canton, Ohio, had invented bowstring designs built from rolled wrought iron members. While King's design employed a hollow top chord with a rectangular section, Hammond's design featured a cylindrical member, also called a Phoenix column. An extremely popular bridge type during the third quarter of the nineteenth century, the bowstring had a high carrying capacity while using a relatively small quantity of iron. This truss form reached its height of popularity in Texas during the 1870s and 1880s.[399]

Although the popularity of the bowstring truss was fairly short-lived, these bridges were a fairly common sight in late nineteenth century Texas, particularly at small to intermediate sized crossings. The 1872 Commerce Street bowstring truss bridge in Dallas (see Figure 1) is the earliest documented example of a metal truss roadway bridge in Texas. The type's early popularity in the state is attributed to its lightweight members and pin connections, which made it relatively easy to haul over primitive roads and to erect at the bridge site. In many counties, the first metal truss spans were bowstring trusses with subsequent bridges conforming to the Pratt or Warren configurations. In 1882, for example, Coryell County contracted with King Iron Bridge Company "to build, paint and make complete, ready for use, by October 1, 1882…the substructure and superstructure for a wrought iron tubular arch [bowstring truss] bridge of the King's latest improved patent over the Leon River…on the West side of Gatesville." The successor to this bridge, a Pratt through truss span, was constructed in 1904 (TxDOT Structure No. 09-050-0-C001-75-001). While no bowstring truss bridges conforming to Hammond's design are known to remain in Texas, a number of King's bowstrings continue to serve traffic on county roads, including the 1884 span over Elm Creek

[398] Victor C. Darnell, *Directory of American Bridge-Building Companies*, 71 and 85-86.
[399] Condit, American Building: Materials and Techniques, 98-100; Hess, section E, 6-7.

on the Marlin-Groesbeck Road in Falls County (TxDOT Structure No. 09-074-0-AA02-36-001). Texas has some of the only bowstring trusses remaining in the southwestern United States.[400]

*Pratt Truss*

By the end of the 1880s the Pratt truss design had largely replaced the bowstring as the standard truss type for short to intermediate spans (30 to 150 feet) and was being manufactured in a wide variety of shapes and sizes. The straightforward design, considerable strength, and ease of erection made the Pratt the predominant truss type for American roadways during the late nineteenth and early twentieth centuries. It quickly gained acceptance throughout Texas as the preferred type for short and intermediate spans, reaching its heyday of popularity from 1895 to 1910. Most of the earliest examples were built in central and north Texas, including the bypassed 1884 Hickory Creek bridge near Denton (TxDOT Structure No. 18-061-0-AA06-19-001, NRHP 1988) and the 1885 bridge over the Clear Fork of the Brazos near Albany in Shackelford County (TxDOT Structure No. 08-209-0-AA01-88-001).[401]

*Truss Leg Bedstead Truss*

Two peculiar Pratt variations that were built on Texas roadways were the truss leg bedstead and the lenticular. The truss leg bedstead is a Pratt with long vertical endposts that extend below the roadway to serve as piers or abutment supports. By anchoring the endposts into the streambed, this design was intended to improve the Pratt's overall rigidity and strength. The truss leg bedstead never gained widespread popularity in the United States, and was used only occasionally for short spans during the late nineteenth and early twentieth centuries. A few examples of the truss leg bedstead are known to survive in Texas, including an 1898 span, now bypassed, over Big Elm Creek near Cameron (formerly TxDOT Structure No. 17-166-0-AA02-12-002) and an 1888 truss over Mulberry Creek near Schulenburg (formerly TxDOT Structure No. 13-076-0-AA02-91-001, now relocated to Wolters Park in Schulenburg).[402]

*Lenticular Truss*

The lenticular configuration features curved upper and lower chords that form the shape of a lens. This truss form originated in Europe in the mid-1800s but did not arrive in the United States until some decades later. William O. Douglas patented an American version of the lenticular truss in 1878, producing hundreds of small to intermediate size lenticular spans during the next fifteen years. An 1889 bridge catalogue of the Berlin Iron Bridge Company lists a William Payson from Edna, Texas, as the company's only bridge salesman outside of the New England or New York area. Through William Payson's association with the company, Texas acquired at least a dozen lenticular trusses from 1889 to 1895.[403] At least five of these spans were built in San Antonio. The most prominent

---

[400] Historic Bridge Files, Texas Department of Transportation, Environmental Affairs Division, located at TxDOT headquarters in Austin; Coryell County, Commissioners' Court Minutes, volume C, 210.
[401] T. Allan Comp and Donald Jackson, "Bridge Truss Types: A Guide to Dating and Identifying." *History News* 32 (May 1977); Historic Bridge files, Texas Department of Transportation, Environmental Affairs Division, located at TxDOT headquarters in Austin.
[402] Fraserdesign and Hess, Roise and Company, "Highway Bridges in Nebraska, 1870-1942," National Register of Historic Places Multiple Property Documentation Form, Section F on Metal Beam Highway Bridges, June 29, 1992, 5-6.
[403] Thomas Boothby has demonstrated that the lenticular trusses constructed by the Berlin Iron Bridge Company, such as those in Texas, are more properly described as “Pauli trusses.” “Lenticular” is used throughout this MPS out of custom and clarity.

of these was a 93-foot truss originally constructed in 1890 over the St. Mary's Street crossing of the San Antonio River (TxDOT Structure No. 15-015-0-B038-25-001). Currently, this bridge serves vehicular traffic at a river crossing in the city's Breckenridge Park. Victorian flourishes such as elaborate cast-and wrought-iron railings with rosette motifs, decorative portal cresting, and urn finials help to provide relief for this large utilitarian structure. A survey of other states' bridge inventories reveals that Texas has the only lenticular trusses remaining west of the Mississippi River.[404]

*Whipple Truss*

During the late 1840s railroad-bridge engineers began creating Pratt-related designs with greater rigidity and longer span lengths. The earliest of these designs was the double-intersection Pratt or Whipple truss, invented by Squire Whipple, an influential American inventor best known for his groundbreaking discourse, *A Work on Bridge Building*. Whipple received a patent for his namesake design in 1847, the same year that he published his famous treatise. The Whipple configuration, with diagonals spanning two panels, provided a solution to the problem posed by long truss spans. In order to increase the length of a truss span, the height of the truss must also be increased. A corresponding increase in panel length must occur if the degree of inclination of the diagonals is to remain at 45 degrees, the angle considered most efficient at the time. The resulting panel length may exceed the limits of the timber stringers. The Whipple design introduced the double-intersection diagonal that spans two short panels at or near a 45-degree angle. By creating shorter panel lengths with each diagonal crossing two panels, the Whipple configuration provided an economical, innovative solution to the problem of spanning longer distances.[405]

The Whipple was a popular type for long railroad and highway spans between 1865 and 1890. An 1885 pamphlet of the Wrought Iron Bridge Company of Canton, Ohio, indicates that the Whipple truss is best suited for spans of 150 to 300 feet with "wide or double roadways,…heavy traffic, where deep girders are desirable to avoid a squatty end view." While the double-intersection Pratt was a fairly uncommon type in Texas, it was used occasionally at long crossings. One of the earliest examples in the state was a six-span Whipple truss structure built in 1883 over the Colorado River in Austin. Three of the bridge's original 148-foot spans now serve a pedestrian walkway in Richard Moya Park in Travis County (TxDOT Structure No. 14-227-0-AA17-11-001). One of the most impressive Whipple truss bridges that is still standing in the state is the 1887 bridge on Faust Street over the Guadalupe River in New Braunfels, which includes two 220-foot Whipple spans (TxDOT Structure No. 15-046-0-B005-30-001). The bridge is now in pedestrian use only.[406]

---

See Thomas Boothby, "Designing American Lenticular Truss Bridges 1878-1900," in *IA, The Journal of the Society for Industrial Archeology* 30.1 (2004), 5-17.

[404] Victor Darnell to Tom Eisenhour, 5 April 1987, 12 June 1987 and 30 December 1987, Environmental Affairs Division, Texas Department of Transportation, located at TxDOT headquarters in Austin; Berlin Iron Bridge Company, *The Berlin Iron Bridge Co.: Engineers, Architects and Builders in Iron and Steel* (Hartford, Conn.: Press of Plimpton Manufacturing Co., n.d.); Bruce Clouette and Matthew Roth, *Connecticut's Historic Highway Bridges* (Hartford, Con.: Connecticut Department of Transportation, 1991), 7-10.

[405] Condit, American Building: Materials and Techniques, 98-101.

[406] Quoted in D. W. Church, "Wrought Iron Bridges Built by Wrought Iron Bridge Co.," pamphlet, Canton, Ohio, 1885, 7; Condit, *American Building: Materials and Techniques*, 98-101.

*Parker and Camelback Trusses*

A second variant of the Pratt that facilitated the construction of longer spans was the Parker truss, designed by railroad engineer C.H. Parker in the mid-1800s. Parker's configuration was comprised of a Pratt with deep web members and a multi-sided top chord, a design that increased the rigidity of the Pratt and allowed for span lengths up to 250 feet or more. The camelback was a sub-type of the Parker characterized by its five-sided top chord. In Texas, pin-connected Parkers and camelbacks were common from about 1905 to 1920. Relatively long span lengths are provided by the 235-foot Parker span, built in 1906, over the Little River near Gause (TxDOT Structure No. 17-166-0-AA05-25-001) and the 200-foot camelback span, built in 1909, over the Little River at the Bryant Station Crossing (formerly TxDOT Structure No 17-166-0-AA02-75-001). The Parker found extensive use in twentieth century Texas as an all-riveted truss.[407]

*Subdivided Pratt Variants*

During the 1870s, the Pratt, Parker, and camelback configurations were further improved by subdividing the panels with half-length members called sub struts and subties. These designs minimized buckling and distributed the loads more uniformly over the truss, enabling the construction of even longer spans. The principal subdivided types included: the Baltimore (a subdivided Pratt), Pennsylvania (a subdivided Parker) and sub-divided camelback. By 1900, the simple Parker truss and the various subdivided forms had replaced the Whipple as the standard types for long truss spans. Initially, these bridges were built with pin-connections, but by 1915, most examples were completed by field riveting. While no Baltimore trusses survive in Texas, a few Pennsylvania and subdivided camelbacks continue to serve traffic on rural roadways in the state. An extant example is the 450-foot Pennsylvania span, built in 1901 to carry Washington Avenue over the Brazos River in Waco (TxDOT Structure No. 09-161-0-B003-31-001).[408]

*Warren Trusses*

Another important truss type invented during the nineteenth century was the Warren truss, patented by English engineer James C. Warren in 1848. This configuration, which conforms to a "W" shape, is characterized by rigid diagonals that function both in tension and compression. While the Warren was initially introduced in America as a pinned truss, this configuration did not fare well against the Pratt. A few pin-connected Warren pony trusses survive in Texas, including the end panels of the CR 1321 Bridge over Aquilla Creek in Hill County (TxDOT Structure No. 09-110-0-AA05-49-001). By the turn of the century, some bridge builders were constructing Warren trusses using a connection method that combined shop-riveting with field-bolting. This type of connection is illustrated in the 1907 bridge over Jimmy's Creek near Comanche, now relocated (formerly TxDOT Structure No. 23-047-0-AA01-40-001). The Warren's simple configuration and lightweight members provided many advantages, and by the early 1900s, it had superseded the Pratt as the preferred type for short spans (usually 30 to 90 feet). By

[407] Carl W. Condit, *American Building Art: The Nineteenth Century* (New York: Oxford University Press, 1960), 153. On the early history of the Parker truss see: Victor C. Darnell, "The National Bridge and Iron Works and the Original Parker Truss," *Journal of the Society for Industrial Archeology* 24(2):5-20, 1998.
[408] Condit, American Building: Materials and Techniques, p. 143; Condit, American Building Art, 148-153.

the 1910s, some bridge builders were also designing Warren trusses with polygonal top chords and through configurations, enabling the construction of spans up to 125 feet or more.[409]

*Cantilevered Trusses*

Before the end of the century, the very longest truss spans in the United States were cantilevered spans. This sophisticated engineering practice demonstrated the high level of technical skill that American bridge builders had achieved over a relatively short period of time. Unlike a simple truss that is supported at both ends, the cantilever truss is held only at one end and, hence, must be anchored by a second span from the opposition direction. Visually, a cantilever bridge differs from a simple truss in that the trusses usually become deeper or taller at the points where they pass over the piers. Cantilever bridges of this property type are typically erected as through trusses. In order to extend a bridge's span length over a channel, railroads often built cantilevered trusses with a third suspended span in between the two projecting truss arms. The cantilever truss reached its greatest size in America during the nineteenth century with the completion of the Kansas City, Fort Scott, and Memphis Railroad Bridge over the Mississippi River at Memphis, Tennessee, in 1892. The structure included an irregular combination of cantilevers, anchors, and suspended truss spans, providing a main channel span of about 800 feet and a total length of more than 2,100 feet.[410]

A spectacular example of a cantilever bridge completed in Texas was the Pecos River built by the Galveston, Harrisburg, and San Antonio Railroad between Comstock and Langtry, Texas (1891-92). The viaduct was 2,180 feet long between abutments and was comprised of a series of cantilevered and simple truss and girder spans with a central 80-foot suspended truss unit. The most extraordinary feature of the bridge was its tall steel towers that rose 320 feet above the surface of the water. According to Carl W. Condit, engineering historian, the bridge's extreme height made it appear "like a stretched thread over the water far below it." The bridge was replaced by the present structure in 1944. The cantilevered truss construction featured in the Pecos River Bridge was extremely rare on Texas roadways until the 1920s.[411]

The THD's Bridge Division designed several cantilever trusses beginning in the early 1920s and continuing through the 1950s; the latest cantilever truss erected in the state dates from 1970. Cantilever truss bridges could usually be erected using falsework for the anchor spans and cantilevered construction for the main suspended span. This truss type was most appropriate for locations where it was impractical to erect falsework and piers in the middle of the streambed and at crossings where interior piers would have impeded navigation.

*Truss Connections*

The evolution of truss connections paralleled that of truss design. Pins were first used to connect a bridge on the Lehigh Valley Railroad in 1859. A pin-connected bridge was typically assembled by inserting large metal pins through reinforced holes punched in the ends of adjoining truss members. By the early 1860s, railroad bridge engineers had developed forged eyebars to connect slender tension rods with other built-up members in a truss. The pinned technology was advantageous since it allowed trusses to be manufactured, shipped, and hauled to the

---

[409] Jackson, 27-30.
[410] Condit, American Building Art, 152-162.
[411] Quoted in Condit, *American Building: Materials and Techniques*, p. 148; "The Pecos Viaduct," *Engineering News* 29 (5 January 1893), 2-4.

bridge site in small pieces. Pinning greatly facilitated erection at the bridge site and was rapidly adapted to the Pratt and related types during the late nineteenth century. The flexibility of the pins, however, caused considerable wear and tear around the connections and produced significant vibrations. These deficiencies prompted railroad engineers to experiment with other methods, such as combination riveting and bolting. Portable pneumatic riveting systems became available in the late 1880s, providing a more rigid and durable method of connection. Eventually, this method was applied to longer truss types, such as the Parker and to shorter trusses like the Warren pony. By 1920, field riveting had replaced pinning as the universal method for connecting trusses in Texas.[412]

**Suspension Bridges**[413]

Suspension bridges in general have certain economic advantages, namely:

- Flexibility of span length reduces the number of piers.
- Erection does not require falsework.
- Prefabrication is less expensive compared to metal trusses.
- Typically smaller parts ease transport to remote locations.
- Wire manufacturers often provided the ancillary materials such as anchor-block castings and hangers.

While generally thought of as most suitable for long-span bridges, the suspension bridge clearly proved to be an economic alternative for a range of needs in Texas, although they did not find favor in the far west, the Panhandle, or central Texas. Both the Trans Pecos and the Panhandle are historically very dry and as such do not require many bridges. Extensive areas of the eastern two-thirds of the state, however, experience dramatic floods, particularly in the Brazos, Colorado, and Trinity River basins. Rocky conditions in central Texas spare bridge builders the difficulty of finding solid footings in alluvial flood plains and coastal marshlands. Local tradition reports, for example, that the Rock Church Bridge is located where it is because only there do the banks of the Paluxy, a tributary of the Brazos, not collapse. Indeed, the designer of the Bluff Dale and Barton Creek suspension bridges pointed out that:

it is greatly desirable to make a single span from shore to shore, or at most to have but one pier embedded in the river, because of the difficulty in sinking coffer-dams and finding strata of sufficient density to form stable anchors for the piers.

Just as the John A. Roebling Suspension Bridge connecting Covington, Kentucky, with Cincinnati, Ohio, demonstrated the potential of suspension bridges to promoters throughout the Ohio Valley, so too did the Waco Suspension Bridge made a strong impression on the people of the Brazos basin. The 475-foot main span opened in 1870, just three years after the Covington-Cincinnati Bridge, though it was substantially shorter than the latter's

---

[412] J.A.L. Waddell, 2 vols. *Bridge Engineering* (New York: John Wiley & Sons, Inc., 1916), 1:23 and 747-750; James L. Cooper, *Iron Monuments to Distant Posterity: Indiana's Metal Bridges, 1870-1930* (n.p., 1987), 47-49; "Advance in the Design of Bridge Superstructure," *Engineering News* 30 (27 July 1893), 80-81; U.S. Department of Transportation, Federal Highway Administration, *America's Highways, 1776 to 1976: A History of the Federal-Aid Program*, (Washington, D.C.: U.S. Government Printing Office, 1976), 428-429; Historic Bridge Files, Texas Department of Transportation, Environmental Affairs Division, located at TxDOT headquarters in Austin.

[413] The discussion of Texas suspension bridges in this and other sections draws heavily from: Historic American Engineering Record (HAER), National Park Service, U.S. Department of the Interior. “Texas Suspension Bridges.” No. TX-98.

1,057-foot span. Waco's bridge was a monumental undertaking that required importing cable and fittings from eastern foundries, 2.7 million bricks for the crenellated towers, and the expertise of academically trained civil engineer Thomas M. Griffith. The final $141,000 cost was such a massive sum that it could only have been raised through a stock offering and tolls, and accomplished by an ambitious community seeking to make a bold statement. Besides validating the value and potential of suspension bridges, Waco set several precedents. It was a parabolic, or catenary, suspension bridge with inclined stays and a stiffening truss. While these features would become standard or, as in the case of inclined stays, fairly common on subsequent Texas suspension bridges, Waco used pre-manufactured wire ropes. Most Texas suspension bridge builders would fabricate in situ cables. When Texans needed to build long-span highway bridges before World War II, they followed the precedent of Waco and turned to privately financed suspension bridges. This would happen only across the Rio Grande and the Red River, where the added complexities of negotiations between sovereign states must have further hindered public construction.

The success of prefabricated trusses, the dominant form of bridge construction from the 1880s until the creation of the THD in 1917, also gave energy to the counter-trend of the suspension bridge. Most metal trusses were fabricated by bridge companies outside the state in more heavily industrialized midwestern and northeastern states. It was a measure of the resentment over its dependence that the state legislature created a special tax for "clairvoyants, fortune tellers, cock-fighters" and bridge salesmen.

Taxing the bridge salesmen did not solve the problem because the taxes would have ultimately been borne by the counties. The solution was for Texas to train its own engineers and establish bridge-building companies. Despite its name, however, Texas Agricultural and Mechanical University only began to depart from its initial curriculum centered on classics, literature, languages, and math in 1879. Progress came with the organization of a new Department of Civil Engineering in 1885. Significant program enhancements followed during the rest of the century. Nevertheless, less than 50 percent of A&M's graduates could find good positions in the mid-1890s. The University of Texas established its College of Engineering in 1894. Graduates of these young programs would require substantial experience and capital before they could compete on their own with out-of-state bridge companies. The problem of indigenous bridge building capacity was significantly addressed with the establishment of the THD in 1917. As its universities developed a pool of trained civil engineers, the extant suspension bridges forcefully demonstrate that Texas continued a tradition of highly inventive citizenry. The success of the Waco Bridge established the many advantages of suspension bridges and offered a real alternative to prefabricated trusses.

***Suspension Bridges:*** *Inventors*

Ironically, it was the arrival of railroads in the 1870s and 1880s that increased an existing demand for better roads and bridges. The railroads offered access to distant markets and contributed to cotton displacing grain and cattle as the dominant agricultural product in Texas. Railroads also contributed to the emergence of early industrial centers. Financing hindered politicians seeking to accommodate rural demands for improved railroad access. In a series of measures and amendments between 1884 and 1887, the legislature empowered counties to issue road and bridge bonds backed by property taxes. At the same time, however, the legislature limited bonded indebtedness to control tax rates. In 1893, the counties' limited construction programs dramatically expanded when the bonding limits were raised at least six hundred percent. In light of the legislative history, it does not seem coincidental that Joseph Mitchell, E. E. Runyon, and William Greer each received their first bridge patents in 1887, 1888, and 1889, respectively. That each sought to build strong bridges using a minimum of material points to the limits imposed by the legislature. Each developed wire-based systems that reduced prefabrication expenses and facilitated transportation to often remote construction sites.

*Joseph Mitchell*

Joseph Mitchell was a bridge builder in Montague, Montague County, Texas, whose work first appears on the historical record in March 1887. While no examples of his work survive, he may have had an influence on the remarkable work of E. E. Runyon. The 1880 census for Montague County records that Joseph Mitchell was a 43-year-old farmer from Illinois with a wife, four daughters, and three sons. In 1887, Mitchell filed his first bridge patent in March, received the patent on August 16, 1888, and was ordered by the Montague Commissioners' Court "to repair all Bridges built by him in this County" in November. The only other reference to Mitchell in the Commissioners' Minutes is from 1888, which once again speaks only of repairing existing bridges. He seems to have had better luck immediately to the east in Cooke County—Runyon's home. Cooke County commissioned a total of four bridges from Mitchell in 1887 and 1888. Mitchell's bridge is of special interest because the same day it was accepted by Cooke County, September 10, 1888, is also the first reference to a Runyon bridge commission. All of this information about Mitchell might be of mere antiquarian interest given that Mitchell's patent was not for a suspension bridge *per se*, and given that the name Mitchell is rather common, but for the fact that Mitchell was paid for "Three Cable Bridges of his Patent of August 16, 1887," in Fulton County, Indiana, on October 27, 1888. Minutes recording later transactions made it clear that the Joseph Mitchell Bridge Company was based in Independence, Kansas.

More germane to the discussion of Texas suspension bridges is that in 1889, Mitchell constructed a cable-stayed bridge with pipe towers over the Whitewater River in Richmond, Indiana, that is strikingly similar to Runyon's cable-stayed work in Erath County of the following year. The bridge at Richmond consisted of six 25-foot panels, stiffening trusses based on either the Howe or Pratt pattern fabricated from strap-iron and rounds, and pipe tower bents. A local engineer and college professor thought it novel that "the cables were brought to a proper tension by thrusting a lever through the strands and then twisting it up to the supposedly proper stress; to hold it, the lever was then pushed through until it bore upon the ground."

It also probably had hand-twisted wire cables running beneath the deck. Longitudinal cables were a central feature of Mitchell's patent, but at Richmond he substituted a metal truss for the wood-and-metal variant of a king-post system in his patent. In 1890, Runyon would use a truss similar to that depicted in Mitchell's patent at Barton Creek. Mitchell's pipe towers were similar, but not identical to, Runyon's patents. The similarities between Mitchell's Whitewater River Bridge and Runyon's bridges raise the question of influence. Were Mitchell and Runyon familiar with each other's work? Did they adapt, license, or share technology?

*E.E. Runyon*

The work of Runyon and Greer will only be summarized in this overview because it has been discussed at greater length elsewhere. Edwin Elijah Runyon's first recorded appearance is in 1879, in southeastern Cooke County, Texas, as a schoolteacher and then as a shopkeeper. He moved to Pilot Point in nearby Denton County in 1890. Between December 1888 and March 1893, Runyon earned six bridge patents. Runyon developed a structural vocabulary based on gas-lighting pipe, hand-twisted cables, and elaborate connection castings, while consistently seeking structural simplicity and economy. While other Texas suspension bridge builders made extensive use of pipe, and while Mitchell made use of hand-twisted cables, Runyon's connections are extraordinary accomplishments in design and founder's execution. Runyon's connections have an unusual complexity that suggests a lack of formal engineering training. He seemed to get an idea for a connection only to find he needed another part to keep the first in place, and perhaps a third to keep the second in place. If Runyon's wonderful and inventive mind developed visually striking and appealing connections, however, it was his use of a pure cable-

stayed suspension system that was his most striking and telling achievement. The concept of connecting the towers directly to the deck panel-points dates at least to the late Renaissance. Throughout the nineteenth century, bridge designers experimented with a variety of suspension arrangements including pure cable-stayed and hybrid parabolic and cable-stayed systems. Examples of the latter include the Brooklyn and Waco bridges. In a situation closely parallel to north central Texas, blacksmiths in Scotland and Ireland built a series of short-span cable-stayed structures before 1834. Cable stays lost favor with academically trained engineers in 1823. In that year Navier published his *Memoir sur les ponts suspendus*, arguably the most influentially treatise on suspension bridges. His negative assessment of cable-stayed bridges severely limited future development. Likely neither Mitchell nor Runyon was aware of this. Regardless, they perceived a community need, seized an opportunity provided by the legislature, and sought appropriate solutions for their conditions. Despite his inventive work and despite the demand for bridges in north central Texas, Runyon's known output was only between four and six bridges.

*William Greer*

William Henry Clay Greer was the last of the Texas suspension bridge patentees. A resident of Sherman, Texas, Greer was neither as prolific nor as energetic an inventor as Runyon. He received four patents between 1888 and 1912, with a 16-year hiatus between the second and third. With his last two patents, Greer clearly had a working relationship with the Sherman Ironworks—the only documented relationship between a north-central Texas suspension bridge builder and a supplier. While the Choctaw Creek Bridge is the only known surviving example of his work, Greer built bridges in Montague and Grayson counties. In many respects, his design work is in the tradition of his peers. He used such readily available materials as pipe, castings, metal rods, and wire rope. Wire rope, while cheaper than site-fabricated cables, was more cumbersome to transport and made less effective use of the strength of each wire. Greer's patents make it clear that his concern was not loadbearing strength, but rather vertical oscillation of the deck. In fact, two of his patents explicitly acknowledge that the previous patent proved ineffective. His interest in this problem is understandable, because even to this day Texans refer to short span suspension bridges as "swinging bridges." From the perspective of the late twentieth century, Greer's patent designs could have been effective, or at least more effective, if he had made adjustments to his construction procedures and/or used more material. For example, the trusses Greer depicted in his second and third patents could have substantially stiffened the designs. Consistent with the origins of vernacular bridges, which are the focus of this study, Greer had neither the training to do the former, nor clients who could afford the later.

By the time the Texas vernacular suspension bridge era came to an end, its inventors had experimented with a wide range of systems. While the designs were not always highly stable, the inventors often dared to do what "proper" engineers "knew" not to do. For a brief time, demand and limited local resources motivated these inventors in their competition with prefabricated trusses. The patent system that suspension bridge inventors shared with many truss inventors was not sufficient to guarantee either of them success. Nevertheless, Texans were grateful to have their suspension bridges, and Runyon's work in particular foreshadowed the international development of cable-stayed bridges after 1950.

***Suspension Bridge*** *Builders in Texas*

*William Flinn*

William Flinn was the most successful suspension bridge builder in nineteenth-century Texas. Flinn was a Kansan who arrived in Weatherford, Parker County, Texas, in the early 1880s. In 1885 he was a carpenter with a small, single-story building at 105 Dallas Street, just northwest of the courthouse square. His bridge building career can

be documented from at least 1885 until his death in 1904, during which time he built bridges in at least eleven counties. In November 1885, "Wm. Flinn, Contractor," was paid for three bridges and contracted to build two additional ones by the Parker County Commissioners. A sign from a building completed in 1888 styles Flinn a "Contractor for Bridges and Buildings." His reputation as a contractor and bridge builder may have attracted E. E. Runyon's attention. Runyon and Flinn became partners by 1890, perhaps solely for the Erath County contract of that year. Whatever the case, there is no further evidence of the partnership after the completion of the Erath County bridges. That Flinn built a ferryboat for Brannon's Crossing, later the site of a Mitchell & Pigg bridge, on the Brazos River in Parker County is an indication that he kept up his carpentry. In what might have been his biggest contract to date, Flinn agreed in 1893 to build a bridge at an unspecified Parker County Brazos River crossing for $12,500. Flinn did not have the capital to finance the startup of such a costly project and offered to post a bond for $3,125. The county gave him an equal advance in return. In the 1890s, Parker County was an important cotton center and clearly had the ambition to build such an expensive bridge. The county could finance such an undertaking bridge because of the legislature's significant county debt limit liberalization the same year. What is of further interest is that the county initially contracted with William Flinn and A. A. Moyer, but for unspecified reasons, Moyer withdrew from the contract. Beginning around 1896 Flinn and Moyer were regular partners on many bridge contracts. Nevertheless, Flinn often built bridges on his own despite his partnership with Moyer.

In March 1904, almost three months prior to his death, Flinn was commissioned to build two monumental bridges across the Brazos River in Palo Pinto County (see Table 6). Not only do they represent the crowning achievements of his career, but they also marked the beginning of the period that saw the construction of substantially larger suspension bridges in Texas. The smaller of the two bridges, 873 feet long overall, crossed the Brazos River at the town of Brazos near the Texas & Pacific Railroad's bridge, and cost $15,000. Its 300-foot main channel span was flanked by two 150-foot side spans, and had 272 feet, 6 inches of approaches that carried the 16-foot-wide roadway. The second bridge carried the Palo Pinto-Graford Road across the Brazos near the mouth of the Dark Valley Creek. The still extant south anchorages are embedded in a cliff approximately 60 feet above the river. Two main channel spans of 250 feet were flanked by 125-foot side spans. An additional 80-foot suspended span and 234-foot approach completed the bridge on the north. It too had a 16-foot-wide roadway, but cost $20,000. While both bridges had the distinctive Howe stiffening truss fabricated of pipe associated with much of Flinn's work, the towers and the piers they rested on were built not of pipe as at Clear Fork and Beveridge, but of riveted sheet metal filled with concrete.

While it is not exactly certain who completed the Palo Pinto bridges, it is clear that Flinn assembled a talented team, or teams, that could complete major projects in his absence. Even today the ruins of the Dark Valley Crossing are impressive. Most of the metal has corroded or was removed when the bridge was replaced by the THD in 1957, but the dramatic site, the south anchorages and the concrete that once filled the piers are testimonials to a forgotten high point in the history of Texas suspension bridges.

**Table 6. William Flinn's 1904 Palo Pinto County Suspension Bridge Specifications**

| | Dark Valley Crossing Bridge | Brazos Crossing Bridge |
|---|---|---|
| **Overall length** | 1,064' | 873' |
| **Main span(s)** | two spans @ 250' | 300' |
| **Secondary spans** | two 125' side spans & 80' span on north | two 150' side spans |
| **Approaches** | 234' iron approach on north | 58'-6" approach on west & 214' approach on east |
| | 400* wires per cable | 300 wire per cable |
| **Price** | $20,000 | $15,000 |
| **Date accepted** | December 17, 1904 | March 31, 1905 |
| **Common features:** | | |
| 16' roadways; 7" diameter x 10' long pipe anchor bars; concrete-filled channel piers 6' diameter at base; roller saddles; No. 9 gauge galvanized steel wire; 1" diameter suspender rods at 10' intervals connected to 3" diameter pipe floor beams, truss-stiffened spans. | | |

*Source: Palo Pinto County, Minutes of the Palo Pinto County Commissioners' Court E: 559-67 (19 Mar. 1904). (Contract included a third bridge for $1,200.)*
**The diameter of cables embedded in the south anchorages is approximately 6 inches.*

*Flinn's Successors: Mitchell & Pigg*

Similarities between the larger suspension bridges by Mitchell & Pigg of Parker County and Flinn's 1904 Palo Pinto County bridges suggest a continuity of personnel and technical experience. Between 1905 and perhaps the early 1920s, H.F. Mitchell and J. W. Pigg built a series of suspension bridges. Little else is currently known about the firm. The situation is further aggravated by the fact that not a single positively identified example of their work stands today. A phone directory places H.F. Mitchell in Weatherford, Texas, in 1916, and he is in Fort Worth by the 1920s. Less is known of Pigg, except he is styled "Col." in a history of the Austin Bridge Company of Dallas. Austin Bridge emerged in the 1910s as the major bridge contractor in the state. In the 1920s Austin Bridge hired several Mitchell & Pigg employees, who gradually evolved into a suspension bridge division.

Surviving images and contracts give us some idea of Mitchell & Pigg's bridges. In 1905 they constructed the practically identical Brannon's Crossing and Hightower Valley Bridges across the Brazos in Parker County. The former was a 440-foot clear span while the later, also known as Tin Top, was 400 feet. The 200-foot-high towers were made of laced steel angles resting on stone piers. Each had 600 wires per main cable and a 6-foot-high Pratt stiffening truss. Flinn, it will be remembered, used Howe trusses, but both companies show a kinship in the manner in which the trusses are fabricated and assembled. In addition to the main cables, each bridge had two additional "floor cables" that ran at just about the level of the 3.5-inch-diameter pipes that served as deck beams for the 16-foot-wide roadways. The contracts make no mention of the function of these cables, but each held 200 strands. These cables were certainly used as platforms during construction and were not a part of the deck system as in Runyon and Joseph Mitchell's patents. This conclusion is supported by construction photographs of what is almost certainly the Dark Valley Crossing Bridge and the presence of similar, but much smaller, cables at the Rock Church Bridge that carry no load. Rather inexplicably, however, the contracts mention tension rods running the length of the bridge under the Brannon's Crossing and Hightower Valley decks. Several other interesting features should be pointed out. Many of Mitchell & Pigg's bridges had a few wires separated out from the backstays. These wires were attached to a hook a little below the saddle castings. Engineering consultant Steven Buonopane has suggested that these may have supported the towers during construction.

In 1908 Young County purchased a pair of Mitchell & Pigg's suspension bridges to cross the Brazos near Newcastle and at South Bend. Here, Mitchell & Pigg used concrete-filled steel cylinders for the towers. The main span of the Newcastle Bridge was a stunning 700 feet, suspended from main cables of 700 wires. Mitchell & Pigg used 500 wires in each cable to support the 400-foot main span at the South Bend crossing of the Brazos. Consistent with practically every extant Texas suspension bridge using parallel-wire cables, and contrary to long standing practice among professional engineers, the cables in Young County were not continuously wrapped like a spool of thread. Rather, they were wrapped with a smaller gauge wire with one turn every 2 inches. The Young County contracts give us rare details of the anchorages. At Newcastle, a 20-foot by 20-foot by 10-foot block of concrete encased an 18-foot-long, 10-inch-diameter pipe. South Bend's anchorage was a bit smaller at 20-foot by 20-foot by 6-foot, with a 14-foot by 10-inch pipe. The last known work that can be attributed to Mitchell & Pigg was the 98th Meridian Suspension Bridge across the Red River between Clay County, Texas, and Jefferson County, Oklahoma, near Byers, Texas. It had three 567-foot spans, one 107-foot span, and could only have been financed by a toll company.

*Flinn's successors: Austin Bridge Company*

The Austin Bridge Company entered the suspension bridge business by repairing the bridges built by Mitchell & Pigg as well as those by William Flinn. Examples of their repair work can be seen at Clear Fork of the Brazos and Beveridge suspension bridges. In 1924 Austin Bridge contracted with the Nocona Bridge Company to build a 700-foot suspension bridge across the Red River north of Nocona, Montague County, for Harry F. Mitchell & Associates of Fort Worth. Surely this was the same Mitchell of Mitchell & Pigg, then acting as a developer of Red River toll bridges. If so, it is somewhat ironic that he was using former employees at Austin Bridge. The bridge itself appears to have been an unstiffened version of Newcastle. Perhaps it was difficult to maintain a stiffening truss made of pipe. Certainly, improved transportation and trail systems meant it was very easy to get rolled steel sections in Texas, but for whatever reason, Austin Bridge did not use stiffening trusses in its original construction or most major repairs. In the 1920s and 1930s Austin Bridge expanded its suspension bridge business with jobs that included many other bridges across the Red River, the 1926 Hidalgo-Reynosa Bridge across the Rio Grande, and the recently rehabilitated Regency Suspension Bridge of 1939.

***Suspension Bridges -****Conclusion*

The suspension bridge seems to have had a short efflorescence in Texas. While the story seems to have started in the 1870s with the construction of Waco, it did not gain much strength until legislation in the late 1880s provided for a funding mechanism. Between the topography of North Central Texas and the concentration of inventive designers and entrepreneurial builders, the short span suspension bridge had some success competing with out-of-state metal truss builders. Momentum shifted away from suspension bridges and more firmly toward trusses around 1905, shortly after the death of William Flinn. The establishment of the THD in 1917, in turn, had a significant impact on the variety of truss types and bridge companies in Texas. By then, suspension bridges were largely limited to long-span crossings that required private funding. The age of the short-span suspension bridge in Texas came to a definitive close with World War II.

*Bridge Developments in Early-Twentieth-Century Texas*

Entrepreneurial approaches to bridge design did not stop in 1900 with J. P. Morgan's consolidation of the bridge industry with the American Bridge Company. Rather, much of it shifted to the less mature technology of

reinforced concrete. Engineers like Ernest Ransome, C. A. P. Turner, Daniel Luten, and many others experimented with the new material. The most notable example in Texas is the 1918 concrete truss bridge in Mason, Mason County. However, the first two decades of the twentieth century also saw advances in engineering education and the near eclipse of the American Standard truss by riveted steel trusses.

*Texas Bridge Fabricators*

Prior to the early 1900s, virtually all I-beam and truss bridges in Texas were fabricated by out-of-state bridge companies. While these fabricators relied primarily on exclusive agents to market their bridge products in Texas and other states, in some cases, local engineers or contracting companies also acted as agents for these firms. These independent Texas companies usually did not have the same level of company loyalty as exclusive agents. They tended to change associations with bridge fabricators frequently, marketing trusses for one company for a year or two and then switching to another firm. For some of these companies, the marketing of metal truss bridges represented a fairly minor part of their overall operations. Often, a firm that marketed metal truss bridges also sold road machinery, structural steel for buildings, and other related products, and in some cases offered engineering consulting services as well. For these companies, it was standard practice to purchase steel trusses and other products from out-of-state companies and to sell them in Texas under their own name. A number of bridge contracting firms operated out of the Fort Worth and Dallas area. A 1900, city directory for Fort Worth lists both a senior and junior Montague S. Hasie as bridge builders. In this directory, Montague S. Hasie Jr. is also described as the "general Southwestern agent" for Groton Bridge and Manufacturing Company of Groton, New York. By 1902, Montague S. Hasie Sr. had moved to Dallas and had established himself as the president of the Texas Bridge Company, Inc. County commissioners' records of the early 1900s indicate that the company was actually an agent for American Bridge Company of New York, New York. A number of American Bridge Company trusses survive in Texas with documented construction dates of 1905 to 1911. By 1908, Montague S. Hasie, Jr. is also listed in the Dallas city directories as a bridge engineer and contractor. A second Dallas-based bridge firm was Hess and Skinner Engineering Company, which bid on several bridge projects in Texas during the 1910s. Various documentation materials evidence that the company was actually acting as agents for the Missouri Valley Bridge and Iron Company of Leavenworth, Kansas, during much of this period.[414]

Southwestern Bridge and Iron Company of Fort Worth was also involved in metal truss bridge projects. The 1896 to 1897 Fort Worth city directories list the company as "general contractors for bridges; iron and steel structural work, foundry and machine works." During the late 1890s, the company bid on a number of metal truss bridge projects in Texas. The officers of the company included Thomas A. Tidball, president; R.N. Hatcher, vice president; E.C. Orrick, secretary; and William T. Young, engineer. The company had a downtown office, as well as a yard along the Texas and Pacific Railroad in Fort Worth. While the company apparently operated a foundry, there is no evidence that the company performed bridge fabrication work as well. Instead, the firm probably operated as a contractor for out-of-state bridge companies, utilizing their Fort Worth yard to store bridge components until they were ready for shipment to a bridge site.[415]

---

[414] *Morrison and Fourmy's Directory of the City of Fort Worth, 1899-1900* (Galveston: Morrison and Fourmy, 1899), 125; for information on Montague Hasie Sr. and Jr. in Dallas, see *John F. Worley and Company's Dallas Directory* (Dallas: John F. Worley) for the years 1902 to 1912. For information on Hess and Skinner Engineering, see *Worley's Directory of Dallas, Texas*, 1913 (Dallas, John F. Worley Directory Co., 1913), 691.
[415] Morrison and Fourmy's General Directory, Fort Worth, Texas, 1896-97 (Galveston: Morrison and Fourmy, 1896), 11 and 318.

El Paso Bridge and Iron Company of EI Paso is also known to have sold metal truss bridges in Texas beginning in 1908. The city directories for El Paso list a downtown El Paso location, but do not indicate whether the firm was acting as a bridge fabricator or a bridge agent for another company. With an office location in downtown El Paso, it seems unlikely that the company was a metal truss fabricator. The 1909 El Paso city directory lists three principals in the company: W.E. Robertson, E.B. Holt and W.D. Webb. By 1914, the company had also brought E.P. Rankin, Jr. into its ranks. In 1920 the El Paso city directory includes two companies under the category of "Iron and Steel." The first of these is the EI Paso Bridge and Iron Company, which is listed as "engineers, designers and contractors," providing "structural steel for every purpose." The company is also shown for the first time as having a warehouse in the city. The second firm listed is the Wisconsin Bridge and Iron Company of Milwaukee, Wisconsin, with E.P. Rankin, Jr., formerly of El Paso Bridge and Iron Company, as the principal contracting engineer. The ad goes on to list the Milwaukee firm as "engineers and fabricators" specializing in various types of steel equipment and frames, including "trusses" and "girders." This chronicle of events suggests that the El Paso Bridge and Iron Company was probably not fabricating bridges in Texas, but rather was acting as agents for out-of-state bridge fabrication companies, such as the Wisconsin Bridge and Iron Company.[416]

The Alamo Construction Company of San Antonio bid on numerous metal truss bridge projects in Texas from 1914 to 1918 or later. Various engineers were associated with the company, including a G.H. Bradford and H.L. Miles. A 1916 San Antonio city directory lists a C.G. Sheely as the firm's president. The city directories provide a downtown office location for the company, but do not mention a plant or warehouse facility. During the late 1920s, Sheely is listed as president of another company, Monarch Engineering, located at 1146 W. Laurel Street in San Antonio. A Sanborn map of the period shows a couple of office buildings at the site, but shows no evidence of a fabrication plant, foundry, or warehouse.[417]

The only major Texas bridge fabricator prior to the creation of the THD in 1917 was Austin Bridge Company of Dallas. The Austin name first became known in Texas bridge building when George L. Austin became an agent for George E. King Bridge Company of Des Moines, Iowa, in 1889. He was joined by his brother, Frank E. Austin, five years later, but by 1896, George had moved to Atlanta to operate a Georgia-based bridge contracting business. In 1902 the brothers formed a new partnership called Austin Brothers, Contractors, and agreed to split the Texas and Georgia profits equally. In addition to marketing bridges, the company sold road machinery and construction equipment. Six years later, the brothers severed their connection with George E. King Bridge Company and began to make plans to open their own bridge fabricating business. Finally, in 1910, the company purchased property in Dallas and built a small fabrication plant for bridge and building components. A second fabrication plant was opened in Atlanta.[418]

Relying on their past experience and knowledge with bridge contracting and construction in the South, the two brothers developed a sizeable bridge building business. Unlike other companies that used independent agents to

---

[416] See *John F. Worley's Directory of El Paso, Texas* (Dallas: Jolm F. Worley Directory Co.) for the years 1909 to 1918 and the *EI Paso City Directory 1920* (EI Paso: Hudspeth Directory Co., 1920).
[417] For information on the Alamo Construction Company, see *Jules A. Appler's City Directory of Greater San Antonio* (San Antonio: J.A. Appler) for the years 1914 to 1918. Information on Monarch Engineering is found in *John F. Worley Directory Co.'s San Antonio City Directory* (Dallas: John F. Worley Directory Co.) for the years 1927-1928 and 1929-1930 and *Sanborn's Fire Insurance Map*, San Antonio, Texas, 1911 (revised) (New York: Sanborn Map Company, 1911 with revisions to 1951), volume 1, sheet 55.
[418] Shannon Miller, *Austin Bridge Company and Associated Companies: The First Fifty Years, 1918-1968* (Dallas: Taylor Publishing Company, 1974), 1-3.

market their bridges, the two brothers hired and trained their own bridge salesmen and erection crews. The company's use of in-house salesmen, its relatively low shipment fees, and its quick response times gave the firm a significant advantage over its out-of-state competitors. The Austin brothers summarized their bridge building philosophy in a 1915 company publication:

Our long experience in building bridges throughout the Southern States under various conditions, and the mistakes we have naturally made in this line of work in the past, certainly ought to enable us to know the territory and to design the right bridges for the right places. The location of our shops, at Dallas and Atlanta, were arrived at after we had been in business many years and ascertained proper points from which we might best serve the territory. Having our own bridge shops and raw materials, our own contractors, erection men and equipment, we are able to furnish bridges complete without having to pay a profit to others.[419]

Austin Brothers continually expanded its store yard in Dallas to provide bridge customers with quicker response times to bridge orders. By keeping a large stock of rolled steel products on hand, the company could produce fabricated bridge products within a week after an order was received. A 1915 company advertisement features a photograph of the Austin Brothers store yard with the caption "more than a million pounds of steel." The advertisement explains that the "materials shown…consist of I-beams, channels and angles, in lengths from 20 to 70 feet, just as we received them from the rolling mills." During the year ending March 1, 1915, the company handled 360 carloads of steel through its Dallas shops. This extensive stockpile of materials verified the ad's claim that the company could "fill most any requirements, and make prompt shipments."[420]

Another marketing strategy of Austin Brothers was to develop sales literature and materials on its products. One of the company's primary sales tools was its book of standard plans that included drawings of roadway bridges in various lengths, widths, and strengths. These drawings allowed the company's salesmen to prepare detailed plans and cost estimates for virtually all bridges in the field. Most of the standard plans in the book were for Warren pony trusses with 10 to 15 ton loading and lengths of 30 to 80 feet. The book also included designs for Pratt and Warren polygonal-chord pony trusses, typically in lengths of 80 to 118 feet. The company's publication, *The Highways*, provided the company with another major advertising medium. Beginning in 1912, monthly issues of the magazine were mailed to county judges and commissioners all over the South. The publication provided information on the company's stock spans and featured articles on bridge and road progress in Texas and other parts of the country.[421]

Following the example of Sears Roebuck, American mail-order companies, and other bridge companies, Austin Brothers issued a 276-page catalog featuring its bridge and road products in 1915. The company's *"Catalog and Handbook for Buyers, Engineers and Builders"* encouraged counties and cities to purchase their bridges direct from the company's catalog. The catalog included instructions and advice for measuring bridge crossings and arriving at cost estimates for steel structures. While the catalog claimed that "most anyone that can use a common level and tape line" to secure basic bridge measurements, it also offered to send engineers to counties "without charge" to furnish exact bridge measurements and estimates. The various charts, drawings, and photographs in the catalog

---

[419] Miller, 2-3; Quote taken from Austin Brothers, *Catalog and Handbook for Buyers, Engineers, Builders* (Dallas: Johnston Printing and Advertising Co., 1915), 139.
[420] Austin Brothers, *Catalog and Handbook*, 195.
[421] Miller, 3; Austin Brothers, "Book of Standard Steel Truss and Beam Span Bridges," located at Austin Industries headquarters in Dallas, n.d.; Austin Brothers, "The Highways," 1912-1915 issues, located at Austin Industries headquarters in Dallas.

provided detailed information on culvert, I-beam, and truss bridge types. The section on I-beam bridges, for example, included technical data on 26 different I-beam spans with lengths of 8 to 40 feet. The catalog offered culverts and I-beam bridges in ready-to-assemble kits that were "so simple in make-up that it does not require a bridge man to erect them." The catalog asserts that all of the necessary components are included in a bridge order: "With each bridge is shipped all the necessary bolts for putting bridge together, as well as bolts for securing floor to steel joist and also full instructions as to how to build the abutments and erect the bridge complete." The catalog also included instructions for building concrete and steel abutments and piers. Most noteworthy was a plan for a concrete pier with solid web-walls and rounded end columns. This design represented a significant advancement over metal bent piers and caissons, which were common in metal truss construction during this period.[422]

Austin Brothers, Contractors, benefitted greatly from its efficient operations and dynamic marketing approach, and by the mid-1910s it had become a major force in the Texas bridge building field. Higher costs, slower response times, and other factors made it increasingly difficult for out-of-state companies to compete against the prosperous Dallas firm. The business failings of several large out-of-state bridge companies accelerated this trend, and by the beginning of World War I, Austin Brothers, Contractors, had become the largest bridge builder in Texas. The company's lightweight trusses sold especially well and were built in all areas of the state, including West Texas and the Panhandle. Numerous examples of these bridges survive on Texas roadways throughout the state.[423]

Despite the company's rapid growth and success, Frank L. Austin grew tired of bridge contracting work. In 1918 the Austin Brothers sold the bridge part of the business to Charles R. Moore, an enterprising employee who had served as the company's "Traveling Agent, Contracting Agent, and Chief Engineer." Within two years, Moore changed the company's name to Austin Bridge Company (also called Austin Brothers Bridge Company) and moved the bridge operations to the Wyatt Metal & Boiler Works property near the Gulf, Colorado and Santa Fe Railroad tracks in Dallas. The company continued to grow and expand under the leadership of Moore, selling a large quantity of small metal truss spans, I -beam bridges, and timber structures. Most of the company's contracts for the 1920s were for simple Warren pony trusses with spans of 80 feet or less.[424]

By the mid-1930s, many counties and cities in Texas were designing and constructing their own bridges and were no longer dependent on Austin Bridge Company to provide them with pre-fabricated metal spans. Offsetting this loss was the company's contract work for THD highway bridges, oil pipeline structures, and railroad bridges. Many of the THD contracts of the 1930s were for large concrete and steel girder highway bridges (including railroad underpasses). Although the company's contracts for small county spans declined during this period, it continued to market its line of small metal truss spans into the 1940s. By 1945, the company had secured more than 3,000 bridge contracts, mostly for county, city, and highway bridges in Texas. While several large out-of-state fabricating firms returned to Texas after THD's creation in 1917, Austin Bridge Company continued to play a leading role in Texas bridge construction in the decades that followed. The company survives today as a subsidiary of Austin Industries in Dallas.[425]

---

[422] Quotes taken from Austin Brothers, *Catalog and Handbook*, 143 and 173.
[423] Historic Bridge Files, Texas Department of Transportation, Environmental Affairs Division, located at TxDOT headquarters in Austin.
[424] Miller, 1-14; Austin Bridge Company, Contract Records, located at Austin Industries headquarters in Dallas; Historic Bridge Files, Texas Department of Transportation, Environmental Affairs Division, located at TxDOT headquarters in Austin.
[425] Austin Bridge Company, Contract Records, located at Austin Industries headquarters in Dallas; Historic Bridge Files, Texas Department of Transportation, Environmental Affairs Division, located at TxDOT headquarters in Austin.

Two other Texas companies that were involved in bridge fabrication at a relatively early date were Alamo Iron Works of San Antonio and Mosher Steel and Machinery Company of Dallas. In 1877, J. Schuhle and R.G. Nixon established a foundry and machine shop called Alamo Iron Works in central San Antonio. Within several years George Holmgreen had taken over as the company's sole proprietor. A 1902 advertisement in the city directory indicates that the company was producing a wide range of iron products, including "ice and refrigerating machines, horse powers, pumping jacks, well drilling machines, hay presses, etc." A 1912 Sanborn map shows the company's buildings clustered around the Southern Pacific Railroad, consisting of a small foundry, a machine shop, a warehouse, blacksmith shop, pipe cutting building, gasoline engine repair shop, woodworking shop, boiler shop, office, and various storage units. While there is no evidence that Alamo Iron Works fabricated metal bridges at this time, it was probably producing portal elements, finials, and other decorative features for bridges in the region. Several metal truss spans in San Antonio exhibit exemplary and unusual cast iron work, providing some evidence of the company's participation in early bridge-building projects. During the 1920s, the company built a structural shop for fabricating a wide range of steel structures including buildings, towers, church steeples, and bridges. In 1922, the company opened a subsidiary plant in Houston, Alamo Steel & Supply Company that operated as a supplier of reinforcing steel, structural steel, paving equipment, and other equipment. Alamo Iron Works produced a wide range of highway and railroad bridges during the 1920s and 1930s. With the advent of World War II, Alamo Iron Works retooled its machines to produce war ships, but in 1946, the company resumed its regular operations.[426]

The second company, Mosher Steel, was established by Theodore Mosher in Dallas in 1885. While the company initially opened as a machine shop, a foundry was added within several years. By 1892, Mosher Steel employed 75 to 80 men, providing an annual payroll of $36,000. The Mosher Manufacturing Company was incorporated shortly after Theodore's death in 1893. Ten years later, the company extended the plant site and added a structural steel fabricating plant that concentrated primarily in steel for building construction. The company expanded into the Houston market in 1908, establishing a subsidiary called Houston Structural Steel Company. By 1918, the Mosher Manufacturing Company employed 360 men and the name of the Dallas plant was changed to Mosher Steel and Machinery Company. There is no evidence that the company was fabricating steel bridges in Texas before the creation of THD in 1917. By the early 1920s, however, both operations were fabricating metal steel spans as part of their regular operations. The two affiliated companies proclaimed their ability to design, fabricate, and erect steel bridges in a 1924 advertisement of the *Texas Highway Bulletin*, which also featured a picture of a Pratt through truss span. During the 1920s, contractors for the THD relied heavily on Mosher Steel and Machinery Company and the affiliated Houston Structural Steel Company for bridge fabrication work. By the 1930s, the two Mosher-related firms were fabricating steel truss highway bridges on a fairly large scale. In 1936, the company moved its home offices to Houston, operating under the new name of Mosher Steel Company.[427]

**Bridge Types of the Early Twentieth Century**

*Steel I-beams*

---

[426] Information on the Alamo Iron Works is found in: "Alamo Iron Works," unpublished brochure (San Antonio, Alamo Iron Works, n.d.), 2; *Jules A. Appler's General Directory of San Antonio, Texas*, 1901-1902 (San Antonio: J.A. Appler, 1901), 598; *Sanborn's Fire Insurance Map, San Antonio, Texas, 1912* (New York: Sanborn Map Company, 1912).
[427] Mosher Steel Company, "The Story of Mosher Steel," Seventy Fifth Anniversary Brochure, 1960) at the Dallas Public Library.

The rise of rolling mills and fabricators also stimulated an interest in I-beams for short stringer spans. Several of the eastern railroad companies utilized wrought iron I-beams for trestles and small beam structures immediately after the Civil War. By the late nineteenth century, bridge building companies across the country were utilizing wrought iron and steel I-beams in place of timber. The transition from timber to steel I-beams was relatively slow in Texas, due to the abundance of timber and its easy adaptability to stringer bridge construction. Shipping charges also added significantly to the cost of using steel stringers in Texas, making them only marginally competitive against conventional timber stringers.

The few unaltered non-truss steel bridges remaining from this period are typically located on county roads and feature short I-beams with spans of 30 feet or less, carrying a timber deck and erected over either masonry or timber supports. Gradually, the rolling mills developed the technology to produce deeper I-beams, which increased the practical length of steel stringer spans to 40 feet or more.[428] It was not until the 1910s, when steel fabricators began operating in the state, that steel I-beams were used more extensively in Texas. Typical of an early-twentieth-century steel I-beam is the three-span Bosque River Relief Bridge in Hamilton County (TxDOT Structure No. 09-098-0-C001-15-002). Located on Elm Street in Hico, this 1920 bridge is composed of 30-foot-long steel spans, with a nail-laminated deck supported on concrete piers.[429]

The earliest steel beam bridges constructed by the State Highway Department were based on standard plan specifications issued by the U.S. Bureau of Public Roads. The THD developed its own standard designs for steel I-beam bridges in 1919.[430] Due to the limited capability of the rolling mills to produce longer beams, steel beam bridges built before 1925 were usually restricted to single spans of 20 to 50 feet. Only a small number of steel bridges were built during World War I due restriction of materials needed for the war industries. After the war, the total amount of structural steel used for bridge construction rapidly increased from 873,231 pounds in 1919 to 1,303,353 pounds in 1920.

The strength and size of the I-beam bridge increased during the 1930s to be able to carry heavier loads over a reinforced concrete deck. The I-beam bridge of the 1930s is visually characterized by the size of beam or web plate, which had grown proportionally in depth since the 1920s. A typical bridge of this period carries a concrete deck, which extends beyond the outer beams of the bridge, and is supported on concrete or timber pile bents. A good example of a State Highway Department design in the 1930s is the 799-foot-long Elm Creek Bridge located on the original alignment of SH 23 (now Park Ave), in Ballinger in Runnels County (TxDOT Structure No. 07-200-0-B002-55-024). Erected in 1932, the bridge consists of 16 simple steel I-beam and concrete deck units supported on reinforced concrete bents and abutments.

Up until the 1930s, steel I-beam bridges were usually constructed as a series of one-span units supported at each end by a bent or an abutment. With advances in welding technology in the late 1930s, continuous steel beams could be fabricated to span lengths of over 200 feet. The continuous unit was usually placed over the main channel of a stream and approached by either simple steel I-beam or reinforced concrete girder units. Because the sheer force of the continuous span is experienced at its supports, the bridge commonly had solid concrete piers placed under the main span.

---

[428] Fraserdesign and Hess, Roise and Company, p. 5
[429] Ralph K. Banks, "Short Spans, About Bridges, Part ITI," *County Progress Magazine,* November 1994, p. 16-17; Ralph K. Banks, "Short Spans About Bridges, Part IV," *County Progress Magazine,* January 1995, 26-27.
[430] Texas Department of Transportation, *Bridge Design Manual*, 7-108.

In 1934, the State Highway Department began experimenting with increasing the length of the main span of a steel bridge by extending the steel units beyond their supports. Commonly referred to as a cantilever-suspended span, the bridge type consists of an independent steel unit placed between cantilevered arms projecting beyond the main supports of the bridge. These independent units were connected together by riveted notched beam seats or pin and hanger assemblies.

The advantage of the cantilevered suspended configuration was that it enabled a bridge to carry a significantly longer main span and thinner deck, thus reducing the number of supports and overall cost of the bridge. The Nueces River Bridge carrying BI 35 traffic in Cotulla is a good example of the State Highway Department's utilization of a cantilevered suspended span configuration (TxDOT Structure No. 22-142-0-0018-09-040). Completed in 1938, the 1,226-foot-long bridge features a 291-foot-long riveted cantilever-suspended span over the main channel of the river and is ornamented with special design steel railing. Only a small number of cantilever-suspended bridges were constructed by the state between 1934 and 1948. Corrosion problems affecting the connections and refinements in field-welding techniques soon rendered this technology obsolete.

After World War II, the production of steel I-beams for bridge construction increased. Advancements in welding technology, especially field-welded splicing, permitted the fabrication of longer continuous units. These long-span steel bridges were built prolifically by the State Highway Department during the expansion of the state highway system in the 1940s. The Village Creek Bridge, located on US 96 Northbound in Lumberton in Hardin County, is typical of a long-span steel bridge of this period (TxDOT Structure No. 20-101-0-0065-05-059). The 1,672-foot-long bridge is one of the longest of its type in the state and consists of a 230-foot-long field-welded continuous steel span unit resting on reinforced concrete pile bents.

*Fabricated Steel Girders*

By the late nineteenth century, many bridge fabricators were building large built-up beams called plate girders for short to intermediate spans. By 1916, the renowned American bridge engineer J.A.L. Waddell noted that the ordinary limit for plate girder spans was about 100 feet, although spans of 120 feet or more were common for swing spans. These girders typically consisted of metal angles and plates riveted together to form relatively large beams. The railroads used plate girders extensively for simple bridge spans, but also employed them occasionally for swing bridges. The pre-fabricated girders were usually placed on a flat car and shipped by rail to the site. The transportation of large girder units was more problematic for roadway crossings, particularly when the girders had to be hauled long distances over land.

Transportation difficulties and the preference for light spans prevented a widespread use of girders on Texas roadways until the 1920s and 1930s. Steel fabricated girders never became part of the State Highway Department's standard plan designs. Because of its cost and difficulty in transporting the fabricated girders were used only in special situations.[431] Good representative fabricated girder bridges include the 1931 through-girder Benton Street Overpass, in Big Spring (TxDOT Structure No. 08-115-0-B054-90-001); the 1937 South Main Street overpass of the BNSF railroad in Fort Worth (TxDOT Structure No. 02-220-0-ZM06-70-001), and the 1943 multi-girder

[431] Banks, "Short Spans, About Bridges, Part ITI," 16-17; Banks, "Short Spans About Bridges, Part IV," 26-27; Waddell, 1: 408-409; Condit, *American Building: Materials and Techniques,* 225-226; James L. Cooper, *Iron Monuments to Distant Posterity: Indiana's Metal Bridges, 1870-1930,* 42-43.

overpass on Zang Boulevard (State Loop [SL] 354) at Cedar Creek, in Dallas (TxDOT Structure No. 18-057-0-9Z05-40-009).

*Reinforced Concrete Bridges*

European engineers began experimenting with concrete reinforcement in the 1840s. Prior to that, non-reinforced or plain concrete had been employed with some success as a building material. First used without reinforcement in bridge building, plain or mass concrete worked solely under compression and was only applicable to the arch form. Concrete became more common for bridge construction after methods of reinforcement with metal wire and steel were introduced, improving concrete's tensile strength (resistance to lengthwise stress). The earliest patented reinforcement system is credited to Josef Monier, a French gardener; who in 1876 encased wire mesh in concrete to create flowerpots. This less than eventful beginning of reinforced concrete would result in the development of the "Monier System" of reinforcement. The "Monier System" became commercially viable for bridge construction when German engineer G.A. Wayss purchased Moiner's patents in 1885 and refined them by replacing the wire grid with a sturdy grill of metal bar.

While Europeans made great strides in concrete bridge design in the last quarter of the nineteenth century, Americans, due to a lack of technical training, produced modest concrete structures based more on economics than scientific principles. American interest in reinforced concrete began with Thaddeus Hyatt, an American lawyer, who conducted a series of tests in the 1850s on reinforced concrete beams to determine the effect of the size and placement of metal reinforcement in beams. His tests revealed that it was not necessary to utilize the entire I-beam as only the metal in the lower portion of the beam absorbed tensile stresses. Hyatt revolutionized concrete reinforcement by replacing steel I-beam with small metal rods, which could efficiently handle the tensile stresses with less material. Julius Kahn, a native of Detroit, introduced another reinforcement system that influenced American bridge design. Kahn's invention featured square bars with spurs on each side embedded in concrete. The first real application of reinforcement for bridge building occurred in 1889 with a concrete arch built in San Francisco with a twisted bar reinforcement system patented by Ernest Ransome.

By far, the most commercially successful reinforcement systems in the United States were developed by Daniel B. Luten. A native of Michigan, Luten taught engineering at Purdue University between 1895 and 1900, where he promoted the idea of material elasticity first put forth in Turneaure and Maurer's "Principle of Reinforced Concrete Construction." Luten's approach to bridge design was essentially empirical rather than theoretical. Luten's experiments with intuitive design revolutionized concrete bridge construction during the first decades of the twentieth century. Luten's many inventions resulted in 30 patents for concrete girder, truss, slab, and closed-and open-spandrel bridge reinforcement systems. Many of his patents became standard bridge designs sold by construction agents working for Luten Bridge companies across the country.[432] The 1923 Mockingbird Lane Bridge over Turtle Creek (TxDOT Structure No. 18-057-0-9HP4-80-001), in Dallas, is a good example of one of Luten's standard patent designs for a closed-spandrel arch. Far more impressive is the Scott Avenue (BU 287) Bridge (TxDOT Structure No. 03-243-0-0044-10-063) at the Wichita River, in Wichita Falls. The design, issued from Luten's main office in Indianapolis, consists of a three-span open-spandrel arch composed of five rib-type arches.

[432] James L. Cooper, *Artistry and Ingenuity in Artificial Stone: Indiana's Concrete Bridges, 1900-1942*, 36-65.

*Concrete Bridges: Closed-spandrel Arch*

The earliest concrete bridges constructed in Texas were closed-spandrel arches, which essentially mimicked stone masonry arch construction. One of the first documented reinforced concrete bridges in the state is the 1908 Euclid Avenue Bridge crossing a tributary of Turtle Creek in Highland Park (TxDOT Structure No. 18-057-0-9HP2-30-001). This short bridge is composed of one closed-spandrel arch ornamented with decorative railing and depressed geometric panels. Not only is the bridge exemplary design, it is also typical of many small closed spandrel arches constructed across the state during the first quarter of the twentieth century. Other representative examples include the 1910 Main Street (FM 51) Bridge at Town Creek in Weatherford (TxDOT Structure No. 02-184-0-0313-02-008), and a 1915 arch located on the Austin to San Antonio Post Road (now named Kyle Crossing St), crossing the Bunton Branch in Kyle in Hays County (TxDOT Structure No. 14-106-0-C000-57-001). Closed-spandrel arches were also a component of city improvement programs operating in Texas in the 1910s and 1920s. Few closed-spandrel bridges appeared after the 1920s. One notable exception is the 1935 Spur 536 Bridge at the San Antonio River in San Antonio (TxDOT Structure No. 15-015-0-0253-06-029).

*Concrete Bridges: Open-spandrel Arch*

While the closed-spandrel bridge relied on spandrel walls to retain fill, the open-spandrel arch revolutionized the design by replacing the solid walls with individual members. Opening the spandrel walls gave the bridge a lighter appearance, making it an ideal medium for architectural treatment. The open-spandrel form was used to construct two large concrete bridges over Buffalo Bayou in Houston in 1914. The 1,273-foot-long Main Street Bridge at Buffalo Bayou (TxDOT Structure No. 12-102-0-B416-97-003) consists of one concrete arch barrel reinforced by the "Kahn System."[433]

The State Highway Department occasionally employed the open-spandrel design to create gateway bridges along highways entering cities. The State Highway Department achieved its highest artistic expression with the 1934 Guadalupe River Bridge on the original alignment of SH 2 (now BI 35), in New Braunfels (TxDOT Structure No. 15-046-0-0016-11-016). This 818-foot-long bridge is composed of five open-spandrel arches with classically detailed spandrel columns and Art Deco pilasters. The open spandrel arch was constructed up until the 1940s, when the last bridge of this type, the Lamar Avenue Bridge at the Colorado River (TxDOT Structure No. 14-227-0-0113-12-065) in Austin opened for traffic in 1943. Other noteworthy examples of open-spandrel construction include the 1923 Comal River Bridge on San Antonio Street in New Braunfels (TxDOT Structure No. 15-046-0-B015-50-001) and the Henderson Street Bridge (SH 199) at the Clear Fork of the Trinity River in Fort Worth (TxDOT Structure No. 02-220-0-0171-05-018).

*Concrete Bridges: Concrete Girder*

Early reinforced concrete girder bridges consisted of steel I-beams encased in concrete beams. This primitive reinforcement system was short lived, as the concrete had a tendency to crack and peel away from the I-beams. A few examples of this formative girder technology exist in Texas, including the 1928 Dry Comal Creek Bridge on Landa Street (BS 46) in New Braunfels (TxDOT Structure No. 15-046-0-0215-02-013). The girder-and-floorbeam is another example of an early reinforced girder form that had limited use in Texas. In the girder-and-floorbeam

[433] Richard W. Steiger, "The Kahn Reinforcing Bar," *Concrete Construction* (May 1990), www.concreteconstruction.net/images (accessed 28 March 2013).

bridge, the reinforced concrete floorbeams are arranged perpendicular to the girder and slab floorsystem. The only known example of this bridge type is a four-span structure located on Stone Bridge Drive at Turtle Creek, in Dallas (9S76-60-001). The earliest reinforced concrete girder structures date from the 1910s and consist of relatively short spans with solid parapet railing. Typical of these designs is a short span located in Navarro County (TxDOT Structure No. 18-175-0-AA02-73-001) carrying County Road NE 1040 over the Tupelo Branch. This 43-foot-long bridge is composed of four concrete girders reinforced with twisted steel bars. The construction of reinforced concrete girders increased dramatically after the organization of the State Highway Department in 1917. The bridge type became a building block in the expansion of the state highway system, reaching its greatest popularity in the 1930s. The longest intact concrete girder bridge of this period is the Tunis Creek Bridge (TxDOT Structure No. 06-186-0-0140-03-021) located on the original alignment of SH 27 (now IH 10 SB frontage road), in Pecos County. The 741-foot-long bridge consists of 26 spans of standard reinforced girder supported on concrete bents and outlined with Type K railing.

The cantilever reinforced concrete girder bridge made a brief appearance in the 1920s and 1930s as an alternative to concrete arch construction. Employing essentially the same technology as the cantilever-suspended span steel bridge, the cantilever girder could produce a longer span than a non-continuous type and be used where unsatisfactory foundation conditions would prohibit a true arch. The State Highway Department built the first cantilever concrete girder bridge in 1922 along the Old Spanish Trail (FM 1579) at the East Navidad River in Fayette County (TxDOT Structure No. 13-076-0-1498-01-002). Designed by Bridge Division engineer A. T. Granger, this graceful crossing features three curved cantilever girder and pier units elaborated with incised geometric panels. This bridge was followed in 1930 by a 472-foot-long concrete cantilever girder bridge carrying South Oakes Street over the North Concho River (TxDOT Structure No.07-226-0-B023-10-002). The State Highway Department used the form again in the early 1930s to construct two bridges over the Trinity River on US 377 (East Belknap Street) (TxDOT Structure No. 02-220-0-0081-01-001) and the West Fork of the Trinity River on SH 199 (TxDOT Structure No. 02-220-0-0171-05-017), both in Fort Worth. In both situations, the bridge designers utilized the cantilever reinforced concrete girder form to give the artistic effect of an arch.

*Concrete Bridges: Concrete Slab*

Along with the girder, the reinforced concrete slab bridge emerged in the second decade of the twentieth century as an economical bridge for small to medium spans. Minnesota engineer C.A.P. Turner introduced the reinforced continuous slab to the United States in the early 1900s with a system that improved slab design by thickening the pier caps and placing additional reinforcement at the juncture of the slab and support. Dubbed the “Mushroom System” because of the pier’s distinctive shape, Turner’s slab innovation was soon adapted by railroad engineers for short span structures. Before Turner’s system became an accepted practice with highway engineers, early slab structures consisted of steel I-beams embedded in a concrete slab. This reinforcement method proved impractical, as it was often difficult to a secure bond between the concrete and steel, and if successful, the bridge tended to be exceedingly heavy having to carry the weight of the beams, concrete floor, and traffic load. A few short span structures of this type were constructed in Texas, with the practice being generally abandoned after 1920.

As confidence grew in metal bar reinforcement systems, the flat slab became increasingly utilized for short span highway bridges. The first reinforced concrete slab bridges in Texas were small structures, having thick slabs and integral parapet railing.

With improved methods of calculating the amount of reinforcing bar needed to carry loads evenly, the bridge type became part of the State Highway Department’s standard plan designs in 1918. During the 1920s, the State Highway Department used reinforced concrete slabs almost exclusively for short spans. The majority of bridges

featured spans measuring 20 feet or less and supported on reinforced concrete bents. The CB-6 design was utilized widely across the state for spans 8 to 20 feet in length. A few examples of this bridge plan survive on bypassed highways. CR 270 over West Bernard Creek (TxDOT Structure No. 13-241-0-AA03-47-001) in Wharton County is a good example of this early bridge form.

Although the concrete slab was considered a rudimentary form, a few examples incorporated aesthetic design principles. A bridge built in 1940 along Vassar Drive at Turtle Creek in University Park (TxDOT Structure No. 18-057-0-9UP3-10-001) is a good example of where the utilitarian form was adapted to create a graceful bridge. Utilizing a curved variable depth span and decorative steel railing, the bridge presents a pleasing appearance for the passing motorist and harmonizes with the nearby park setting. The production of reinforced slab bridges increased incrementally over the ensuing decades, reaching its highest number during the 1940s, when hundreds of small standard slabs were utilized under the state's Farm-to-Market road program.

*Concrete Bridges: Rigid-frame*

One last reinforced concrete form that deserves mention is the rigid-frame. Arthur G. Hayden introduced the rigid-frame bridge to the United States in the early 1920s for the development of a system of parkways in Westchester County, New York. Based on European experiments, the rigid-frame is unique in that the superstructure and substructure are poured monolithically as a single unit. This method of construction allowed the thick shoulder joints of the bridge to absorb the load normally carried by the deck, permitting a thinner deck floor. Their slender proportions and narrow, flat arches made the bridge well suited for projects where architectural design and a clear span were important. For these reasons, rigid-frame bridges were a popular choice for short span bridges in urban areas, parks, underpasses, and railroad grade separations.

During the early 1930s, Texas was at the forefront of rigid-frame construction in the United States. San Antonio engineer J.W. Beretta, who designed at least four rigid-frame structures in the area, championed Texas's use of the bridge form in a 1934 article in the *Journal of the American Concrete Institute*. Erected in 1931, Beretta's design for the Lincoln-Garden Street Bridge over the Comal River (TxDOT Structure No. 15-046-0-B005-90-001) in New Braunfels, utilized continuous girders in rigid frame continuity with the piers. Another rigid-frame bridge receiving attention in engineering journals was the Upper Shoal Creek Bridge on Shoal Creek Blvd in Austin (TxDOT Structure No. 14-227-0-B013-56-006). The one-span bridge consists of a reinforced rigid-frame design with hinged footings and is noteworthy for its chrome-plated steel rod and ornamental concrete post railing system. Constructed in 1934, the bridge was built as part of a project to develop a park and boulevard system along Shoal Creek. The State Highway Department used the rigid-frame on a limited basis for grade separations and railroad bridges. The North Main Street Overpass at US 77 in Schulenburg (TxDOT Structure No. 13-076-0-0269-01-036) is the only surviving example of a vehicular overpass designed by the State Highway Department using a rigid-frame design prior to World War II.

*City Beautiful Aesthetics in Concrete Bridge Design*

During the first quarter of the twentieth century a number of cities in Texas financed artistic bridges as part of ambitious city improvement plans or bond issue programs. These predominantly reinforced concrete arch and girder bridges commonly exhibit a uniform design and architectural vocabulary reflecting a city's aesthetic standards and the lingering effect of the City-Beautiful movement influence on bridge design. In the early 1900s, as the City-Beautiful movement was at its peak of popularity nationally, Texas was experiencing a period of rapid growth. The construction of rail lines across the state at the end of the nineteenth century resulted in a dramatic

increase in population from 800,000 in 1870 to 3 million in 1900, with the urban population increasing from 7 to 17 percent. Typical of this tremendous growth was Dallas, which mushroomed from 4,000 in the 1870s to over 40,000 by the turn of the century.

Like other cities across the nation, the effects of rapid urban growth strained the infrastructure and transportation systems of these cities. To address these problems, city officials and civic groups sought the advice of professional city planners. Fort Worth and Dallas hired nationally renowned landscape architect George E. Kessler to develop master plans for their cities, while Houston turned to Arthur C. Comey, a professor of landscape architecture at Harvard, to create parkway boulevard systems along its bayous. City Beautiful plans initially drafted in the 1910s were not always fully implemented. The scope of the plans in many cases overwhelmed municipal governments, which often lacked sufficient funds to carry them out. Because of this, many of the improvement programs were carried out in piecemeal fashion, often completed years after their initial conception.

Bridges built under city improvement programs in Texas followed national trends in design, emphasizing the aesthetic form and incorporating classical architectural details of the City-Beautiful movement. Reinforced concrete arch bridges were preferred for longer spans because of their potential architectural quality and the ease with which decorative embellishments could be incorporated. A typical City-Beautiful influenced bridge took the form of a shallow arch with concrete balustrade railing featuring urn-type balusters. If a concrete arch proved impractical, the bridge engineer used a continuous concrete girder or rigid-frame design, with girders formed with a curve to give the impression of an arch. Typically additional attention was given to small details such as a raised arch ring, incised panels, pier pilasters, and decorative light standards. A number of impressive bridges survive from city improvement programs enacted in the 1910s and 1920s in Dallas, Fort Worth, Austin, Houston, and San Antonio. The majority of these bridges reveal a uniform design standard in their span type, railing, and ornamentation.

***City Beautiful in*** *Dallas*

The Maple Avenue Bridge at Turtle Creek (TxDOT Structure No. 18-057-0-9M09-80-004) in Dallas is an early example of a concrete arch constructed under a city improvement program. The c.1919 single span reinforced concrete arch features incised spandrel panels, square abutment pilasters, urn-type balustrade, and steel classical column light standards. The city built this bridge and four other concrete structures during the 1910s as a response to a proposal for a parkway in George E. Kessler's master plan for Dallas. As part of his 1910 "A City Plan for Dallas," Kessler proposed a parkway boulevard along Turtle Creek featuring tree-lined roads meandering along both sides of the creek and connected together with City-Beautiful inspired concrete structures. Although the parkway was never developed to Kessler's specifications, the city erected artistic concrete structures worthy of his original conception.

*City Beautiful in Austin*

Though the city of Austin did not begin its beautification program until 1928, well beyond the time period typically associated with the City-Beautiful era, the city built a number of graceful concrete bridges that reflect the lingering influence of this movement. In 1926 the adoption of a city manager form of government led Austin's citizens to approve a $4 million bond issue to improve the city's image as a state capital. The city hired the planning firm of Koch and Fowler the following year to draw up a five-year beautification program. Koch and Fowler's "City Plan" centered on the improvement of city streets and the development of parkway boulevards along Shoal and Waller creeks. The Shoal Creek Bridge on Fifth Street (TxDOT Structure No. 14-227-0-B000-15-001) is typical of a

bridge built under the five-year program. As part of the "City Plan," Fifth Street was widened and extended to serve as a relief route for Sixth Street. For this crossing, city bridge engineer Carl Levander designed a graceful curved girder bridge consisting of three spans of cantilever arms supported on pedestal piers. The design of the bridge was further enhanced by textural treatment given to the spandrels and wing walls and the use of balustrade railing. A number of smaller bridges were constructed with this standard design and include the impressive twin East Twelfth Street Bridges at Waller Creek, east of the State Capitol (TxDOT Structure Nos. 14-227-0-B000-37-007 and 14-227-0-B000-37-008).

*City Beautiful in Houston*

In 1912, the City of Houston voted for a $250,000 bond issue to acquire land to improve its park system. The Houston Park Commission hired landscape architect and city planner Arthur C. Comey to develop a master plan for the city. Comey, a graduate of Harvard and former superintendent for the park system in Utica, New York, published his city improvement plan for Houston in 1913. The plan called for a system of boulevards and parkways to link the growing suburbs in the northwest with the newly completed Grand Central Station downtown. Parks and parkways were to encircle Buffalo and White Oak bayous, and connect with the downtown via Main Street Viaduct. For bridges on the proposed parkways, Comey recommended a concrete design and cautioned that the beauty of a bridge should follow the simplest form of construction. Several handsome concrete bridges were constructed in the 1920s as part of Comey's plan. Only the Sabine Street Bridge at the Buffalo Bayou (TxDOT Structure No. 12-102-0-B564-01-669) survives from this period and features six spans of continuous reinforced concrete girders erected over reinforced concrete bents. Curved concrete fascia walls were placed on the outside of the bridge to give the appearance of an arch structure. The final phase of Houston's parkway boulevard and street extension plan was completed in the early 1930s. City bridge engineer J.G. McKenzie continued to utilize the reinforced concrete curved girder and urn balustrade bridge design, but streamlined the form and ornamentation to reflect changes in bridge design. The Almeda Road Bridge at Brays Bayou (TxDOT Structure No. 12-102-0-B026-01-001) is typical of this design. Constructed in 1931, as part of a project to develop a parkway along Brays Bayou, the bridge features three spans of reinforced concrete curved deck girder resting on capital bents and outlined with urn-type balustrade. Other bridges exhibiting this simplified City-Beautiful inspired design include the Yale Street Bridge over White Oak Bayou (TxDOT Structure No. 12-102-0-B174-57-079) and Telephone Road Bridge (TxDOT Structure No. 12-102-0-B636-97-552) over Brays Bayou.

*City Beautiful in San Antonio*

Many of San Antonio's impressive concrete bridges are tied to bond issue programs that aimed at beautifying and providing flood control along the San Antonio River. Beautification of the river began in 1910 when the Civic Improvement League planted flowers and shrubs along sections of waterway. Prompted by local businessmen, a city engineer suggested filling in the river between Houston and Commerce streets and carrying the water by an underground tunnel beyond the business district. The proposal was strongly opposed by the civic groups responsible for beautifying the river, and San Antonians suddenly became City-Beautiful proponents, creating what is thought to be the most broadly based reform movement in the city's history.

The movement took off with the election of Mayor Augustus H. Jones, who within two weeks of taking office appointed a City Plan Committee with a central focus of preserving and beautifying the river. A top priority of the committee was to replace the high-maintenance and flood prone iron truss bridges with concrete structures, detailed with classical lines. In a response to this, a 1913 bond issue set aside $100,000 for the construction of new concrete bridges over the river. The elaborate South St. Mary's Street Bridge at the San Antonio River (TxDOT Structure

No. 15-015-0-B301-35-003) is the last surviving bridge built in 1915 under this program. The two-span, reinforced concrete bridge is representative of San Antonio's exuberance for beautification with its highly ornamented hand railing and decorative substructure components, though it was widened in 1950.

The second period of intense bridge building in San Antonio occurred as result of a devastating flood in September of 1921 that destroyed 13 of the city's 28 bridges. After the flood, the city undertook an extensive rebuilding program to improve flood control along the river. A component of this program included constructing a wide cut-off channel south of the downtown area and replacing the flood damaged bridges with new concrete structures. Although some of the bridges are singular in their design, such as the graceful reinforced closed-spandrel concrete arch bridge at Navarro Street over the San Antonio River (TxDOT Structure No. 15-015-0-B243-55-003), the majority of bridges express a uniform bridge design standard composed of gently curving girder spans ornamented with imitation granite hand railing. The 1929 Convent Street Bridge at the San Antonio River (TxDOT Structure No. 15-015-0-B079-30-002), designed by city engineer C. Raeber, is exemplary of this design and the best preserved example of San Antonio's last great bridge building program.

*Moveable-span Bridges*

A movable bridge is a structure with a deck that can be moved to clear a navigation channel. Movable bridges enable ships to pass along the water route and traffic to flow over the crossing. Depending on its height over the water, a movable bridge may allow small craft to pass under while it continues to carry vehicles over the river. When larger vessels approach, the bridge moves out of the way, returning to its position after the vessel has passed. Prior to the 1830s, moveable span bridges consisted of crude wooden structures resembling medieval drawbridges or floating pontoons. As railroads spread across the nation, bridge engineers began to search for more permanent moveable bridge forms to span navigable waters. Spurred by advances in metal truss technology, engineers fashioned new designs utilizing fabricated steel spans and motorized drive mechanisms.

Three basic steel moveable span types evolved during the late nineteenth century: horizontal swing, bascule, and vertical lift spans. Of these, only examples of horizontal swing bridges remain extant from the early twentieth century in Texas, although a vertical lift bridge from 1953 remains in vehicular use in Cameron County, carrying FM 106 at the Arroyo Colorado in Rio Hondo (TxDOT Structure No. 21-031-0-0630-02-003).

Swing bridges are the earliest and simplest forms of movable bridge. In the 1830s and 1840s, these bridges generally consisted of a crude timber truss span pivoted on a central pier. These primitive structures were manually operated with cables or rope, or simply nudged open by the vessel requiring passage. Engineers improved the design of the swing bridge during the latter part of the century by replacing the timber trusses with steel spans and the steam engine motors with electric drives.

Historically, the majority of moveable bridges were located across major rivers and waterways in the eastern part of Texas. All of the major moveable span bridges designed by the State Highway Department before World War II were constructed over the Sabine River separating Louisiana from Texas. The former Sabine River Bridge at Orange was the first swing bridge built over an interstate waterway. Erected in 1927, this 1,020-foot-long bridge facilitated interstate travel between New Orleans and Houston on the Old Spanish Trail (SH 3) until a new fixed span bridge replaced it in 1947.

Technological advances in vertical lift and bascule forms rendered the swing span virtually obsolete by the late 1920s. In comparison to these bridge types, swing bridges were slow to operate, having to rotate a full 90 degrees to open, and required large piers in the center of the waterway greatly reducing the navigable area of the channel.

However, because of their basic economy of materials and simplified construction, the swing bridge was utilized during the Depression for large work-relief bridge projects.

*Masonry Bridges*

The use of stone as a construction material made an appearance again in the early part of this century as a component of Austin's city beautification program. Considered the most "artistic" choice for small or medium spans, a number of stone arches were constructed on principal streets crossing Shoal Creek and Waller Creek. One of the last surviving examples of one of these arches is the Waller Creek Bridge on East 6th Street (TxDOT Structure No. 14-227-0-B000-17-005). Erected in c.1930, the 37-foot-long structure presents a single arch composed of rough-cut limestone blocks, and features masonry parapet railing on the south side of the structure.

The Great Depression spurred labor-intensive projects that often used stone as a building material. The exceptional Possum Kingdom Bridge (TxDOT Structure No. 02-182-0-0362-02-003) over the Brazos River in Palo Pinto County is one of the few bridges built during the Great Depression to feature true masonry arch construction. The Works Progress Administration (WPA) erected the 433-foot-long stone bridge in 1942 from 3,830 yards of locally quarried limestone. The project employed around 300 workers and is considered the largest masonry bridge construction project undertaken in Texas.

**State Control of Bridge Building**

While the THD was created in 1917, the rise of state highway departments had roots in the Good Roads Movement, the Progressive Era, and increasing federal involvement in road planning and funding years earlier. The systemization that marked Gilded Age railroads and corporate trusts was brought to bear on highways. Step by step, the THD developed a bureaucracy, a highway network, and standard bridge designs in the 1920s. It meant the competitive design and construction of bridges for local entities were replaced by legions of contractors seeking efficient ways to build centrally designed bridges. The resulting institutional infrastructure meant that Texans had the skills and means to design and construct monumental bridges, such as the Loop 481 at South Llano River and the SH 87 at Neches River (Rainbow) bridges.

*Early Operations of the THD Bridge Division*

The THD was established in 1917 to designate a system of state highways and distribute federal funding allocated under the Federal Aid Road Act of 1916. More detailed information regarding the THD's organization and early history is found earlier in this context. By 1918 the THD had expanded into three main divisions: Administration, Federal Equipment and Engineering, with bridge work falling under the Engineering Division. The Texas State Highway Commission approved the position of State Bridge Engineer in a January 24, 1918, resolution. The State Bridge Engineer was charged with the review and approval of bridge and culvert projects funded by federal and state aid, construction inspection and supervision of these projects, and the development of standard and special designs for bridges and culverts on the highway system. The Bridge Section was also directed to assist and advise county and city officials in matters pertaining to bridge construction and maintenance.[434]

[434] Quoted in Huddleston, 39; Banks, "A History of the Bridge Division," 6.

In February 1918, the THD hired George Grover Wickline to serve as the first State Bridge Engineer. His initial salary of $225 a month was THD's third highest following George A. Duren, State Highway Engineer, and David E. Colp, Secretary. A native of Stephenville, Texas, and a 1904 Civil Engineering graduate of the University of Texas, Wickline had considerable experience as a bridge and highway engineer. Like so many of the department's early engineers, Wickline began his professional career with the railroad, working first as an instrument man and then bridge inspector for the St. Louis, Brownsville and Mexico Railway Company. Wickline soon moved into highway work, initially with Dallas County and later with the City of Los Angeles, McLennan County, where he worked until September 1908. After a short stint with the El Paso and Southwestern Railroad, Wickline became assistant city engineer for El Paso. In October 1909, Wickline worked as bridge engineer for Dallas County, designing and supervising construction of highway bridges throughout the county. He left in March 1912 to work on the Texas Electric Interurban Railway in the Dallas, Waco and Corsicana area for two years. His highway experience resumed with employment as assistant highway engineer for McLennan County and then the City of Dallas from 1914 to 1916. As bridge engineer for Dallas County from September 1916 to January 1918, Wickline designed and supervised construction of the concrete viaduct at Commerce Street in downtown Dallas, the precursor to the 1930s structure currently at that location. At the time he was hired by THD, Wickline was working as a bridge engineer for the City of Dallas. Wickline managed the Bridge Section from 1918 to 1928, at which time the section became a full-fledged division. He headed the Bridge Division continuously for 25 years with the exception of a three year leave of absence from 1935 to 1938 when he oversaw the construction of the Port Arthur-Orange (or Rainbow) Bridge across the Neches River (TxDOT Structure No. 20-124-0-0306-03-015, listed in the NRHP in 1996). Wickline's tenure with THD lasted 25 years and ended with his sudden death in November 1943.[435]

Wickline and his small staff immediately turned their attention to developing standard designs and specifications for concrete, timber, and metal bridges. These standards were needed to secure a uniform level of construction throughout the state and to provide counties with an economical and straightforward method for preparing bridge plans. Standard designs also allowed THD bridge engineers to respond quickly to bridge failures and other emergency situations. Most of the early THD standard designs and specifications corresponded closely with federal circulars and bulletins promulgated by BPR. At the time THD was created in 1917, BPR was at the national forefront of bridge design. A Division of Highway Bridges and Culverts had been established under its predecessor agency, the Office of Road Inquiry (established under the United States Department of Agriculture in 1893) in 1910. This special division conducted studies on bridge types and materials and developed standards for bridge design and construction. The agency's 1913 circular, *Typical Specifications for the Fabrication and Erection of Steel Highway Bridges*, formed the basis for bridge specifications developed by THD and other highway departments in the 1910s and 1920s. Subsequent bulletins included typical plans and specifications for bridges and culverts, and other bridge components such as piers and abutments. BPR reviewed all proposed federal aid projects for compliance with federal standards and specifications. Recognizing that states had varying geographical conditions and economic circumstances, however, BPR also allowed individual state highway departments some latitude regarding specific bridge types and designs used. In 1924, the American Association of State Highway Officials (AASHO) formed its Subcommittee on Bridges and Structures, which became a leader in highway bridge design. BPR and the various state highway departments, including THD, relied heavily on the subcommittee's

[435] Banks, "A History of the Bridge Division," 9-11; Texas State Highway Commission, *First Biennial Report*, 54-59.

uniform specifications for highway bridges issued in 1924, 1925, and 1928, as well as its 1931 publication, *Standard Specifications for Highway Bridges.*[436]

Within a relatively short time frame, Wickline and his staff had developed an extensive series of standard bridge designs. The THD Bridge Section issued its first standard designs and standard specifications in 1918, producing updates and revisions of these items on a regular basis. Most of the Bridge Section's early designs were for short to medium spans. The section's focus on short-span bridge designs reflected THD's early emphasis on road surfacing projects and small drainage improvements on state highway routes. Large bridge construction was largely deferred until the 1930s. From 1918 to 1920, THD bridge engineers developed designs for short (typically 40 feet or less) timber stringer, single and multiple concrete box culvert, concrete slab, concrete deck girder, and steel I-beam structures. During this same period, THD also produced standard designs for Warren and Pratt pony trusses in intermediate lengths (35 to 80 feet).[437]

The department's standard specifications, issued in 1918 and periodically thereafter, required that concrete and steel bridges be designed to carry a 15-ton motor truck, a standard that applied to virtually all federal aid bridge projects. Some of the timber trestle designs, however, were designed for 10-to 12-ton loads. While these "low type" bridges were built throughout the state, they were used most extensively in East Texas in order to take advantage of local materials and maximize the number of bridges that could be completed. Timber trestle bridges were also well suited to the many broad and shallow streams found in the East Texas area. Because timber bridges fell short of BPR requirements, they were almost always built as state aid projects.[438]

Initially, THD bridge engineers assigned identification numbers to each standard design based on a one or two letter abbreviation of its bridge type (e.g., T is for truss and CB is for concrete slab bridge) followed by the plan's chronological ranking for that bridge type (e.g., first truss design would be designated T1, second truss design would be designated T2). For example, the CB1 design was the department's first standard design for a concrete slab bridge; the DG3, in contrast, was the third standard design developed by THD for a concrete deck girder structure. The T1 design, developed in 1918, featured a rivet-connected Warren pony truss with a timber deck and represented the department's first standard design for a metal truss bridge. By the early 1920s, the THD was assigning standard design numbers according to the bridge type abbreviation, roadway width, and span length. For example, the T18-150 design, issued in 1922, featured a Pratt through truss with an 18-foot roadway width and a 150-foot length.[439]

From 1918 through the early 1920s, THD bridge engineers designed at least 11 standard Warren pony trusses with timber decks. These designs were probably developed primarily for use in East Texas, where timber was a

---

[436] American Association of State Highway Officials, *A Story of the Beginning, Purpose, Growth, Activities and Achievements of AASHO* (Washington: American Association of State Highway Officials, 1964), 103-104; U.S. Department of Transportation, 429.
[437] State of Texas, State Highway Department, "Specifications: Roads and Bridges," Revised Edition, 1920; Standard Bridge Plans, Texas Department of Transportation, Design Division, located at TxDOT headquarters in Austin; Banks, "A History of the Bridge Division," 11-12.
[438] Texas State Highway Commission, *Third Biennial Report* (Austin: Von Boeckmann-Jones Co., 1923), p. 53; Banks, "A History of the Bridge Division," 11-12; Standard Bridge Plans, Texas Department of Transportation, Design Division, located at TxDOT headquarters in Austin.
[439] Standard Bridge Plans, Texas Department of Transportation, Design Division, located at TxDOT headquarters in Austin.

relatively inexpensive decking material. The only one of the 11 designs that is still represented in Texas today is the T19-50, and there is only one of this type itself that survives. This 1921 design is comprised of three panels, each 16 feet 8 inches long, providing a 50 foot span. The 16-foot timber deck is comprised of timber planks placed perpendicular to the traffic flow, connected to longitudinal timber strips affixed to steel I-beam stringers underneath the floor. The only surviving T19-50 bridge is located in San Augustine City Park at Ayish Bayou, installed for pedestrian use as part of an transportation enhancement project in 1999.[440]

In 1920, the THD Bridge Section released the T5 design, a Warren pony design that was available in lengths of 50, 60 and 70 feet. The 50-foot length was comprised of six truss panels while the 60 and 70-foot lengths included eight panels. This design includes steel floor beams suspended below the lower chords of the truss, so that in elevation the I-beams are visible hanging below the truss. In this type of floor system, the floor beams are actually bolted to vertical truss members extending below the bottom chord. The T5 was one of the most popular early truss types, and was used extensively by county engineers in the early-to mid-1920s. Representatives of the three different T5 configurations remain on the old route of SH 14 through Limestone County (now serving as county roadways). These examples, all built in 1921, include a 50-foot span over Big Creek between Thornton and Kosse (TxDOT Structure No. 09-161-0-AA04-08-004), a 60-foot truss over Rocky Creek between Groesbeck and Thornton (TxDOT Structure No. 09-161-0-AA04-01-001), and a 70-foot span over the Navasota River just north of Groesbeck (TxDOT Structure No. 09-161-0-AA03-11-001).[441]

In 1919, the THD Bridge Section generated its first standard Pratt through truss design (T6), consisting of a 150-foot, pin-connected span with a timber deck. The department's first standard Parker through truss design was produced the following year. By the early 1920s, THD bridge engineers were generating standard designs for long Pratt and Parker through truss spans (100 to 225 feet) with large built-up steel members and substantial gusset plate and rivet connections. One of the most popular Pratt through designs was the T10-100 developed in 1920. This design featured a 100-foot span consisting of six panels, each 16 feet 8 inches long, and distinctive "X" portal bracing. An early example of this design was built on SH 10 over the South Paluxy River in Erath County (TxDOT Structure No. 02-073-0-1332-01-013), which is now out of service.[442]

The THD Bridge Section produced its first Parker through truss design in 1920. Over the next 18 years, bridge engineers would produce at least 24 different standard designs for Parker through truss bridges and at least a dozen special Parker designs. THD-built Parker truss spans in lengths of 120 to 250 feet with roadway widths ranging from 16 to 24 feet. Wickline clearly showed a preference for the Parker through truss, making it the predominant long-span bridge type for Texas at an early date. Texas's use of Parker trusses distinguished it from California, Oregon and other states that often used concrete and steel arches to span the steep slopes and rocky gorges that were more common in these areas. The relatively broad creek basins and flat topography of Texas combined with the significantly higher cost of concrete bridge design and construction to make the concrete arch a relatively

---

[440] Standard Bridge Plans, Texas Department of Transportation, Design Division, located at TxDOT headquarters in Austin; Historic Bridge Files, Texas Department of Transportation, Environmental Affairs Division, located at TxDOT headquarters in Austin.
[441] Standard Bridge Plans, Texas Department of Transportation, Design Division, located at TxDOT headquarters in Austin; Historic Bridge Files, Texas Department of Transportation, Environmental Affairs Division, located at TxDOT headquarters in Austin.
[442] Standard Bridge Plans, Texas Department of Transportation, Design Division, located at TxDOT headquarters in Austin; Historic Bridge Files, Texas Department of Transportation, Environmental Affairs Division, located at TxDOT headquarters in Austin.

unpopular type for Texas. Several other states, such as Oklahoma, preferred the K-truss over the Parker, primarily for its ease of construction and its reduced secondary stresses. In several cases, Oklahoma-designed K-trusses were used over the Red River at the Texas-Oklahoma boundary. The only surviving example of these K-trusses is located on SH 78 at the Red River (TxDOT Structure No. 01-075-0-0279-02-024), listed in the NRHP 1996. A downside of the K-truss was its relatively heavy members and irregular configuration, which caused nationally recognized bridge engineer J.A.L. Waddell and others to comment on its awkward and generally "inferior appearance." Wickline, who showed an acute awareness and appreciation for bridge aesthetics, clearly preferred the more graceful profile and composition of the Parker. Considerable economy was also gained by developing a broad assortment of standard Parker designs to suit a wide range of traffic and site requirements.[443]

Complementing the standard bridge designs were a set of standard plans for other bridge components, such as abutments, piers, and railings. The substructure designs included substantial concrete piers, bents, and abutments. Several of the pier designs, for example, were comprised of massive reinforced concrete piers arranged in a dumbbell configuration (solid web walls connecting two square or circular columns). Similarly, a standard "U" type abutment consisted of a thick reinforced concrete backwall with large concrete wingwalls. Early standard-design railings, designated Types A through J, ranged from simple steel pipe railings (Type A) to ornamental concrete railings with urn-shaped balusters (Type J). Two of the most popular concrete railing designs, Types C and D, consisted of large reinforced concrete posts connected by two rows of reinforced concrete railings spaced approximately one foot apart. These heavy standard design components were characteristic of early THD bridge construction and provided a stark contrast with the thin metal piers and guardrails used on most county bridges in the state.[444]

By the early 1920s, Wickline and his small staff had developed an extensive collection of standard design bridges. The county engineers used the standard plans as basic "building blocks" that were mixed and matched as necessary to form an overall bridge design and layout. In a 1922 report, Wickline noted county engineers had used standard plans on almost every state and federal aid bridge project that had come through his office.[445]

THD constantly revised and improved its metal truss designs in order to reflect technological advances and to accommodate heavier truck and automobile loads. The demand for increased roadway widths provided the primary motivation for many new bridge designs. While the earliest plans featured roadway widths of 16 to 18 feet, by 1922 roadway widths had increased to 20 feet, and by the 1930s roadway widths of 24 feet were standard. Other refinements in metal truss bridge design included the use of riveted joints in place of the earlier pin-connected joints, stiffer and more substantial truss members, and the use of framed floor beams instead of suspended floor beams.[446]

Initially, Wickline and his assistants relied heavily on county engineers and THD division engineers to prepare bridge plans and perform sufficient investigations of bridge sites. THD issued all county engineers copies of its

---

[443] Joseph E. King, *Spans of Time: Oklahoma Historic Highway Bridges* (Oklahoma City, Okla.: 1993), 54; Waddell, 478.
[444] Standard Bridge Plans, Texas Department of Transportation, Design Division, located at TxDOT headquarters in Austin.
[445] Standard Bridge Plans, Texas Department of Transportation, Design Division, located at TxDOT headquarters in Austin; Historic Bridge Files, Texas Department of Transportation, Environmental Affairs Division, located at TxDOT headquarters in Austin; Texas State Highway Commission, *Third Biennial Report*, 53.
[446] Standard Bridge Plans, Texas Department of Transportation, Design Division, located at TxDOT headquarters in Austin.

design guidelines titled *Standards Governing the Preparation of Road Plans Involving State or Federal Aid.* These standards directed county engineers to perform in-depth investigations of all drainage areas and to perform test pits or borings for all bridge foundations. The bridge designs selected were supposed to reflect the findings of these studies. While most county engineers went to great lengths to perform the required investigations, some county engineers took a somewhat more permissive approach.

Without adequate studies on drainage and soil conditions, the bridge plans were often inadequate to meet site requirements. Problems with bridge plans were usually not discovered until a bridge was actually under construction, resulting in significant project delays and cost overruns. Contractors working on bridge projects frequently requested field changes for bridges that were inadequate to cover a drainage area, citing "error discovered in drainage area" as the primary reason for these requests. Contractors encountered similar problems with bridge foundations. In a September 10, 1923, letter to division and county engineers, J. D. Fauntleroy, State Highway Engineer noted that:

it has proven very expensive not only to the county but to the contractor to make excavations for substructure work only to find that the materials encountered are not what the plans indicated,…in many cases it is necessary to stop the work, order piling, rig up a driver and drive piling causing a delay to the work of a month or more…On account of the excess work being generally done by Force Account and due to delays…the county has frequently to pay much more for the work than it would if the work were…based on plans prepared from accurate data.[447]

THD made relatively slow progress with bridge construction during the early 1920s. By the end of 1921, the state had awarded 430 contracts for federal and state aid highway projects, covering approximately 4,276 miles. Although many of the roadway projects included culverts and small drainage structures, only 31 (or 7 percent) of these projects were classified as bridge projects. Bridge construction increased moderately in the following years, with THD giving preference to "low type" structures such as concrete slabs, timber and concrete trestles, and I-beam stringers that were built usually to standard loading levels and possessed the additional advantages of low initial cost and low maintenance. Bridge designs that did not meet federal bridge standards were typically funded as state projects. The most popular types were reinforced concrete slabs and girders, which were built wherever short-span construction was permissible. "Low water" concrete slab and culvert bridges were frequently used in areas that had light traffic volumes and infrequent flooding problems, , such as west and northwest Texas. Low water bridges were characterized by their relatively short or low piers that rose only a few feet above the ordinary stream level. In East Texas, short-span bridges tended to take the form of timber trestles due to the availability of local timber materials in this region.[448]

Metal truss bridges were the major "high type" structure used in early THD bridge construction.[449] Most of the early examples were built in the northern and central portions of the state. Large, fast-flowing streams and rivers and frequent flooding problems justified the greater expense of metal truss bridges in these areas. Dense population

---

[447] Quoted from J.D. Fauntleroy to Division Engineers and County Engineers, 10 September 1923, Environmental Affairs Division, Texas Department of Transportation, located at TxDOT headquarters in Austin; State of Texas, State Highway Department, "Standards Governing the Preparation of Road Plans Involving State or Federal Aid," Austin, n.d.

[448] "State Highway Department: General Review of Road Situation in Texas," *Texas Highway Bulletin 2* (March 1922),1; Texas State Highway Commission, *Third Biennial Report*, 53-55.

[449] The terms “high-type” and “low water” used here should not be confused with “High” and “Low” used by the THD to refer to what are now called “through” and “pony” trusses, respectively. See, for example, THD standard designs T4 and T1.

and high traffic volumes were also factors that led to a greater use of metal truss bridges in this region of the state. Large spans were generally preferred for streams and rivers with deep channels, high velocity currents, frequent flooding, and heavy drift accumulation. One of the largest metal truss highway bridges completed by THD in the early 1920s was the Bastrop Bridge on SH 3-A (now SL 150 and pedestrian use only) over the Colorado River at Bastrop (listed in the NRHP in 1990). Completed in 1923, the bridge was comprised of 18 concrete girder spans, each 39 feet in length, combined with three specially designed 192-foot Parker through truss spans. The bridge extended 1,285 feet across the river and was built at a cost of $167,500, making it one of the largest highway bridges completed by THD up to that time.[450]

Most contracts for THD metal truss bridges were awarded to road contractors, who then subcontracted out the truss portion of the work to steel fabrication companies. Early THD bridge fabrication work was largely split between Texas and out-of-state companies. When THD formed in 1917, many out-of-state bridge companies established offices in Texas, including several who had marketed truss designs in the state during the late nineteenth and early twentieth centuries. Some of the more active out-of-state bridge fabricators operating in Texas during the 1920s and 1930s were the Bethlehem Steel Company of Pottstown, Pennsylvania; Illinois Steel Bridge Company of St. Louis, Missouri (also of Jacksonville, Illinois); Kansas City Bridge Company of Kansas City, Missouri; Pittsburgh - Des Moines Steel Company of Des Moines, Iowa; Vincennes Steel Corporation of Vincennes, Indiana; and Virginia Bridge and Iron Company of Roanoke, Virginia. Some of the more important Texas bridge fabricators during this period included the Austin Bridge Company (or Austin Brothers Bridge Company) of Dallas; Houston Structural Steel Company (a subsidiary of Mosher Steel and Machinery Company) of Houston; Mosher Steel and Machinery Company of Dallas; and Petroleum Iron Works Company of Beaumont.[451]

Because of the department's early emphasis on highway grading and surfacing, many bridge projects were deferred until the 1930s or later. This situation placed an excessive burden on many county-built bridges that had been incorporated into the state highway system in 1917. Most of these bridges were lightweight fabricator-designed trusses with low loading capacities (7 tons or less) and narrow roadway widths (usually 16 feet or less). These bridges were usually insufficient to support the heavier and wider loads carried by motor trucks, army tanks, and farm equipment. In a 1922 article, Wickline noted that there were "innumerable light-type bridges" on the highway system, and that they were "entirely too light" to meet modern traffic requirements. "Frequently," he notes, "the piers or abutments are washed out and the bridge collapses under a heavy load resulting in loss of life, injury, serious delay, and inconvenience to traffic." In a 1923 THD report, Wickline provides several accounts of light-type bridges that had collapsed under heavy highway loading. Without adequate funds to replace deficient bridges, Wickline and his staff set out to repair and strengthen the weaker structures to accommodate 10-to 15-ton loads. The preparation of plans for bridge repair and rehabilitation projects comprised a major portion of the THD Bridge Section's early work. These projects frequently involved replacing timber stringers with steel stringers, adding additional support members underneath the deck, and performing other work as needed.[452]

The problem of deficient highway bridges was aggravated by counties that continued to build light-type bridges on state highways solely with county funds. This situation was largely a result of the state's weak highway law that only gave THD jurisdiction over state and federal aid highway projects. Counties retained overall control over the

---

[450] Texas State Highway Commission, *Fourth Biennial Report* (Austin: Von Boeckmann-Jones Co., 1925), 44; Texas Historical Commission, National Register of Historic Places Registration Form for the Colorado River Bridge at Bastrop, 1990.
[451] Historic Bridge Files, Texas Department of Transportation, Environmental Affairs Division, located at TxDOT headquarters in Austin.
[452] Quoted in Wickline, 9; Texas State Highway Department, *Third Biennial Report*, 51-52.

state highway system and could initiate locally funded bridge projects at will. The lack of state control over the highway system caused inconsistencies in bridge construction along the various state highway routes. A highway route in one county could include a new 15-ton THD bridge while, in an adjacent county, the same route could have county bridges with carrying capacities of 7 tons or less. Wickline provides the analogy of "a chain with a weak link," whereby "the heaviest load…carried over the highway is controlled by the weakest bridge."[453]

State and federal initiatives of the 1920s largely resolved the issue of state control over highways. In 1921, Congress amended the 1916 Federal Aid Highway Act to require that, after 1925, all highway construction and maintenance work be under the direct supervision of the state highway departments. Following years of political and technical obstructions, the 39th Legislature in 1925 passed a revised state highway act that gave the THD total control over highway construction and maintenance; however, it did not completely exclude counties from participation in highway road matters. The inadequacy of state funding and the increased statewide demand for roads meant that Texas would have to continue to accept county assistance until 1932.[454]

The state's win over county road interests did not bring immediate change to the THD. In 1925, the THD became embroiled in a bitter political controversy between state officials and BPR, culminating in the suspension of federal aid monies to Texas in January 1927.[455] The state's relations with BPR improved almost immediately after Dan Moody became governor in 1927, resulting in the restoration of Texas's federal aid monies by April of that year. At the same time, the 40th Legislature authorized an increase in the gasoline tax and a newly-appointed State Highway Commission.[456]

Recognizing that a complete system of highways would require an aggressive program to improve the state's bridges and culverts, the new highway commission established a separate Bridge Division in 1928 to oversee the state's bridge program. The commission appointed Wickline, former head of the Bridge Section, to run the new division. At the time of Wickline's appointment, the Bridge Division staff consisted of a state bridge engineer, a general assistant bridge engineer, four project-specific assistant bridge engineers, and eight draftsmen and checkers. The division also included about 15 resident engineers who specially trained in bridge design and construction work. These bridge specialists would travel from site to site supervising individual bridge construction projects for THD.[457]

With the department's stability re-established and its funding levels renewed, Wickline began to move forward with an aggressive bridge building program. While the level of bridge and culvert construction actually declined in 1925 and 1926, the pace picked up significantly in the following years. By the summer of 1928, Wickline reported that at least 50 new bridge projects were under way. During the biennial period ending August 31, 1930, the THD awarded contracts for several hundred bridge structures, including 68 metal truss bridges. These projects amounted to 29 miles of culvert and bridge structures at an aggregate cost of nearly $15 million, more than twice the amount spent in any previous biennial period. The bridge accomplishments of this period obviously pleased Wickline, causing him to speculate that "if this rate of progress could be kept up for a few years, the day will not be far distant when all of the weak and dangerous bridges will be eliminated." Bridge projects continued at a rapid pace in the

---

[453] Quoted in Texas State Highway Department, *Third Biennial Report*, 51.
[454] Huddleston, 39-52.
[455] Huddleston, 52-111.
[456] Huddleston, 52-111; Texas State Highway Department, "Fifty Year Golden Anniversary, 1917-1967," *Texas Highways*, September 1967, 22-23; Texas State Highway Commission, *Seventh Biennial Report*, Austin, Texas, 1930, 20-23.
[457] Texas State Highway Commission, *Sixth Biennial Report* (San Antonio: Eagle Publishing Co., 1929), 47-48.

years that followed. By 1934, the THD's progress with bridges had helped to "fill in many gaps on the main highways and replace a great number of weak and dangerous old structures."[458]

Many of the larger bridge projects completed in the late 1920s and early 1930s involved standard design Parker through trusses. A relatively early example was built on SH 23 (now US 283) over the Clear Fork of the Brazos River in northern Shackelford County (TxDOT Structure No. 08-209-0-0125-04-019, listed in the NRHP in 1996). Completed in 1929, the truss conforms to the T20-150, a late 1920s design comprised of eight 18-foot 9-inch panels providing a 150-foot span length and a 20-foot roadway width. By the early 1930s, the Bridge Division had generated several new Parker designs, including the T22-150 which was almost identical to the T20-150 except for its slightly wider roadway width of 22 feet. A noteworthy example of the T22-150 was built in 1933 to serve SH 3 (now US 90, eastbound lanes) traffic over the Nueces River west of Uvalde (TxDOT Structure No. 15-232-0-0023-05-038, listed in the NRHP in 1996). Comprised of four T22-150 Parker through truss spans, the SH 3 bridge is the only multiple-span example of this standard design surviving in the state.[459]

Although standard bridge designs were used whenever possible, unusual site conditions or lengthy crossings often required a more customized design approach. Beginning in the early 1920s, THD bridge engineers prepared special designs for several concrete culverts at skewed angle crossings. Several long bridges also required special designs to address unusual site conditions and to provide the most economical design possible. Two early examples of specially designed THD designs were completed in 1925 (since replaced) on SH 3 (now US 90), a primary east-to-west route that connected Orange, Houston, San Antonio, Del Rio, and El Paso. The larger of these two designs was a steel swing bridge built over the Neches River at Beaumont to meet navigational requirements at this site. The bridge consisted of a 240-foot steel swing span, two 125-foot steel truss spans, and approximately 2,735 feet of concrete and timber trestle approaches, providing a total length of about 3,225 feet. The second bridge, a cantilever truss, was built over the Brazos River at Richmond. By using a long central span, this design minimized the need for interior piers in the Brazos River. The monumental structure stretched approximately 1,120 feet and consisted of a 264-foot suspended cantilever truss span with two 132-foot truss arms, and about 592 feet of steel and concrete approaches. The Richmond Bridge was also important as the first cantilever truss built on the state highway system. Other special design bridges soon followed. Most important of these were a large swing bridge completed in 1927 (since replaced) on SH 3 over the Sabine River at Orange, a cantilever truss on SH 43 across the Brazos River at Valley Junction, also completed in 1927 (since replaced), and a Pennsylvania through truss bridge on SH 12 (now SL183/BU 59R), south of Wharton completed in 1930 (TxDOT Structure No. 13-241-0-0089-10-039, listed in the NRHP in 1993).[460]

The Moody highway commission also made interstate bridges a high priority for the department. During 1927, the commission initiated a series of feasibility studies on interstate bridge construction across the Oklahoma and Louisiana boundaries. Federal law dictated that the national government fund 50 percent of interstate bridge construction with the two bordering states each contributing 25 percent. The THD's first three interstate highway bridges were completed jointly with Oklahoma in 1926. A bridge on SH 3 between Orange, Texas, and St. Charles,

---

[458] Quoted in Texas State Highway Commission, *Seventh Biennial Report*, 55. Pages 43 to 55 of the report provide a detailed progress report on THD' s bridge improvements through 1930. Also Texas State Highway Commission, *Ninth Biennial Report*, Austin, Texas, 1929, 6.
[459] Historic Bridge Files, Texas Department of Transportation, Environmental Affairs Division, located at TxDOT headquarters in Austin.
[460] Texas State Highway Commission, *Fifth Biennial Report* (Austin: A. C. Baldwin and Sons, 1927), 50; Texas State Highway Commission, *Sixth Biennial Report*, 47-51.

Louisiana, across the Sabine River followed the next year. A 1927 federal road act allowed states to use federal aid monies to purchase interstate toll bridges and to build free bridges in their place. State legislation of the same year authorized THD to cooperate with neighboring states on the purchase of toll bridges across interstate lines and to construct new free bridges at these same locations. By 1930, the THD had reached agreements with both Oklahoma and Louisiana regarding a cooperative program to build free bridges across the Red and Sabine rivers. These efforts led to a number of major interstate bridge projects during the 1930s.[461]

While most interstate bridges were built without incident, a major political storm erupted over the Red River Bridge on SH 6 (now US 69) linking Denison, Texas with Durant, Oklahoma (formerly TxDOT Structure No. 01-092-0-0047-01-001, since replaced). The construction of the four-span Parker through truss bridge proceeded as planned during 1931 with a scheduled opening date of July 1, 1931. On June 24, however, the Red River Bridge Company obtained a restraining order against the Texas Highway Commission for a breach of contract on a toll bridge purchase near the new Denison bridge site. A federal judge ordered the THD to barricade the new bridge and to keep it closed until the dispute with the toll bridge company was resolved. The situation created considerable friction between Texas and Oklahoma, causing Oklahoma Governor William H. Murray to bring in the Oklahoma National Guard and Texas Governor Ross S. Sterling to dispatch the Texas Rangers to the bridge site. The standoff at the bridge lasted nine days and ended when a federal judge rescinded the restraining order on July 25, 1931.[462]

*Improved Bridge Planning and Design*

Wickline initiated a major overhaul of the state's bridge program almost immediately after the THD gained control over the state highway system. In-house control over bridge projects allowed THD bridge engineers to conduct better bridge investigations and to develop a more sophisticated design approach. Wickline quickly phased out the use of dips, low-water bridges and other bridge types that created dangerous situations in times of heavy rainfall. By 1930, THD bridge engineers were designing bridges that covered the entire valley of a creek or river, so that the highway could be usable for traffic even under heavy flooding conditions. This practice resulted in higher bridge elevations, longer approach spans, and the use of relief structures to accommodate stream overflow. Wickline also required resident engineers to conduct extensive surveys to determine the best and most economical bridge locations. Foundation studies constituted an important part of the preliminary site investigations. Extensive foundation soundings were required to determine the sub-soil formations on all proposed bridge sites. The data on foundation conditions also allowed THD bridge engineers to incorporate soil factors into a bridge's original design and layout and to avoid major design changes while a bridge was under construction. By 1940, the THD had acquired nine test boring rigs to assist with foundation exploration work.[463]

Greater THD control over bridge projects also permitted the Bridge Division to incorporate a broader range of engineering and traffic concerns into the bridge design and selection process. By the late 1920s, bridge engineers were paying special attention to traffic and safety factors, and designing bridges with straighter roadway alignments

---

[461] Huddleston, 151-152; U.S. Department of Transportation, 116; Texas State Highway Commission, *Seventh Biennial Report*, 50.
[462] Huddleston, 150-162.
[463] Texas State Highway Commission, *Seventh Biennial Report*, 144; Texas State Highway Commission, *Tenth Biennial Report*, Austin, Texas, 1936, 11; Texas State Highway Commission, *Twelfth Biennial Report*, Austin, Texas, 1941, 19; Texas State Highway Department, *Texas Highway Department, 1927-1937*, Austin, Texas, 1937, 77-78.

and greater roadway widths and bridge loading capacities. In order to accommodate pedestrian concerns, the THD also began installing sidewalks on bridges located in or near communities.[464]

During this period, Wickline also required that resident engineers conduct more extensive studies on stream flow characteristics and incorporate these findings into their final designs. The department's *Tenth Biennial Report* of 1936 noted that in the selection of structure types consideration must be given to determine the type of substructure required, the waterway opening to be provided, the probable size and volume of drift to be cared for, and to determine the relative stability of the stream channel; that is whether the channel is being subjected to scour or straightening effects or is being silted up and decreasing in section area. THD bridge engineers used these types of studies and investigations to determine the appropriate bridge type and substructure to use and to develop overall layouts for proposed structures. If the proposed bridge site was found to be in an area susceptible to sizable drift material during flooding, THD bridge engineers would typically employ long spans with special substructure designs (such as dumbbell piers with webwalls to prevent drift from getting lodged between pier columns) that allowed debris to move freely beneath the structure. In mountainous areas with high stream velocities, huge trusses with massive substructure were often used to provide greater stability and stronger bridge foundations. Areas with varying stream channels and broad floodplains often resulted in lengthy bridges with one or more related relief structures. If a bridge had navigational requirements, THD designs would typically incorporate a high vertical clearance or employ a movable span to allow for the free passage of ships beneath the bridge.[465]

Important trends in THD bridge design during the late 1920s and 1930s included the increased use of simple I-beams, as well as continuous and cantilever-suspended steel I-beam units, and the discontinuation of short to intermediate truss spans (primarily Warren pony and Pratt through truss). These trends were largely made possible by longer I-beam sections available in the rolling mills, which allowed the construction of span lengths up to 90 feet. A 1937 report indicated that I-beam construction afforded many advantages over truss construction, including "substantial economies, particularly in spans of 50 to 90 feet, reduction of substructure loads, simplicity of design and consequently, simplicity of construction…reduced maintenance as compared to truss designs, improved appearance, and lastly, the possibility of low-cost future widening in the event traffic development on a given section of highway warrants such widening."[466]

Other design trends were also evident during the late 1920s and 1930s. By the late 1930s, Wickline had largely discontinued the use of simple concrete slab structures for short-span bridges, relying instead on reinforced concrete multiple box culverts built in lengths of 20 to several hundred feet. Rigid frame and concrete arch construction also came into use in limited instances. Large trusses remained the preferred type for large creeks and rivers during this period, and were often built with lengthy steel or concrete trestle approaches.[467]

By the mid-1930s the THD was using continuous trusses for long-span bridge construction. Continuous trusses were first used in the mid-nineteenth century, but concerns over secondary stresses (those arising not from the load itself, but from deformations caused by the load), difficulties in calculating stresses (resulting from their static

---

[464] Texas State Highway Department, *Texas Highway Department, 1927-1937*, Austin, Texas, 1937, 75-95.
[465] Quoted in Texas State Highway Commission, *Tenth Biennial Report*, 10-11; Texas State Highway Department, *Texas State Highway Department*, 1927-1937, 75-95.
[466] Quoted in Texas State Highway Department, *Texas State Highway Department*, 1927-1937, 80; Texas State Highway Commission, *Eleventh Biennial Report*, Austin, Texas, 1939, 11.
[467] Texas State Highway Department, *Texas State Highway Department*, 1927-1937, 75-101; Texas State Highway Commission, *Ninth Biennial Report*, 6.

indeterminateness) and other factors precluded a wider use of this type until the 1920s. The limited role of continuous trusses was changed by the Ohio River Bridge built by the Chesapeake and Ohio Railway at Sciotoville, Ohio, from 1914 to 1917. This monumental bridge consisted of a single pair of continuous trusses extending 1,550 feet in length. Continuous trusses were particularly well-suited to use at lengthy crossings and provided several advantages over Parker through truss construction. By carrying the truss over several piers, a continuous bridge works as a unit that provides much greater rigidity than a multiple-span bridge comprised of a series of simple trusses. An early example that survives in good condition is the SH 27 (now SL 481) Bridge at the South Llano River in Junction (TxDOT Structure No. 07-134-0-0142-16-031, listed in the NRHP in 1996). Completed in 1937, the bridge consists of one three-span continuous unit 473 feet long, two three-span continuous units each 382 feet long, a 96-foot truss span and approaches, providing an overall length of 1,424 feet.[468] Many continuous truss bridges, such as the South Llano River Bridge, have a top chord that is bowed or shaped like a catenary curve. Other examples have top chords that are parallel to the bottom chord, such as the Brazos River Bridge on SH 6 in Knox County (TxDOT Structure No. 25-138-0-0098-05-036).

THD bridge designs of the late 1920s and 1930s also showed a growing appreciation and awareness of bridge aesthetics. During this period, bridge engineers began emphasizing overall simplicity and the need to provide harmonious treatment of railings, bridge-ends, and substructure. A priority was also placed on providing bridge designs that blended with the natural environment. In a 1936 report, Wickline noted that: "the growing interest in highway beautification has made it necessary that structures be designed to blend harmoniously with the surroundings, and, in the cases of structures in or near cities…that the structure…add to rather than detract from the general architectural beauty of the city's improvements."[469]

Special efforts were made to provide architectural treatment for bridges that were readily visible to the public. These included bridges in communities and urban areas, and structures located adjacent to parks and railroad lines. In these cases, THD bridge engineers provided a visually pleasing design and applied decorative details and ornamentation to a bridge's piers, railings, and approaches.[470]

In order to provide a transition from the roadway to the bridge structure, THD bridge engineers also began designing bridges with concrete approach railings that flared out at the bridge ends. In urban locations, this end treatment often took the form of solid concrete railings with decorative inset panels. In some cases, roadside plantings were also used to mark the bridge ends. By the late 1930s, the THD began using lower and more streamlined railing designs. In urban locations, picket-style metal railings were often used to provide a more modern and sophisticated appearance. An example of such railing is found on the NRHP-listed Montopolis Bridge, carrying southbound traffic on US 183 over the Colorado River in Austin in Travis County (TxDOT Structure No. 14-227-0-0265-01-034, NRHP 1996). Steel bridges were also provided with a finish coat of paint that blended with the concrete substructure and railings. Relief structures were usually designed to correspond closely to the main bridge. The Bridge Division also began paying closer attention to concrete construction methods and finishes during the 1930s. This resulted in a requirement that contractors submit drawings for all forms and falsework, and

---

[468] George A. Hool and W.S. Kinne, eds., *Movable and Long-Span Steel Bridges* (New York: McGraw-Hill Book Company, 1943), 199-204; Condit, *American Building Materials and Techniques*, 215-218;
Historic Bridge Files, Texas Department of Transportation, Environmental Affairs Division, located at TxDOT headquarters in Austin.
[469] Quoted in Texas State Highway Commission, *Tenth Biennial Report*, 11. Also refer to Texas State Highway Department, *Texas Highway Department, 1927-1937*, 75-95.
[470] Texas State Highway Commission, *Twelfth Annual Report*, 17-19.

use methods that eliminated board marks and irregular surfaces on concrete structures (including piers, abutments, and railings) whenever possible.[471]

*The Onset of World War II*

THD bridge construction was cut drastically as the United States made preparations to enter World War II. By the early 1940s, the War Department severely restricted the use of steel, causing a rapid decline in steel I-beam, girder and truss construction. Because of the restrictions on steel materials, the THD began to use salvaged bridge members as reinforcing in concrete structures. By 1944, bridge construction was largely confined to routes serving military and essential civilian traffic. With few bridge construction projects under way, the THD Bridge Division worked on bridge rehabilitation and improvement projects. An important safety project implemented during this period was the lowering of open concrete railings (primarily Types C and D) built by the THD in the 1920s and early 1930s. Apparently, the tall height (usually 3 feet) provided by these railings caused a bridge to appear extremely narrow to the traveler, causing motorists to veer unnecessarily toward the center of the roadway. The lower height corrected this situation and also allowed truck overhangs to clear the railings. The lowering of the railing was achieved by eliminating the upper row of railing and lowering the railing posts.[472]

*Local Bridge Progress Following the Creation of the THD*

Many counties continued to use small truss and I-beam spans on low traffic volume routes through the 1930s. These types were especially popular in remote locations, such as West and Northwest Texas, with relatively light traffic requirements, small intermittent streams, and infrequent flooding problems. In these areas, pre-fabricated types, such as metal trusses and I-beams, proved advantageous. Metal truss and I-beam spans were highly standardized by the 1920s and were available at a relatively low cost. Short to intermediate spans were also available in ready-to-assemble kits that could be shipped virtually anywhere in the state.[473]

Many Texas counties built small to medium riveted-connected truss spans at minor stream crossings during the 1920s and 1930s. The vast majority of these bridges were products of Austin Bridge Company of Dallas. The company's catalog provided easy-to-follow instructions for ordering bridges, and included various charts and drawings on its stock spans. Using the company's catalog, county commissioners could order small truss and I-beam spans with only minimal engineering experience and at relatively low cost. Warren pony trusses were typically employed for spans of 30 to 80 feet, while I-beams were popular for lengths-of 30 feet or less. A relatively long truss span, since removed, was provided by the 80-foot Warren pony truss built in 1935 over Little Good Creek in Foard County (TxDOT Structure No. 25-079-0-AA02-32-001). The Warren polygonal-chord truss was commonly used for spans of 80 to 120 feet. A typical example is the 110-foot span built in 1930 over Rough Creek in Fisher County (TxDOT Structure No. 08-077-AA01-83-001).[474]

---

[471] Texas State Highway Commission, *Twelfth Annual Report*, 17-19; Historic Bridge Files, Texas Department of Transportation, Environmental Affairs Division, located at TxDOT headquarters in Austin; Texas State Highway Department, *Texas Highway Department, 1927-1937*, 94-95.
[472] Texas State Highway Commission, *Fourteenth Biennial Report*, Austin, Texas, 1944, 11.
[473] Historic Bridge Files, Texas Department of Transportation, Environmental Affairs Division, located at TxDOT headquarters in Austin.
[474] Historic Bridge Files, Texas Department of Transportation, Environmental Affairs Division, located at TxDOT headquarters in Austin.

In contrast to the light Warren pony trusses built in more remote locations, some counties and communities also built more substantial trusses during the 1920s and 1930s. THD bridge engineers began disseminating standard plans and specifications for 15-ton metal truss spans to county engineers in 1918. As cities and counties became more familiar with THD designs and practices during the 1920s and 1930s, many of them began to apply the same standards to local bridge projects. Large, heavy truss spans were most common at urban locations and on local roads accommodating heavy oil equipment or machinery. By 1922, Wickline noted that:

there is a general tendency of…county authorities to insist upon all new bridges-whether on a State highway or not-to be of a heavier type than that formerly used. The work of the State Highway Department is serving as a general education among county road officials in the different methods of highway and bridge construction.[475]

A number of major bridge disasters in the early 1920s also helped bring about an increased interest in more substantial bridge designs. In a 1922 article on the status of Texas bridges, Wickline provides an account of several recent bridge failures on county roads, including one on the Marlin-Belton Road across the Brazos River that caused six deaths. As a result of this disaster, Falls County agreed to build the replacement bridge to THD standards.[476]

While many counties constructed metal truss bridges through the 1930s, by the early 1940s concrete slabs and girders had largely replaced metal truss spans as the preferred types for short to intermediate crossings. Advances in welding technology resulted in a few welded-connected truss spans in the 1940s. By the mid-1940s, however, most counties had abandoned truss bridges in favor of modern concrete designs.[477]

**Post World War II Engineering/Technological Developments**

***Bridge Types***

Several established materials continued to be used in bridge construction during the subject period; however, the period also bore witness to advances in bridge materials and construction methods that enabled longer, more complex structures to be built. Steel, which superseded iron in bridge construction in 1895, grew in popularity through the 1930s. After World War II, steel became very expensive and was often employed in combination with concrete. Concrete had been employed in bridge construction as early as the 1870s, but its use expanded dramatically after methods of reinforcement were introduced in the 1890s. By the 1950s, techniques for prestressing concrete, which compressed the material and thus made the concrete member stronger, brought prestressed concrete into widespread use as a bridge-construction material. In many cases, prestressed concrete girders supplanted steel as the preferred bridge type for medium span lengths.

Several new bridge types were created in Texas between 1945 and 1965, and many bridge types established before 1945 were modified during the subject period. This section discusses the pattern of features present in new bridge types, as well as the modifications and evolution of bridge types that were established prior to 1945. Each bridge-

[475] Quoted in Wickline, 10.
[476] Quoted in Wickline, 10.
[477] Historic Bridge Files, Texas Department of Transportation, Environmental Affairs Division, located at TxDOT headquarters in Austin.

building material is first introduced and then the bridge types that used that material are described. The bridge types are listed in alphabetical order for ease of use.

*Postwar Concrete Bridges*

Reinforced concrete was used by the THD throughout the post-World War II period for a variety of bridge types, as detailed below. A 2009 TxDOT inventory found that bridges with concrete superstructures comprised 61 percent of extant bridges constructed between 1945 and 1965. Developments in prestressing concrete are discussed in detail below.

*Postwar Concrete Bridges: Concrete Box Girder*

The concrete box girder used hollow boxes as its main supporting members. A box girder bridge is a fixed bridge consisting of various "box-shaped" sections used to support the deck. The first reinforced concrete box girders were built in the western U.S. in the late 1930s.[478] The box girder design was improved in the 1950s when designers began using prestressed steel wires rather than reinforcing steel bars to strengthen the box girders. The THD's use of the concrete box girder bridge form was restricted.[479] Variations identified in TxDOT's *Bridge Design Manual* include multiple, single, or spread. Multiple box girders indicate that the girders were built directly adjacent to each other and often tied together, creating an instant driving surface or an instant surface for the deck to be poured. Spread box girders indicate that the girders were spread apart from each other and the girders were tied to the deck and the substructure rather than to each other.

Research reveals that no standard plans for this bridge type were issued by the THD. These bridges may have been used more widely on a national level since the BPR had standard specifications for them in 1957. In a 2009 TxDOT inventory of post-World War II bridges, only three multiple box girders and one spread box girder were identified as extant.

***Postwar Concrete Bridges:*** *Concrete Deck Arch*

Although arch bridges were commonly built on U.S. roads since 1910, the bridge type was not as popular in Texas as it was in other locations. This bridge type converts the downward force of its own weight, and of any weight pressing down on top of it, into an outward force along its sides and base. It has typical span ranges from 40 to 150 feet. Only one extant reinforced concrete arch bridge is known to have been built in Texas between 1945 and 1965—the Speedway Street Bridge over West Waller Creek in Austin (TxDOT Structure No.: 14-227-0-B013-81-002). This 1946 closed spandrel arch is located on the University of Texas at Austin (UT-Austin) campus. It is a late example of a bridge type that was more commonly built in the early twentieth century, and continuing into the 1930s in some states.

[478] California Division of Highways, *Manual of Bridge Design Practice*, 2d ed. ([Sacramento, Calif.]: State of California Highway Transportation Agency, Department of Public Works, Division of Highway, Bridge Department, 1963), 48.
[479] Texas Department of Transportation, *Bridge Inspection Database*, n.p.

*Postwar Concrete Bridges: Concrete Pan-formed Girder*

The pan-formed girder (or concrete pan-formed girder) was a reinforced concrete bridge type developed by the THD immediately after World War II specifically for use on the newly created farm-to-market road system.[480] The THD's design was developed by Charles S. Matlock and E.A. Jelinek, under the supervision of state bridge engineer James P. Exum.[481] B.A. Trice may have also been involved in the development of the design of the pan-formed girder. It was an economic alternative for short crossings where steel I-beams or concrete girders were previously used.[482] The pan-formed girder bridges had typical spans of 30-and 40-foot lengths, and combined the strength of girder construction with the simplicity of slab construction.[483]

The cross section of the deck was a series of repeating arches on 3-foot centers. This design made maximum use of concrete and reinforcing steel. These bridges were economical because they were built by placing reinforcing steel bars in and atop modular steel forms and pouring the concrete directly into the forms. These steel forms were constructed from rolled sheet steel that were identical, interchangeable, and reusable.[484] Since no formwork and very little falsework were required, the forms were self-supporting. In this way, these concrete cast-in-place bridges could be cheaply constructed in quick succession.

Pan-formed girders were initially created and designed for the light H-10 and H-15 loading requirements on farm-to-market roads.[485] The load capacity for these designs increased during the early 1950s with designs of H-15 and H-20, and by 1955 the THD had standard designs for pan-formed girders with HS-20 design loads. THD engineers modified the design to make this type stronger as load requirements increased due to increasing truck size. Additionally, the design loads of these economical bridges were also increased so they could be used on other roadway types that had higher load capacity requirements, such as US and state highways.

Economic and structural advantages of this bridge type were highlighted by THD Bridge Division engineer B.A. Trice in an article in the national journal, *Roads and Streets*, stating "we are able to form and pour concrete having the structural advantage of girder construction at the same unit price required for slab construction." [486] While the design was still in its infancy, Trice wrote an article in the November 1950 edition of the THD's *Construction and Maintenance Bulletin* regarding the cost benefits of using pan-formed girders. In that article, Trice stated that in three example projects the pan-formed girder bridges won the bids by "substantial percentages," beating out FS slab designs on two bids and a continuous I-beam design on the third.[487] The benefits of this economical bridge design were also reported in the national publication *Roads and Streets*. In his 1950 article entitled "Low Cost Bridge," Burleson County Engineer Frank W. Perrin reported that his county was producing the THD-designed pan-formed girders for less than half the cost of alternative bridge types per square foot.[488] The article concluded with the

---

[480] Texas Department of Transportation, *Bridge Design Manual*, 7-27.
[481] B. A. Trice, "Low Cost Concrete Bridge," *Roads and Streets* 91, no. 10 (October 1948): 85.
[482] Texas Department of Transportation, *Bridge Design Manual*, 6-18.
[483] Perrin, "Low Cost Bridge: Design Capitalized in a Texas County Road Program," *Roads and Streets*, 39.
[484] Trice, "Low Cost Concrete Bridge," *Roads and Streets*, 83.
[485] The load requirements of the subject period were based on the number of axels and weight of trucks. Load designation with an H indicated a two axel truck and HS indicated three or more axel truck, with numbers following the H or HS signifying the tonnage the truck carried.
[486] Trice, "Low Cost Concrete Bridge," *Roads and Streets*, 83.
[487] B. A. Trice, "Concrete Girder Spans Built with Steel Forms," *Construction and Maintenance* Bulletin No. 3, (Nov 1950): 83.
[488] Perrin, "Low Cost Bridge: Design Capitalized in a Texas County Road Program," *Roads and Streets*, 42.

assertion that the "entire county organization shares pride in the low cost achieved."[489] With pan-formed girders making up over a quarter of the bridges built during the subject period, these bridges contributed to the state's overall low bridge construction costs during the period.

Perrin's 1950 *Roads and Streets* article was the first Texas or national publication that touted the benefits of the pan-formed girder design. The article recounted how Burleson County purchased a set of forms from Mosher Steel Company of Houston for $2,111.[490] Eight bridges were built in the county, the first of which was the Deanville-Hovadik Road Bridge. Seven of the structures used a single 30-foot span with a deck width of 21 feet, while one was a 60-foot, two-span bridge. Four of the structures were built as part of a five-mile farm highway project on Snook-Joe Baker Road.[491] These four bridges may be the present-day FM 2155 bridges built in 1946 (TxDOT Structure Nos.: 17-026-0-0506-04-009, 17-026-0-0506-04-010, 17-026-0-0506-04-011, and 17-026-0-0506-04-012).

Pan-formed girders were so widely used in Texas because they were easy-to-design and easy-to-construct bridges that employed reusable forms. The main reason for the type's success was the use of standard plans to build these bridges. Research reveals that between 1945 and 1965 the THD designed more standard plan sets for pan-formed girder bridges than any other bridge type. In 1948, the THD issued its first set of standard plans for pan-formed girders, which had a design load of H-10. The original design accommodated a 30-foot span length with 20-inch-wide caps and no skew, but this developed into a basic span length of 30 feet, 4 inches to accommodate a 24-inch cap width.[492] Several 30-foot, 4-inch pan-formed girder standard designs were issued by the THD in the early 1950s. In 1956, a design for 40 feet was introduced, and in the early 1960s standard drawings were distributed for both 30 feet, 4 inches and 40-foot span lengths for five roadway widths and five different skew angles.[493] Standard plans for a 42-foot, 3-inch span length were introduced in 1958, and at a mere 2.25 feet longer than the 40-foot span, it offered the longest standard span for a reinforced concrete pan-formed girder designed between 1945 and 1965.

There is very little variation in the main span lengths for pan-formed girders because the forms used to construct these bridges were uniformly built between 30 feet, 4 inches and 42 feet, 3 inches. During the 1945 to 1965 period, engineers found that the pan-formed girder spans could also be used to build long bridges where short, repeating spans were acceptable.

Pan-formed bridges were built in great numbers between 1945 and 1965 for the reasons outlined above. The THD pan-formed girder is most strongly associated with state-system roadways, with only 12 percent of the type on county or city roads.[494] Regardless of their divisions between on-and off-system, together the concrete pan-formed girders constitute approximately 25 percent of the total number of extant bridges statewide from this period, with the lowest percentage in the Austin District at 10 percent and the highest concentration in the Childress District at 50 percent.[495] Together with reinforced concrete slabs, another bridge type that was inexpensive and often used for short crossings (discussed below), pan-formed girders make up 88 percent of the farm-to-market road bridges built

---

[489] Perrin, "Low Cost Bridge: Design Capitalized in a Texas County Road Program," *Roads and Streets*, 42.
[490] Perrin, "Low Cost Bridge: Design Capitalized in a Texas County Road Program," *Roads and Streets*, 39, 42.
[491] Perrin, "Low Cost Bridge: Design Capitalized in a Texas County Road Program," *Roads and Streets*, 42.
[492] Texas Department of Transportation, *Bridge Design Manual*, 7-27.
[493] Texas Department of Transportation, *Bridge Design Manual*, 7-27.
[494] Texas Department of Transportation, *Bridge Inspection Database*, n.p.
[495] Texas Department of Transportation, *Bridge Inspection Database*, n.p.

during the subject period.[496] Although pan-formed girder bridges were designed to be used on the farm-to-market road system, they were also used on US and state highways. Examples of the pan-formed concrete girder, together with reinforced concrete slab bridges, comprise more than 55 percent of the bridges on US Highways and 65 percent on state highways.[497]

Although the pan-formed concrete girder was widely used during the subject period, some districts used the type sparingly and abandoned it after the subject period. According to TxDOT's *Bridge Design Manual*, pan-formed girder bridges were prematurely deteriorating in salty environments, and as a result the THD searched for an alternative design.[498] Perhaps this is the reason that lower percentages of pan-formed girders are found in the Gulf Coast districts of Corpus Christi, Houston, Pharr, and Yoakum than other places in the state.[499] The pan-formed concrete girder was one of the most economical bridge designs of this period, but prestressed concrete beams later became more economical for longer crossings.[500] Nevertheless, this bridge type was used prevalently by the THD during the subject period and over 2,000 examples built between 1945 and 1965 remain.[501]

***Postwar Concrete Bridges:*** *Concrete Rigid Frame*

The rigid frame was another reinforced concrete bridge type used in Texas during the subject period, albeit somewhat infrequently. Three types of rigid frame bridges were used in Texas during this period: plain rigid frames, rigid frame concrete slabs, and rigid frame Tee beams. All three bridge types were inexpensive, easy-to-construct, and aesthetically appealing for use on urban roadways.[502] They were commonly used for highway and freeway bridge construction and generally had an arched profile. The extant rigid frame bridges are found in Texas's urban areas of Austin, Dallas, Fort Worth, and San Antonio.

Plain rigid frame bridges were introduced in the U.S. in 1922 and have been used in Texas since the early 1930s. These bridges featured the superstructure and abutments as a continuous form, poured monolithically in one mold. Used for a variety of roadway types from the 1920s through the 1940s, rigid frame bridges were mainly used as grade separation structures in urban locations following World War II and had spans ranging from 40 to 120 feet.[503] Since the deck and abutments act as a uniform system, these bridges carried the entire load with little help from a foundation, and were used where logistics, setting, and/or cost prevented the construction of a substantial foundation. Although these bridges were a well-established bridge type, the THD could still be innovative in their construction, such as in the example of the Saunders Avenue and Fleishel Avenue bridges, both of which span SH 31 in Tyler (TxDOT Structure Nos.: 10-212-0-0424-01-030 and 10-212-0-0424-01-031). The superstructure portion of the bridge was poured at the Saunders Avenue ground level and the SH 31 roadway was dug under the

---

[496] Texas Department of Transportation, *Bridge Inspection Database*, n.p.
[497] Texas Department of Transportation, *Bridge Inspection Database*, n.p.
[498] Texas Department of Transportation, *Bridge Design Manual*, 7-53. The alternative design that THD found to replace pan-formed girders in the Gulf Coast region was the prestressed concrete box girder.
[499] Texas Department of Transportation, *Bridge Inspection Database*, n.p.
[500] Texas Department of Transportation, *Bridge Design Manual*, 7-27.
[501] Texas Department of Transportation, *Bridge Inspection Database*, n.p.
[502] Parsons Brinckerhoff and Engineering and Industrial Heritage, *A Context for Common Historic Bridge Types, NCHRP Project 25-25, Task 15* ([Washington, D.C.]: National Cooperative Highway Research Program, Transportation Research Board, October 2005), 3-96.
[503] Parsons Brinckerhoff and Engineering and Industrial Heritage, *A Context for Common Historic Bridge Types, NCHRP Project 25-25, Task 15*, 3-96.

Saunders Avenue superstructure. The abutment walls and foundation were then put into place. Constructing the bridge in this way, the contractor did not have to use false work under the bridge, which is a major expense in the construction of these structures.

In situations where substantial foundations could be built to resist lateral loads, engineers built a modified version of the rigid frame—the rigid frame concrete slab. Like plain rigid frame bridges, rigid frame concrete slabs' superstructure is tied into the abutments; however, in the concrete slab variation, the superstructure is only integrated with the substructure cap. Therefore, the continuous form only extends a few feet onto the top of the abutment and the bridge relies on the foundation (rather than integrated superstructure and substructure) to resist the lateral loads. There are several reasons that engineers built rigid frame concrete slab bridges rather than the plain rigid frame bridges. First, since the superstructure was only integral with the substructure cap, column-type piers could be easily built placed between travel lanes. Plain rigid frame bridges had such substantial substructures that multiple spans were not easy to construct. Rigid frame concrete slab bridges were also less expensive to build than plain rigid frames since they required less reinforcing material and less concrete, while still providing the elegant arched form for urban roads. Furthermore, the thin superstructure of the rigid frame concrete slabs made them an ideal choice where vertical clearance issues were a concern. One disadvantage to the rigid frame concrete slab bridges may have been their maximum span length. According to TxDOT's bridge inspection database, the rigid frame concrete slab bridges built in the state had spans less than 70 feet long.

The rigid frame Tee beam bridge was another type of rigid frame used during the subject period. This bridge type had Tee beam superstructure elements that are monolithically formed with the substructure, creating a series of arching beams. Since the Tee beam form was carried through to the substructure, engineers could easily construct multiple spans, like the rigid frame concrete slabs, and place the piers where needed. Rigid frame Tee beams' spans were longer than the rigid frame slabs, with the longest rigid frame Tee beam span in the state measuring 82 feet. However, with the long span range came a deeper superstructure and the rigid frame Tee beams could not be used where vertical clearance was a concern.

Rigid frame designs declined in popularity when the new prestressed concrete designs of the 1950s proved to be less labor intensive and more economical.[504] The number of extant rigid frame bridges is quite small, with fewer than 15 examples of each rigid frame type built between 1945 and 1965 remaining.

*Postwar Concrete Bridges: Concrete Slab*

This section discusses both simple and continuous reinforced concrete consistent-depth slab (commonly called "flat slab") bridges. The concrete slab was one of the THD's main bridge types used during the subject period, and hundreds of reinforced concrete slab bridges remain in Texas. Concrete slab structures include a rigid horizontal piece that serves as the deck and as a structural member carrying stresses to abutments and/or piers. Since 1910, the reinforced concrete slab type has been used nationwide as the simplest and most economical design for shorter spans. The earliest known reinforced concrete slab in Texas was built in 1915. By 1918, the THD had a standard plan for simple concrete slab spans. This type was used extensively in the 1920s, mostly for spans of less than 20

[504] Parsons Brinckerhoff and Engineering and Industrial Heritage, *A Context for Common Historic Bridge Types, NCHRP Project 25-25, Task 15*, 3-96, 3-97.

feet. Simple spans were lengthened to 25, 30, and 40 feet during the subject period by increasing the depth or thickness of the slab.[505]

Although some simple flat slab spans were built during the subject period, their use was nearly completely eclipsed by a new slab span type. Anticipating the construction of the farm-to-market road system in 1944, the THD redesigned concrete slab bridges for specific use on the new road system.[506] This design, modeled after research conducted at the University of Illinois, was called the FS Slab. Although extensive research did not reveal what "FS" signified, it may have stood for flat slab. The FS Slab design had raised structural curbs that were monolithically poured with the slab; the integrated curbs provided strength that allowed for thinner slab depth and greater overall economy. The monolithically poured curbs acted as small girders and were the main difference between the pre-1944 designed flat slabs and the FS slab. Typically, the high curbs served as railing on the bridge and no added handrails were used. The FS slab proved to be easy-to-construct and ideal for short crossings.

It should be noted that all simple reinforced concrete slab bridges, regardless if they are the pre-1944 designed slabs or FS Slabs, have the same Bridge Inspection Database (BID) code. As a result, determining how many of each type of slab was built is not possible using the BID. While the BID makes no distinction between the FS slab and other simple-span reinforced concrete slab bridges, it is assumed that few off-system concrete slab bridges are FS slabs since these bridges were a THD design.

Continuous slab spans were established before the subject period and their use continued through the 1960s. In the 1930s, the continuous slab was introduced nationally with a single slab extending across several spans, with use of continuous concrete slabs beginning in Texas around 1936.[507] Spans of 20 to 30 feet were typical, with occasional interior spans of up to 40 feet.[508] A review of THD standard plans created between 1944 and 1956 reveals that the THD established many more standard plans for continuous flat slab bridges than they did for continuous FS slabs. Like simple slab spans, continuous flat slabs and continuous FS slabs are coded the same in TxDOT's BID; therefore, distinguishing how many bridges of each type were built is not possible.

The THD developed standards for the simple flat slabs, simple FS slabs, continuous flat slabs, and continuous FS slabs during the subject period. Even though the THD had numerous standard designs for simple flat slabs prior to the subject period, they created new standards for these bridges during the subject period capable of handling H-15 and H-20 loads. After constructing a successful test of an FS Slab bridge in Henderson County, the THD developed a series of standard details for the FS Slabs. The earliest FS Slab standards are dated 1945 and have eight-inch-high curbs, with span lengths of 15, 20, and 25 feet and design loads of H-10 and H-15. Although the THD built these bridges in significant numbers for the farm-to-market road system, fewer than a dozen standards are known to have been issued with the latest dated 1954.

Continuous slab spans include continuous flat slabs and continuous FS slabs. Research revealed that the THD released very few continuous FS slab standard plans, with the first issued in 1945. Standards for 90-and 100-foot continuous FS slab units were developed with an H-15 design load. Research also shows that the THD issued

---

[505] Parsons Brinckerhoff and Engineering and Industrial Heritage, *A Context for Common Historic Bridge Types, NCHRP Project 25-25, Task 15*, 3-85.
[506] Texas Department of Transportation, *Bridge Design Manual*, Section 7-16.
[507] PAC Spero & Company and Louis Berger & Associates, *Historic Highway Bridges in Maryland: 1631-1960: Historic Context Report*, Rev. ed. (Baltimore, Mar.: October 1995), 145.
[508] Texas Department of Transportation, *Bridge Design Manual*, 7-19.

several standard plans for continuous flat slabs between 1944 and 1956. These standards had continuous units measuring up to 110 feet with design loads up to HS-20.

Substructure standards for simple and continuous spans were also issued for these bridges. They specified two-column, spill-through type bridge abutments and three-pile bent piers using a cast-in-place concrete cap on precast concrete, steel, or timber piles, or two-column reinforced concrete framed bents on individual footings.[509]

A 2009 analysis of TxDOT's bridge inspection database revealed that concrete slab bridges, along with pan-formed girders, made up 88 percent of the extant farm-to-market road bridges built between 1945 and 1965.[510] Reinforced concrete slab bridges were also built on other types of roads. Together with pan-formed girder bridges, these two bridge types comprised more than 55 percent of the extant bridges built between 1945 and 1965 on US highways and 65 percent on state highways.[511] Concrete slab bridges also made up approximately one-third of city bridges in the state from the period.

Although reinforced concrete slabs are found in every district in the state, the San Antonio District used reinforced concrete slabs most often for its short crossings. While no documented evidence pointed to reasons for this preference for concrete slabs, Leroy Surtees, a retired San Antonio District bridge engineer, provided information regarding this anomaly during an interview conducted for TxDOT's 1945-1965 bridge inventory. Surtees said concrete slab bridges were thinner structures and were often chosen over the pan-formed girders when hydraulic issues called for a bridge with a slimmer profile.[512] This may also account for the high percentage (over 43 percent of extant bridges from the 1945-1965 period) of concrete slab spans in the flood-prone Austin District.[513]

*Postwar Concrete Bridges: Concrete Tee Beam*

A Tee beam structure features concrete "T-shaped" beams supporting an integral deck slab or a cast-in-place concrete deck that is used for the roadway surface. Steel rods are concentrated in the bottom of the web and in the top flange steel rods are laid perpendicular to the web. When the tee beam and deck are integrated together, steel reinforcing in the Tee beam's web and reinforcing in the deck are usually tied together by U-shaped hangers.[514] By doing this, the slab and beams become unified structural components, which increases the bridge's strength and allows greater span lengths. With typical spans ranging from 30 to 50 feet, Tee beams were often more economical than slabs for lengths exceeding 25 feet.[515]

Introduced in the 1910s, concrete Tee beams were prevalent in the U.S. from the 1920s to the 1940s. While simple spans were most common in Texas during the subject period, continuous spans were also built.[516] Although

---

[509] "Texas 1946 Secondary Road Program Established New Construction Record," *Engineering News-Record*, 101-102.
[510] Texas Department of Transportation, *Bridge Inspection Database*, n.p.
[511] Texas Department of Transportation, *Bridge Inspection Database*, n.p.
[512] Leroy Surtees, Telephone interview by Mead & Hunt, Inc, digital audio recording, Austin, Texas, November 17, 2006, n.p.
[513] Texas Department of Transportation, *Bridge Inspection Database*, n.p.
[514] Parsons Brinckerhoff and Engineering and Industrial Heritage, *A Context for Common Historic Bridge Types, NCHRP Project 25-25, Task 15*, 3-88.
[515] Parsons Brinckerhoff and Engineering and Industrial Heritage, *A Context for Common Historic Bridge Types, NCHRP Project 25-25, Task 15*, 3-88.
[516] *Safety Inspection of In-Service Bridges: Participant Notebook*, vol. 1-2 ([McLean, Va.]: U.S. Dept. of Transportation, Federal Highway Administration, National Highway Institute, January 1992), 8.3.3.

continuous concrete Tee beams were introduced nationally in the 1930s, this variant was not used in Texas until the 1950s. Use of continuous concrete Tee beams in Texas ended in the 1960s.[517]

THD produced standard plans for simple span Tee-beams in 1951 and 1956. The standard plans had span lengths of 35, 40, and 48 feet. Depending upon their deck width, they had design loads of H-15 and H-20. The THD issued standards for continuous spans in 1956 for units 190 and 230 feet long, with H-15 and H-20 design loads. The last standard design for a concrete Tee beam was issued in 1956 for use on interstate crossovers in select districts.

Although quite common prior to World War II, reinforced concrete Tee beam bridges were largely superseded by pan-formed girders in the post-World War II period. Pan-formed girders were more economical than Tee beams due to their reusable forms and need for little false work. In the early 1960s, engineers began building Tee beam bridges with prestressed steel wires rather than steel reinforcing bars.

***Postwar Concrete Bridges:*** *Concrete Variable Depth Slab and Tee Beam*

Reinforced concrete variable depth bridges have been used in the U.S. since the 1930s. In the 1950s THD engineers built variable depth slab bridges and variable depth Tee beam bridges as grade separation structures. These bridges are designed with the same principles as reinforced concrete bridges that have consistent depths; however, variable depth slabs and tee beam bridges concentrate the reinforcing steel bars over the piers with less rebar (and concrete) at mid-span. Although the bridges still function as slabs and Tee beams respectively, they resemble parabolic arch bridges. In modifying slabs and tee beams in this way, engineers can achieve longer spans. TxDOT's *Bridge Design Manual* notes that variable depth slab interior spans could measure up to 60 feet; however, former Waco bridge engineers Richard Casbeer and Ron Koester recalled in a 2006 interview that continuous variable depth slab spans could reach 80 feet.[518] Koester noted that variable depth Tee beam spans could reach 90 feet long.

While examples of these bridge types are scattered throughout the state, the Waco District built many of these bridges. The Waco District bridge designers pushed for the use of these bridge types for grade separation structures, particularly for use on IH 35. The Waco District preferred using variable depth reinforced concrete slabs and variable depth reinforced concrete Tee beams for many crossings that required long spans.[519] Casbeer and Koester indicated that the Waco District used the FS slab bridges and pan-formed girder bridges for farm-to-market roads, but found that for long spans, variable depth reinforced concrete slab and Tee beam bridges were the most economical types.[520] Although variable depth Tee beam bridges could span longer distances than the slabs, the variable depth reinforced concrete slab spans were chosen when minimum depth was needed for grade separation structures. The district generally limited use of these variable depth reinforced concrete slabs and tee beams to overpasses and underpasses because the formwork required for them was difficult to build in a streambed.

---

[517] Texas Department of Transportation, *Bridge Design Manual*, 7-22, 7-34.
[518] Texas Department of Transportation, *Bridge Design Manual*, 7-16, 7-19; Dick Casbeer, Ron Koester, and Frank Leos, Interview by Mead & Hunt, Inc. and TxDOT Bridge Division, Texas Department of Transportation, digital audio and visual recording, Waco District Bridge Office, Waco, Texas, October 16, 2006.
[519] Casbeer, Koester, and Leos, Interview by Mead & Hunt, Inc. and TxDOT Bridge Division, Texas Department of Transportation.
[520] Casbeer, Koester, and Leos, Interview by Mead & Hunt, Inc. and TxDOT Bridge Division, Texas Department of Transportation.

According to Casbeer, the Waco District built these variable depth bridges cheaper than prestressed concrete bridges because the bids from their contractors were lower per square foot. Local contractors had good aggregate, inexpensive concrete, and cheap labor. This was confirmed in the *Bridge Design Manual*, which mentions that the Waco District's use of continuous variable depth reinforced concrete tee beam bridges on interstate highways and primary roads was economical because of "construction volume."[521]

While the Waco District's use of variable depth continuous reinforced concrete bridges is well known and documented, the Abilene, Fort Worth, and Houston districts also used this bridge type for their grade separation structures. According to database analysis, Abilene has triple the number of extant variable depth continuous reinforced concrete slab bridges than the Waco District. All of Abilene's variable depth continuous reinforced concrete slab structures are grade-separation bridges constructed on IH 20. Other concentrations of these bridges are found in the Wichita Falls and Fort Worth Districts. While the variable depth continuous reinforced concrete slabs in Wichita Falls and Fort Worth are slightly different and are found on a variety of on-system roadways, their general form and function are consistent with Waco District's structures. Similarly, variable depth continuous reinforced concrete slabs were used over IH 10 in Houston according to Ed Suchiki, a former Houston Urban Expressway Office bridge engineer. However, many of these structures are no longer extant and only a small pool of these bridges remains.

Although few simple variable depth flat slabs and variable depth tee beams are extant in Texas, the continuous spans are more plentiful, with more than 250 continuous variable depth slabs and over 100 continuous variable depth tee beams identified in TxDOT's 2009 inventory of bridges built between 1945 and 1965.

*Other Postwar Concrete Bridge Types*

The following bridge types are coded as "other concrete" in TxDOT's BID. Since these bridge types are not specifically identified in the BID by individual type, their earliest use, span lengths, structure lengths, and numbers of extant bridges could not be readily discerned. The following text includes information compiled during bridge inspection review and field investigations.

*Reinforced Concrete Girder (not pan-formed and not tee beam)*

Reinforced concrete girders that are not pan-formed and are not built in a Tee-beam configuration are coded in the BID as other concrete bridges. These bridges are generally reinforced concrete cast-in-place structures. These simple span, concrete girder bridges were a building block of the state highway system after World War I and peaked in popularity during the 1930s.[522] Their continued use during the post-World War II period was sparse and mainly confined to off-system roads.

A 2009 review of bridge inspection files and site visits revealed that there were six reinforced concrete girder bridges (not pan-formed and not tee beam), with the earliest example built in 1945. Of these examples, main spans range from 14 to 49 feet long and total structure length ranges from 86 feet to 1,054 feet.

---

[521] Texas Department of Transportation, *Bridge Design Manual*, 7-34.
[522] Texas Department of Transportation, "Texas Historic Bridge Inventory: Survey of Non-Truss Structures," 29.

*Reinforced Concrete Channel Beam*

Reinforced concrete channel beams have been used in the U.S. since 1910. The use of the bridge type continued after World War II, with a few examples still extant. Channel beams look similar to Tee beams as they have a vertical web and a horizontal flange. However, channel beams have two vertical webs extending from the flange, forming a flattened U-shaped beam. These were usually precast beams that generally have span lengths of less than 50 feet.[523]

A 2009 review of bridge inspection files and site visits at the bridge revealed that there were five reinforced concrete channel beams built in the post-World War II period, with the earliest example built in 1950. This bridge type's main spans range from 14 to 40 feet long, and the structure length range for the two channel beam bridges that have more than one span is 30 feet to 131 feet.

*Reinforced concrete double Tee beam*

Reinforced concrete double tee beam bridges are very rare in Texas and only one extant example of this bridge type built between 1945 and 1965 was identified. This bridge type consisted of reinforced concrete members that look similar to tee beams; however, rather than the members being T-shaped, the beams look like two T's (TT) directly adjacent to each other. Careful inspection of the seams between the beams will indicate whether the beams are channel beams or double Tee beams, as the double Tee beam will have wide flanges on either side of the webs. The extant bridge of this type (TxDOT Structure No. 12-102-0-B416-45-285, Magnolia Point Drive at HCFCD Ditch, Harris County) was built in 1950 and has one span that is 27 feet long.

*Reinforced concrete slab beam*

Little information is known about reinforced concrete slab beam bridges. With only one extant bridge from the post-World War II period, this bridge type, which consisted of a solid slab superstructure, was very rare. The extant bridge of this type (TxDOT Structure No. 16-089-0-AA01-41-001, Nordheim Road at Goat Creek, Goliad County) was built in 1960, has a span length of 19 feet, and an overall structure length of 40 feet.

*Prestressed Concrete*

Experiments with prestressing concrete took place as early as the late nineteenth century, but only decades later was it practical to use. In the 1920s, the idea of linear stressing became more practical through the work of French engineer Eugene Freyssinet. In 1939, he patented the process that allowed the depth of large spans to be reduced by about half for the same concrete section.[524] Prestressing offered economic advantages; therefore, during the Depression state engineers began to study and experiment with the material. State departments of transportation in Florida, Tennessee, California, and Pennsylvania were involved in early development and use of prestressing. The first significant prestressed bridge in the U.S. was the Walnut Lane Bridge in Philadelphia constructed in 1949. Prestressed concrete was used widely across the country by the early 1950s.

---

[523] Parsons Brinckerhoff and Engineering and Industrial Heritage, *A Context for Common Historic Bridge Types, NCHRP Project 25-25, Task 15*, 3-91.
[524] Kenneth Frampton, *Modern Architecture: A Critical History* (New York: Oxford University Press, 1980), 40.

Prestressed concrete offers advantages over reinforced concrete. Prestressed concrete uses high-strength concrete containing high-strength steel that has been stretched and anchored to the concrete with sufficient force to substantially eliminate tension from occurring in the member. Overall strength of the concrete is increased by prestressing the load for an individual member. As a result, less concrete and steel can be used than in reinforced concrete spans. Prestressed concrete beams (or girders) are constructed by initially compressing the concrete sufficiently to resist all anticipated tensile stresses from applied loads. Applied loads, which cause these stresses, include a beam's own weight, the weight of the deck, and the expected traffic loading. Due to this initial compression force, the entire beam resists the applied loads, making it more efficient. In contrast, a reinforced concrete beam uses much of its load-carrying capacity just to support its own weight. Prestressing introduces a controlled strain in the member during construction to counteract unwanted stresses from the live or dead load.[525] The steel present in reinforced concrete beams resists the tension stresses in the beam, while the concrete resists the compression stresses. The depth, and to a smaller extent the width, of the beam are proportioned to achieve the strength required to support the weight of the bridge and the intended traffic. Due to this, the length of the structure is limited in that eventually the beam cannot be made deep enough to carry additional loading unless it is constructed with voids in the middle of the concrete beam to eliminate weight. This causes a loss of efficiency because fabrication costs increase and durability is reduced due to the inherent presence of moisture within the voids.

Like the reinforced concrete beam, a prestressed concrete beam is made deeper to span further. However, the prestressed beam can be proportioned to achieve longer spans without adding significant weight by increasing the compression force in the beam. As a result, prestressed concrete beams are shallower than their reinforced concrete counterparts, providing more clearance and enhancing their adaptability to grade separation structures for expressways and the Interstate. Prestressed concrete beams are approximately two-thirds the size and weight of reinforced concrete beams. In addition, prestressed concrete beams utilize approximately one-fourth of the longitudinal steel of reinforced concrete beams, though the steel must be of high tensile strength. Unlike reinforced concrete, prestressed concrete does not crack under working loads and deflections are reduced under dead and live loads. Because prestressed concrete beams typically do not crack, they are more durable and resistant to corrosion than reinforced concrete beams.[526] Prestressed concrete is used for continuous and simple spans and is an effective way to increase concrete span lengths and control deflections, which are the vertical movements that occur in a structure as a result of loading.

There are two types of prestressed concrete: post-tensioned and pre-tensioned. Few THD bridges are made of post-tensioned concrete, which is formed when the steel rod or wire is inserted through open recesses or along the outside of the concrete member and is stretched and attached with a permanent anchor to maintain stress.[527] Post-tensioned concrete was used sparingly by the THD for bridge construction during the subject period because it was completed at the project site and required that the contractor be knowledgeable about how to correctly tension the members. For this reason, the THD and other state highway departments used pre-tensioned members most often and only used post-tensioned members when specific circumstances required.[528]

---

[525] Live load is weight a structure carries that is temporary in nature, such as traffic, wind, and seismic loads. Dead load is the permanent weight of the structure, including its deck, railings, and structural elements.
[526] Tung Y. Lin, *Design of Prestressed Concrete Structures*, 2d ed. (New York: John Wiley & Sons, 1963), 30-33.
[527] Texas Department of Transportation, *Bridge Design Manual*, 5-2.
[528] Don Harley, Interview by Mead & Hunt, Inc. and TxDOT Bridge Division, Texas Department of Transportation, digital audio and video recording, Travel Division Studio, Riverside Campus Building 150, Austin, Texas, November 3, 2006.

To form pre-tensioned concrete, steel reinforcing rods are stretched and placed into forms and held under stress until the concrete is poured. Once the concrete is hardened, it holds the steel to its stressed length. Pre-tensioned concrete became a common material for the THD's bridge construction program because it was precast and transferred to the construction site. This made it easier and cheaper for contractors to use.

Precast, prestressed concrete was an economical innovation that was popular throughout the U.S. in the late 1950s. These beams require specialized tensioning or casting beds for their manufacture. The design and construction of the beds were technological advancements in their own right in the early years of prestressed usage, thus limiting prestressed concrete to those precasters who made the investment in beds and could provide transportation of the beams to the site. On the other hand, precasting of prestressed concrete units allowed cost savings as large quantities of beams could be mass produced at factories and then delivered to construction sites, allowing reuse of forms.[529] Historian Carl Condit describes the importance of precast beams: "The precasting and prestressing of girders for concrete bridges have brought their construction as close to the methods of mass production as the building arts have yet come."[530]

In Texas, use of prestressed concrete began in 1952, when the THD experimented with the material by post-tensioning a pan-formed girder, a bridge type that was normally built with reinforced concrete. This bridge is the 60-foot structure over the San Bernard River Bridge built in 1952 on SH 60 in Austin County (TxDOT Structure No. 13-008-0-0240-01-008).[531] In the mid-1950s THD Bridge Division engineer James Graves researched the use and success of prestressed concrete in California, Florida, and Tennessee.[532] Based on the information he gathered, he completed standard shapes for prestressed concrete girders in 1956, which were distributed to THD engineers in 1957. The THD continued to issue standards shapes for prestressed concrete beams from 1956 through the mid-1960s.

At the national level, the BPR also published engineering specifications for prestressed concrete bridges in its early 1950s publication, *Criteria for Prestressed Concrete Bridges*. Prestressed concrete was not included in the AASHO specifications until 1961 due to continuing research and innovations throughout the 1950s.[533] In 1963, AASHO and the Prestressed Concrete Institute (PCI) published recommendations and plans for standard shapes of prestressed concrete I-beams, piling, slabs, and box beams.[534] The purpose of the plans was to "establish a limited number of simple, practical sections leading to uniformity and simplicity of forming and production methods." Plans were included for I-beams with span lengths of 30 to 100 feet, box beams with spans up to 103 feet, and slabs with spans up to 55 feet.[535]

---

[529] Lin, Design of Prestressed Concrete Structures, 31; Tung Y. Lin and Felix Kulka, "Fifty-Year Advancement in Concrete Bridge Construction," Journal of the Construction Division, Proceedings of the American Society of Civil Engineers 101, no. CO3 (September 1975): 494-495.
[530] Carl W. Condit, *American Building: Materials and Techniques from the First Colonial Settlements to the Present*, 2d ed. (Chicago: University of Chicago Press, 1982), 257.
[531] Graves, "Prestressed Concrete," *Texas Highways*, 40.
[532] Robert L. Reed, "Elastomeric Bearings for Texas Highway Bridges" (San Antonio, Texas: The 2nd World Congress on Joint Sealing & Bearing Systems for Concrete Structures, 2 October 1986, n.p.
[533] American Association of State Highway Officials, *A Policy on Arterial Highways in Urban Areas*, xxiii.
[534] Tentative Standards for Prestressed Concrete Piles, Slabs, I-Beams and Box Beams for Bridges and an Interim Manual for Inspection of Such Construction, n.p.
[535] Tentative Standards for Prestressed Concrete Piles, Slabs, I-Beams and Box Beams for Bridges and an Interim Manual for Inspection of Such Construction, n.p.

In the 1950s and 1960s, prestressed concrete was used for interstate structures throughout Texas as it was often found to be more economical than steel. An early prestressed concrete interstate bridge was incorporated into the Dallas Expressway. The extant Pine Street Overpass (1956) uses three 58-foot post-tensioned concrete spans (TxDOT Structure No.:18-057-0-0092-01-053).[536] Another early example is the extant IH 35 overpass in Austin, completed in 1962, crossing Sixth, Seventh, and Eighth streets (TxDOT Structure No.: 14-227-0-0015-13-191). This 898.5-foot structure incorporates 50-to 70-foot prestressed concrete spans.

In the early 1960s, an innovation of prestressed concrete was realized when the THD used prestressed concrete panels both as structural members and as the form for casting reinforced concrete slabs. The panels supported their own weight and that of the cast-in-place concrete. The THD's design to develop prestressed concrete panels eliminated the need for form building to construct the bridge deck. Three bridges of this type were constructed in 1962 on the US 75 Expressway project in Grayson County, south of Sherman.[537] These three extant bridges cross Choctaw Creek (TxDOT Structure Nos.: 01-092-0-0047-03-154, 01-092-0-0047-03-155, and 01-092-0-0047-03-156).

[536] "Interstate 35 Section Opens," *Texas Highways* 9, no. 6 (June 1962): 6-7.
[537] C. C. Cagle, "Prestressed Concrete Panel Bridge," *Texas Highways* 9, no. 12 (December 1962): 18.

*Prestressed Concrete Beam and Girder*

Prestressed concrete beams grew in popularity in Texas in the late 1950s and early 1960s, and several hundred examples completed by the THD during this period remain.[538] Subsets of prestressed concrete beams identified in TxDOT's BID are discussed below. Types included the box girder, I-beam/girder, pan-formed girder, and slab.

*Prestressed Concrete Box Girders*

Prestressed concrete box girders are precast, box-shaped girders that are strengthened with pre-tensioned steel wires. From their initial use in the 1950s until 1965, the majority of these girders were placed in a row with individual boxes directly adjacent to each other. The BID identifies these as multiple prestressed concrete box girders. A pedestrian bridge over Memorial Drive in Houston (TxDOT Structure No.: 12-102-0-B441-85-016) is the only prestressed concrete box girder bridge built during the subject period that uses a single girder.

Prestressed concrete box girders were first used in the state by a local contractor in Victoria named Herman Baass. In an interview with Baass and his son Allen, Baass revealed that he began experimenting with prestressed concrete in the early 1950s when his biggest competitor, Texas Concrete, began fabricating prestressed concrete I-beams. At the time Baass, who was not a trained engineer, worked for local county governments. According to Baass, contractors could choose the bridge type that was used at the crossing.[539] Baass indicated that he began building prestressed concrete box girders because he could place the girders directly adjacent to each other and tie them together. This created an instant wearing surface, and depending on the location an asphalt or concrete deck did not have to be built atop the box girders. This produced instant cost and time savings to the county governments, and Baass built several of these bridges throughout eastern Texas.

The THD did not build prestressed concrete box beams until the late 1960s.[540] Hearing of Baass' successful prestressed concrete box girder design in the Gulf Coast region, the THD adopted the premise of his design as a standard and as an alternative to pan-formed girders that were performing poorly in salty environments.[541] Although the THD did not have standard plans for these bridges until the late 1960s, the BPR had standard plans for these bridges in 1956.

*Prestressed Concrete Girder*

Developments in prestressed concrete during this period included the use of precast concrete beams. Prestressed concrete beams consist of tensioned reinforcing rods that are covered by high-strength concrete. Once the concrete has cured, the forms are removed, allowing the tensioning in the reinforcement to be transferred to the concrete. This creates a positive camber (or upward curve) and increases the compressive strength of the concrete. The prestressing allows the beam to withstand greater loads without, or with very little, deflection. To provide an adequate anchorage bearing for the pre-tensioned or post-tensioned steel at the end of each beam, fabricators

---

[538] Texas Department of Transportation, *Bridge Inspection Database*, n.p.
[539] Baass, Interview with Mead & Hunt, Inc. and TxDOT Bridge Division, Texas Department of Transportation.
[540] Texas State Department of Highways and Public Transportation, *Bridge Design Guide*, First ed. ([Austin, Texas]: [Texas State Department of Highways and Public Transportation], 1990), 5-39.
[541] Charlie Covill, Interview by Mead & Hunt, Inc. and TxDOT Bridge Division, Texas Department of Transportation, digital audio and video recordings, Travel Division Studio, Riverside Campus Building 150, Austin, Texas, August 29, 2006.

increased the beam web width, which resembled a block. These features, called "end blocks," are present on prestressed concrete beams built during the subject period.

In the 1950s, most states were constructing bridges that used simply supported beams. The use of prestressed concrete beams for continuous construction was limited to only a few states, and very few continuous prestressed concrete beams were built on Texas roads during the 1950s or early 1960s.[542] The THD developed a group of standard precast, pre-tensioned concrete beams in 1956 and 1957. According to a 1986 presentation given by former THD bridge engineer Bob Reed, in the mid-1950s, THD Bridge Division engineer James Graves was tasked with researching prestressed concrete for the THD. After gathering information from highway agencies in California, Florida, and Tennessee, Graves decided that the prestressed concrete beams were worth using in Texas. According to Charles Walker, a retiree of the TxDOT Bridge Division, in 1956, Graves designed a pre-tensioned, precast, prestressed concrete beam bridge for FM 237 at Coleto Creek in Victoria County (TxDOT Structure No.: 13-235-0-0941-04-007). As a result, in 1956, he created the THD prestressed concrete beam standard shapes—the A, B, and C beams.[543] These standards were developed independent of the AASHO standard beam shapes noted above.[544] The THD's initial designs were successful as the standards and these beams have changed very little since the 1950s.[545] In fact, the Texas A beam was adopted by AASHO as the AASHO Type I beam.

Prestressed concrete beams were used for medium-span stream crossings and grade separations in place of steel beam bridges, which had slow delivery periods and were very expensive.[546] Like other state highway departments, the THD soon found that precast, pre-tensioned concrete beams proved to be the most economical bridge type for medium-span length bridges.[547] In 1962, AASHO and the PCI published recommendations for standard shapes of prestressed concrete I-beams, piling, slabs, and box beams. By the early 1960s, prestressed concrete girders were found largely to be economical and practical for span ranges of 40 to 100 feet, but were generally not cost competitive for spans below 30 feet.[548] With advances in technology, use of precast, prestressed concrete became more common in Texas and the nation.

Although rare, cantilevered prestressed concrete girder bridges were built during the subject period. These bridges have short superstructure members that are tied into the pier caps and extend out over the pier, and the ends of the specially designed prestressed concrete girders rest on the cantilevered extensions. By cantilevering the prestressed

---

[542] Based on the article, Florida is assumed to be one of the states that were using precast, prestressed concrete beams of continuous construction. The other states are not identified. W. E. Dean, "Continuous and Cantilever Bridges with Precast-Prestressed Concrete Beams," in *Proceedings Convention Committee Meeting Papers, New York, New York, October 5-7, 1965* (Washington, D.C.: American Association of State Highway Officials, General Offices, 1965), 267-268.
[543] Robert L. Reed, n.p.
[544] The May 2004 *Slab, Beam & Girder Bridges in Oregon: Historic Context Statement* notes that AASHO developed its first prestressed concrete beam standard in 1956. Mead & Hunt's research in Nebraska points to that state issuing standards for prestressed concrete beams in 1958. Ohio's 2004 historic context for 1951-1961 bridges states that Ohio did not issue standards for prestressed concrete beams until 1960. With THD engineers reviewing information from California, Florida, and Tennessee regarding their use of prestressed concrete, it is assumed that these states may have pre-1956 standards. Therefore, it appears that the THD's development of prestressed concrete beam standards is neither particularly early nor late compared with other states and AASHO.
[545] Texas State Department of Highways and Public Transportation, *Bridge Design Guide*, 5-69.
[546] Texas Department of Transportation, *Bridge Design Manual*, 6-18.
[547] Texas Department of Transportation, *Bridge Design Manual*, 1-4.
[548] Norman L. Scott, "Suggestions for Reducing Costs in Prestressed Concrete Bridges," in *Highway Research Record Number 34: Bridge Design, Analysis, and Costs* (Washington, D.C.: Highway Research Board, 1963), 117.

concrete girders, the engineers were able to maximize the span length of the structure while maintaining the cost savings of using a prestressed concrete beam.

Although several small bridge projects in Texas used prestressed concrete in the early and mid-1950s, the first major project in the state that employed prestressed concrete was the Corpus Christi Harbor Bridge (1959) constructed in Nueces County (TxDOT Structure No.: 16-178-0-0101-06-041). Special precast and post-tensioned concrete beam shapes were used for this extant bridge's 2,000 feet of 40-and 60-foot prestressed concrete I-beam approach spans.[549] Special shapes were also developed for the Buena Vista and Commerce Street overpasses in San Antonio (TxDOT Structure Nos.: 15-015-0-B046-95-002 and 15-015-0-B075-10-004, respectively). Constructed in 1957, the bridges had parallel 1,600-foot spans carrying city streets over a series of railroad tracks.

*Prestressed Concrete Pan-formed Girder*

Two types of prestressed concrete pan-formed girder bridges were built during the subject period. The first type resembles the repeating arch-shaped pan-formed girder that is usually strengthened with steel reinforcing bars. The prestressed pan-formed concrete girder was the first prestressed concrete bridge type used in Texas. Since the agency had been using the pan-formed girder design for several years, they tried their first attempt at a prestressed concrete bridge with a pan-formed shape. As noted above, the THD first built a prestressed concrete pan-formed girder on the SH 60 Bridge in 195, across the San Bernard River between Austin and Wharton counties (TxDOT Structure No.:13-008-0-0240-01-008).[550]

The second type of prestressed pan-formed girder bridge is a post-tensioned, precast bridge that had a slab and the vertical girders integrated together. Although formed in a steel form, these prestressed bridges do not have the repeating-arch shape at the top of the girders as those noted above. A bridge of this type is the extant Pine Street Overpass (1956) on a section of the Dallas Expressway (TxDOT Structure No.: 18-057-0-0092-01-053). It contains three 58-foot simply supported, post-tensioned concrete pan-formed spans. Another example of the use of this type is the extant Lavaca Bay Causeway Bridge (1959) on SH 35 in Calhoun County (TxDOT Structure No.: 13-029-0-0179-10-061).[551] As the longest bridge built in Texas during the subject period, most of the bridge is comprised of these prestressed concrete pan-formed girders. This type was ideal for the crossing since the slab and girder were integrated together and an instant working surface was available once they were laid in place. This bridge used so much prestressed concrete that a plant was built adjacent to the bridge just to build the approach spans for the structure.

A continuous post-tensioned bridge of this type was constructed in the Waco District during the subject period, but the design was not used again due to construction problems.[552] The status of this bridge is unclear because its location was not provided in research source materials. Although the THD used the pan-formed girder to build its first prestressed concrete bridge, the type was very rarely employed.

---

[549] Texas Department of Transportation, *Bridge Design Manual*, 7-72.
[550] Texas Department of Transportation, *Bridge Design Manual*, 7-44.
[551] Texas Department of Transportation, *Bridge Design Manual*, 7-43.
[552] Texas Department of Transportation, *Bridge Design Manual*, 7-44.

*Prestressed Concrete Slab*

Prestressed concrete slabs are cast-in-place post-tensioned bridges, few of which were built during the 1950s or 1960s. These complex bridges were built in rare cases where structure depth was critical or where aesthetic design was a consideration.[553] TxDOT's *Bridge Design Manual* notes that this bridge type was rarely used and that several problems were experienced when constructing the bridge.[554] Only one prestressed concrete slab bridge is known to be extant, and it is a continuous prestressed concrete slab located in the San Antonio District. It carries West Martin Street over Alazan Creek (TxDOT Structure No.: 15-015-0-B219-85-011).

*Other Prestressed Concrete Bridge Types*

The following bridge types are coded as "other prestressed concrete" in TxDOT's BID. The following text includes information compiled during bridge inspection review and field investigations completed for TxDOT's 2009 inventory of bridges built between 1945 and 1965.

*Prestressed Concrete Channel Beam*

Like the reinforced concrete channel beam, prestressed concrete channel beams are precast members that have a flattened inverted U-shaped beam. The majority of the nine extant prestressed concrete channel beams were built by the City of El Paso. The earliest bridge of this type was built in 1960. Main span lengths for the type range from 29 to 65 feet. Of the nine extant Texas bridges of this type, only one has multiple spans, and its structure length is 309 feet.

*Prestressed Concrete Tee Beam*

Although the THD developed standard drawings for prestressed concrete Tee beam superstructures, this type was very rarely used. It represented an advance in materials from the reinforced concrete Tee beam developed in the 1910s. The prestressed concrete Tee beam design, referred to as the Lin Tee, was available in Texas in the early 1960s. The Lin Tee was introduced in 1962 and named after its inventor, T.Y. Lin, a former professor of Civil Engineering at the University of California at Berkley, who is considered a global leader in the use of prestressed concrete. The El Paso District developed standard designs and drawings for a precast, prestressed single Tee beam bridge. During the 1960s, the El Paso District built some of these bridges as pedestrian structures in the city of El Paso. They also used this design for the twin bridges on IH 10 near Van Horn in 1968.[555] One prestressed concrete Tee beam was built in 1965 by the City of Wichita Falls (TxDOT Structure No.: 03-039-0-3429-01-001). It carries FM 2606 over Lake Arrowhead Spillway in Clay County. The THD Bridge Division developed standard drawings for a prestressed concrete Tee beam in 1969 that were never used.[556]

A 2009 review of bridge inspection files and site visits revealed that there were five extant prestressed concrete Tee beam bridges, with the earliest example built in 1960. This bridge type's main spans range from 37 to 74 feet long, and total structure length ranges from 129 feet to 1,595 feet.

---

[553] Texas Department of Transportation, *Bridge Design Manual*, 7-40.
[554] Texas Department of Transportation, *Bridge Design Manual*, 7-40.
[555] Texas Department of Transportation, *Bridge Design Manual*, 7-65.
[556] Texas Department of Transportation, *Bridge Design Manual*, 7-65.

**Postwar Steel Bridges**

Steel was used less often than reinforced concrete and prestressed concrete between 1945 and 1965. In the late 1940s, following World War II and during the Korean War in the early 1950s, steel was more expensive than concrete due to material shortages. Even though steel prices began to fall in the late 1950s, prestressed concrete was the preferred bridge-building material when mid-range spans were needed. Although used less than in the pre-World War II era, steel was still used on some Texas bridges because the increased use of welding after World War II allowed the design of more economical and lighter steel superstructures. Additionally, steel was often used to build the state's longest bridges, as well as interchange structures. A 2009 bridge inspection database review showed that steel-superstructure bridges comprised 25 percent of the extant bridges built between 1945 and 1965.[557]

After World War II, one of the major improvements to steel was the development of weldable low-alloy steel with a higher yield point, which raised the level at which steel incurred permanent deformation from stresses.[558] During the subject period, steel companies introduced proprietary low-alloy steels of higher strength than mild steel. These high-strength products, including Bethlehem Steel's Mayari R and U.S. Steel's Cor-Ten B, allowed for a reduction in steel beam depths, reducing the amount of steel required for a comparable-strength beam. Additionally, Mayari R and Cor-Ten B were corrosion-resistant, high-tensile weldable steels that required no painting during a bridge's lifetime because the steel rusted in a consistent and predictable way. Because of their high-strength and corrosion-resistant properties, these low-alloy products offered cost savings in materials and maintenance.[559] Structural low-alloy steel was addressed by AASHO standard specifications as early as 1949, with design requirements added for high-strength low-alloy steels added in 1969.[560]

***Postwar Steel Bridges:*** Steel Beam (including simple, continuous, and cantilevered with suspended span)

Between 1945 and 1965 the well-established steel I-beam bridge was utilized by city and county governments in its simple-span form, while the THD used the newly-developed all-welded continuous-span steel I-beams for long spans, interchanges, and skewed structures. Steel I-beam bridges take their name from the structural elements of which they are composed. An I-beam is a joist or girder fabricated of rolled steel that has short flanges (or protruding edges) and a cross section formed like the letter "I". A steel I-beam bridge may also be referred to as a steel stringer. It was one of the leading bridge types in Texas during the 1940s through 1960s, and many are extant, including simple spans and continuous and cantilevered variants.

By 1945, steel I-beam bridges were a well-established design with which most bridge engineers and fabricators were familiar, but in the late 1940s long-time THD bridge engineer Percy Pennybacker pushed to dramatically

---

[557] Texas Department of Transportation, *Bridge Inspection Database*, n.p.
[558] A. P. Fisher, "Letter to Clayton Anderson (St. Paul Foundry and Manufacturing Co.)," 21 March 1967, n.p; Albert E. Hall, "I. H. 45 Soars Through the Air," *Texas Highways* 12, no. 6 (June 1965): n.p; John Fisher et al. "Steel Bridges in the United States: Past, Present, and Future," *Transportation Research Circular* E-C104, (September 2006): 36.
[559] O. A. Kerensky, "Critical Survey of Bridge Design," *Engineering* (11 September 1959): 181-182; "Bridge Evolution: Many Factors at Work in Billion-A-Year Program," *Roads and Streets* 111, no. 1 (January 1968): 203.
[560] American Association of State Highway Officials, *Standard Specifications for Highway Bridges*, 5th ed. (Washington, D.C.: American Association of State Highway Officials, 1949a), xix; American Association of State Highway Officials, *Standard Specifications for Highway Bridges*, 10th ed. (Washington, D.C.: Association General Offices, 1969c), xxviii; American Association of State Highway Officials, *Standard Specifications for Highway Bridges*, xxvii.

change the way steel I-beams were used.[561] He promoted and initiated the replacement of riveted steel construction with all-welded construction, which allowed for simpler splicing of continuous units. With Pennybacker promoting welded bridge construction, the THD nearly abandoned the use of simple steel I-beam bridges in favor of continuous steel I-beam spans by the 1950s.[562] In the 1950s the THD used continuous steel I-beam bridges extensively, finding this type to be most economical for spans that ranged from 40 to 90 feet.[563] These continuous bridges were used widely on US and state highways, representing 19 and 13 percent of the extant structures built between 1945 and 1965 on these routes, respectively.[564] As a result, the continuous steel I-beam bridge was used when long spans were needed, and often utilized in interchanges for these same reasons.

Although the THD built few simple steel I-beams, county governments and their contractors had been constructing simple steel I-beam bridges for several decades as these easy-to-construct bridges did not require skilled workers. As a result, these bridges remained popular with county governments, and they were used on Texas county roads in significant numbers. As of 2009, simple steel I-beams constituted more than 25 percent of the extant county bridges built between 1945 and 1965.[565]

In 2009, steel I-beam bridges made up 22 percent of the extant structures built in Texas between 1945 and 1965. The 2009 analysis of TxDOT's BID showed that steel I-beams are not as evenly dispersed through the state as pan-formed girders or concrete slabs. Of the extant bridges built during this period, the range of their distribution extends from 2 percent of the Pharr District's bridges to 54 percent in the Lubbock District's bridges. Lubbock's concentration of steel bridges may be skewed because it has only 26 bridges built between 1945 and 1965. Yet the San Antonio District exhibits similar proportions, with nearly 43 percent of its 472 bridges built between 1945 and 1965 being steel I-beams.[566] Former San Antonio District bridge engineer Leroy Surtees recalled in an interview that a San Antonio Urban Expressway design engineer named Fuller was from the East Coast and was familiar with steel I-beam bridges.[567] Surtees recalled that Fuller promoted steel I-beam use over other bridge types.[568] Perhaps Fuller's knowledge of steel construction factored into the San Antonio District's greater use of steel beam bridges over cheaper prestressed concrete structures.

Although popular prior to and during the late 1940s and 1950s, long delivery times, high steel prices, and the development of prestressed concrete beams in the mid-1950s, ended the popularity of the steel I-beam bridge in the early 1960s.[569] Regardless, hundreds of steel I-beam bridges are extant on Texas roads.

As mentioned above, another variation of the steel I-beam bridge is the cantilevered steel I-beam with suspended span. This bridge type, which had been used in Texas since the 1930s, allowed for longer interior spans than continuous steel I-beams. Although first applied to truss construction, cantilever support methods were applied to other bridge types during the subject period, including concrete girders and steel I-beams. Not only do cantilevered

---

[561] Farland C. Bundy, Interview by Mead & Hunt, Inc. and TxDOT Bridge Division, Texas Department of Transportation, digital audio and visual recordings, Travel Division Studio, Riverside Campus Building 150, Austin, Texas, July 14, 2006.
[562] Texas Department of Transportation, *Bridge Design Manual*, Section 7-108.
[563] Farland C. Bundy, "Design of Welded Bridge Structures," *Texas Highways* 2, no. 1 (November 1954): 132.
[564] Texas Department of Transportation, *Bridge Inspection Database*, n.p.
[565] Texas Department of Transportation, *Bridge Inspection Database*, n.p.
[566] Texas Department of Transportation, *Bridge Inspection Database*, n.p.
[567] Surtees, Telephone interview by Mead & Hunt, Inc.
[568] Surtees, Telephone interview by Mead & Hunt, Inc.
[569] Texas Department of Transportation, *Bridge Design Manual*, 7-108.

spans provide for longer span lengths, but they also can be erected without falsework and without obstructing the channel. These cantilevered steel beams with suspended spans also have interior spans that are suspended from anchored spans that extend over substructure supports. A pin and hanger structural connection joins the suspended span to an anchored span. Due to their complexity, these structures are often an expensive bridge type that was rarely built between 1945 and 1965. Few of these bridges are extant in Texas.

***Postwar Steel Bridges:*** *Steel Plate Girder (including simple, continuous, and cantilevered with suspended span)*

Steel plate girder bridges were not widely used in Texas prior to 1945, although standard plans were available by 1910 for these bridges nationally. The THD did not have standard plans for these bridges; however, they were used sparingly and they were generally employed for bridges that required long span lengths. A plate girder, or fabricated steel girder, consists of built-up riveted or welded plates with a deep web fabricated to form a section that looks like the letter "I." The web lies between the top and bottom flanges, which are fabricated by plate steel placed horizontally over the webs of the girder. With their deep web, plate girders are able to span beyond the length of a standard steel I-beam. Steel I-beams are limited to standard sizes due to physical and economic limitations in the steel mills. A plate girder, on the other hand, can be fabricated to any required depth. Typical span lengths between 1945 and 1965 were 30 to 100 feet in Texas.[570]

In Texas, fabricated steel was less available than concrete and, as a result, more expensive. The type's relatively high cost, and the THD's preference for lighter spans, resulted in plate girders being used only in special situations in the state.[571] Approximately 250 known examples remain in Texas that date from the 1945-1965 period. Two basic forms of plate girder bridges built during this time period are plate girders with floor beam system, which were riveted structures, and a multi-girder system with several parallel girders that do not require floor beams and had welded connections. Although plate girders with floor systems outnumbered the multiple plate girder bridges by 4 to 1 during this period, the multiple plate girder bridges were more economical than girder bridges with floor systems once welded connections were established.

Another variation of steel plate girder bridges is the variable depth plate girder. Variable depth steel plate girders are multiple plate girder bridges that do not have floor systems. As with variable depth concrete slabs and variable depth concrete girder bridges, when the superstructure members are very deep over the piers and taper to a thinner depth at mid-span, longer spans can be achieved. Like other variable depth bridges, they are generally built in continuous span configurations. Examples of variable depth steel plate girder bridges are the Buffalo Bayou Twin Bridges (1956) on US 90-A in Houston, Harris County (TxDOT Structure Nos.: 12-102-0-0027-10-062 and 12-102-0-0027-10-063).

Steel plate girders with cantilevered, suspended spans are another variation of steel plate girders. Unlike other cantilevered bridges that have a span that projects out from a pier or abutment and is supported at one end by an anchor span, these bridges have a span that is suspended between two cantilevered spans. These bridges are difficult to design and construct, thus making them rare nationally and in Texas. Only one bridge of this type is known to have been built in Texas between 1945 and 1965—the extant US 90 at Devils River bridge (TxDOT Structure No.: 22-233-0-0022-09-070).

---

[570] Texas Department of Transportation, *Bridge Design Manual*, 7-112.
[571] Texas Department of Transportation, "Texas Historic Bridge Inventory: Survey of Non-Truss Structures," 22.

*Postwar Steel Bridges: Movable Bridge Types*

There are three types of movable bridges: horizontal swing, vertical lift, and bascule. Examples of each type were built in the mid-twentieth-century, and extant examples of each type were identified in TxDOT's 2009 inventory of bridges constructed between 1945 and 1965. Although movable bridges were used in Texas since the nineteenth century, a limited number of movable bridges were built in the state after World War II, as causeways and elevated roadways were preferred since they were easier and cheaper to build and maintain.

Introduced in the U.S. by 1870, horizontal swing bridges are the simplest and earliest movable bridge types; however, they are slow to open and require the placement of a pier in the middle of the waterway.[572] The swing bridge employs a superstructure that, anchored to a central pier, rotates 90 degrees to allow vessels to pass through. The bridge could move on a central pivot or pin (known as a center-bearing swing span) or a circular drum with rollers (known as a rim-bearing swing span).[573] When the swing bridge is open, each half is cantilevered over the water. Two channels are cleared for a ship to pass. As ship traffic increased, this bridge type fell out of favor due to the amount of space it occupied in the channel. As noted earlier, swing bridges largely gave way to bascule and lift bridges in the early twentieth century. However, two known horizontal swing bridges were constructed in Texas after World War II. One of these was built in 1958 and carried SH 82 over the Sabine River in Jefferson County (TxDOT Structure No.: 20-124-0-2367-01-002; removed from service). It featured a Pennsylvania truss swing span on a central pivot.[574] The other bridge was built in 1960 on East Round Bunch Road over Cow Bayou in Orange County (TxDOT Structure No.: 20-181-0-AA26-90-006). It has a rim-bearing 180-foot long plate girder swing span.

Introduced in the 1890s, vertical lift bridges typically use beams or trusses to span between two towers. The bridge deck is raised using cables attached to rotating drums in the towers. The deck maintains its horizontal position as cables raise the deck vertically, creating a channel for ships to pass through. The bridge is then lowered to allow vehicles to cross the waterway. Although two known examples of lift bridges were constructed after 1945, only one was identified as extant in 2009—the FM 106 bridge over the Arroyo Colorado in Cameron County (TxDOT Structure No.: 21-031-0-0630-02-003). The bridge, which was built in 1953, has riveted connections, is 382 feet long, and has a 145-foot movable span.

Bascule bridges, introduced in the 1890s, utilize a beam or truss deck that can be raised to an inclined or vertical position. To clear the waterway, the deck is either raised in a vertical plane or rolls back on a segmental rack. Bascule bridges can be single-leaved, lifting the entire bridge to one side, or double-leaved, in which the bridge separates at the center. Types of bascule bridges include simple trunnion, Strauss trunnion, and Scherzer-type rolling lift. Two known examples of bascule bridges are simple trunnion bascule bridges and were constructed after World War II: FM 521 at the Colorado River in Matagorda County (TxDOT Structure No.: 13-158-0-0846-03-009) and Seawolf Parkway at Pelican Island Channel in Galveston County (TxDOT Structure No.: 12-085-0-B007-90-001). During a 2009 site visit, the FM 521 bridge was being dismantled and had been replaced by another structure. The Pelican Island Bridge, however, was extant in 2009.

---

[572] Parsons Brinckerhoff and Engineering and Industrial Heritage, *A Context for Common Historic Bridge Types, NCHRP Project 25-25, Task 15*, 3-115.
[573] Parsons Brinckerhoff and Engineering and Industrial Heritage, *A Context for Common Historic Bridge Types, NCHRP Project 25-25, Task 15*, 3-115, 3-118.
[574] Texas Department of Transportation, "Texas Historic Bridge Inventory: Survey of Non-Truss Structures," 42-43.

*Postwar Steel Bridges: Steel Arch*

Although used in the U.S. since the 1860s, the THD constructed few steel arch bridges, with only one known steel arch built in Texas between 1945 and 1965. This bridge carries Dallas' Hampton Road over IH 30 (TxDOT Structure No.: 18-057-0-1068-04-109). Built in 1957, this bridge features a 192-foot, two-hinged arch that was the first example of an all-welded, box girder type arch rib in the U.S. The two-hinged arch pins the hinges at the base of the arch to limit rotational effects between the structure and the foundation. The two-hinge system also controls abutment movement and allows use of lighter construction materials. The Hampton Road Bridge won an American Institute of Steel Construction award in 1957 for its unique construction. Since steel arches were difficult to fabricate and to erect, these bridges are very rare in Texas and nationwide. Although metal multi-plate arches or pipes are coded in Texas's BID as metal arch bridges, these bridges are bridge-class culverts and do not have the complex design illustrated in the steel arch described above.

*Postwar Steel Bridges: Steel Truss*

The use of steel truss bridges for a wide variety of crossings was common nationally and in Texas prior to World War II but decreased dramatically after the war. As the steel truss was heading into obsolescence for small and medium spans in the 1950s and 1960s, existing trusses, built before World War II, were being systematically replaced by non-truss types. Due to the expense of their steel members, truss bridges were rarely constructed after 1945, and were reserved for use only where long spans were required.

When exceptionally long spans were required, continuous or cantilevered designs were employed in the late 1940s and 1950s. Continuous truss designs are used on through or deck trusses. In these bridges, the web configuration continues uninterrupted over one or more piers, making the continuous unit work as one rigid member.[575] As such, continuous trusses require more design considerations and are more complex structures than multi-span bridges. Cantilevered truss bridges are usually two through trusses that project out and carry a suspended central truss span. These bridges were ideal for navigable waterways where piers in the water would obstruct ship traffic below the bridge. An example of the exceptional span length that can be achieved with continuous truss bridge design is the Pecos River Bridge on US 90 west of Del Rio in Val Verde County (TxDOT Structure No.: 22-233-0-0022-06-068). The 1,310-foot continuous deck truss was built in 1957 and has a main span length of 415 feet. Similarly, cantilevered trusses also allow for exceptional span lengths, as is seen with the Corpus Christi Harbor Bridge (1959). This bridge, which carries US 181 over the Corpus Christi Ship Channel in Nueces County, is a cantilevered through truss with suspended tied arch that uses trusses for its arch ribs (TxDOT Structure No.: 16-178-0-0101-06-041).[576]

Three truss configurations built between 1945 and 1965 were identified as extant on Texas roadways in 2009: Warren, Parker, and Camelback trusses. Warren trusses were used in Texas since the early 1900s, and as noted earlier, the THD developed standard designs for these bridges by 1918.[577] Although popular in Texas in the early twentieth century, they were constructed in limited numbers between 1945 and 1965. The span of this truss type

[575] Stocklin, "Historic Bridges of Texas, 1866-1945," *National Register of Historic Places Multiple Property Documentation Form*, F-8, E-40.
[576] Stocklin, "Historic Bridges of Texas, 1866-1945," *National Register of Historic Places Multiple Property Documentation Form*, E-29, E-43.
[577] Stocklin, "Historic Bridges of Texas, 1866-1945," *National Register of Historic Places Multiple Property Documentation Form*, E-29.

generally ranged from 50 to 400 feet; however, during the post-World War II period, Warren trusses were built as relatively short bridges. Of the Warren trusses extant in 2009, the longest span measured 114 feet.

Another type of extant truss in Texas is the Parker truss. The THD had developed standard designs for Parker trusses by 1920, and it soon became the dominant type for long spans in Texas.[578] Parker truss bridges spanned between 100 to 300 feet. The THD continued to build Parker through truss spans through the late 1940s for mid-to long-range spans, although only one Parker through truss built during the subject period is extant.[579] It carries Business Route 71 over the Colorado River in Columbus (TxDOT Structure No.: 13-045-0-0266-08-043). This 1949 bridge has an overall structure length of 1,042 feet and three Parker through truss spans, with the longest main span measuring 225 feet. As-built construction plans show that this bridge replaced an existing truss bridge, and the Parker truss was chosen due to hydraulic issues.

The THD also constructed a few examples of the Camelback truss bridges between 1945 and 1965. The Camelback truss, introduced in the late 1800s, is a Parker truss with a polygonal top chord that has exactly five slopes. The Camelback truss bridge was used for spans between 100 and 300 feet. Two extant Camelback trusses in Texas were built between 1945 and 1965: South University Drive at the Clear Fork of the Trinity River in Fort Worth (TxDOT Structure No.: 02-220-0-ZU40-00-005) and Craft Road at a Draw in Gregg County (TxDOT Structure No.: 01-092-0-AA01-09-002). These bridges have relatively short maximum span lengths at 102 and 82 feet, respectively.

*Other Steel Bridge Types*

The following bridge types are coded as “other steel” in TxDOT’s BID. The following text includes information compiled during bridge inspection review and field investigations completed for TxDOT’s 2009 inventory of bridges built between 1945 and 1965.

*Other Steel Bridge Types: Railroad Flat Fars*

Eight extant bridges built between 1945 and 1965 have superstructures that are recycled railroad flat cars. The railroad cars are simply placed upon the substructure and a deck is placed on the cars. The earliest extant railroad car built during this period is dated 1951. These bridges’ main spans range from 38 to 50 feet long. Two bridges have more than one span, each with a maximum overall structure length of 131 feet.

*Other Steel Bridge Types: Truss Girders*

Little information is known about truss girder bridges, which are only known to have been built during this period in the Abilene District only. These bridges consist of multiple girders that are laid longitudinally under the deck. These girders are built up members with two steel members that are connected with welded, laced steel angles. Three extant bridges of this type were built between 1945 and 1965, although one was widened with new members

[578] Stocklin, "Historic Bridges of Texas, 1866-1945," *National Register of Historic Places Multiple Property Documentation Form*, E-29, E-30.
[579] Stocklin, "Historic Bridges of Texas, 1866-1945," *National Register of Historic Places Multiple Property Documentation Form*, F8.

in 1959. The widened bridge was built in 1945 and the other two bridges were built in 1951. All three bridges have more than one span, have a main span length of 40 feet, and the maximum overall span length is 140 feet.

*Timber Bridges*

In 2009, timber bridges comprised only four percent of the extant structures constructed between 1945 and 1965.[580] Timber was used for the earliest American bridges and continued to be used in certain locations due to its availability and low cost. An exposed wood bridge may be expected to last 20 to 30 years if it is not damaged by fire or a flood. Its impermanence was an accepted fact of bridge-building practice in early America. Wood fell out of favor for highway bridge construction as transportation loads increased and new materials became economical. In Texas, the transition from timber to steel was slower than in other parts of the country due to the availability of timber and the extra cost to ship steel beams to Texas. Only a small percentage of the THD's expenditures were spent on timber structures after the early 1950s.

Twentieth-century innovations improved the functionality of timber construction and design and included creosote-treated timber and glue-laminated timber, known as Glulam. Creosote is a wood preservative that is obtained by the distillation of coal tar. A light treatment of creosote could approximately double the life of an untreated timber bridge by preventing decay and termite destruction. Glulam structures were experimented with nationally in the 1940s. Glulam is comprised of lumber layers that are bonded with a waterproof structural adhesive. Glulam was used nationally for girder and slab bridges.[581] AASHO standard specifications included a section on creosote and preservation treatments for timber structures in 1949, and the section was revised in 1957.[582]

[580] Texas Department of Transportation, *Bridge Inspection Database*, n.p.
[581] Sheila R. Duwadi and Michael A. Ritter, "Timber Bridges in the United States," *Public Roads* 60, no. 3 (winter 1997): 5.
[582] American Association of State Highway Officials, *Standard Specifications for Highway Bridges*, xi; American Association of State Highway Officials, *Standard Specifications for Highway Bridges* (Washington, D.C.: American Association of State Highway Officials, 1957b), xxii.

Timber stringer bridges were simple structures that represented an established bridge type well before the mid-twentieth century. The THD had developed standard designs for short-span timber stringers by 1920. Timber stringers were used extensively in east Texas, where timber was available and economical construction was especially important. However, the THD's use of timber stringers declined after 1950 as the transportation loads increased and new materials became economical. Furthermore, timber beams could only span about 20 feet and an exposed timber bridge could be expected to last 20 to 30 years, if it was not damaged by fire or flood. Since timber bridges do not generally require complex engineering analysis, these structures were occasionally used by county governments in the post-World War II period.

*Conclusion*

Between 1945 and 1965, the THD's implemented transportation plan included both established bridge designs and new types, based on the research and technological advancements of the period. Several established types, including arch, truss, and movable bridge, were used sparingly in Texas during the period; however, other established types such as steel I-beam and concrete slab were used extensively by the THD. Through continuous research and experimentation, new types were introduced throughout the post-World War II period. Types such as pan-formed concrete girder and prestressed concrete girder provided economic alternatives to more established types. These two types, in particular, were used extensively in Texas in the late 1940s, 1950s, and 1960s. More than 800 prestressed concrete girders and 2,000 pan-formed concrete girders constructed between 1945 and 1965 remained extant in the state in 2009. Through ongoing research and experimentation, the THD adroitly adapted established designs and generated new bridge types in an effort to provide Texans with economic, efficient, and safe bridges. The next section will examine, in detail, research efforts that enabled and enhanced the THD's

**Postwar Bridge-Related Research**

Innovations in bridge design and construction impact every era in bridge design; this is true of the 1945 to 1965 period as well. The THD's post-World War II bridge-building efforts included experimentation and research to identify technical advances and new materials that could meet the demand for a large number of structures and be applied to the design of efficient and economic bridges. One motivation was to apply new technology and materials developed for the World War II effort to increase the speed and efficiency of postwar bridge-building. Another motivation was to exploit new materials since the steel supply had been depleted during the war and the available stock largely applied to other building projects after the war. The results of these efforts were the increased use of concrete and the more efficient use of steel. With the new types of bridge materials and construction techniques, the THD undertook a significant amount of research during the subject period. This section presents an overview of the technological advances and design solutions implemented by the THD involving superstructure and substructure design and construction methods.

Additionally, this section discusses the research that the THD directly conducted, as well as research conducted in conjunction with educational institutions in the state. Prior to 1945, the THD had established working relationships with both Texas A&M University (originally A&M College of Texas) and UT-Austin, and joint research was conducted through the schools' engineering programs. These institutions conducted research on a variety of topics that assisted the THD with its mission. In 1948, the THD established its cooperative research program that combined the needs of the THD with the interdisciplinary engineering studies at the universities. Both Texas A&M's Texas Transportation Institute (TTI) and UT-Austin's Center for Highway Research (currently the Center

for Transportation Research) were established and participated in the cooperative research program.[583] The facilities' research focused on methods and economics of bridge construction, material innovations, and safety and use of facilities. Many of the research efforts and projects undertaken by the THD and institutions for the THD between 1945 and 1965 were highlighted in national journals and THD publications.

*Texas Highway Department Research and Design Activities*

In the post-World War II period, the THD developed innovations in design, material use, and construction methods that assisted its bridge-building efforts. Some advances and design solutions received national recognition as they were incorporated into standard specifications developed by AASHO and the BPR.[584] A likely reason that Texas was a leader in technical bridge innovations was the attitude fostered by Dewitt C. Greer, the state highway engineer. Many interviewees noted that their supervisors encouraged staff to pursue alternative designs. Bridge engineers who were willing to modify their designs and try different construction techniques helped to transform the bridges of the time. This section will discuss the new innovations and design practices that were implemented in Texas and had a major impact on bridge design during this period, such as all-welded construction, the use of high-tensile bolts, and the development and use of neoprene bearing plates. Also addressed in this section are the THD's other research projects, including studies to alleviate icing on bridges, use of continuous reinforced concrete pavement, and development of neoprene bearing plates.

*Welding*

After World War II, the THD and state highway departments across the nation embraced arc-welding over riveting for fabricating built-up steel girders. Welding meant a reduction in the size and weight of structural members, which allowed a lighter superstructure, reduced fabrication time and expense, and smoother surfaces with lower maintenance costs and less corrosion. It also reduced the time to prepare bridge plans by limiting the number of detailed drawings.[585] Compared with riveting, welding typically resulted in a 15-to 20-percent savings in steel weight by making possible edge-to-edge joints without flange angles, splice plates, and rivets.[586]

The American Welding Society (AWS), a national professional organization, first published specifications for bridge-construction welding in 1936. Welding was first used in the 1930s to connect metal bridges and was readily accepted as a connection method in the 1940s; it became common practice by the 1950s and later. In the early 1930s, all-welded highway bridges were constructed in France and Germany. By 1935, a few all-welded structures were constructed in Canada and the U.S., with the states of Connecticut, California, and Kansas taking the lead. At the time, wider use of welding seems to have been hindered by the federal government's reluctance to grant federal aid on all-welded, built-up girders.[587]

During World War II, shipbuilders advanced steel welding processes by introducing the automatic submerged arc-welding (SAW) process, which was later routinely applied to steel bridges. Automatic submerged arc-welding

---

[583] "Celebrating 50 Years of Cooperative Research," Texas Transportation Researcher Online, <http://tti.tamu.edu/researcher/newsletter.asp?vol=34&issue=4&article=0> (accessed 8 November 2004), 1.
[584] "Structural Engineering," Handbook of Texas Online, <http://www.tsha.utexas.edu/handbook/online/articles/view/CC/stc1.html> (accessed 24 May 2004).
[585] Bundy, "Design of Welded Bridge Structures," *Texas Highways*, 131.
[586] A. L. Elliott, "How To Use High-Strength Steel Effectively," *Engineering News-Record* 164, (18 February 1960): 52-56.
[587] Bundy, "Design of Welded Bridge Structures," *Texas Highways*, 130.

became the most popular of the automatic arc-welding processes.[588] During the 1960s, numerous revisions were made to the AWS' specifications for welded highway and railroad bridges. Included in these were new provisions was the SAW process in 1963. Provisions included specifications for the filler metal and flux and optional testing to ensure the adequacy of welded joints.[589]

After World War II, the THD embraced the idea of welding over riveting for construction methods with Percy Pennybacker, a supervising THD bridge engineer, promoting the welded construction. There are several advantages of welding that attracted the THD to this connection method. Randle B. Alexander, a bridge engineer with the THD, described the THD's approach in a 1950 *Engineering News-Record* article:

Immediately following the war, we were of the opinion that welding had come of age. We believed that the great strides made during the war in its general use and the development of new techniques – together with the many new facilities and the greatly increased number of qualified welders – indicated that postwar construction would adopt welding as being more economical than riveting.[590]

To educate THD staff on this new connection method, the TxDOT Bridge Division conducted a welding school for key personnel to learn about the technique and revised standard plans and specifications to permit welding as an alternative to riveting in many cases of standard construction.[591]

Even though the THD promoted welding in some areas of continuous I-beam and plate girder construction, it found that, early on, fabricators and contractors were reluctant to abandon the riveted-construction method, even if they had to absorb the cost of the extra steel required for riveting. The THD realized that many contractors and fabricators were not as familiar with welded construction and, as a result, were more comfortable using riveting. To promote the use of welding, the THD required welded construction for all diaphragms (structural members that are placed within another member or superstructure to distribute stresses and improve strength) and bracing on several I-beam bridge jobs.[592] Once welded construction became accepted by contractors, the THD returned to the practice of offering both welded and riveted alternatives where appropriate.

By June of 1950, the THD had completed 27 projects using welding for parts of continuous I-beam construction and 11 more were under contract.[593] During these first years of welded steel I-beam construction, these bridges were not concentrated in certain areas of the state; they were built from El Paso to the Paris District. In 2009, seven continuous steel I-beams with welded structural connections and few alterations were extant. Due to increased use of welded continuous I-beam designs, a five-member Welding Inspection Section was added to the division to inspect contractor's welding operations in the field.

In the early 1950s, the THD began using welded designs for steel plate girder bridges, which are comprised of built-up steel plates with a deep web between the top and bottom flanges of the girder. These became the most common type of welded bridge because of their wide range of spans, economy, ease of fabrication, and flexibility

---

[588] *Procedure Handbook of Arc Welding Design and Practice*, 11th ed. (Cleveland, Ohio: Lincoln Electric Company, 1957), 2.89.; Ebbe Almqvist, *History of Industrial Gases* (New York: Kluwer Academic/Plenum Publishers, 2003), 373-374.
[589] La M. Grover, "Welding for Bridges," *Civil Engineering* 33, (December 1963): 60-63.
[590] Randle B. Alexander, "Texas' Experience with Welding Bridges," *Engineering News-Record* 145, no. 3 (20 July 1950): 44.
[591] Alexander, "Texas' Experience with Welding Bridges," *Engineering News-Record*, 44.
[592] Alexander, "Texas' Experience with Welding Bridges," *Engineering News-Record*, 44.
[593] Alexander, "Texas' Experience with Welding Bridges," *Engineering News-Record*, 44-45.

of application.[594] The first all-welded plate girder, designed by the THD and completed in 1951, was the Sabine River Bridge. This three-span, continuous structure over the Sabine River between Smith and Upshur counties features end spans of 100 feet and a center span of 130 feet.[595] This bridge is currently scheduled for removal (TxDOT Structure No.: 19-230-0-0520-02-032). The THD's internal publication, *Texas Highways*, highlighted THD bridge designers Farland C. Bundy and Milton D. Randall for their honorable mention in a national competition for this bridge design involving arc welding that conserved steel.[596]

During the design selection process for the Sabine River Bridge, Bundy and Randall found that a four-girder welded bridge resulted in savings in both structural steel and overall cost, compared to a two-girder riveted bridge with floor beam and stringer system. The THD designers stated that increasing the number of girders to eliminate the floor system of the riveted design was one of the important trends in welded bridge design of the time.[597] Welding soon found broader applications, and by the early 1950s, welding was used to replace rivets in many bridge details.[598]

Due to his efforts to promote welded connections, Greer recommended Pennybacker for the L.I. Hewes Award in 1953 for "his outstanding contribution in the use of welding for the repair and construction of highway bridges."[599] Greer and the THD recommended Pennybacker for the award because they considered "his contribution to the increased use of welding…to be outstanding, far above that expected of any single person in an organization like the THD."[600] In his obituary, Pennybacker was recognized as an engineering innovator who saved the state of Texas millions of dollars with the new processes he introduced.[601]

Another welding innovation was developed in the mid-1950s in response to the need to widen reinforced concrete bridges that were too narrow to accommodate increased traffic and higher traveling speeds. The THD worked with the Houston section of the AWS to develop a procedure to weld reinforcing bars described to be of "difficult-to-weld quality." Welding the reinforcing bars of the concrete structures provided a cost savings in both materials and labor because less concrete was removed than in the conventional method of lap slicing. With lap slicing, the bar steel reinforcement is lengthened by placing a new bar alongside the existing bar so that the two bars overlap each other a prescribed length. The overlapping bars behave like a continuous bar after the placement of concrete around the reinforcing bars. Welding a higher strength bar steel was more economical than lap slicing because less overlap was needed to ensure full transfer of forces between the bars, resulting in lower material costs. An additional benefit to this method of widening was fewer disturbances to traffic during the construction.[602]

---

[594] James G. Clark, ed., *Welded Interstate Highway Bridges* (Cleveland, Ohio: James F. Lincoln Arc Welding Foundation, January 1960), 15.
[595] Bundy, "Design of Welded Bridge Structures," *Texas Highways*, 130-131.
[596] "Bridge Division Employees Win National Recognition," *Highway News*, n.p.
[597] James G. Clark, ed., *Comparative Bridge Designs*, 40-41.
[598] Alfred E. Pearson, "Welded Connections for Buildings and Bridges," in *Proceedings of the Texas Structural Engineering Conference, March 21-22, 1952* (Austin, Texas: The University of Texas, Department of Civil Engineering and Bureau of Engineering Research, [1952]), 16.
[599] "Pennybacker Receives Welding Award," *Texas Highways* 1, no. 2 (December 1953): 15.
[600] "Pennybacker Receives Welding Award," *Texas Highways*, 15-17.
[601] "Rites Conducted at Austin for Percy V. Pennybacker," *The Dallas Morning News*, 7 February 1963, sec. 1, Section 1, 23.
[602] P. V. Pennybacker, "Texas Bridges Benefit From an Improved Welding Program," *Welding Engineer* 41, no. 10 (October 1956): 34.

It should be noted that many off-system steel I-beam bridges have recycled beams that have been welded together and technically have "all-welded" structural connections. These bridges, however, are short structures, usually less than 50 feet long, and in many cases construction dates included in the BID are incorrect with many of these bridges built after 1965. Since these bridges do not possess the engineering complexity of the all-welded structures mentioned above, steel I-beam bridges with recycled, welded beams do not reflect the innovative development of

*High-tensile Bolts*

Use of high-tensile (or high-strength) bolts, manufactured from carbon steel and heat-treated for strength, was fairly new for structural steel connections in the 1950s. High-tensile bolts were used on railroad bridges and were seen as a favorable option because they were cheaper to use in the field than rivets.[603] Although bolts had been used for structural connections on highway bridges for many decades, these connections, which were called "unfinished bolts," could not be tightened sufficiently to eliminate the possibility of slipping under shear loads.[604] The transition from rivets to high-tensile bolts on highway bridges was slow nationwide and may have been prompted by the Research Council on Riveted & Bolted Structural Joints' formation in 1947. The Research Council was established "to advance the state of the art of civil engineering structural connections using threaded fasteners and rivets." In January 1951, soon after the council's formation, it approved and issued the "Specification for Assembly of Structural Joints Using High Tensile Bolts," allowing high-strength bolts to be substituted unit-for-unit for structural steel rivets of the same diameter.[605]

The Research Council was "largely responsible for high-strength bolting as we know it today," wrote W.H. Munse, professor of civil engineering at the University of Illinois, Urbana, in a 1967 *American Institute of Steel Construction (AISC) Engineering Journal* article on "High-Strength Bolting." Munse cites 10 advantages of the American Society for Testing and Materials (ASTM) A325 and A490 high-strength bolts and the bolting process; he found that high-strength bolts were considered superior to rivets and riveting in almost every way. High-strength bolts were stronger than rivets in both shear and tension. Unit for unit, the installed cost of bolts was as much as 20 percent less than rivets. A two-man bolting crew could install or fix more bolts in a given time than a four-man riveting crew could install rivets, and because bolts and bolting were more uniform, less inspection was necessary. Other advantages of high-tensile bolts were the related issues of crew training, such as less training needed with bolting crews; equipment, such as fewer tools and scaffolding for bolting; and a reduced fire risk since riveting required on-site furnaces.[606]

A major proponent of high-tensile bolt use in Texas was THD Senior Designing Engineer Wayne Henneberger. He described the high-tensile bolts as "'revolutionary' for they have been accepted by both structural and bridge engineers as a fastener suitable not only for static loads but also for all ranges of dynamic loads."[607] As Henneberger describes in his 1954 *Texas Highways* article, "High Tensile Bolts to Replace Rivets," the Association

---

[603] T. R. Higgins and Mace H. Bell, "High-Strength Bolts - A New Structural Fastener," in *Proceedings of the Texas Structural Engineering Conference, March 21-22, 1952* (Austin, Texas: The University of Texas, Department of Civil Engineering and Bureau of Engineering Research, [1952]), 43.
[604] Wayne Henneberger, "High Tensile Bolting of Highway Structures," *The Texas Engineer* 27, no. 7 (August 1957): 9.
[605] Higgins and Bell, "High-Strength Bolts - A New Structural Fastener," in *Proceedings of the Texas Structural Engineering Conference, March 21-22, 1952*, 28, 47.
[606] W. H. Munse, "High-Strength Bolting," *AISC Engineering Journal* (January 1967): 36.
[607] Henneberger, "High Tensile Bolting of Highway Structures," *The Texas Engineer*, 9.; Wayne Henneberger, "High Tensile Bolts to Replace Rivets," *Texas Highways* 2, no. 1 (November 1954): 142.

of American Railroads (AAR) tested high-tensile bolts by replacing rivets with high-tensile bolts on several railroad bridges to determine if the bolts would retain their clamping force under dynamic load conditions.[608] The study found that the high-tensile bolts retained their full clamping force after six years without maintenance. This resulted in cost savings and safety considerations since rivets had to be replaced on these same test bridges on a yearly basis in many cases.

Due to their reliability and cost savings, THD contractors who were building large bridges opted to use high-tensile bolts rather than rivets. At the contractor's request, the THD allowed use of high-strength bolts of the same diameter as rivets, substituting one bolt for one rivet. The THD first used high-strength bolts in about 1953 and, by 1956, had constructed approximately 15 plate girder bridges using these connectors.[609]

Four large bridges that were built with high-tensile bolts are the Loop 12 bridge at the West Fork of the Trinity River in Dallas County, the IH 10 bridge at the Trinity River, and the US 90 bridge over the Pecos River. The Loop 12 bridge in Dallas, which is no longer extant, was a 340-foot continuous plate girder bridge with two-girder system with floor beams and stringers and a main span measuring 140 feet. According to Henneberger's 1954 article, the Loop 12 bridge was built using skilled iron workers at $2.00 per hour rather than riveters who charged $2.78 per hour.[610] Approximately 5,400 high-tensile bolts were used on the bridge, with approximately 500 bolts tightened per day by a two-man crew, which allowed for an extremely efficient erection time.[611]

Later large steel bridges also used high-tensile bolts. Built in 1955, the IH 10 bridge over the Trinity River was the longest continuous plate girder bridge built with high-tensile bolts during the subject period at 2,849 feet long (TxDOT Structure No.: 20-036-0-0508-02-048). The US 90 bridge over the Pecos River (TxDOT Structure No.: 22-233-0-0022-06-068) is a 1,310-foot long continuous deck truss bridge that used high-tensile bolts when it was constructed in 1957.

State departments of transportation throughout the U.S. were slow to adopt the use of high-tensile bolts during the subject period. Contractors were some of the biggest proponents of the transition away from riveted connections and departments of transportation conservatively resisted the change to high-tensile bolts. States such as Minnesota did not begin using high-tensile bolts until 1959, two years after AASHO included standard specifications for high-strength bolts in their 1957 publication.[612] With Henneberger pushing for the use of high-tensile bolts in the early 1950s, it is not surprising that the THD built several bridges with these connections well before the release of the 1957 AASHO standard specifications. Since the 1960s and 1970s, rivet connections have been eclipsed by high-tensile bolts and rivets are no longer used on highway bridges.

*Neoprene Bearing Plates*

In the mid-1950s the THD began using neoprene plates (or elastomeric plates) on abutments as a bearing pad for precast, prestressed concrete beams. Previously Portland cement, asphaltic fiberboard, steel rockers, or lubricated

---

[608] Henneberger, "High Tensile Bolts to Replace Rivets," *Texas Highways*, 140.
[609] Henneberger, "High Tensile Bolting of Highway Structures," *The Texas Engineer*, 10., Henneberger, "High Tensile Bolts to Replace Rivets," *Texas Highways*, 142.
[610] Henneberger, "High Tensile Bolts to Replace Rivets," *Texas Highways*, 142.
[611] Henneberger, "High Tensile Bolts to Replace Rivets," *Texas Highways*, 142.
[612] American Association of State Highway Officials, *Standard Specifications for Highway Bridges*, xxiii; R. L. Levorsen, "Policy on Substitution of High-Strength Bolts in Lieu of Rivets," 7 October 1959, n.p.

metal sliding plates were used for shorter reinforced concrete spans. However, none of these offered both the function and economy that was needed for longer precast members in prestressed designs. In his autobiographical account of his career entitled "The World as I Saw It," long-time THD engineer James R. Graves recalls that he asked the DuPont Company to create the neoprene bearing plates, which had been used for the construction of buildings. DuPont referred him to a manufacturer of rubber products, Oil States Rubber Company of Arlington, Texas, which offered several sample pads.[613] Neoprene bearing pads were used for the first time in Texas and the U.S. in 1958, when the THD built the extant 53-foot prestressed concrete girder bridge on FM 237 over Coleto Creek near Victoria (TxDOT Structure No.: 13-235-0-0941-04-007).[614]

Although primarily used on prestressed concrete girder bridges, the THD also experimented with using neoprene bearing plates on other bridges types, such as reinforced concrete Tee beam and pan-formed girder bridges. THD engineers discovered that the neoprene plates, which were made of high-grade synthetic rubber, were more economical, durable, and easier to maintain than other bearing materials. The elastomeric plate was found to be resistant to deterioration due to water, ice, solvents, or other environmental factors that affected steel bearings. This made them more durable and economical for use in bridge structures in that they did not contribute to the premature deterioration of the bridge and required less maintenance than steel bearings. The THD's innovation in the use of neoprene bearing pads was incorporated into the AASHO specifications in 1961 and was recommended for concrete spans up to 80 feet.[615] Research on the use of neoprene bearing plates continued at Texas A&M, where they were found to be suitable for steel structures as well as concrete bridges. The results of this study were published in the *Journal of the Structural Division, Proceedings of the American Society of Civil Engineers* in December 1961.[616] The influence of neoprene bearing plates is evident in that they became the standard bearing pad material for beam/girder bridges and continue to commonly be used 45 years later in bridge construction.

*High-strength Reinforcing Bars*

High-strength reinforcing bars allowed for smaller concrete girders that reduced material costs. On a conventional bridge, the girders would typically be 3 feet wide and the bridge deck would be 7 inches, but with the use of high-strength steel bars, girder width could be reduced to 2 feet, 4.5 inches and deck thickness to 6.5 inches.

*Deicing Research*

Deicing research began in 1960 when the THD initiated a research project to introduce heat into bridge slabs. Like many other states, icing or glazing of bridges in Texas created hazardous road conditions. Icing is a problem in northern Texas, where flash freezes can occur during the winter months and bridges ice over more quickly than roads because there is air flow both above and below them. Icing of bridges was also a maintenance problem for the THD because application of deicing salts contributed to deterioration of the structure's concrete deck. As a result, in 1961, the THD designed and installed an electrical heating system in twin structures on US 287 at City View Drive, northwest of Wichita Falls. Electrical heating cables were placed in conduits within the deck slab of each span of the three-span, continuous concrete slab. For the experiment, conduits were placed at varying levels

[613] Graves's autobiography appears to be unpublished; excerpts included in Reed's presentation. Robert L. Reed, n.p.
[614] James R. Graves, "Rubber Seats for Prestressed Beams," *Engineering News-Record* 158, no. 20 (16 May 1957): 67.
[615] A. E. Johnson, ed., Published on the Occasion of the Golden Anniversary American Association of State Highway Officials: A Story of the Beginning, Purposes, Growth, Activities and Achievements of AASHO, 105.
[616] "Elastomeric Bearings are Suitable for Steel Bridges," *Texas Engineering Experiment Station News* 13, no. 1 (March 1962): 11.

within the bridge deck and at varying distances apart.[617] This test was the first of its kind in Texas, but electrical heat for deicing had previously been used on bridges near Detroit, New York, and Chicago.[618] The research project was funded jointly by the THD and BPR.[619] These bridges are no longer extant.

The THD, in cooperation with the BPR, also conducted experiments into the effectiveness and economic feasibility of insulating undersides of bridges to prevent icing. Insulation was applied in 1963 on twin continuous I-beam structures that carry US 287 over the Fort Worth and Denver Railroad in Wichita Falls, near the location of the structures discussed above with the electrical heating system. The conclusion of the research was that insulation provided some benefits during short periods of cold weather, but for longer periods there were decreased benefits. These bridges that included experimental insulation are nonextant. The THD's research into deicing continued and, in February 1966, the THD published results of another study to prevent icing, reduce the number of freeze-thaw cycles, and reduce salt use on concrete bridge decks.[620] However, it was found that internal deicing posed ongoing maintenance issues. Don Harley recalled that although the technology worked, the large internal electrical systems proved impracticable due to numerous maintenance problems.[621] As a result, its use was discontinued by the THD.

*T-shaped Bent Cap*

The THD developed an inverted T-shaped bent cap in 1965 for the IH 45 elevated roadway in downtown Houston, which was completed in 1967 (TxDOT Structure Nos.: 12-102-0-0500-03-216 and 12-102-0-0500-03-229). The roadway was six lanes and traveled for nearly a mile, crossing 11 major north-south streets. Caps, largely made of concrete, were used to "give the structure a neat and slender appearance."[622] Where caps had to cross at an oblique angle, they were fabricated from steel beams, and two coats of vinyl were applied to match the color of the concrete beams.[623]

*Continuity of Continuous Reinforced Concrete Pavement*

In the mid-1960s the research section of the THD's Highway Design Division conducted a study of the performance of a continuous roadway design that eliminated the transition between highway pavement and bridge deck. The transition from highway to bridge deck had caused several problems, including poor sealing of pavement and deck slabs, road roughness due to the seal and the joint, and difficulty anchoring pavement slabs due to contractive and expansive movement.[624] The THD conducted its research on the Irving Lee Street Overpass located in the northbound lanes of IH 35 in McLennan County in 1964 and published the results in 1966. The Irving Lee Street Overpass was extant in 2009 (TxDOT Structure No.: 09-161-0-0015-01-374). Based on observations between the control structure and the experimental structure, the THD noted that complete continuity between

---

[617] Philip B. Rapstine, "Research Study Seeks Ice-Free Bridges," *Public Works* 94, no. 2 (February 1963): 84-87.
[618] "No More Ice on Bridges?," *Texas Highways* 8, no. 2 (February 1961): 16-17.
[619] Rapstine, "Research Study Seeks Ice-Free Bridges," *Public Works*, 84-87.
[620] H. D. Butler, *Insulation of Bridge Decks for Ice Prevention and Reduction of Freeze-Thaw Cycles, Research Report Number 62-1-F* (Texas Highway Department, February 1966), 1-3, 13-16.
[621] Harley, Interview by Mead & Hunt, Inc. and TxDOT Bridge Division, Texas Department of Transportation.
[622] Hall, "I. H. 45 Soars Through the Air," *Texas Highways*, 9.
[623] Hall, "I. H. 45 Soars Through the Air," *Texas Highways*, 9.
[624] B. F. McCullough and Fred Herber, *A Report on Continuity Between a Continuously Reinforced Concrete Pavement and a Continuous Slab Bridge, Research Report 39-3* ([Austin, Texas]: Highway Design Division, Research Section, Texas Highway Department, August 1966), 1-2.

highway pavement and deck was not feasible at the time, but steps could be taken toward this goal. Improvements could save money, reduce maintenance and construction costs, and improve riding quality of the pavement. The report suggested elimination of the terminal anchorage system and special approach slabs that were being used, as well as elimination of some expansion joints.[625] It is unknown if the results of this research were implemented by the THD. This bridge is considered not eligible for NRHP listing by TxDOT because it carries interstate traffic and this bridge is not on the Final List of Nationally and Exceptionally Significant Features of the Federal Interstate Highway System, published in the Federal Register on December 19, 2006.

*Texas Engineering Experiment Station and Texas Transportation Institute*

Organized research at Texas A&M began in engineering labs as early as 1914 as part of the Texas Engineering Experiment Station (TEES).[626] The mission of TEES over the years "has been to conduct research to produce answers to urban difficulties and thus enhance the quality of life in Texas."[627] TEES research efforts encompassed a wide variety of topics, among which were design and construction of roads and associated bridges and culverts, and use of construction materials. In addition to research efforts, short courses were offered annually at Texas A&M after 1927 to bring together researchers and THD engineers.[628] Research efforts at Texas A&M increased when the structural engineering program began a cooperative agreement with the BPR in 1943 to develop "criteria, methods or other practical information that will contribute to the design of safe and efficient types of modern bridges and other highway structures."[629] Details of increased research efforts are not known.

Limited specific transportation-related research was conducted by TEES after 1950, but structural research was applied to bridges, as appropriate. During this period, TEES did conduct research of load studies on drilled shaft footings, which was utilized by the THD for bridge construction.[630] Also in 1954, TEES began a long-range study of cost and ease-of-use of prefabricated and prestressed structural elements in construction work. One objective of research efforts was to find methods that would lead to the design of economic structures.[631]

A separate research group, Texas Transportation Institute (TTI), was established at Texas A&M in 1950 by the College's Board of Directors for the specific purpose of serving as a research agency for the THD. TTI was founded by Thomas H. McDonald, former chief of the BPR, and Gibb Gilchrist, Texas A&M system chancellor

---

[625] McCullough and Fred Herber, *A Report on Continuity Between a Continuously Reinforced Concrete Pavement and a Continuous Slab Bridge, Research Report 39-3*, 12-13.
[626] Louis J. Horn, "The Texas Engineering Experiment Station Serving the People of its State," *Texas Engineering Experiment Station News* 9, no. 4 (December 1958): 6.
[627] "Mission and History," Texas Engineering Experiment Station, <http://tees.tamu.edu/portal/page?_pageid=33,31458&_dad=portal&_schema=PORTAL> (accessed 22 February 2005).
[628] Thomas H. MacDonald, "Remarks on Transportation Research," *Texas Highways* 1, no. 1 (November 1953): 11-12.
[629] Arthur W. Melloh, Research Activities of the Texas Engineering Experiment Station for 1950-51 and 1951-52, Research Report (Texas Engineering Experiment Station); no. 38 (College Station, Texas: Texas Engineering Experiment Station, A&M College of Texas, October 1952), 34.
[630] L. A. DuBose, "Results of Load Studies on Drilled Shafts," *Texas Highways* 2, no. 1 (November 1954): 3.
[631] Truman R. Jones, Jr., "Possibilities of Precast Concrete," Texas Highways 2, no. 1 (November 1954): 68; Arthur W. Melloh, Activities of the Texas Engineering Experiment Station for 1952-53 and 1953-54, Research Report (Texas Engineering Experiment Station); no. 50 (College Station, Texas: Texas Engineering Experiment Station, A&M College of Texas, November 1954), 22.

and former Texas State Highway Engineer, and began its research activities in 1955.[632] The 51st Texas State Legislature passed a bill that formalized the relationship between the THD and Texas A&M, such that TTI would supplement research conducted at THD in-house labs. The state legislature also authorized the transfer of funds between the agencies; state monies were the main funding source for TTI's research, with a small percentage of federal dollars also augmenting the fund. The legislation also stated that equipment and research laboratories of Texas A&M were available to the THD without rental or other charges. According to documented sources and interviews with retired THD engineers, the TTI research that focused on the replacement or conservation of bridge materials was quite useful during the subject period.[633] Additionally, McDonald believed "transportation is a prime economic force," not just a service; therefore, in addition to TTI's direct research in new materials, TTI conducted research of the impacts of transportation on Texas economic development, including studies on the food, cotton, and gasoline industries.

Beginning in 1955, TTI coordinated and administered research activities for the THD and provided graduate-level courses. Research topics undertaken by TTI encompassed a broad spectrum, including economics, materials, specifications, design, construction, and maintenance.[634] During the first four years, structural research at TTI focused on construction of "cheaper and better bridges" to assist the THD in its bridge construction efforts.[635] Specific research included study of prestressing and prefabricating concrete bridge structures, structural quality of lightweight concrete, development of nondestructive methods for inspecting structural welds, and methods for corrosion prevention. TTI's tests on prestressed and prefabricated concrete beams and girders helped the THD develop specifications that reduced construction time and increased performance of the bridge.[636] Prefabrication of bridge members also allowed structures to be constructed efficiently. Labor and material costs were saved by eliminating forms that had been previously used on-site to pour concrete.

In an article discussing current research into the possibilities of precast concrete, Truman R. Jones, Jr., assistant research engineer at Texas A&M, stated "we do not expect precasting or prestressing concrete to be a cure-all solution to the bridge-building problem, but if savings of as little as 3 to 5 percent can be effected, we can save from $500,000 to $1,000,000 per year in Texas alone." [637] As part of the research into prestressed elements, TTI developed new end anchorages for post-tensioned construction. End anchorages are reinforced areas of the beam that accept high post-tensioning or prestressing forces and transfer these forces into the beam as compression forces. The new anchorages saved time and money in construction and eliminated several problems of the previous anchorages, which required steel to be ordered in exact lengths and had fittings that extended beyond the bearing plate at the end of each member.[638] This created difficulty with fabrication that required steel to be ordered in exact lengths and were more difficult to fabricate.

---

[632] Louis J. Horn, "The Texas Transportation Institute - Meeting the Needs for Mobility," in *One Hundred Years of Engineering at Texas A&M, 1876-1976*, ed. Charles W. Crawford (N.p.: Published by Editor, 1976), 201-202.
[633] Texas Transportation Institute, *Texas Transportation Institute: Its Purpose, its Achievements, 1955-58* (College Station, Texas: Texas Transportation Institute, A&M College of Texas, n.d.), 2-3.; L. A. Wilke, "Research in Transportation," in *Greer (DeWitt Carlock) Papers* (N.p., n.d.), .; "TTI: Building a Better Highway," *Texas Highways* 6, no. 5 (May 1959): 5.
[634] "Research Program Set Up...," *Texas Highways* 1, no. 2 (December 1953): 19.
[635] Texas Transportation Institute, *Texas Transportation Institute: Its Purpose, its Achievements, 1955-58*, n.p.
[636] "Celebrating 50 Years of Cooperative Research," Texas Transportation Researcher Online, 108.
[637] Jones, Jr., "Possibilities of Precast Concrete," *Texas Highways*, 72.
[638] Jones, Jr., "Possibilities of Precast Concrete," *Texas Highways*, 72.

Another major research project of TTI that assisted the THD's bridge-building program was the study of lightweight concrete. The study reviewed the structural quality of lightweight concrete produced in Texas with expanded shales and clays. The study was driven by scarcity of sand and gravel aggregates for conventional concrete, the cost of transporting of the aggregates, and an interest in designs that utilized lightweight concrete.[639] The concrete was created by using a synthetic aggregate that enabled the concrete to weigh less per cubic foot than conventional concrete. Lightweight concrete unit weight can vary depending on the type and amount of lightweight aggregate used.[640] Although lightweight concrete weighed less than conventional concrete, it had equal compressive strengths. Lightweight concrete was used by the THD on bridge decks and in prestressed concrete beams. TTI developed a new lightweight concrete superstructure design that utilized prefabrication to reduce costs. In accordance with TTI recommendations, the THD constructed a two-span, precast, prestressed multiple-beam bridge of lightweight concrete in 1957 on FM 2038 over Brazos County's Bowman Creek for research purposes (TxDOT Structure No.: 17-021-0-2236-01-001).

TTI's publications promoted that their research into field practices for lightweight concrete resulted in policy recommendations that were adopted nationally. Some physical properties of lightweight concrete were also included in the "Proceedings of the Third World Conference on Prestressed Concrete."[641] It is not specifically known how influential TTI's and the THD's research was in encouraging use of lightweight concrete for structures.

The widespread use of lightweight concrete was somewhat limited by the THD due to the fact that it was difficult to employ and could be less economical. During interviews, retired THD engineers recounted that designers were initially excited about this material because by reducing the dead load on the substructure, the concrete spans could be lengthened. However, the structures proved too flexible and ultimately the THD abandoned use of the material due to severe maintenance issues. Bridges such as the Buffalo Bayou Twin Bridges (1956) on US 90-A in Houston (TxDOT Structure Nos.: 12-102-0-0027-10-062 and 12-102-0-0027-10-063) and the US 90 bridge at the Pecos River (TxDOT Structure No.: 22-233-0-0022-06-068) were originally built with lightweight concrete, but their decks had to be replaced due to severe cracking.

Additional research projects in the 1950s undertaken by TTI included experimental work with steel columns, utilization of traffic data in design, study of equivalent design loads, and development of cast-in-place concrete piles, or columns that are driven into the ground to provide support for a structure. This research resulted in material and cost savings.[642] The THD incorporated many of the results of these research efforts into its bridge construction program. For example, by 1959, the THD began utilizing the design for cast-in-place concrete piles.

---

[639] "Structural Researchers Evaluate Lightweight Concrete for Enduring Construction," *Texas Engineering Experiment Station News* 10, no. 4 (December 1959): 13.
[640] Farland Bundy and Ed Suchiki remembered that lightweight concrete was approximately 50 pounds per cubic foot lighter than conventional concrete, while Don Harley recalled it being 20 pounds lighter. Bundy, Interview by Mead & Hunt, Inc. and TxDOT Bridge Division, Texas Department of Transportation; Bill Ward and Ed Suchiki, Interview by Mead & Hunt, Inc. and TxDOT Bridge Division, Texas Department of Transportation, digital audio and video recording, Houston District Office, Bridge Section, Houston, Texas, November 15, 2006; Harley, Interview by Mead & Hunt, Inc. and TxDOT Bridge Division, Texas Department of Transportation.
[641] Texas Transportation Institute, *Texas Transportation Institute: Its Purpose, its Achievements, 1955-58*, n.p.
[642] "TTI: Building a Better Highway," *Texas Highways*, 2.

The THD's bridge project on FM 2038, described above, also used precast members, stemming from TTI's experiments in mass production of concrete bridges.[643]

Research at TTI continued into the 1960s and beyond. In 1964, TTI opened a research laboratory at the former airbase at the Texas A&M Research and Development Annex, which provided space for TTI's safety and materials testing. A year later, TTI began publishing results of its research activities in *Texas Transportation Scientist*, which is now *Texas Transportation Researcher*.[644] TTI continues to conduct research that assists the THD with design, construction, and maintenance of an economical and safe statewide transportation system.

*Balcones Engineering Laboratory (now the Ferguson Structural Engineering Laboratory)*

Activities of the Balcones Engineering Laboratory began in 1950 as part of the Department of Civil Engineering at UT-Austin. The research facility was officially named the Balcones Engineering Laboratory in 1953, and in 1980, it took its present name of the Ferguson Structural Engineering Laboratory in honor of Professor Phil M. Ferguson, who served as department chair from 1943 to 1957.[645] Research at the facility included bridge and building design, construction, and maintenance, and it is estimated that approximately two-thirds of the research has been related to bridges. Faculty at UT-Austin specialized in reinforced concrete and welded-steel structures and often served on committees to develop national specifications for the use of these for structures. The Ferguson Structural Engineering Laboratory was well-equipped for research and had equipment to study fatigue-testing of larger structural members that was unmatched in the U.S.[646] Fatigue-testing involves subjecting steel elements and welds to tensioning cycles to determine the steel's ability to withstand repeated loading and unloading in tension. The number of cycles required to eventually cause failure of the steel or weld is documented in the laboratory to provide a measure of how the steel or weld will operate in normal use under traffic. Fatigue-testing provided engineers with the ability to observe and predict the behavior of steel within a laboratory prior to introducing the design detail or steel type in the field. Modifications to designs could be made to provide the desired fatigue-resistance prior to implementation.

Little evidence was found as to specific research activities of the Ferguson Structural Engineering Laboratory during the subject period that were conducted for the THD or influenced the THD's bridge designs. The research facility gained an international reputation from research activities conducted after the subject period. Research on bridges continues at the Ferguson Structural Engineering Laboratory, which is currently completing a number of studies sponsored by TxDOT.[647]

---

[643] Texas Transportation Institute, *Texas Transportation Institute: Its Purpose, its Achievements, 1955-58*, n.p; "Mass Production of Concrete Bridges is Given Experimental Trial in Texas," *Texas Engineering Experiment Station News* 8, no. 3 (September 1957): 12.
[644] "Celebrating 50 Years of Cooperative Research," Texas Transportation Researcher Online, 2.
[645] The *Handbook of Texas* cites that the Ferguson Structural Engineering Laboratory began 10 years later in 1960. Ned H. Burns, "History of the FSEL Lab," The University of Texas at Austin, <http://www.utexas.edu/research/fsel/lab/history.html> .
[646] Burns, "History of the FSEL Lab," The University of Texas at Austin; "Civil Engineering," Handbook of Texas Online, <http://www.tsha.utexas.edu/handbook/online/articles/view/CC/stc1.html> (accessed 24 May 2004).
[647] Burns, "History of the FSEL Lab," The University of Texas at Austin.

*Center for Highway Research*

In 1963, the Center for Highway Research was established at UT-Austin. The ongoing mission of the Center for Highway Research has been to conduct leading transportation research, provide educational opportunities for students, and to conduct research that responds to the needs of Texans.[648]

Another research project undertaken by the Center for Highway Research was a study to learn about orthotropic steel deck plate construction. The idea of orthotropic plate construction was introduced in the 1930s, but it was following World War II that some of the first bridges were built in Germany. The THD's need to reconstruct a large number of bridges and the shortage of steel led to the research and development of the design.[649] In orthotropic steel plate deck construction, cross-stiffened steel deck plates are used to replace concrete decks and "the deck plate serves as the upper flange for the ribs, the floor beams and the main girders."[650] Specifically, the THD was interested in determining fatigue strength of several weld details of a deck stiffened with closed trapezoidal ribs.[651] No orthotropic bridges built prior to 1965 remained extant in Texas in 2009.

Many other studies were completed by the Center for Highway Research for the THD in the 1960s. The following list includes those research efforts that were featured in their publications during this period. The significance and/or influence of these studies on the THD's and other bridge-building programs is not known. Other topics investigated were:

- Tests on the fatigue of welded hybrid plate girders under constant moment, which entails subjecting the girders to continuous loading to cause a sustained tension in the girder. This provided a measure as to the ability of the welds and plates to withstand a sustained load without cracking or separating.
- The behavior of the pan-formed concrete slab and girder bridges, including evaluation of transverse load distribution characteristics of pan-formed concrete bridge systems and current design procedures.
- Bent cap analysis program used to analyze bending in both multiple columns and single columns.[652]

In the late 1960s, the THD had the Center for Highway Research conduct studies into new methods of precast box girder construction for long spans.[653] The Center for Highway Research later merged with the Council for Advanced Transportation Studies to become the Center for Transportation Research, as it is known today.

---

[648] "CTR Celebrates 40 Years of Research, Education, and Public Service," Center for Transportation Research, <http://www.utexas.edu/research/ctr/symposium/history.html> (accessed 23 February 2005).
[649] Harry L. Davis, "Fatigue Tests of Orthotropic Plate Bridge Elements" (MS thesis, University of Texas, 1965), 1.
[650] Davis, "Fatigue Tests of Orthotropic Plate Bridge Elements," 1.
[651] Davis, "Fatigue Tests of Orthotropic Plate Bridge Elements," 3.
[652] G. C. Lacey and J. E. Breen, *Long Span Prestressed Concrete Bridges of Segmental Construction, State of the Art, Research Report Number 121-1* (Austin, Texas: Center for Highway Research, University of Texas, May 1969), 1; H. S. Lew and A.A. Toprac, *Fatigue Tests of Welded Hybrid Plate Girders Under Constant Moment, Research Report Number 77-2F* (Austin, Texas: Center for Highway Research, The University of Texas, January 1967), 1; E. V. Leyendecker and J. E. Breen, *Behavior of Concrete Slab and Girder Bridges, Research Report 94-3F* ([Austin, Texas]: Center for Highway Research, University of Texas, May 1969), 1-3; Texas Department of Transportation, *Bridge Design Manual*, 8-13.
[653] Lacey and Breen, *Long Span Prestressed Concrete Bridges of Segmental Construction, State of the Art*, 2.

*Conclusion*

During the period of 1945 to 1965, the THD and cooperating institutions conducted studies that directly and indirectly affected bridge-building efforts in Texas. THD-directed studies resulted in design solutions that often gained national recognition and were incorporated into standard specifications developed by AASHO and the BPR, such as those involving neoprene bearing plates. Efforts to conserve materials, as well as time and money, resulted in the adoption of all-welded structural connections and the use of high-tensile bolts. TEES and TTI, affiliated with Texas A&M, and the Center for Highway Research, located at UT-Austin, conducted research and provided educational experience on a wide variety of transportation and engineering topics, including the materials, design, and construction of roads and associated bridges. Research attention was also given to economic factors with the goal of providing economically efficient structures. Balcones Engineering Lab, associated with the Civil Engineering department at UT-Austin, developed nationally recognized testing facilities and housed faculty who were instrumental in implementing national specifications for reinforced concrete and welded-steel structures. During this period, the THD's research efforts focused on developing economic and efficient structures that could meet Texas's large demand for bridges. In collaboration with institutes at Texas A&M and UT-Austin, the THD's bridge engineering research projects generated nationally recognized material and structural advancements.

*Standardization of Bridge Types*

As they had since the late 1910s, standard bridge plans continued to play an integral role in postwar bridge construction by providing economical and efficient bridge designs. In a time when the THD was embarking on massive building campaigns, first of the farm-to-market system and then the interstate system, the use of standard plans and details was more important than it was previously in the agency's history. Efforts to build bridges faster, cheaper, and better was pervasive throughout the country and within Texas. As a result, standards for bridge building were issued by the BPR and AASHO, the two main vehicular transportation agencies in the U.S., and standards were created by individual state highway agencies, like the THD. This section discusses the influence national design standards had on bridge building throughout the country and in Texas. This section also addresses the THD's use and development of standard plans and their impact on bridge building within the state, as well as the THD's influence on national design standards.

**Influence of National Design Standards for Bridges**

Design and construction of bridges nationwide, and in Texas, was influenced by standards created by national transportation organizations. Two such organizations played a prominent role in setting and disseminating design standards. Plans and guidance developed by the BPR and professional transportation organizations, like AASHO, were instrumental in setting federal transportation policy and disseminating information regarding new materials and technology, standard bridge designs, and best practices to state departments of transportation. These organizations had influenced bridge design standards since the 1910s. During the subject period, national design standards, plans, and specifications were frequently adopted by state departments of transportation, including Texas. As described in earlier sections, the Federal-Aid Highway Act of 1956 formalized efforts of the BPR and AASHO to work together on national design standards.

*Bureau of Public Roads (BPR)*

As noted earlier, the federal government formally became involved in road construction activities in 1893 with the organization of the Office of Road Inquiry in the U.S. Department of Agriculture. This agency underwent several

name changes and reorganization over the years. In 1939, the agency was named the Public Roads Administration (PRA), which it remained until it became the BPR in 1949. The BPR is the federal agency that provided the THD and other state departments of transportation guidance on bridge design, material use, and innovations. The BPR evolved to become the present-day Federal Highway Administration in 1967. During the subject period, the BPR defined national standards and specifications for transportation facilities, approved state's proposals for road and bridge construction projects utilizing federal funds, provided guidance on road and bridge construction, and prepared and distributed standard bridge plans. This information was disseminated through publications of research studies and design manuals.[654] Standard plans and other publications of the BPR significantly influenced state departments of transportation activities and design practices. An overview of activities of the BPR is presented to provide a context for understanding bridge-building efforts in Texas during this time.

The BPR published its first edition of standard bridge plans in 1953 and periodically updated these plans to reflect new technologies and materials. The 1956 edition includes plans for a variety of highway superstructures of varying span lengths and roadway widths, including I-beams, plate girders, and concrete slabs. Bridge types included in the BPR standard plan set reflect established bridge types and designs commonly constructed during this period. A summary of bridge plans in 1956 is included in Table 7. Most, if not all, of these types appear to have been used in Texas during the period.

[654] "Brief History of the Direct Federal Highway Construction Program," Federal Highway Administration, <http://www.fhwa.dot.gov/infrastructure/blazer01.htm> (accessed 3 March 2005).

**Table 7. BPR Standard Plans (1956)[655]**

| Superstructure Type | Roadway Width (feet) | Maximum Span Length (feet) |
|---|---|---|
| I-beams (simply supported) | 24 | 80 |
| | 28 | 70 |
| I-beams (composite, simply supported) | 24 and 28 | 100 |
| I-beams (three-span continuous) | 24 and 28 | 80-100-80 |
| Riveted deck plate girders | 24 and 28 | 140 |
| Welded deck plate girders | 24 and 28 | 140 |
| Reinforced concrete slabs | 24 and 28 | 35 |
| Reinforced concrete Tee beams | 24 and 28 | 60 |
| Reinforced concrete box girders | 24 | 120 |
| Precast concrete deck units with channel sections | 24 and 28 | 30 |
| Pre-tensioned precast concrete deck units with cylindrical voids | 28 | 45 |
| Box girder (also known as pre-tensioned precast concrete deck units with hollow box sections) | 28 | 70 |
| Pre-tensioned precast concrete I-beams | 24 and 28 | 70 |
| Post-tensioned precast concrete I-beams | 24 and 28 | 100 |
| Five forms of timber spans (including solid timber joists, laminated timber, and glue-laminated timber joists) | 24 | 65 |

Editions were updated every few years to include new and improved bridge plans. In 1962, the BPR expanded its standard plans to a five-volume series, including concrete superstructures, structural steel superstructures, timber bridges, continuous bridges, and pedestrian bridges. By 1968, these standard plans were updated to reflect new uses of technology and materials. Plans were included for cast-in-place Tee beams and box girders, precast channel sections, precast prestressed voided slab sections, box girder sections, and pre-tensioned and post-tensioned I-beams.[656]

[655] United States Bureau of Public Roads, *Standard Plans for Highway Bridge Superstructures*, 2d ed. (Washington, D.C.: G.P.O., 1956), n.p.
[656] United States Bureau of Public Roads, *Standard Plans for Highway Bridges, vol. 1, Concrete Superstructures*, Rev. ed. (Washington, D.C.: G.P.O., August 1968), n.p.

The BPR also offered guidance on use of new materials, incorporating results of testing that was done throughout the country and internationally. Guidance on prestressed concrete in the early 1950s was provided to the THD and other state departments of transportation in the BPR's *Criteria for Prestressed Concrete Bridges.* This volume highlighted best European practices, prior to the material's widespread use in the U.S.

*American Association of State Highway Officials (AASHO)*

From 1945 to 1965, AASHO was another organization that provided state departments of transportation guidance on bridge design and technical innovations. AASHO, a professional organization of state highway officials, has a long history of defining and disseminating standard practices for road and bridge engineering. State highway officials established this national professional organization in 1914 to allow a discussion of issues related to road construction to take place, including legislation, economics, and design. As early as 1921, AASHO had established a subcommittee on bridges and structures with the following mission:

Cooperate with the different States and Federal departments and other associations, societies, and institutions with a view to assisting in establishing uniform standard methods of construction and maintenance and in standardizing as much as possible the various kinds of construction used in connection with highway development.[657]

In working toward its mission, AASHO published its first set of bridge specifications in 1931, although informal versions were available as early as 1926. AASHO's bridge specifications were intended to be a model for state highway departments providing minimum requirements of standard practice for bridge construction that could be tailored to meet local needs. AASHO specifications became the industry standard for guidance on bridge design and construction. Specifications were also developed for "ordinary" highway bridges with spans typically less than 300 feet.[658] Changes in standard specifications were reviewed annually by AASHO, and revised versions were published periodically with new versions in the subject period in 1949, 1953, 1957, 1961, and 1963. In the introduction to the seventh edition in 1957, AASHO stated that "the vast amount of research and development of both steel and concrete structures practically dictates the necessity of revising the specifications every three or four years."[659] Regular updates reflected rapid changes in new materials developed during this period.

Several innovations were introduced in AASHO specifications during the period from 1945 to 1965. Incorporated innovations trace new technologies that were being embraced by the bridge construction industry. In 1949, a design method for plate girders was introduced that permitted thinner webs for long girders.[660] The 1957 specifications included new discussions on the use of high-tensile bolts and concrete box girders. Specifications were also added for structural steel welding that were "developed largely to meet the demand for weldable steel for highway bridges."[661] Although the AASHO committee had studied prestressed concrete design and construction, prestressed concrete was not included in the 1957 specifications. Continuing research and experimentation with the material resulted in developments that were changing too quickly to address in this version.

---

[657] A. E. Johnson, ed., Published on the Occasion of the Golden Anniversary American Association of State Highway Officials: A Story of the Beginning, Purposes, Growth, Activities and Achievements of AASHO, 105.
[658] American Association of State Highway Officials, *Standard Specifications for Highway Bridges*, xxiv.
[659] American Association of State Highway Officials, *Standard Specifications for Highway Bridges*, xxiii.
[660] A. E. Johnson, ed., Published on the Occasion of the Golden Anniversary American Association of State Highway Officials: A Story of the Beginning, Purposes, Growth, Activities and Achievements of AASHO, 105.
[661] American Association of State Highway Officials, *Standard Specifications for Highway Bridges*, xxiii.

Prestressed concrete was included in AASHO standard specifications for the first time in 1961. The guidance was largely based on the joint American Society of Civil Engineers and American Concrete Institute Committee on Prestressed Concrete report of 1958.[662] Other significant revisions in the 1961 edition, based on the latest research and developments, addressed the following topics: neoprene (elastomeric) bearing plates, reinforced concrete, plate girders, and high-strength bolts.[663]

Like the BPR, AASHO also published roadway and bridge standards to address varying traffic needs, loads, and speeds. In 1945, AASHO adopted specific recommended design standards for interstate highways. The AASHO guidance emphasized steel, reinforced concrete, and masonry bridges, preferably using a deck configuration, where the structural system lies beneath the deck.[664] AASHO's publication recommended grade separations at intersections in rural areas, where higher traffic counts warranted this safety measure.[665]

AASHO also issued guidance and policies on grade separation structures throughout the post-World War II period. In 1944, AASHO published *A Policy on Grade Separations for Intersecting Highways*. The policy recommended that deck-type structures span as much of the roadway that passes underneath it as possible.[666] These were preferred because they have few supports and provide drivers a limited sense of restriction. In 1956 AASHO adopted *A Policy on Design Standards, Interstate System*, which also included standards for crossroad overpasses and underpasses. Bridges and overpasses were recommended to be of deck construction to fit the overall alignment and profile of the highway. For all structures, the bridge clear height was recommended to be 16 feet to allow large vehicles to pass underneath. For all structures of 150 feet or less, including grade separations, the bridge was recommended to be the full width of the roadway, including pavement and shoulders.[667] In 1957, AASHO published *A Policy for Arterial Highways in Urban Areas*, which built upon the policy for rural highways and included substantial guidance on interchange design and grade separations in metropolitan areas.[668] AASHO provided additional recommendations for grade separation structures in its 1954 and 1965 editions of *A Policy on Geometric Design of Rural Highways*. In the 1965 edition, AASHO continued to advocate the use of deck-type structures for overpass highways and recommended prestressed deck designs for longer spans.[669] Additional AASHO recommendations included that structures be visible to approaching traffic both day and night, and that they be aesthetically pleasing. Many of the policies, research information, and specifications developed and

---

[662] American Association of State Highway Officials, *Standard Specifications for Highway Bridges*, xxiii.
[663] American Association of State Highway Officials, "Geometric Design Standards for the National System Interstate and Defense Highways," *American Highways* (October 1961): n.p.
[664] American Association of State Highway Officials, *Policies on Geometric Highway Design* (Washington, D.C.: American Association of State Highway Officials, 1945), 4.
[665] George L. Carver, "The Interstate System Survey," in *Proceedings of the Twenty-Third Annual Short Course in Highway Engineering*, ed. Fred J. Benson (College Station, Texas: Texas Engineering Experiment Station, A&M College of Texas, 1949), 54-55.
[666] American Association of State Highway Officials, *A Policy on Grade Separations for Intersecting Highways* (Washington, D.C.: American Association of State Highway Officials, 1944), 43.
[667] American Association of State Highway Officials, *A Policy on Design Standards: Interstate System* (Washington, D.C.: American Association of State Highway Officials, 1959), 5-6.
[668] American Association of State Highway Officials, *A Policy on Arterial Highways in Urban Areas*, n.p; American Association of State Highway Officials, *Standard Specifications for Highway Bridges*, n.p.
[669] American Association of State Highway Officials, *A Policy on Geometric Design of Rural Highways*, n.p. American Association of State Highway Officials, *Standard Specifications for Highway Bridges*, 9th ed. (Washington, D.C.: American Association of State Highway Officials, 1965), 502.

promoted by AASHO and the BPR were incorporated into the THD's postwar bridge program, some with modifications that are discussed more below.

*The THD's Creation and Use of Standard Plans*

The THD had established a Bridge Section in 1918, with responsibility for preparation of standard bridge designs and drawings. In 1928, the Bridge Section was reorganized, expanded, and renamed the Bridge Division, with a staff that included bridge engineers, bridge designers, draftsmen, and resident engineers who worked in the field on construction projects.[670] By 1957, the Bridge Division included 55 full-time and a minimum of 10 part-time employees. The Bridge Division was responsible for designing all structures constructed by the THD, including the design of standard plans and project-specific plans for more difficult bridge crossings. Division engineers also provided guidance during planning, surveying, and construction, and worked closely with district offices on projects.[671] THD bridges were an important component in providing a complete state transportation system. Texas Highway Commission Chairman Herbert C. Petry, Jr. highlighted the importance of bridges in a 1964 *Texas Highway* article titled "As a Diamond is to a Ring...so is a Bridge to a Road." Petry states "…to the Texas Highway Department a bridge is only a link in 65,000 miles of highways designed with one overriding function in mind: Bringing total road service to all the people."[672]

Texas, like most states nationwide, utilized standard plans and specifications to efficiently and economically meet increased demand for bridges, coinciding with major road-building efforts after the war. Texas's standards were often based on national guidance, but the THD also developed a number of its own specialized bridge plans and details. Standardization of bridge plans was recognized by the THD and other departments of transportation across the country as a useful tool for the design and construction of economic structures. For frequently used bridge types, standard plans saved both design and construction time. By 1945, development and use of standard plans was common practice for the THD's Bridge Division, which had been using standard plans since the late 1910s for a wide variety of bridge types.[673]

Early standard plans developed by the THD for concrete slabs and rolled steel I-beam structures as early as 1918 and 1919, respectively, continued to be updated and utilized during the subject period. For example, in looking for an economical method of construction for structures on the farm-to-market road system, the THD developed a new design for slab construction. This design, known as the FS slab, used monolithically-poured curbs to carry part of the load, allowing for a thinner slab. THD issued its first set of FS slab standards in 1944. Many structures were constructed according to these standards on farm-to-market roads.[674] Around 1948, the THD developed another set of standard plans for slabs that allowed easier constructability and required less concrete. In these plans, span lengths were adjusted for different skews so that the same length of bar joists could be used to support the forms.[675]

The THD prepared and routinely revised its standard bridge plans to address new bridge types or incorporate updates as necessary. For example, the THD modified plans for continuous concrete slabs for span lengths of 50,

---

[670] Ralph K. Banks, "A History of the Bridge Division," Copy provided by author, [1991], 9.
[671] Banks, "A History of the Bridge Division," 4-9.
[672] "As a Diamond is to a Ring...so is a Bridge to a Road," *Texas Highways* 11, no. 8 (August 1964): 6.
[673] Stocklin, "Historic Bridges of Texas, 1866-1945," *National Register of Historic Places Multiple Property Documentation Form*, E-28 - E-30.
[674] Texas Department of Transportation, *Bridge Design Manual*, 7-16.
[675] Texas Department of Transportation, *Bridge Design Manual*, 7-16.

80, 100, and 110 feet between 1945 and 1950. In 1944, flat slab standard designs were also prepared in lengths of 15, 20, and 25 feet for a number of variations; many of these designs were based on AASHO specifications.[676] Standard drawings for rolled steel I-beams were also revised and widely used. In the early 1960s, this type fell out of favor due to rising steel prices and increased use of prestressed concrete beams or girders.[677]

The THD also developed standard plans in the late 1940s and 1950s for new bridge types, such as pan-formed girder bridges. The first standard plan for the concrete pan-formed girder type was developed in 1948 as an economical and easily constructed bridge for the state's farm-to-market roads. The creation of standard plans for these bridges allowed rapid design and construction, which led to their widespread use during the period. In the 1950s, the THD developed plans for precast, pre-tensioned concrete girders, which were described as "best sellers" in the THD's bridge-building program.[678] In 1956, the THD prepared a standard plan for a continuous concrete girder to be used for interstate overpasses, but this plan had limited use.[679]

The majority of bridges constructed in Texas during the post-World War II period reflect designs and materials of national bridge-building trends influenced by plans and specifications disseminated by AASHO, the BPR, and other national associations. However, in some cases, the THD either modified BPR and AASHO specifications and standard plans or definitively stated that the existing THD standards took precedence. Documentation of the THD's interest in pursuing their own bridge designs rather than BPR and AASHO designs is found in an Administrative Circular from State Highway Engineer Dewitt C. Greer to THD engineers on May 6, 1949. In his cover memo, which introduced the 1949 AASHO Design Standards, Greer stated that if there was a conflict between the 1945 THD Standards and the AASHO standards, the Texas standards took precedence.[680] Another example is seen in the THD's decision to not use AASHO's prestressed slab and box beam units. TxDOT's *Bridge Design Manual* states that when AASHO and the PCI published recommendations for standard shapes of prestressed bridges in 1962, the THD was not interested in using the slab and box beam units and continued its use of the THD I-beams and pilings.[681] Furthermore, Leroy Crawford, a former THD Bridge Division engineer, recalled that in the mid-1950s the THD established the Texas Types A, B, and C prestressed concrete beams to make more effective use of the strand patterns than the AASHO beam Types I, II, and III. Texas's adaptation was more economical, and as Crawford remembered, the Texas type C beam was adopted by AASHO in later years.[682]

In addition to standard plans for superstructures, the THD developed standard details for railings during the 1940s, 1950s, and early 1960s. Railing standards were developed by the THD as early as the late 1910s for a variety of post materials, including metal, wood, and concrete.[683] The THD continued to modify and add new railing designs during the subject period in response to increased safety standards, material innovations, and new bridge types.

---

[676] Texas Department of Transportation, "THD Standard Designs for Concrete Flat Slab and Continuous Slab Bridges, 1918-1950," N.p., n.d., n.p.
[677] Texas Department of Transportation, *Bridge Design Manual*, 7-108.
[678] Banks, "A History of the Bridge Division," 6-7.
[679] Texas Department of Transportation, *Bridge Design Manual*, 7-7.
[680] Greer, Administrative Circular No. 3-49, 6 May 1949.
[681] Texas Department of Transportation, *Bridge Design Manual*, 7-61.
[682] Leroy Crawford, Interview by Mead & Hunt, Inc. and TxDOT Bridge Division, Texas Department of Transportation, digital audio and video recording, Home of Leroy Crawford, Huntsville, Texas, October 27, 2006.
[683] "Texas Historic Bridge Survey: THD Railing Standards," N.p., n.d., n.p.

*Economies of Scale and Standardization*

During the postwar years, the cost of bridges increased due to scarcity of skilled labor and materials. In the 1950s it was estimated that the THD was spending $30 million on bridge construction, while unit cost per bridge rose 250 to 300 percent during the decade.[684] As a result of large bridge expenditures, the THD was continually challenged to find economical construction methods and bridge designs. Constructing economical bridges was the THD's emphasis during the post-World War II period.

One of the ways the THD helped to keep costs low was the open lines of communication among the Bridge Division and district bridge engineers. Interviewed engineers noted that the bid prices for all structures were compiled and circulated to the Bridge Division and district engineers on a regular basis. This enabled engineers across the state to see cost comparisons of bridge types used statewide. Additionally, the Bridge Division and bridge engineers from the districts met approximately once a year to discuss a variety of issues from new bridge technologies to strategies to help save time and money. Other factors that contributed to the low cost of Texas bridges included the use of in-house engineers, the availability of cheap manual labor, and long building seasons. According to Ed Suchiki, a retired THD bridge engineer who began his career in the northeast U.S., other states were using consulting firms rather than in-house engineers to complete their design work. In his opinion, this led to higher design costs and higher construction costs because the decision-making was taken out of the government officials' hands. Suchiki also stated that the cost of construction was much cheaper in Texas compared to the northeast states because not much of the labor in Texas was unionized.[685] Lastly, the long building season was also noted by interviewed engineers as a reason for decreased building costs. When contractors were able to work year-round, they did not have to inflate their bids to help recoup the expense of their equipment sitting idle for several months, which contributed to overall lower construction costs for the state.

The THD's efforts to design and construct economic structures were discussed in a 1948 article in the national publication *Roads and Streets*. B.A. Trice, THD engineer, stated that "in the search for economical methods, the designer's choice is presently influenced by two prime factors: simplicity and mass production."[686] Both of these factors are demonstrated in the THD's research, design innovations, and construction methods employed during the period. Methods for mass production as an economic means of construction were investigated and implemented by the THD.

The THD's initiative to create economies of scale is demonstrated during this period in its development of a standard plan for a low-cost concrete bridge to be used on farm-to-market roads. In developing the standard plan for pan-formed girders, the THD placed careful consideration on reducing the overall cost of the structure by limiting the amount of formwork needed. The resulting design met both principles of simplicity and mass production. Economy was achieved because the series of arches enabled efficient use of both concrete and reinforcing steel, and self-supporting forms eliminated formwork, which had become expensive due to the shortage of lumber and skilled carpenters following the war. Contributing to its economy was the fact that this bridge type required very little equipment to construct, could be erected quickly with little skilled labor, and the steel forms could be reused. The cost of construction for this bridge type was lower than any other type in Texas, if the cost of original reusable steel forms was not included.[687] This bridge type also allowed the THD to have a structure with

[684] "Celebrating 50 Years of Cooperative Research," Texas Transportation Researcher Online, 108.
[685] Ward and Suchiki, Interview by Mead & Hunt, Inc. and TxDOT Bridge Division, Texas Department of Transportation.
[686] Trice, "Low Cost Concrete Bridge," *Roads and Streets*, 83.
[687] Trice, "Low Cost Concrete Bridge," *Roads and Streets*, 85.

the advantages of girder construction at the same unit price as slab construction.[688] In a *Construction and Maintenance* bulletin, C. E. Gresham, a District 25 (now Childress District) engineer, stated that "the use of the steel form for the construction of (pan-formed) bridges is the nearest approach we have made towards 'mass production' of bridges to date."[689]

Another example of the THD's economies of scale initiative is construction of interstate bridges. *Highway News*, an internal THD publication, reported in 1963 that "Texas is building bridges across its Interstate System at the lowest cost per square foot of any state surveyed in a nationwide report." [690] Specifically, in the early 1960s, Texas was most economical in construction of prestressed cast-in-place concrete and structural steel interstate crossroad bridges.[691] Standard plans developed by the THD contributed to the low bridge construction costs for types including prestressed concrete girders and concrete pan-formed girder forms.[692]

Investigation of new materials, including prestressed concrete and welding, also identified economies in material, construction, and maintenance costs. Research at the TTI and TEES at Texas A&M focused on construction of economical and improved structures. Prestressed and prefabricated concrete beams and girders were investigated for their ability to reduce construction costs, improve bridge performance, and maximize the use of structural materials.[693] At a conference in 1953, James R. Graves, a senior design engineer with the THD, presented on cost-effectiveness of prestressed concrete. Graves cited that prestressed concrete offered a more economical material and construction method, which could reduce maintenance over time and offer more opportunities for possible future widening.

---

[688] Trice, "Low Cost Concrete Bridge," *Roads and Streets*, 83.
[689] C. E. Gresham, "Comparison Cost of Concrete Girder and Slab Design Bridges," *Construction and Maintenance* Bulletin No. 20, (Feb 1953): 40.
[690] "Building Bridges Costs Texas Less," *Highway News*, 6.
[691] "Building Bridges Costs Texas Less," *Highway News*, 6.
[692] "Building Bridges Costs Texas Less," *Highway News*, 6.
[693] Melloh, *Activities of the Texas Engineering Experiment Station for 1952-53 and 1953-54*, 22.

*The THD's Influence on National Design Standards*

THD engineers attended national AASHO meetings and likely participated in the review of bridge specifications and recommendation of improvements and new initiatives. As a result, THD engineers were able to bring their experience and perspective to a national audience, influencing some specifications and standards adopted nationally.

These specific design innovations were developed by the THD and associated university research facilities at UT-Austin and Texas A&M. For example, in the 1950s, the THD began utilizing shoulder-width bridges, where the bridge was the same width as the approach road and shoulder. This design change addressed the problem of accidents occurring at the beginning of the bridge, where the horizontal clearance (or width) became restricted. Similarly, the THD had previously begun incorporating gravel shoulders on major highways to provide a safety margin for veering drivers. Recognizing the shoulder-width bridge's advantage of improved roadway safety, AASHO incorporated this design in its standards in 1969.[694] AASHO's delay in including this as part of the standard specifications may have been due to additional construction costs of wider structures.

In another example, standards developed by the TTI and the THD for lightweight concrete were adopted as the recommended policy nationally and were included in the "Proceedings of the Third World Conference on Prestressed Concrete."[695] Standards developed through the THD's research for lightweight concrete are believed to be important, but the literature does not discuss the nature of these specifications. The THD's innovative use of neoprene bearing pads on abutments (concrete or piling supporting the end of a bridge deck) was included in AASHO's 1961 *Standard Specifications for Highway Bridges.*[696] Additionally, according to Leroy Crawford, AASHO adopted the Texas Type C prestressed concrete beam due to its economical and effective use of strand patterns.[697]

Although THD developed bridge standards as early as 1918, standard plans played a more vital role in the 1945 to 1965 period, when the THD (and other state highway agencies) focused on building bridges quicker and more inexpensively than they had before World War II. The use of standard plans during the postwar years helped this effort since highway engineers spent less time designing the bridges and the contractors could familiarize themselves with standard plans that were used repeatedly. The standardization of new bridge types, such as pan-formed girders and prestressed concrete girders, also helped to introduce these types in a consistent and uniform way. The majority of bridges constructed in Texas between 1945 and 1965 reflect designs influenced by national trends; however, the THD's innovative drive led to the development of many new and original standard plans that benefited the agency during this period and after.

*Aesthetics in Postwar Bridge Design*

The THD's primary focus in the post-World War II period was on construction of economic structures; a lesser priority was placed on the incorporation of aesthetics. High labor costs, the need to build many bridges quickly,

---

[694] Texas Department of Transportation, *Bridge Design Manual*, 4-2.
[695] Texas Transportation Institute, *Texas Transportation Institute: Its Purpose, its Achievements, 1955-58*, n.p.
[696] A. E. Johnson, ed., Published on the Occasion of the Golden Anniversary American Association of State Highway Officials: A Story of the Beginning, Purposes, Growth, Activities and Achievements of AASHO, 105.
[697] Crawford, Interview by Mead & Hunt, Inc. and TxDOT Bridge Division, Texas Department of Transportation.

and improved methods of mass production contributed to the inattention to aesthetics in bridge design. Whether or not a bridge design has aesthetic significance can be a subjective determination. In addition, aesthetic ideals change over time. The National Register recognizes aesthetic achievement in design and construction under *Criterion C* when a structure displays "high artistic values." British engineer Oscar Faber explained in 1945 that achieving beauty in bridge design depended on harmony, composition, character, expression of function, expression of construction, rhythm, color, and texture of materials.[698] David Billington, author of notable books on bridges, described the criteria for structural art as "minimum materials, minimum cost, and maximum aesthetic expression."[699] This section provides a general background history of aesthetic principles as applied to bridge design in the U.S. in the mid-twentieth century and explores how and when aesthetics were incorporated in Texas bridges.

*Design Principles of the Postwar Period*

Following World War II, the U.S. entered a time of unprecedented prosperity and optimism due to the triumph of democracy over fascism. New artistic styles were embraced as a way to convey the spirit of the era. Modernism, as had been previously introduced in Europe by architects such as Ludwig Mies van der Rohe and Walter Gropius, increasingly influenced architectural design throughout the U.S., including in Texas. At the foundation of modernist principles, in all design arts, was rejection of traditional styles and ornamentation. Standardization and prefabricated parts played an increasingly important role in advancing construction methods. Availability of high quality craftsmanship had been largely absorbed and dispersed by the war effort.[700] Rational and technologically sophisticated designs proliferated for bridges, buildings, and structures of all kinds.

In the post-World War II era, the Modernist principle that "form follows function" was the primary driver of aesthetics of bridge design. This principle was introduced by Chicago architect Louis Sullivan in the late nineteenth century. Application of "form follows function" in bridge design was generally understood to mean that structural efficiency leads to aesthetic quality. THD engineers echoed this philosophy in comments about bridge design. For example, as discussed in more detail below, Farland C. Bundy noted that welding resulted in an efficient superstructure that was also aesthetically pleasing.[701] In a recent article reflecting on twentieth-century bridge designers, Professor Paul Gauvreau of the University of Toronto notes that structural efficiency and economic use of materials alone did not result in aesthetic bridges. He cites gifted designers such as Othmar Ammann and Robert Maillart as rare in their ability to use the discipline imposed by efficiency and economy to achieve structures of aesthetic significance.[702]

Modernism as applied to bridge design was profoundly influenced by new technology as innovative steel and concrete structural systems made possible unprecedented span lengths during the subject period. Bridge engineers often selected reinforced and prestressed concrete for their economy, but these materials also had aesthetic potential. In her 1949 book *The Architecture of Bridges*, Elizabeth Mock advocated that bridge designers use new materials to achieve aesthetic expression in bridge design. Mock prescribed that reinforced concrete's potential for

---

[698] A. C. Liebenberg, "Aesthetic Evaluation of Bridges," in *Bridge Aesthetics Around the World* (Washington, D.C.: Transportation Research Board, National Research Council, 1991), 3.
[699] David P. Billington, "Bridges and the New Art of Structural Engineering," in *Bridge Aesthetics Around the World* (Washington, D.C.: Transportation Research Board, National Research Council, 1991), 72.
[700] Frampton, *Modern Architecture: A Critical History*, 222-223.
[701] Bundy, "Design of Welded Bridge Structures," *Texas Highways*, 136.
[702] Paul Gauvreau, *The Three Myths of Bridge Aesthetics* (N.p.: n.d.), 4-5.

aesthetic expression could best be realized in two-and three-hinged arches, slender spandrel columns, and thin bridge decks.[703] Maillart, a Swiss engineer, was singled out by Mock and other authors for his success in using reinforced concrete to create new and visually appealing forms in his early twentieth-century bridge designs.[704] In addition to being aesthetically pleasing, Maillart's designs of two main types—the deck-stiffened arch and the three-hinged arch with a hollow box section—used materials efficiently. His most famous work, the Salginatobel Bridge (1930), spectacularly set over a gorge in Switzerland, was the most economical of 18 designs submitted and exploited the potential of reinforced concrete to create a new, visually appealing arch form.[705]

Prestressed concrete emerged as a significant material in bridge design internationally and was broadly adopted in the U.S. in the 1950s. Eugene Freyssinet of France, a leader in prestressed concrete design, was credited with the economical use of this material to accomplish slender bridge designs of aesthetic importance. His Caracas-La Guaria Bridge (1954) in Venezuela, with its three separate arch ribs, exemplifies his aesthetic accomplishments.[706] Beginning his career in the 1960s, Swiss engineer Christian Menn used prestressed concrete to create bridges that were both beautiful and economical, as noted by David Billington.[707]

Writing in 1949, Mock noted that design excellence required an engineer's respect for economy of materials and proportion, combined with refinement of structural elements. She saw promise for the future of bridge aesthetics in the relatively new idea of structural continuity, which allows structural elements to be "literally fused into a single working shape," and in welded steel, as a material that can be molded into thin shells.[708] Billington observed that American engineers did not embrace possibilities of developing new forms in reinforced concrete, as introduced by Maillart, due to their complexity.[709]

In the postwar U.S., a preoccupation with "the reassuring weightiness of stone construction" was said to stand in the way of achieving aesthetic contemporary bridge designs.[710] While engineers of the late nineteenth century, such as John Roebling and Gustave Eiffel, had used new materials to create beautiful bridges, American engineers of the twentieth century were faulted for reversing this trend by choosing expediency over beauty.[711] Mock described that rather than designing with clean lines and an efficient form, her contemporaries used external "styling" on bridges, often to approximate the appearance of stone. Examples of false styling include horizontal members "distorted into arches" and abutments that are designed to appear excessively solid.[712] A 1948 *Bridge Design* textbook, published in London, recommended against disguising concrete by covering it with a masonry veneer.[713] Characterizing

---

[703] Elizabeth B. Mock, *The Architecture of Bridges* (New York: The Museum of Modern Art, 1949), 88.
[704] Mock, *The Architecture of Bridges*, 102; Billington, "Bridges and the New Art of Structural Engineering," in *Bridge Aesthetics Around the World*, 68-72.
[705] Mock, *The Architecture of Bridges*, 103; Billington, "Bridges and the New Art of Structural Engineering," in *Bridge Aesthetics Around the World*, 72-73.
[706] Mock, *The Architecture of Bridges*, 101; Jean M. Muller, "Aesthetics and Concrete Segmental Bridges," in *Bridge Aesthetics Around the World* (Washington, D.C.: Transportation Research Board, National Research Council, 1991), 19.
[707] Billington, "Bridges and the New Art of Structural Engineering," in *Bridge Aesthetics Around the World*, 75-77.
[708] Mock, *The Architecture of Bridges*, 9.
[709] Billington, "Bridges and the New Art of Structural Engineering," in *Bridge Aesthetics Around the World*, 74.
[710] Mock, *The Architecture of Bridges*, 8.
[711] Mock, *The Architecture of Bridges*, 8; Billington, "Bridges and the New Art of Structural Engineering," in *Bridge Aesthetics Around the World*, 68-72.
[712] Mock, *The Architecture of Bridges*, 8.
[713] David Y. Hill, "The Architectural Design of Concrete Bridges," in *Highway Bridge Design* (London: Charles Griffen & Company Limited, 1948), 253.

American bridges as "grossly over-dimensioned," Mock blamed low cost of materials and high expense of labor as making it easier to use extraneous materials than to build a lighter design that requires skilled craftsmanship.[714]

Suspension bridges were highlighted as a noteworthy exception to predilection for massiveness in bridge design in the U.S., offering America's "one important contribution to modern bridge design," according to Mock's 1949 assessment.[715] Suspension bridges achieved strength without apparent mass and represented a true expression of economy of material.[716] Plate girder arches (three-hinge arches built up of steel plates) garnish more restrained praise in this book of the period. Described by Mock as "today generally considered the handsomest of all possible types of steel bridges, with the single exception of the suspension bridge," plate girder arches are said to be "elegant," although they fall short by not expressing "the special nature of their material."[717] No suspension bridges were built in Texas during the subject period; a small number of metal arches were built, although they did not appear to employ plate girders.

In the post-World War II era, American styles from earlier in the twentieth century still found expression in more conservative building programs, especially for public architecture. In bridge design, this conservatism may have resulted in predilection for external "styling" as noted by Mock. Styles that were prevalent in the two decades prior to the war included Art Deco, Moderne, and Period Revival. The Art Deco style, which enjoyed its peak of popularity between 1920 and 1930, was characterized by the use of ornate geometric motifs to express contemporary trends of industrialization and modernization. Moderne style, or Streamlined Moderne, was a more restrained version of the Art Deco style and was popular from 1930 until World War II. Moderne designs featured smooth surfaces and curved corners. Designs based upon the continuation of the traditions of classical architecture are recognized by the general stylistic term Period Revival.[718]

By the end of the subject period, aesthetic considerations were even less likely to be part of bridge designs. Author Kenneth Frampton has noted that, by the mid-1960s, the "reductive codes" of contemporary design had "led to an impoverishment of the urban environment" in American cities.[719] A 1964 article in *Traffic Engineering* found fault with the design of grade separation structures of the era, calling for them to "pay more attention to architectural excellence."[720] The article's author, Joseph Barnett of the BPR, was encouraged by a recent trend toward minimizing piers and columns through use of greater floor depth, which he thought resulted in an improved appearance. Barnett called for bridge engineers to be attentive to proportion and shadow lines.[721] Nationally, bridge design publications and standards were generally silent on aesthetics.

*The Texas Highway Department and Aesthetics*

In post-World War II Texas, aesthetics was a minor consideration in bridge design. Publications of the THD during the era gave little mention to aesthetics. TxDOT's *Bridge Design Guide* (1990 version) acknowledged that

---

[714] Mock, *The Architecture of Bridges*, 8.
[715] Mock, *The Architecture of Bridges*, 9.
[716] Mock, *The Architecture of Bridges*, 54.
[717] Mock, *The Architecture of Bridges*, 45.
[718] "Architecture," Handbook of Texas Online, <http://www.tsha.utexas.edu/handbook/online/articles/view/AA/cmask.html> (accessed 8 October 2004).
[719] Frampton, *Modern Architecture: A Critical History*, 288.
[720] Joseph Barnett, "Road Design: Some Modern Aspects," *Traffic Engineering* 34, no. 4 (January 1964): 22.
[721] Barnett, "Road Design: Some Modern Aspects," *Traffic Engineering*, 22.

"Architectural harmony has been subordinated to economy for the majority of Texas's bridges."[722] Aesthetic principles, when incorporated, typically appeared in railings and, after the late 1940s, in the shape of bents and piers.[723] Award-winning designs were presented in the THD's newsletter, *Texas Highways*. A neat appearance and clean lines were attributes that were typically praised and were almost always mentioned in tandem with economy and function.

One conscious attempt to incorporate aesthetics into bridge design occurred in 1945, when the THD engaged architectural engineers to help the Bridge Division develop new functional and architectural ideas, especially for the design of grade separation structures. Their stated aim was to achieve simplicity in design. Designs that used slender columns and continuous superstructures to produce streamlined effects without appearing overly "modernistic" were praised.[724]

Concrete rigid frame bridges were sometimes acknowledged as aesthetic. Mainly used on urban roadways in Texas during the subject period, concrete rigid frame bridges were often used as grade separation structures. A concrete rigid frame bridge, built on US 81 in Bell County in 1957, was described in a *Texas Highways* article as having enhanced aesthetics due to its metal, picket style railing, and arched profile.[725]

In 1954, Farland C. Bundy of the THD wrote of the advantages of all-welded plate girder bridges, mentioning their "architectural features." He noted that: "Welding provides for clean lines and light appearance of the superstructure. The accompanying railing, wing walls, and substructure should not be overly ornate or massive in keeping with the appearance of the girders. . . Much can be done with the railing and railing ends to add to the appearance of a bridge."[726] Bundy's accomplishments in the design of welded bridges were later recognized in two national awards for the Buffalo Bayou Twin Bridges (1956), including the "Most Beautiful Bridge" award from AISC.

In the 1950s and 1960s, continuous concrete girders with parabolic girder soffits were considered aesthetic by some THD engineers. This type was particularly popular in the Waco District where individual bridges were designed by district staff. It was also used on major highways in Austin, Amarillo, and Wichita Falls, and over interstate highways in the Abilene and Bryan Districts.[727] Variable-depth concrete slabs were also considered an attractive design in the 1950s and were designed with a parabolic soffit for interstate crossover structures.[728]

Periodically, the THD recognized beautiful bridge designs in its internal publications. In the September 1964 issue of *Texas Highways*, the THD reprinted excerpts and photographs from a feature that had appeared recently in *Time* magazine. As quoted, the article referred to a "golden age of bridges" in which money, materials, and technology were combined to create bridges of "breath-taking beauty."[729] Four Texas bridges pictured in *Time* were the Pecos River Bridge (1957) in Val Verde County—a continuous steel deck truss (TxDOT Structure No.: 22-233-0-0022-06-068); the Buffalo Bayou Twin Bridges (1956) in Houston, Harris County—a pair of continuous welded plate

---

[722] Texas State Department of Highways and Public Transportation, *Bridge Design Guide*, 3-24.
[723] Texas State Department of Highways and Public Transportation, *Bridge Design Guide*, 3-24, 6-04.
[724] "Texas Bridge Designers Looking Ahead," *Roads and Streets* 88, no. 7 (July 1945): n.p.
[725] C. H. Barclay, Jr., "Evolution of a Rigid-Frame Bridge," *Texas Highways* 4, no. 11 (November 1957): 20, 27.
[726] Bundy, "Design of Welded Bridge Structures," *Texas Highways*, 136.
[727] Texas Department of Transportation, *Bridge Design Manual*, 7-34.
[728] Texas Department of Transportation, *Bridge Design Manual*, 7-19.
[729] "A Thing of Beauty," *Highway News* 18, no. 9 (September 1964): 5.

girders and national prize winner (TxDOT Structure Nos.: 12-102-0-0027-10-062 and 12-102-0-0027-10-063); and the Corpus Christi Harbor Bridge (1959) in Nueces County—with its cantilevered through steel arch central span (TxDOT Structure No.: 16-178-0-0101-06-041).[730] All of these bridges were extant in 2009. A 1965 *Texas Highways* article gave credit to the engineers of the elevated, one-mile-long section of IH 45 (1965) through downtown Houston for using inverted T-shaped bent caps to "give the structure a neat and slender appearance."[731] The THD felt that the Bridge Division's design overcame concerns that the elevated highway would divide downtown or be unsightly and credits its efforts to "streamline the facility" with overcoming these challenges.[732] The resulting design was also described by the THD as economical and functional.[733]

Several bridges won national awards for their overall aesthetic designs. Since simplicity and clean lines were the main aesthetic ideal, it is not surprising that many of these bridges won awards for applying these principles. Seven Texas bridges were honored by the American Institute of Steel Construction; at least five of these were THD designs. The bridges with structure identification numbers were the only bridges that were confirmed extant in 2009. Honored bridges, in order by date of construction, were:

- Gulf Freeway Overpass (1950) carrying IH 45 over the Galveston, Harrisburg & San Antonio Railroad and Griggs Road in Houston, Harris County, (TxDOT Structure Nos:12-102-0-0500-03-010 and 12-102-0-0500-03-363)[734]
- Neches River Bridge (1952) on IH 10 in Beaumont, on the Jefferson-Orange County Line, (TxDOT Structure No.: 20-181-0-0028-09-065)[735]
- Roberts Street Underpass (1953), a pedestrian bridge over IH 35W (then known as US 81) in Fort Worth, Tarrant County[736]
- Buffalo Bayou Twin Bridges (1956) on US 90-A in Houston, Harris County, (TxDOT Structure Nos.:12-102-0-0027-10-062 and 12-102-0-0027-10-063)[737]
- Hampton Road over IH 30 (1957) in Dallas County (TxDOT Structure No.: 18-057-0-1068-04-109)[738]
- Devils River Bridge (1965) on US 90, west of Del Rio in Val Verde County (TxDOT Structure No.: 22-233-0-0022-09-070)[739]
- Morningside Drive Underpass (construction date unknown) on IH 35W (then known as US 81) in Fort Worth, Tarrant County[740]

Entries were classed by the American Institute of Steel Construction according to size, cost, and operating conditions, and judged on appearance only by leading architects, engineers, educators, and museum curators.

---

[730] "A Thing of Beauty," *Highway News*, 5.
[731] Hall, "I. H. 45 Soars Through the Air," *Texas Highways*, 9.
[732] Hall, "I. H. 45 Soars Through the Air," *Texas Highways*, 8.
[733] Hall, "I. H. 45 Soars Through the Air," *Texas Highways*, 8-9.
[734] "Five Most Beautiful Bridges," *Texas Highways* 4, no. 7 (1957): n.p.
[735] "'Beauty Award' Goes to Neches River Bridge," *Texas Highways* 1, no. 2 (December 1953): 13.
[736] California Division of Highways, *Manual of Bridge Design Practice*, 9; "Five Most Beautiful Bridges," *Texas Highways*, n.p.
[737] "Buffalo Bayou Twin Bridges Win National Recognition in Contest," *Highway News* 11, no. 9 (October 1957): 1.
[738] "$10,000 Design," *Texas Highways* 5, no. 9 (September 1958): 19; James G. Clark, ed., *Welded Interstate Highway Bridges*, 12, 189-197.
[739] "Devils River Bridge," *Highway News* 19, no. 12 (December 1965): n.p.
[740] "Five Most Beautiful Bridges," *Texas Highways*, n.p.

Simplicity of design seemed to appeal to both judges and designers. Aesthetic features of the Neches River Bridge (1952) were identified in *Texas Highways* as having "clean design which is devoid of extraneous ornamentation" and "serene and graceful lines."[741] The award-winning design for the Hampton Road two-hinged arch (1957), which used box girders for its four arch ribs, was likewise credited with "architectural simplicity" and "clean-cut lines."[742] The graceful design of the Devils River Bridge (1964) was said by judges to show "great thought, economy, and restraint."[743] The "rhythm-like treatment" of the deck and repetitive theme of the squared piers were credited for the pleasing design.[744] One winner in the American Institute of Steel Construction contest, the Roberts Street Underpass (1953), was also internally selected by Bridge Division engineers as among the most outstanding bridges in the country based on its beauty, function, and design.[745]

THD Bridge Division engineers Farland C. Bundy and Charles S. Matlock won another award for their design of the Buffalo Bayou Twin Bridges (1956) where aesthetics was one of several factors considered. Sponsored by the James F. Lincoln Arc Welding Foundation, the 1958 contest was open to welded bridges on interstate and defense highways. The criteria by which bridges were judged included economical use of labor and steel, appearance, cost, general quality, and use of advantages of welded construction.[746] Bundy and Matlock explained their design as economical to fabricate and in its use of materials, as well as pleasing in appearance.[747] Based on the THD's philosophy during the subject period, it is likely that economy and function were these engineers' primary considerations and aesthetic appeal was almost an incidental result.

THD's engineers also examined aesthetic improvements to railing design.[748] At a time when cost savings was paramount, decorative features were also applied to bridges of the subject period as an attempt to create aesthetically-pleasing bridges, particularly in urban areas and in parks. Although less dramatic than the classical elements on bridges during the early twentieth century, the decorative detailing on the bridges of the subject period were muted but showed a recognition that aesthetic designs were important. With the cost of steel being very expensive in the 1940s and 1950s, the use of metal picket railings, which are mainly found on urban bridges, is an example of the THD's attention to applying aesthetic detailing to bridges of the time period. Likewise, the uses of concrete modillions on the sides of superstructures, the creation of stone or brick parapets, and the employment of decorative lighting also illustrate an awareness of aesthetic ideals.

*Post World War II Engineering/Technological Developments: Conclusion*

During the 1945 to 1965 period, aesthetic principles focused on the clean lines with little ornamentation to detract from a structure's form. Such ideals were true in the design and construction of buildings, as well as in bridge engineering throughout the country. While a few of the bridges built during the study period were awarded from their aesthetically impressive designs, these were generally large signature structures built by THD engineers. In urban areas, visually pleasing structures such as variable depth slabs and rigid frame bridge types were used, as were decorative features. However, the majority of the bridges built in the state during the subject period had no or

---

741 "'Beauty Award' Goes to Neches River Bridge," *Texas Highways*, 13.
742 James G. Clark, ed., *Welded Interstate Highway Bridges*, 189-190.
743 "Devils River Bridge," *Highway News*, n.p.
744 "Devils River Bridge," *Highway News*, n.p.
745 "Five Most Beautiful Bridges," *Texas Highways*, n.p.
746 "Bundy and Matlock Receive Award," *Highway News* 12, no. 7 (August 1958): n.p.
747 James G. Clark, ed., *Comparative Bridge Designs*, 41.
748 "Texas Bridge Designers Looking Ahead," *Roads and Streets*, n.p.

limited artistic design qualities. As noted throughout this context, economical design and construction dominated bridge building during the subject period and high artistic value of bridges was not a priority among bridge designers and contractors.

*Late 1960s Bridge Developments*

To provide a glimpse at the next era in bridge building, limited research was conducted on design and construction techniques from the late 1960s. This research reveals that bridge types and innovations established and used in Texas from 1945 to 1965 continued through 1970. Bridge design and advancements established in the mid-1960s, as well as bridge types, innovations, and technologies established between 1966 and 1970, may illustrate important transitions and modifications in design, technology, and fabrication. The known developments in bridge design and construction established between 1966 and 1970 are as follows:

- Reinforced concrete slabs have been used in Texas and nationally since the 1910s; however, a new development in the bridge type, the two-way reinforced concrete slab design, was first used by the THD in 1967.
- Although the prestressed concrete single Tee beams were used on pedestrian overpass structures in El Paso and Waco during the early and mid-1960s, the THD's first known use of prestressed concrete single Tee beams for vehicular structures was in 1968 on IH 10 in the El Paso District.[749]
- Research indicates that the first prestressed concrete box beams had been designed by Herman Baass for county bridges in the 1950s. However, the THD did not begin designing prestressed box beams until 1969 when the THD modified Baass' design. The THD's adapted design required the use of a large cast-in-place concrete shear key with transverse reinforcing bars threaded through the boxes and bolted for lateral restraint.
- Sometime between 1965 and 1968, the THD stopped its requirement of the use of endblocks on prestressed concrete girders. The endblock is the location of the prestressed wire anchorages. Although contractors had been promoting the elimination of end blocks since the early 1960s, THD engineers were reluctant to allow it until studies later in the decade proved that the endblocks could be eliminated. Since removing the endblocks allowed for a more efficient casting of the prestressed concrete girders, this represents a major shift in the fabrication of these bridge members.

Some innovations were developed in other U.S. states at the end of the subject period, in the early to mid-1960s, but were not utilized in Texas between 1945 and 1965. Since these innovations and developments were not applied in Texas until after 1965, limited information about them is presented in the following list.

- American Welding Society developed provisions for submerged arc-welding in 1963.
- ASCE Subcommittee on box girders assessed the economy of using steel box girders in 1963.
- First orthotropic steel plate deck girder bridge was built in St. Louis in 1964.
- U.S. Steel published a design handbook regarding the use of horizontally curved steel girders in 1965Significant Postwar Designers, Fabricators, and Contractors

[749] Texas Department of Transportation, *Bridge Design Manual*, 7-65.

**Significant Bridge Engineers in Texas**

Bridge designs during the postwar period were largely completed by the THD, which was responsible for standard plans and other bridge designs that were used to construct bridges throughout Texas. Individual engineers at the THD who were recognized for their contributions to research, innovative construction techniques, design variations, and/or awarding-winning designs are noted throughout this historic context. During contextual research, masters were identified as those engineers or contractors who had designed an award-winning or landmark bridge, or directly contributed to the development of an innovative design or construction technique. Additionally, leading engineers at research laboratories are also considered master builders. These significant engineers are identified and organized below in alphabetical order by last name.

*Randle B. Alexander*

Randle B. Alexander was a THD engineer and was a proponent of the economical use of arc-welding for highway bridges. His promotion of the construction technique appeared in a 1950 *Engineering News-Record* article.

*Herman Baass*

Although not an engineer, Herman Baass, president of Baass Brothers Construction Company, designed and built prestressed concrete box beams for counties beginning in the late 1950s, prior to the THD's use of the bridge type. Later, the THD created a prestressed concrete box beam standard based on Herman Baass' prestressed box beam units that Baass Brothers Construction Company was building for county governments.[750]

*Joe C. Bridgefarmer*

Joe C. Bridgefarmer was a construction engineer for Harry Newton, Inc. Along with William L. Powell and THD bridge engineer Douglas A. Nettleton, he received awards from the AISC and the James F. Lincoln Arc Welding competition for a bridge that used a two-hinged welded arch design. This bridge, which carries Dallas' Hampton Road over IH 30 (TxDOT Structure No.: 18-057-0-1068-04-109), was the first example of an all-welded, box girder type arch rib in the U.S.[751]

*G.P. Brown*

G.P. Brown, THD supervising resident engineer, and Amos Humphrey received the AISC's top "Prize Bridge" award in the medium-span high-clearance category for the Devils River Bridge west of Del Rio built in 1964 (TxDOT Structure No.: 22-233-0-0022-09-070). Judges of the award mentioned that the structure's graceful design showed "great thought, economy, and restraint."[752] The "rhythm-like treatment" of the deck and repetitive theme of the squared piers were credited for the pleasing design.[753]

---

[750] Covill, Interview by Mead & Hunt, Inc. and TxDOT Bridge Division, Texas Department of Transportation; Baass, Interview with Mead & Hunt, Inc. and TxDOT Bridge Division, Texas Department of Transportation.
[751] "$10,000 Design," *Texas Highways*, 19; James G. Clark, ed., *Welded Interstate Highway Bridges*, 12, 189-197.
[752] "Devils River Bridge," *Highway News*, n.p.
[753] "Devils River Bridge," *Highway News*, n.p.

*Farland Bundy*

Farland Bundy was a THD engineer who began his career with the agency in 1948. He won two awards, along with Charles S. Matlock, for the Buffalo Bayou Twin Bridges in Houston (TxDOT Structure Nos.: 12-102-0-0027-10-062 and 12-102-0-0027-10-063): the Lincoln Arc Welding Award and the AISC Award. The Buffalo Bayou Bridge was one of the longest welded bridges with the lowest unit price bid in the U.S.[754] According to interviews with Bundy, he also recalled receiving an award for design for overall steel conservation with serrated beam design from the Lincoln Arc Welding Foundation. However, he could not recall if that award was for a particular bridge.[755]

*James P. Exum*

Supervising THD bridge engineer James P. Exum supervised the development of the pan-formed girder bridge. This bridge type, which was created by the THD in the late 1940s, was the most economical and most popular type of the 1945 to 1965 period with more than 2,000 extant bridges still on Texas roads in 2009.

*Hardy E. Fairbanks*

In the early 1960s, Hardy E. Fairbanks, a civil engineering instructor at Texas A&M, researched the use of neoprene as a bearing for steel beams and bridges. Fairbanks found that neoprene bearing plates were suitable elastomeric bearings that were cheaper, more easily installed, and required less maintenance than conventional steel shoes.[756] Until that point, neoprene bearing plates had only been approved for use on concrete girder bridges and Fairbanks' research led to expanded use of neoprene bearing plates.

*Phil M. Ferguson*

Former FHWA bridge engineer Don Harley identified Phil Ferguson, a University of Texas at Austin professor, as "the god of prestressed concrete."[757] Harley, who attended college at the University of Colorado at Boulder, remembered that his textbook on prestressed concrete was written by Ferguson. Initially, Ferguson's research and specialty was reinforced concrete; however, as prestressed concrete became more well-known and popular, Ferguson became the preeminent prestressed concrete expert in UT-Austin engineering laboratory that was later named for him.[758] While Phil Ferguson did not design bridges, he is considered noteworthy for his influence on Texas bridges. As part of the Department of Civil Engineering at UT-Austin, the Balcones Research Laboratory was established in 1950. In 1980 the institution took its present name of Ferguson Structural Engineering Laboratory, in honor of Ferguson, who served as department chair from 1943 to 1957.[759]

---

[754] James G. Clark, ed., *Welded Interstate Highway Bridges*, 12, 15-19. The Buffalo Bayou Bridge also won the American Institute of Steel Construction's "Most Beautiful Bridge" award in 1957.
[755] Bundy, Interview by Mead & Hunt, Inc. and TxDOT Bridge Division, Texas Department of Transportation.
[756] "Elastomeric Bearings are Suitable for Steel Bridges," *Texas Engineering Experiment Station News*, 11.
[757] Harley, Interview by Mead & Hunt, Inc. and TxDOT Bridge Division, Texas Department of Transportation.
[758] Burns, "History of the FSEL Lab," The University of Texas at Austin.
[759] The *Handbook of Texas* cites that the Ferguson Structural Engineering Laboratory began 10 years later in 1960. Burns, "History of the FSEL Lab," The University of Texas at Austin.

*Gibb Gilchrist*

Gibb Gilchrist was a Texas A&M system chancellor and former Texas State Highway Engineer. In 1950, he and Thomas H. McDonald established the TTI at Texas A&M. TTI began its research activities to supplement THD research in 1955.[760]

*James R. Graves*

James R. Graves, a senior design engineer with the THD, is recognized as one of the leading proponents of use of prestressed concrete and the development of neoprene bearing plates. In 1953, only four years after the first prestressed concrete bridge in the US was built, Graves presented a conference paper on the cost-effectiveness of prestressed concrete. He acknowledged that prestressed concrete was an economical material and construction method. According to Bob Reed, a former THD engineer, Graves was responsible for the THD's widespread adoption of prestressed concrete units.[761] Reed also attributed the THD standard design of the Types A, B, and C beams to Graves and notes him as a major promoter of the new technology.

According to Charles Walker, retiree of the TxDOT Bridge Division, in 1956, Graves designed a pre-tensioned, precast prestressed concrete beam bridge for FM 237 at Coleto Creek in Victoria County (TxDOT Structure No.: 13-235-0-0941-04-007). This bridge may have been the first pre-tensioned, precast bridge built by the THD in the state and was reportedly the first bridge in the U.S. to use neoprene rubber bearing pads (TxDOT Structure No.: 13-235-0-0941-04-007).[762] In his autobiographical account of his career entitled "The World as I Saw It," Graves recalls that he asked the DuPont Company to create the neoprene bearing plates, which had been used for the construction of buildings. DuPont referred him to a manufacturer of rubber products, Oil States Rubber Company of Arlington, Texas, which offered several sample pads.[763] These test pads proved successful and became widely used throughout Texas and the U.S. Graves's most notable accomplishment, however, was as the designer of the Corpus Christi Harbor Bridge's combination of precast prestressed and precast post-tensioned concrete beam approaches in 1956. All the beams were special designs as neither AASHO nor the THD had yet completed standards for post-tensioned beams.[764]

---

[760] Horn, "The Texas Transportation Institute - Meeting the Needs for Mobility," in *One Hundred Years of Engineering at Texas A&M, 1876-1976*, 201-202.
[761] Robert L. Reed, n.p.
[762] Charles Walker, 17 February 2005, e-mail to Mead & Hunt.
[763] Graves' autobiography appears to be unpublished; excerpts included in Reed's presentation. Robert L. Reed, n.p.
[764] Charles Walker, Interview by Mead & Hunt, Inc, digital audio and video recording, Travel Division Studio, Riverside Campus Building 150, Austin, Texas, May 30, 2006.

*Dewitt C. Greer*

Although not directly associated with any specific bridges, material innovations, or technologies of the period, Dewitt C. Greer was the state highway engineer from 1940 until 1967. He was the driving force behind the THD's focus on economies of scale and he encouraged the innovative spirit of the THD engineers to further his emphasis on the construction of economical bridges. Furthermore, his activities were essential to the state's planning and prioritization of road and bridge-building activities and insistence on economy of design and materials.

*Wayne Henneberger*

THD Senior Designing Engineer Wayne Henneberger promoted high-tensile bolts in the early 1950s, which were a more economical alternative to field-riveted bridge connections. As noted earlier, Henneberger's promotion of the connection type came several years before AASHO's 1957 specifications. Since their first use in the 1950s, high-tensile bolts replaced the use of rivets on steel bridges in Texas.

*Amos Humphrey*

In 1965, Amos Humphrey, THD bridge designer, and G.P. Brown, THD supervising resident engineer, received the AISC's top "Prize Bridge" award in the medium-span high-clearance category for the Devils River Bridge west of Del Rio built in 1964 (TxDOT Structure No.: 22-233-0-0022-09-070). Judges of the award mentioned that the structure's graceful design showed "great thought, economy, and restraint."[765] The "rhythm-like treatment" of the deck and repetitive theme of the squared piers were credited for the pleasing design.[766]

*E.A. Jelinek*

In 1948, THD bridge designer E. A. Jelinek, along with Charles S. Matlock, developed the pan-formed concrete slab and girder bridge. This bridge type was the most economical and most popular type of the 1945 to 1965 period, with more than 2,000 extant bridges still on Texas roads in 2009.

*Truman R. Jones, Jr.*

Truman R. Jones, Jr. was a research engineer at Texas A&M's TTI. Along with Henson K. Stephenson, he experimented with prestressed and precast concrete bridge elements. In 1957, Jones and Stephenson designed a precast and prestressed concrete bridge design that was approved and employed by the THD through Bridge Division and District 17 (now Bryan District) offices. The prefabricated two-span, multiple-beam bridge proved to be a successful and economical design.[767]

---

[765] "Devils River Bridge," *Highway News*, n.p.
[766] "Devils River Bridge," *Highway News*, n.p.
[767] "Mass Production of Concrete Bridges is Given Experimental Trial in Texas," *Texas Engineering Experiment Station News*, 12-13.

*Charles S. Matlock*

Along with Farland Bundy, Charles S. Matlock, a THD bridge design engineer received the top award in the James F. Lincoln Arc Welding competition in 1958 for the Buffalo Bayou Bridge (TxDOT Structure Nos.: 12-102-0-0027-10-062 and 12-102-0-0027-10-063). The Buffalo Bayou Bridge was one of the longest welded bridges with the lowest unit price bid in the U.S.[768] Matlock was also a designer of early pan-formed girder standard plans.

*Thomas H. McDonald*

Thomas H. McDonald, former chief of the BPR, established the TTI at Texas A&M in 1950 along with Gibb Gilchrist, Texas A&M system chancellor and former Texas State Highway Engineer. TTI began its research activities to supplement THD research in 1955.[769] McDonald believed "transportation is a prime economic force," not just a service. Thus, TTI conducted research in new materials and also the impacts of transportation on Texas economic development, including studies on the food, cotton, and gasoline industries.

*Vigo Miller*

Although trusses were nearly obsolete for small and medium spans in the 1950s and 1960s, the type was used for a small number of bridges requiring long spans. Vigo Miller, a THD bridge designer, designed the Corpus Christi Harbor Bridge (1959), which included cantilevered trusses (TxDOT Structure No.: 16-178-0-0101-06-041). This bridge, which was featured in *Time* magazine, carries US 181 over the Corpus Christi Ship Channel in Nueces County.[770] It is a cantilevered through truss with suspended tie arch that used trusses for its arch ribs.[771]

*Douglas A. Nettleton*

Douglas A. Nettleton was a bridge engineer in District 18 (now Dallas District). Along with Joe C. Bridgefarmer and William L. Powell, he received awards from the AISC and the James F. Lincoln Arc Welding competition for a bridge that used a two-hinged welded arch design. This bridge, which carries Dallas' Hampton Road over IH 30 (TxDOT Structure No.: 18-057-0-1068-04-109), was the first example of an all-welded, box girder type arch rib in the U.S.[772]

*Percy V. Pennybacker*

A long-time THD Bridge Division Engineer, Percy V. Pennybacker was noted by nearly all of the project's interviewees as the major promoter of all-welded construction in Texas. Pennybacker received the L.I. Hewes Award in 1953 for "his outstanding contribution in the use of welding for the repair and construction of highway

---

[768] James G. Clark, ed., *Welded Interstate Highway Bridges*, 12, 15-19. The Buffalo Bayou Bridge also won the American Institute of Steel Construction's "Most Beautiful Bridge" award in 1957.
[769] Horn, "The Texas Transportation Institute - Meeting the Needs for Mobility," in *One Hundred Years of Engineering at Texas A&M, 1876-1976*, 201-202.
[770] "A Thing of Beauty," *Highway News*, 5.
[771] Stocklin, "Historic Bridges of Texas, 1866-1945," *National Register of Historic Places Multiple Property Documentation Form*, E-29, E-43.
[772] "$10,000 Design," *Texas Highways*, 19; James G. Clark, ed., *Welded Interstate Highway Bridges*, 12, 189-197.

bridges."[773] D.C. Greer and the THD recommended Pennybacker for the award because they considered "his contribution to the increased use of welding…to be outstanding, far above that expected of any single person in an organization like the THD."[774] In his obituary, Pennybacker was recognized as an engineering innovator who saved the state of Texas millions of dollars with the new processes he introduced.[775]

*William L. Powell*

William L. Powell, along with Douglas A. Nettleton and Joe C. Bridgefarmer, received awards from the AISC and the James F. Lincoln Arc Welding competition for a bridge that used a two-hinged welded arch design. This bridge, which carries Dallas' Hampton Road over IH 30 (TxDOT Structure No.: 18-057-0-1068-04-109), was the first example of an all-welded, box girder type arch rib in the U.S.[776]

*Robert L. Reed*

Robert (Bob) Reed was an early and consistent proponent of the multiple uses of prestressed concrete in the 1950s and 1960s. Reed was also one of the designers of the 1957 Pecos River bridge located on US 90 west of Del Rio in Val Verde County (TxDOT Structure No.: 22-233-0-0022-06-068).[777] This important 1,310-foot continuous deck truss had a main span length of 415 feet, one of the longest span lengths of any bridge in the state regardless of construction date.

*W.E. Simmons*

W.E. Simmons, THD district engineer, along with E.R. Young, THD supervising urban engineer, received an award in 1952 from the AISC for the Neches River Bridge at Beaumont (TxDOT Structure No.: 20-181-0-0028-09-065). The bridge was identified in *Texas Highways* as a "clean design which is devoid of extraneous ornamentation" and "serene and graceful lines."[778] The award-winning design for the two-hinged arch, which used box girders for its four arch ribs, was likewise credited with "architectural simplicity" and "clean-cut lines."[779]

*Henson K. Stephenson*

Henson K. Stephenson, a research engineer at Texas A&M's TTI, experimented with prestressed and precast concrete bridge elements along with Truman R. Jones. Jones and Stephenson designed a precast and prestressed concrete bridge design that was approved and employed by the THD through Bridge Division and District 17 (now

---

[773] "Pennybacker Receives Welding Award," *Texas Highways*, 15.
[774] "Pennybacker Receives Welding Award," *Texas Highways*, 15-17.
[775] "Rites Conducted at Austin for Percy V. Pennybacker," Section 1, 23.
[776] "$10,000 Design," *Texas Highways*, 19; James G. Clark, ed., *Welded Interstate Highway Bridges*, 12, 189-197.
[777] *Austin American-Statesman*, "Robert Louis (Bob) Reed Obituary," 21 August 2006.
[778] "'Beauty Award' Goes to Neches River Bridge," *Texas Highways*, 13.
[779] James G. Clark, ed., *Welded Interstate Highway Bridges*, 189.

Bryan District) offices in 1957. The prefabricated two-span, multiple-beam bridge proved to be a successful and economical design.[780]

*J. Neils Thompson*

One of Phil Ferguson's initial research collaborators was J. Neils Thompson, a professor of civil engineering at UT-Austin (see information about Phil Ferguson above). Like Ferguson, Thompson was involved with materials testing and research. In 1954, Thompson won the Wason Medal from the American Concrete Institute, recognizing the most distinguished paper on materials research, for his paper on diagonal tension.[781]

*B.A. Trice*

The THD Bridge Division's B.A. Trice, who worked on the development of the pan-formed concrete girder, wrote on the THD's early design efforts and resulting economy of design. In both a national journal and an internal bulletin, Trice considered the cost benefits of using pan-formed girders, including "having the structural advantage of girder construction at the same unit price required for slab construction."[782] This design was an economical alternative for short crossings where steel I-beams or concrete girders would have normally been used.

*E.R. Young*

E.R. Young, a THD supervising urban engineer, along with W.E. Simmons, a THD district engineer, received an award in 1952 from the AISC for the Neches River Bridge at Beaumont (TxDOT Structure No.: 20-181-0-0028-09-065). The bridge was identified in *Texas Highways* as a "clean design which is devoid of extraneous ornamentation" and "serene and graceful lines."[783] The award-winning design for the two-hinged arch, which used box girders for its four arch ribs, was likewise credited with "architectural simplicity" and "clean-cut lines."[784]

---

[780] "Mass Production of Concrete Bridges is Given Experimental Trial in Texas," *Texas Engineering Experiment Station News*, 12-13.
[781] John E. Breen et al. "In Memoriam: J. Neils Thompson," University of Texas at Austin: Memorials Index, <http://www.utexas.edu/faculty/council/1999-2000/memorials/ThompsonJ/thompson.html> (accessed 13 August 2009).
[782] Trice, "Low Cost Concrete Bridge," *Roads and Streets*, 83; Trice, "Concrete Girder Spans Built with Steel Forms," *Construction and Maintenance*, 85.
[783] "'Beauty Award' Goes to Neches River Bridge," *Texas Highways*, 13.
[784] James G. Clark, ed., *Welded Interstate Highway Bridges*, 12, 189-197.

## Section F: Associated Property Types

*Introductory Note*

This study intends to provide a framework in which to evaluate historic elements commonly found in transportation rights-of-way throughout Texas: roads, bridges, culverts, roadside parks, and other landscaping installations. It focuses mainly on the road itself—horizontal and vertical alignments, slope, design, shape, and width—as crucial in assessing significance, with the built environment and cultural landscape surrounding it as character-defining aspects only under very specific circumstances. This method allows for an understanding of both the road corridor as a whole and for how the different road-related resources perform as interrelated components within a larger roadway system.

For purposes of this study, the following definitions were used throughout this evaluation framework:

ROADWAY – the physical structures directly associated with the conduct of vehicular travel on the road facility, including all engineered improvements such as the roadbed, surface treatment, bridges, and culverts, as well as adjacent aspects such as paved shoulders, drainage elements, and associated rights-of-way.

ROAD CORRIDOR – roadways and their contextually significant adjunct developmental patterns, particularly associated property types such as gas stations, motels or tourist courts, restaurants, inspection stations, and tourist attractions.

ROAD/ROUTE/ALIGNMENT – synonymous terms for the physical location of transportation facilities.

Categorization of properties requires attention to the context for evaluation. Significant associations with *Engineering*, for example, place a higher value on the internal aspects of the roadway. Thus, evaluation of a roadway as an engineering system is most readily undertaken with the property categorized as a structure. Segments of historic roadways should be considered structures comprised of contributing elements such as bridges, culverts, and other engineering features. Thus, the segment of Route 66 including the bridge over the Chicago, Rock Island, and Gulf Railroad in Wheeler County is listed in the NRHP as a structure.

Evaluation of road corridors should include significantly associated adjoining commercial or agricultural development. Significant associations with *Transportation* or *Community Planning and Development* would require stronger associations with the adjoining land use patterns. Significant development of an early-twentieth-century transportation network should therefore reflect appropriate road-related property types (gas stations, tourist courts, restaurants, or other tourist attractions) essential to understanding a road's significant role in auto-related changes to its surroundings. In such circumstances, roadways should be classified as contributing or noncontributing structures within a larger historic district. The NRHP nomination for the historic alignment of Route 66 in Amarillo, for example, categorizes the roadway as a contributing structure within the Route 66-Sixth Street Historic District.

Bridges may contribute to the significance of a road corridor or to a historic district. Bridges may also possess historical or engineering significance individually, even when part of a road segment lacks significance. In contrast, culverts, including bridge-class culverts with spans greater than 20 feet, typically lack sufficient complexity to be individually significant for engineering. Culverts can be significant, however, for associations with federal Depression-era work-relief programs.

**Associated Property Types: Roads**

*General Road Description*

Currently, the NPS and THC do not provide specific guidance for evaluating non-park roads or road corridors. Most appropriate for this task is the examination of the road and its road-related resources as interrelated components within a larger system, rather than as individual resources.

Multiple property documentation is one of the currently accepted methods of approach for evaluating road corridors, as evidenced by the NRHP-nominated and listed segments of Route 66 in New Mexico, as well as other roads across the country. Examining the road as a whole system, but also for its individual property types and subtypes, this method allows for an understanding of the roadway as a whole and how the different road-related resources associated with the roadway perform as interrelated components. As noted in the National Trust's *Historic Roads* publications, it is mainly the road itself—horizontal and vertical alignments, slope, design, shape, and width—that is important in assessing the significance, as well as, to a lesser extent, the built environment and cultural landscape surrounding it. Clarification of evaluating a road in its entirety versus individual segments and thresholds of eligibility are outlined below.

An NRHP-eligible or NRHP-listed historic district along the route of the road does not necessarily equate to an NRHP-eligible road segment or corridor. It must be shown that the district specifically relates to the development of the road, either as a result of the road construction in that area *or* that the district reached its height of significance during the same period of significance of the road at that location. "Mere association with historic events or trends is not enough, in and of itself, to qualify under Criterion A."[785] A district's association with the road simply because it is located along the road is not sufficient for NRHP listing. A segment of the road that bisects an NRHP-eligible or NRHP-listed historic district must also possess significance and retain integrity within the area of *Transportation* or have performed a significant role in the development of the district. In looking at various patterns of associated roadside architecture, the presence or absence of historic gas stations, motels, or cafes exerts little influence on the eligibility of a road as a historic engineering structure, but is crucial in justifying eligibility of a corridor under NRHP *Criterion A* in the area of *Transportation*.

**Road Subtype Descriptions**

***(a) County and Local Roads in the Nineteenth and Early Twentieth Centuries***

Roads of this subtype consist of:

- Early links between neighboring properties
- Roads linking cities
- Roads from rail line to rural communities
- Post routes and stage routes

[785] U.S. Department of the Interior, National Park Service, *National Register Bulletin: How to Apply the National Register Criteria for Evaluation*, http://www.nps.gov/nr/publications/bulletins/nrb15/, 12.

*Design/Engineering Characteristics*

- Topography and property lines determined alignment (shown in 90-degree turns for example)
- Improved drainage (not all cases) (shown in sloping and construction of ditches, or curb and gutter in cities)
- Improved crossings of waterways
- Lack of pavement
- Funded and maintained by locals (tolls likely)
- No common design standards
- No thought as to connectivity between counties

***(b) Named Auto Trails***

Examples of this subtype are roads that were usually formed by simple adoption of existing roadway or railroad alignments.

*Design/Engineering Characteristics*

- Improvements in paving materials and bridges
- At-grade railroad crossings
- Connectivity between counties
- Tests of materials for surfacing (macadam or concrete rather than gravel)
- Signage by auto trail associations

***(c) Early Development of the THD and U.S. Highway System***

Roads of this subtype:

- Continued to follow existing established road alignments
- Were rarely in a new location (although new alignments were established to straighten curves or flatten grades as money became available to purchase right-of-way [ROW])
- Were the first demonstration of state-owned roads (standards begin)

*Design/Engineering Characteristics*

- Widened further and paved
- Bridges were increasingly constructed using standard designs developed by the THD
- Removal of at-grade railroad crossings
- Uniform signage (eventually reflecting national numbering system)
- Uniform designation: first (trunk system), second, or third class
- Local materials for surfacing (shell pieces, gravel, rock asphalt, dirt)
- ROW increased to 80-foot minimum to 120-foot maximum

### *(d) Texas Roads in the Great Depression and World War II*

Funding changed from an even mix of county, state, and federal in the late 1920s to mostly federal with a state match by the early 1940s. The THD strove to fill in the gaps in the trunk system and improve roads rather than build new ones. Park and scenic roads were built or upgraded in order to provide for work relief programs and aesthetics were seen in design, even for non-park roads. Federal road and bridge standards were increasingly common during this era.

*Design/Engineering Characteristics*

- May demonstrate beautification/landscaping projects (landscape incorporated into roadway rather than reverse)
- Federal relief projects
- Could be narrow pavement width, two lanes with small shoulders (scenic/aesthetic)
- Increasingly wider as built under THD auspices (100-foot ROW width in early 1930s, increasing to 160-foot ROW width by 1940)
- Hand workmanship in some cases
- Improvements to county and local roads including incorporated towns
- Masonry drainage components including box and pipe culverts, check dams, lined drainage canals, drop inlets, and tree rings
- Greater use of erosion control
- Grade separations for railroad crossings
- Employment of traffic circles in urban areas
- Roadside parks built in ROW
- Bus shelters and stock underpasses constructed by the THD
- Centennial and state line markers of granite installed in ROW

### *(e) Post-World War II and Network Developments*

Roads of this subtype consist of FM and Ranch-to-Market (RM) highways on what were known previously as "trunk lines." These roads were designed to help rural citizens more easily access urban markets. Non-interstate limited access freeways developed during this time. These first generation freeways allowed for greater speeds, more standard geometry, greater turn radiuses on curves, construction of on and off ramps and cloverleaf interchanges, and frontage roads (in some cases).

Interstate highways are not discussed here as they are exempt from NRHP eligibility unless included on the *Final List of Nationally and Exceptionally Significant Features of the Federal Interstate Highway System*, published in the Federal Register on December 19, 2006. There are no such segments of interstate highways in Texas, although there are bridges on the interstate system in Texas on this list, some of which are discussed in Section E.

*Characteristics*

- Rarely built on new location, but followed existing alignments of county or local roads and in many cases made improvements for safety such as widening, straightening curves, and requiring purchase of ROW
- Multi-level interchanges

- Traffic circles
- Cloverleaf or diamond interchanges
- Pavement width standard increased to 28 feet for FM system (two-lane)
- Expansion of urban networks
- Include short links called loops and spurs in urban areas
- Urban routes through city centers utilized grade separations
- Limited access allowed higher volume
- Design influenced by national standards (speeds, grades, lane width, median, shoulder width, clear height for bridges)
- Frontage roads (unique to Texas) for expressways and interstates
- At least four lanes for expressways, evolving to six to ten lanes
- Reintroduction of tolled roads

## B. Significance

### (1) *Criterion A*

For roads, significance resides within associations to appropriate historic themes that could include *Agriculture*, *Community Planning and Development*, and *Entertainment/Recreation*, or a combination thereof. Adjoining historic land use patterns of development are particularly relevant to analyses of eligibility under *Criterion A* and highly dependent on the area of significance established for the roadway. Significant associations with *Agriculture* or *Community Planning and Development* would require stronger associations with the adjoining land use patterns.

For historic roads, identified character-defining features and surrounding setting must facilitate comprehension of the road as a historic resource associated with specific historic themes. Evaluations must establish the direct connection between such resources and the period of significance before weighing their potential contributions as character-defining features of a historic road segment. Using the model of the current roadway conveying the experience of driving a historic road, evaluations must consider the relevant aspects of setting and feeling necessary for the associated historic theme to remain recognizable. For example, road-related property types (e.g., gas stations, motels or tourist courts, restaurants, inspection stations, tourist attractions) can be essential to understanding a road's significant role in the development of an early-twentieth-century transportation network. However, such resources should be considered ancillary components of a historic roadway in most evaluations necessitated by transportation undertakings. Unless the road's significance can be tied to the establishment of such resources, corridors may be better evaluated as historic districts with contributing road segments rather than as historic roadways with contributing buildings.

### (2) *Criterion B*

To be eligible for NRHP listing under *Criterion B*, a property must represent a person's productive life. In this case, while roadway engineers, county judges, and commissioners may be associated with the development of a road, it is more likely there are other extant properties or public works that would better represent these officials' productive lives and, therefore, demonstrate their significant achievements. Local research and field work (e.g., names on bridge plaques) should serve to verify eligibility under *Criterion B* and determine an understanding of an individual's direct association with a road and that it best represents their contributions.

**(3) *Criterion C***

For roads, significance under *Criterion C* resides within associations to appropriate historic themes that could include *Transportation* or *Engineering*. Significant associations with *Transportation*, for example, place a high value on the internal ROW aspects of the roadway. Significance is exhibited by early or innovative engineering methods or experimental programs.

**(4) *Criterion D***

*Criterion D* is not addressed in this MPS as it is more appropriately tied to archeology. However, abandoned segments can provide clues as to historic methods of road building and/or treated as historic archeological sites under *Criterion D*.

**(5) Specific Road Subtype Significance**

***(a) County and Local Roads in the Nineteenth and Early Twentieth Centuries***

A road of this subtype may be significant at the state level under *Criterion A: Transportation* if it is associated with experimental programs conducted by county engineers, sometimes under direction of federal entities such as the OPR, which operated under the Department of Agriculture, or the Post Office Department. A road of this subtype may be significant at the state level under *Criterion C: Engineering* if it contains features reflective of the time period that may include truss bridges or improved drainage. The period of significance for these routes is limited to pre-1916, representing the period prior to the passage of the Federal-Aid Road Act of 1916.

***(b) Named Auto Trails***

A road of this subtype may be significant at the state level under *Criterion A: Transportation* if justified as demonstrating ideals of the initiative or efforts to get named routes constructed and promoted. A road of this subtype may be significant at the state level under *Criterion C: Engineering* if it contains features demonstrating the time period which may include signage or improved road surfaces. The period of significance for these routes is limited to pre-1925 after which time a national highway numbering system was adopted.

***(c) Early Development of the THD and U.S. Highway System***

A road of this subtype may be significant at the state level under *Criterion A: Transportation* if demonstrated use of additional state and federal matching funding mechanisms for road development. A road of this subtype may be significant at the state level under *Criterion C: Engineering* if it contains features reflective of the time period, which may demonstrate first use of standard bridge plans and/or the adoption of road standards. Examples may include any of the 38 designated state highways from 1919 reflective of this era's significance. The period of significance for these routes begins with the establishment of the THD in 1917. The period of significance ends with the passage of the State Assumption Highway Bond Act in 1932, which completed the centralization of highway design and funding with the THD.

### *(d) Texas Roads in the Great Depression and World War II*

A road of this subtype may possess significance as an example of nationwide work-relief programs designed to put people to work during the Depression. Eligibility as a road associated with a work-relief program might occur at the state level under *Criterion A: Transportation* but it should be justified with a direct association (through research) that the road was built using federal funds or labor of a work relief program. Defense access highways may also possess significance at the state or even national level if built to provide access to important industrial or defense plants or air fields, military bases, ordinance plants, and the like just before and during World War II. A road of this subtype may be significant at the state level under *Criterion C: Engineering* if it contains features reflective of its time period which may include the demonstrated use of manmade components (1930s) or bridges and roads designed to standards to support military routes (1940s

### *(e) Post-World War II and Network Developments*

A road of this subtype may possess significance at the state level under *Criterion A: Transportation* if justified as demonstrating components reflective of the program they were built or improved under. A road of this subtype may be significant at the state level under *Criterion C: Engineering* if it contained materials, workmanship, and design aspects that were influential for the time period such as restricted access or multi-level overpasses. Significance associated with conversion to state standards is more routinely associated with early phases of experimentation with evolving FM system standards.

## C. Registration Requirements

### (1) *Criterion A*

To be listed in the NRHP under *Criterion A*, a road should possess significance through documented associations with a road subtype as noted in the preceding section. A road should also retain integrity sufficient to convey its significant historical associations. Under *Criterion A*, a property should exhibit "the essential physical features that made up its character or appearance during the period of its association with the important event, historical pattern, or person(s)."[786] In addition to possessing significance, a road's integrity of location, setting, feeling, and association should remain intact for NRHP listing under *Criterion A*. Integrity of design, materials, and workmanship is not as important under *Criterion A*, but some aspects of these should remain.

### *(a) Setting and Feeling*

Setting is the physical environment of a historic road while feeling is a road's expression of the aesthetic or historic sense of a particular time.[787] Intact setting provides for high integrity of feeling. Research should be conducted to determine adjoining historic land use patterns of development. Construction plan sets, historic aerial photos, and age of trees can help guide these analyses. Integrity of setting and feeling may be demonstrated by vegetation in and near the ROW, width of the roadway, and associated property types surrounding the segment. Patterns of vegetation present in the ROW during the period of significance, such as tree canopies, should remain. Consistent patterns of vegetation present outside of the ROW during the period of significance, such as crops or pasture, also

[786] Ibid, 46.
[787] Ibid, 44-45

provide good indicators that the setting retains its historic integrity. In some segments, a lack of vegetation may be historically accurate, so the presence of heavy vegetation in such segments would detract from integrity of setting. Adjoining land use should be at least 50 percent intact as it was during the period of significance to retain integrity of setting. Comparisons drawn from historic maps and photos (including aerials) are the best sources for this type of information.

As discussed further in the *Criterion C* section, width of the roadway should generally remain as it was historically. Minimal numbers of minor adjustments, such as adding paved shoulders or new drainage features necessary for the safety of modern operations, are acceptable changes within the setting if the proportional ROW, pattern of boundaries, open spaces, and pavement remains discernible. Minor shoulder-widening projects, for example, would not necessarily adversely affect the roadway's visible relationship with the specific associated historic themes comprising the roadway's significance. However, widening to more than double current width outside the period of significance would negatively impact its integrity of feeling (as well as design).

Adjoining historic land use patterns of development are particularly relevant to analyses of eligibility under *Criterion A* and highly dependent on the area of significance established for the roadway. Significant associations with transportation, for example, place a higher value on the internal ROW aspects of the roadway, while significant associations with agriculture or community planning and development would require stronger associations with the adjoining land use patterns. Disruptive land use changes adjacent to the roadway (e.g., the introduction of large modern-age subdivisions or commercial strip malls) can dramatically compromise the integrity of setting and feeling for listing under *Criterion A*, but would be of less consequence for analysis of the engineering significance of a roadway under *Criterion C*. Setting and feeling are never the most important aspects of integrity in evaluating historic roadways, but can be an essential tool in justifying a segment's eligibility for NRHP listing.

When considering integrity of setting for an eligible segment of a road corridor, the limits of the surrounding setting *must be quantified*. For example, rather than statements like "the view to the horizon," the discussion must include statements such as "all parcels directly adjacent to the roadway" or "all properties within 500 feet of the limits of the current ROW" to avoid ambiguity. However, requiring a standard length of a corridor or segment necessary to possess or convey significance is not an appropriate approach to evaluation as all segments and corridors vary and possess different character-defining features depending on the original design and aesthetic of the road. Instead, a more appropriate approach, as outlined in some statewide historic highway surveys and Route 66 listings, is that the segment must be long enough to convey the experience of driving a historic road. As noted in the Arizona Route 66 MPD, the segment "should be of sufficient length to preserve the feeling and setting of a continuous road…an ideal would be an uninterrupted view down the road to the horizon."[788] This should be specifically defined when writing a synopsis of the historic roadway using feet or miles for distance instead of stating "view to the horizon" or "everything in sight distance" as this is ambiguous and subject to change over time.

### *(b) Association*

Association is the direct link between the important historic event or person and a historic property. Integrity of association is retained if the property is the place where the event or activity occurred and is sufficiently intact to

[788] Teri Cleeland, *Historic US Route 66 in Arizona*, National Register of Historic Places Multiple Property Documentation Form (Washington, D.C.: National Register of Historic Places, National Park Service, 1988).

convey that relationship to the observer. Association requires the presence of physical features that convey a property's historic character.[789] Association is demonstrated by retention of a combination of elements such as setting, feeling, use of adjacent properties, width, alignment, vegetation in the ROW, and presence of historic features such as bridges, culverts, and signage that show the visible link to the era or program. Because feeling and association depend on individual perceptions, their retention alone is never sufficient to support eligibility.

#### *(c) Location*

Location is an aspect integral to NRHP eligibility under *Criterion A*. Location is particularly crucial for conveying *Criterion A* significance for roads that follow traditional or established routes (e.g., stage routes and mail routes).

### (2) *Criterion B*

When considering integrity under *Criterion B*, one must determine the individual's direct association with a road and that the road best represents their contributions to history. Integrity of a majority of the seven aspects is required.

### (3) *Criterion C*

#### *(a) General Road Requirements*

To be listed in the NRHP under *Criterion C*, a road should possess engineering or design significance recognizable to the period of significance. "All properties change over time. It is not necessary for a property to retain all its historic physical features or characteristics"; however, it should retain "the essential physical features that enable it to convey its historic identity."[790] Examination of plan sheets and past transportation-related nominations and survey reports resulted in a concise list of possible character-defining features of a historic road. Please note that these features should date from the period of significance to be contributing, mere presence of these features does not necessarily mean a roadway is historic:

1. Width of pavement
2. Surface material
3. Alignment
4. Striping
5. Markers
6. Road signage
7. ROW width
8. Bridges and culverts
9. Sidewalks
10. Roadside parks
11. Landscaping
12. Guardrails
13. Retaining walls

---

[789] *How to Apply the National Register Criteria for Evaluation*, 12.
[790] Ibid, 46.

14. Fencing
15. Toll booths or border crossing (state or national) checkpoints
16. Lighting
17. Weigh stations or inspection stations
18. Surrounding setting (adjacent property use, vegetation, and transportation-related properties, including but not limited to motels/hotels, gas stations, drive-ins, auto dealerships, restaurants, and designated stops)

Roadway and ROW width, striping (or lack thereof), alignment, and to a lesser extent, the surrounding setting, provide key character-defining features that should retain enough integrity to convey the experience of driving a historic road. Absence of road signage and markers does not preclude eligibility of the corridor or segment, but their presence would enhance the historic feeling of the roadway. Similarly, adjacent roadside related properties do not have to be present for a road to be historic, but they may serve to enhance the historic roadway if they date from the period of significance and retain integrity.

Bypassed segments of roadway still in use by local auto traffic are more likely to demonstrate engineering elements from the period of significance due to lack of alteration or modernization. These are usually city streets or county roads not under control of the department of transportation and therefore not required to meet the more stringent safety standards enforced by the FHWA.

Integrity of location, design, materials, and workmanship should be retained to a level sufficient to convey a historic road under *Criterion C*.

*(i) Location*

Location is generally the most commonly retained feature of historic roads in Texas. Historic maps and construction plan sheets prove invaluable to determining the original road alignments. If any realignment has occurred, it is usually at one or both ends of a road segment. Realignment of the road diminishes integrity of location, particularly if the majority of a segment, the entire segment, or major curves that would have historically followed property lines have been realigned or abandoned. Part of the significance of historic roads, particularly in the late nineteenth and early twentieth centuries, rests with the road alignment along property boundaries, usually creating a road with sharp curves and angles instead of a straight line. These segments often form isolated, interrupted segments distinctly separated from other sections by larger, later roadways that bypassed them to create straighter lines. In some cases, a long historic roadway may be bisected once or twice by interstates or another intrusive road, yet retain eligibility as a discontiguous historic district.

*(ii) Design*

Historic pavement width, striping (or lack of), alignment, and ROW width would generally need to be intact, though there are allowances for minor widening of a historic roadway.

Minor widening would not negatively impact the integrity of a roadway, but the definition of what constitutes a minor widening will vary depending on the roadway. Minor widening for Texas roads is usually represented as 4 feet or less added to the original width. The addition of 2-foot-wide shoulders on each side of the roadway is a standard widening for roads under state control in Texas, as evidenced by current and past projects. This slight widening would generally allow roadways to retain the width necessary to retain integrity. In contrast, more than doubling the pavement width of a roadway will most always be considered adverse to its integrity.

Many roadways were not striped when they were constructed as they were composed of gravel, were not wide enough, or lacked sufficient travel density to necessitate lane markings. Striping becomes necessary as roadways are widened or become more heavily used. Center line and edge striping do not preclude eligibility of a segment. However, striping to separate multiple lanes of traffic that extend the roadway beyond the acceptable width outlined above would adversely affect the design, feeling, and setting of the roadway.

The threshold for changes to ROW width as it relates to integrity should be considered on a case-by-case basis as it relates to the historic roadway. The same is true for pavement width. The proportional relationship between pavement width and ROW width should remain as it did during the period of significance for the roadway. ROW width can be determined using plan sets or visual cues such as fencing or utility lines.

If research shows that sidewalks were present during the period of significance, they should remain extant. Sidewalks built after the period of significance, such as for a large-scale enhancement project, detract from integrity of workmanship (as well as design, feeling, and setting) of the road.

Curbs in urban areas are utilized for both drainage and safety purposes as they guide water to drainage outlets and prevent vehicles from leaving the street. As such, they are integrated into the construction of the road itself. Curbing at corners is rarely intact due to damage from vehicles, street widening, Americans with Disabilities Act (ADA) ramp improvements, sidewalk replacements, and curb cuts for parking lots.[791] There are groups of curbs that are eligible for NRHP status as contributing elements of historic districts, such as in Fort Worth (blue and white WPA-era curb tiling) and cities where the height ratio of the curb to sidewalk to building is character-defining, as in Linden. These could be contributing to a historic road if they retain integrity.

*(iii) Materials*

Pavement is transient in nature and maintenance and upkeep is expected, as discussed in the Route 66 nominations. Original surfacing is the least likely original material to be retained. However, changes to original surfacing may be acceptable as surfacing is not a crucial feature necessary to convey significance. Therefore, the pavement itself need not be character-defining. An exception could be that if a road was historically paved with bricks that are still in good condition, then brick pavement could be a character-defining feature of a roadway.

Bridges and culverts should date from the period of significance and retain their historic design and materials. Evaluation of any remaining road signage or guard rail is necessary; however, as previously noted, absence of road signage and markers from the period of significance does not preclude eligibility of the corridor or segment; their presence may enhance the historic feeling of the roadway. Electronic traffic and railroad signals were not developed until the 1930s, but the presence of these features along a roadway today does not necessarily detract from a historic roadway's significance if the features are minor in scale and number.

[791] Knight and Associates, *Reconnaissance Level Survey of Multiple Intersections in the Houston District for ADA Curb Ramp Improvements*. TxDOT, 2011. And *Survey Report for the 5000 Block and 5100 Block of Broadway Avenue, Galveston, Galveston County, TX*. TxDOT, 2003.

*(iv) Workmanship*

Integrity of workmanship is not easily applied to an entire road due to expected changes such as re-paving and minor widening. However, if bridges and culverts within a road segment are significant for the artisans' labor or skill (e.g. masonry), then they should retain the original design and materials to convey workmanship.

(b) Additional Road Subtype Registration Requirements

*(i) County and Local Roads in the Nineteenth and Early Twentieth Centuries*

To be eligible for the NRHP under *Criterion C*, a road of this subtype should possess significance and integrity as presented above. In addition, to retain integrity it should possess the following:

- A narrow width (less than 20 feet) of pavement or even have gravel surface
- A narrow ROW (less than 40 feet)
- Setting as it was historically for at least 50 percent of the segment
- Alignment following land parcels

Bridge types may include:

- Truss bridges
- Low water crossings
- "City Beautiful" bridges

*(ii) Named Auto Trails*

To be eligible for the NRHP under *Criterion C*, a road of this subtype should possess significance and integrity as presented above. In addition, to retain integrity a road of this subtype should possess the following:

- A narrow width of ROW (less than 50 feet)
- Narrow pavement (less than 25 feet)
- Culverts, bridges, or other drainage with integrity from the period of significance
- Sidewalks (including same width and materials as the period of significance) if originally present in urban areas
- Signage or painted stripings from the period of significance such as seen on the Bankhead Highway

Bridge types may include:

- Some truss bridges[792]
- Small scale concrete slab bridges

[792] Truss bridges, like the Canadian River Wagon Bridge (now pedestrian only), Canadian, Hemphill County, were constructed on named auto trails, but they represent the exception.

*(iii) Early Development of the THD and U.S. Highway System*

To be eligible for the NRHP under *Criterion C*, a road of this subtype should possess significance and integrity as presented above. In addition, to retain integrity, a road of this subtype should possess the following:

- Pavement width and ROW width from the period of significance (these measurements can vary depending on location and original design intent but were standardized to generally less than 24-foot pavement in less than 120-foot ROW)
- Drainage structures with high integrity (may contain technological advances that were important such as changes in elevation for drainage)
- Federal aid project markers may be present at ends of segments
- Standard culverts: concrete box, concrete or iron pipe, concrete or stone slab with masonry substructure

Bridge types may include:

- Include early experimental prototypes
- Standard plans including: , concrete slab, concrete girder, steel beam, pony truss, through truss
- Concrete arch,

*(iv) Texas Roads in the Great Depression and World War II*

To be eligible for the NRHP under *Criterion C*, a road of this subtype should possess significance and integrity as presented above. In addition, to retain integrity a road of this subtype should possess the following:

Great Depression:
- Location that takes advantage of scenery (aesthetics rather than engineering) if the road's location, alignment, and setting was consciously designed with aesthetics in mind
- Depression-era materials (usually masonry) that also retain aspects of good workmanship (unaltered or minimally altered)
- Hand-skilled labor should be intact and visible (workmanship)
- Parks may be present alongside/in the ROW; if present during the period of significance, they must remain extant and also retain integrity to reflect the time period; some roads were sited to take advantage of scenery and overlooks, with surrounding natural environment integrated into the overall design concept
- Rustic materials such as wooden guardrails
- Wooden signage may be present
- Bridges may have masonry components in the substructure or superstructure

World War II:

- Only designated defense highways received improvements so must be designated
- Structure improvements (pavement, culverts, bridges) demonstrating upgrades during that period
- Pavement width and ROW width from the period of significance (these measurements can vary depending on location and original design intent, but ROW increased to 200 feet where possible)
- Bridges:
    - Exhibit standard design plans

- Many with as little steel as possible, new designs for bridges from restriction of materials
- Bailey truss (none extant)
- Multiple box concrete
- Concrete girder
- Timber trestle
- Concrete or masonry arch

*(v) Post-World War II and Network Developments*

To be eligible for the NRHP under Criterion C, a road of this subtype should possess significance and integrity as presented above. In addition, to retain integrity a road of this subtype should possess the following:

- ROW width and pavement width from time period when the state first took over or was constructing the roadway; these types demonstrate wider widths than any other type of roadway
- Exemplify the design characteristics of the standards used when constructed or first improved by the state

Bridges

- From the time period of first improvement by the THD should be retained and not further widened since the period of significance
- Concrete pre-stressed spans
- Use of new materials such as neoprene
- Variable depth concrete slabs
- Concrete pan formed girder

**2. Bridges**

**A. General Information – All Bridge Types**

**(1) Introduction**

Highway bridges are structures that provide transportation across diverse obstacles such as rivers, arroyos, railroads, ship channels, and bays. There are more than 50,000 active vehicular bridges on Texas roadways with spans of 20 or more feet, dating from 1884 (CR 3112 at North Bosque River Bridge, TxDOT Structure No. 09-018-0-AA03-33-001) onward.

A bridge is made up of a superstructure and substructure. The superstructure is the horizontal portion of the bridge upon which vehicles drive, and the substructure is the vertical portions of the bridge that support the superstructure.

Generally, vehicular bridges are classified by basic superstructure configuration and structural behavior (e.g., suspension, arch, truss). These types can be further divided into subtypes based on function of component members and types of material used (e.g., stone, steel, reinforced concrete). A bridge with multiple spans may use more than one structural type. The following property type and subtype analysis reflects the wide variation and development within this broad class of resources. Bridge types and subtypes included within this MPS are presented as follows:

***(a) Metal Truss Bridges***

- Pratt and Pratt variants
  - Pratt
  - Pratt half-hip
  - Truss leg bedstead
  - Parker
  - Camelback
  - Pennsylvania
  - Murphy-Whipple
  - Lenticular
- Warren and Warren variants
  - Warren
  - Warren Parallel Top Chord (pony)
  - Warren Polygonal Top Chord (pony)
- K-truss
- Bowstring

***(b) Non-truss Bridges***

- Suspension
  - Parabolic
  - Cable-stayed
- Reinforced concrete
  - Slab
  - Tee beam
  - Girder
  - Arch
  - Rigid frame
- Prestressed concrete
  - Girder
  - Other prestressed concrete types
- Steel
  - Beam
  - Plate girder
  - Arch
  - Other steel types
- Moveable
  - Swing
  - Bascule
  - Vertical lift
- Timber stringer
- Masonry arch

In analyzing the form of a bridge, its structural and support systems provide important distinctions. At a basic level, bridges can be separated into three categories according to the configuration of their structural system:

- deck (structural system lies beneath the roadway deck);
- pony, or part-through (usually referring to a truss bridge without lateral bracing between the top chords, with the roadway supported on a floor system and the roadway located between the load-carrying members); and
- through (usually referring to a truss bridge with lateral bracing between the top chords over the deck, with the roadway supported on a floor system and traffic traveling through the truss).

Bridges can also be distinguished by their type of support system. Four means of support exist:

- simply supported, or simple-span (superstructure completely supported between two supports with moment releases at each support);
- continuous (superstructure spans uninterrupted over one or more intermediate supports);
- cantilevered (a span projects beyond a supporting column or wall and is counterbalanced and/or supported at only one end); and
- suspended (an interior span suspended between two anchored spans).

A bridge is supported by a substructure, which is made up of abutments at either end of the bridge. If a bridge has more than one span, intermediate supports are called piers or bents. Piers are substructure units adjacent to a waterway, while bents are substructure units made up of two or more columns connected at their tops by a cap or other member holding them in place.

Bridges may be eligible for the NRHP under many, sometimes overlapping, historic contexts. This MPS provides registration requirements under transportation development and engineering contexts; however, it does not preclude eligibility under other historic themes or contexts. Also, additional research may establish other avenues for significance under the contexts discussed in this MPS.

### (2) General Bridge Significance

#### *(a) Significance under Criterion A*

For evaluation in conjunction with the *Historic Road Infrastructure of Texas* context, bridges may be eligible for the NRHP under *Criterion A* for their contributions to the broad patterns of transportation history. As structures built primarily to convey passengers and materials, bridges usually fall under the general area of *Transportation* for *Criterion A* significance. In some cases, a bridge's significance relates primarily to its function as a transportation structure but is also associated with underlying themes such as *Politics/Government*, *Industry*, or *Commerce*. In this situation, it could be appropriate to evaluate the bridge within the context of transportation history and development, as well as additional areas of significance. For additional guidance, see the preceding discussion of the evaluation methodology for F.1. Roads.

Under *Criterion A* in the area of *Transportation*, significance for bridges may be found at both the state and local levels. For example, under the "County and Local Roads in the Nineteenth and Early Twentieth Centuries" subcontext, a bridge could significantly illustrate the development of transportation and transportation networks both local and statewide. For a bridge to possess significance under *Criterion A* at the local level for *Transportation*, it must be associated with a subcontext discussed in this MPS and also be constructed within the period of significance for the local community. A modest Warren pony truss could thus illustrate how a county

used its bond authority to provide all-weather crossings for small streams prior to the THD undertaking statewide road construction.

To possess significance under *Criterion A* at the state level, a bridge must have documented association with one of the overarching subcontexts discussed in this MPS. An example of a particular THD standard design Parker through truss could illustrate the significant developments of the state highway system and the THD's standardization initiatives. Parker trusses, for example, were not particularly difficult to design for the lengths that the THD standardized in the 1920s. Rather, the accomplishment and the innovation were in the development and promulgation of the standards. Bridges at the state level of significance should be important crossings constructed on the state or federal highway system (e.g. bridges on FM, US, or interstate roads). Early examples of grade-separation structures for highway and railroad intersections can also be significant on the state level, often under the subcontexts of the "Early Development of the THD and U.S. Highway System" or "Texas Roads in the Great Depression and World War II."

The following questions are most appropriate to assist in determining the *Criterion A* significance of a bridge:

- Has the bridge played a critical role in the development of a transportation system at the local, regional, or statewide level?
- Has the bridge significantly improved passage through a local community or region, and has this access facilitated major economic development, growth, or settlement?
- Is the bridge's history directly related to the major subcontexts in this MPS at a local, state, or national level?

(3) Significance of Specific Bridge Subcontexts

*(a) County and Local Roads in the Nineteenth and Early Twentieth Centuries*

A bridge associated with this subcontext may be significant at the local level under *Criterion A: Transportation* if it is documented to be associated with significant road-improvement programs initiated by local governments. Counties often issued bonds for transportation improvements, including the construction of new bridges. For example, Delta County issued 1 million dollars in bonds in a significant campaign of road improvements in 1919 in response to the growth of cotton as a cash crop in the county. This campaign provided improved linkages between the farms and regional markets. The improvements included the purchase of forty-seven bridges commissioned from the Austin Brothers Bridge Company. Bridges identified as extant from a similar local period of economic growth and subsequent road construction in a community may be significant at the local level. Bridge types within this subcontext will likely include wooden bridges, metal truss bridges, "City Beautiful" concrete arch bridges, and low water crossings.

*(b) Named Auto Trails*

A bridge may be significant at the state level under *Criterion A: Transportation* if justified as demonstrating ideals of the initiative or efforts to get named routes constructed and promoted. Bridges are unlikely to have local significance as the construction and designation of named auto trails was a statewide effort. A bridge on a named auto trail must date to the original construction or designation of the named trail. While it is unlikely to be significant individually under Criterion A unless it is a rare surviving feature from that period of significance, it

may contribute to the overall significance of a historic road segment or road corridor. Bridge types within this subcontext will likely include small concrete slab bridges.

*(c) Early Development of the THD and U.S. Highway System*

A bridge may be significant at the state level under *Criterion A: Transportation* if demonstrated to be part of the first use of standard bridge plans or as a safety measure to eliminate dangerous at-grade crossings with railroads across the state. Bridges must have been constructed for current or former state or U.S. highway alignments to be significant under this subcontext.[793] For example, the Warren pony located on CR 402 over the Navasota River in Limestone County (TxDOT Structure No. 09-147-0-AA03-11-001) is significant as an example of a THD-designed bridge that carried SH 14 over the Navasota prior to the route's realignment. Bridge types within this subcontext will likely include concrete slab, concrete girder, steel I-beam, and metal truss bridges.

*(d) Texas Roads in the Great Depression and World War II*

A bridge may possess significance as an example of a nationwide work-relief program of the Depression era. Eligibility as a bridge associated with a work-relief program typically reflects state level significance under *Criterion A: Transportation* if documentation establishes a direct association with federal funds or a work relief program administered by the state. Local county governments also participated in such programs, so significant associations could similarly be documented at the local level. Masonry bridges and culverts are the bridge types most significantly associated with this subcontext as they reflect the goals of encouraging gainful employment during the period of significance.

Bridges along defense access highways or directly associated military base construction may also possess significance at the local or state levels. Bridges are significant for a documented association with an important transportation initiative directly associated with the war effort. Initiatives may include industrial or defense plants, air fields, military bases, ordnance plants, and troop transport routes. . Masonry bridges constructed to upgrade access to Camp Bowie in Brownwood exemplify significance under *Criterion A: Transportation* at the local level. Bridges significant under this subcontext are most likely to be concrete bridges, such as concrete girder, multiple concrete box, and concrete arch bridges.

*(e) Post-World War II and Network Developments*

A bridge may possess significance at the state level based for a documented association with an important transportation initiative in the years following World War II. These initiatives include constructing urban multi-level interchanges, the construction of international bridges between Texas and Mexico, and the construction of all-weather bridges designed to improve the rural transportation network in association with the Farm-to-Market program. More specific guidance regarding *Criterion A* significance is provided in Section F, (3) (c). Bridge types within this subcontext will likely include pre-stressed concrete spans, variable depth concrete slabs, and concrete pan formed girders.

---

[793] Precedent for requiring a bridge be constructed on current for former US highway alignment can be found in the Oklahoma DOT Historic Bridge Survey, Phase IO: A Re-Evaluation of *Spans of Time: Oklahoma Historic Highway Bridges*, page 2. Accessed on April 7, 2014 here: http://www.okladot.state.ok.us/memorial/pdfs/pln_span-of-time_survey-phase-1.pdf

### *(b) Significance under Criterion B*

A bridge may possess significance under *Criterion B* for associations with a historically significant person or persons. However, *Criterion B* significance for bridges is uncommon, as other extant properties are more likely to better represent the person's contributions during their productive life. In addition, significance associated with a bridge's designer or builder is evaluated under *Criterion C* for potential as work of a master.

Research conducted for individual bridges could reveal *Criterion B* significance. However, it is not feasible to investigate such significance through this statewide MPS. Evaluation under *Criterion B* will only be considered on a case-by-case basis using NRHP criteria (36 CFR 60.4).

### *(c) Significance under Criterion C*

A bridge may be significant for its physical design or construction if it embodies distinctive characteristics of a type, period, or method of construction; represents the work of a master; or possesses high artistic value. As an engineering work, the design or construction significance of a bridge is appropriately evaluated under *Criterion C* in the area of *Engineering*. Under this context, a bridge could be significant at the state level. Bridge companies like Austin Brothers, or their out-of-state competitors, practiced on a statewide, regional, or national scale. Further, their engineers typically trained with the railroads, universities, or the military. Professional societies and journals broadly disseminated innovations and standards in bridge design. In similar fashion, THD engineers worked out of centralized offices in Austin, Houston, and other major cities. For these reasons, the state level of significance is the most appropriate level for evaluation of bridges under *Criterion C*. Intensive-level research conducted for this MPS and for previous studies does not support listing bridges under *Criterion C* in the area of *Engineering* at the local level because such research has not identified engineers or builders working in Texas on such a limited geographic basis. While previous intensive research identified builders/engineers William Flinn and William Greer, who were based in a particular locality or region, their work is significant at the state level as they worked in wide areas of north-central Texas. Intensive-level research could identify a different context wherein a bridge would be significant under *Criterion C* in the area of *Engineering* at the local level. For example, a Fredericksburg stone mason working on a commercial building could have constructed a stone arch bridge at the request of a client.

When comparing related properties, The National Register bulletin *How to Apply the National Register Criteria for Evaluation* notes:

> Once the historic context is established and the property type is determined, it is not necessary to evaluate the property in question against other properties *if:*
>
> - It is the sole example of a property type that is important in illustrating the historic context, or
> - It clearly possesses the defined characteristics required to strongly represent the context.

If these two conditions do not apply, then the property will have to be evaluated against other examples of the property type to determine its eligibility. The geographic level (local, state, or national) at which this evaluation is made is the same as the level of the historic context.[794]

[794] *How to Apply the National Register Criteria for Evaluation*, 9.

As a consequence, registration requirements are not provided for sole-example bridges, such as the Broad Street Bridge concrete truss in Mason (TxDOT Structure No. 14-157-0-B003-00-001) or the SH 78 K-through truss across the Red River (TxDOT Structure No. 01-075-0-0279-02-024), as standards of comparison are not required. Further, with respect to *Criterion C*, locally isolated bridges, such as bedstead pony trusses, are evaluated for significance at the state level as there is insufficient basis for comparison with other similar properties at the local level.

#### *(d) Significance under Criterion D*

*Criterion D* requires that information yielded by a property should be evaluated within an appropriate historic context and should answer specific important research questions that cannot be otherwise answered. Bridges, particularly those built before 1945 (after which data and record retention improved), could yield important information that cannot be discerned from archived bridge plans and other written records that do not exist. The ruins of Flinn-Moyer's c.1898 CR 120 Bridge in Erath County (TxDOT Structure No. 02-073-0-AA01-20-002) represent such an example. However, it is not feasible to investigate such significance through this statewide MPS. Instead, evaluation under *Criterion D* is most appropriately considered on a case-by-case basis using NRHP criteria (36 CFR 60.4).

### (3) General Bridge Registration Requirements

In addition to possessing significance under one of the National Register Criteria, a bridge must also be shown to have historic integrity to be eligible for the NRHP. The National Register bulletin *How to Apply the National Register Criteria for Evaluation* defines historic integrity as "the ability of a property to convey its significance." Though evaluation of integrity is subjective and requires professional judgment, assessments of integrity must be grounded in an understanding of a property's physical features and how they relate to its significance. The *National Register Bulletin* states, "the National Register criteria recognize seven aspects or qualities that, in various combinations, define integrity." Determining which of these aspects are most important to a particular structure requires knowing why, where, and when the bridge is significant.

When evaluating National Register eligibility, the property boundaries of a bridge are generally limited to the bridge itself, and do not include relief structures or other structures intended to facilitate overflow from a bridge.[795]

Finally, registration requirements and guidance cannot be written for every possible situation or condition. Professional judgment informed by this document, NRHP bulletins, the Secretary of the Interior's Standards, and other regulations is required in uncommon or unanticipated situations.

#### *(a) General Bridge Registration Requirements under Criterion A*

To be eligible under *Criterion A*, a bridge must possess historical significance as discussed above and must retain integrity. Assessing the integrity of bridges should be done through a tiered approach. Bridges must retain integrity of location and association, as these two aspects are critical for bridges to convey the significance of transportation Bridges should also have integrity of setting and design, but some changes to these aspects of

[795] A bridge and nearby relief structures could be evaluated together using the road corridor methodology under *Criterion A* for the road segment and under *Criterion C* for the individual bridges.

integrity are to be expected. Materials, workmanship, and feeling are not as important for *Criterion A* eligibility, but if a bridge has a high level of integrity in these aspects it could compensate for less integrity of setting or design.

- Location

A bridge must remain in its original construction location, unless its new location dates to its justified period of significance. This latter provision reflects the readily-transportable nature of metal truss bridges, which were designed to be easily delivered to remote locations, which in turn facilitated recycling to new crossings as the transportation network evolved. In such instances, the new location must be demonstrated to reflect a significant association with one of the subcontexts. For example, relocation of a metal truss bridge displaced by conversion of a county road to a Farm-to-Market route might obtain significance at its new location if it facilitated subsequent oil field exploration.

- Association

The bridge must retain a specific link with the subcontext from the appropriate period of significance. It must also be recognizable to this period of significance, retaining sufficient appearance to convey its significant associations. This includes retaining integrity of location, even if setting and feeling were compromised. For example, a bridge may be currently part of the interstate system on a frontage road. However, research indicates that the frontage road bridge was originally on a Named Auto Trail route, so the bridge would retain its association with the Named Auto Trail subcontext, not the interstate system.

- Design

A bridge should retain the majority of its character-defining features as defined in the subtypes outlined below. The design of a bridge is closely linked to its association, as the type of design usually illustrates the subcontext and the type of bridges chosen for the road or crossing. For example, no metal truss bridges were constructed on THD's FM road system, because the technology had been surpassed by that time period. If a truss is currently on an FM road, the design should indicate that the road was originally locally constructed or that the bridge is a major crossing.

Bridges must continue to function as they were originally designed, although integration of updated technology is expected. Replacement of the deck system for a metal truss bridge does not impact integrity of design. Furthermore, metal trusses do not need to function as a truss so long the character-defining truss panels are still recognizable (as a Warren system or a Pratt system, for example). Installation of a crash-tested railing is also allowable with minimal disruption to original design features.

- Setting

A bridge's setting comprises the basic physical conditions under which it was built. Setting incorporates the topographical features that inform the bridge's location and design. The physical environment, including crossing and adjacent viewshed, should be recognizable from the period of significance to retain integrity of setting.[796]

---

[796] The Plemons Road/Stinnett Road Bridge across the Canadian River in Hutchinson County (TxDOT Structure No. 04-118-0-AA02-25-002, HAER TX- 42) demonstrates why setting is important for *Criterion A*. This bridge was constructed to connect a refinery with oil wells on the other side of the very broad Canadian River Valley. It consists of thirty 80-foot Warren pony trusses with an overall length of 2,471 feet. Not only does the setting call for such a long bridge, but the alignment of the three northernmost spans was noticeably shifted downstream to avoid an escarpment. Excavation of the escarpment that influenced the alignment shift could impact integrity of setting.

- Feeling

Feeling is the presence of physical features that convey a historic sense of the period of significance. For bridges, the integrity of location, association, and design combine to create integrity of feeling. For example, a rural bridge constructed by the local government to assist farmers in connecting to a larger transportation network has integrity of feeling if the bridge is in its original location, retains a rural agricultural setting, and has integrity of design. Conversely, if the bridge was originally in a rural setting but is now surrounded by suburban development, the bridge thus has diminished integrity of setting and feeling.

- Materials and workmanship

Integrity of materials and workmanship are not as important for *Criterion A* eligibility of bridges as they are more closely aligned with engineering than with the broad pattern of events. However, integrity of materials and workmanship can be diminished over the years through insensitive repairs and the overall physical deterioration of the bridge. Higher integrity in materials and workmanship may compensate for lower integrity of design or setting.

### *(b) General Bridge Registration Requirements under Criterion C*

To be eligible under *Criterion C*, a bridge should possess design or construction significance as discussed above and should retain integrity of location, design, setting, materials, workmanship, feeling, and association. Of these, integrity of design, workmanship, and materials are typically more important because they allow engineered structures to convey their physical features and to characterize the types, periods, or methods of their construction. To retain integrity of location, a bridge should remain in the same location as it was located during its period of significance. Thresholds for the six other aspects of integrity vary by type and subtypes and are addressed later in this section.

## B. Metal Truss Bridges

### (1) General Discussion

### *(a) Description (common to all metal trusses)*

*Introduction*

A metal truss bridge is a structural unit comprised of iron or steel members that are combined in a geometric arrangement to form a rigid structural framework. Each bridge consists of two trusses, one on either side of the roadway, which are attached to one another through transverse beams underneath the deck. A truss acts like a perforated beam, with the top chord handling compressive or squeezing forces and the bottom chord carrying tensile or stretching forces. To resist the loads exerted on a truss bridge, the upper and lower chords are connected by a series of diagonal members, supplemented in many cases by verticals and with inclined posts placed on either end of the two trusses. The diagonal and vertical members are usually placed either in compression or tension, although some members can handle both types of forces. Thicker members, such as stiff, heavy posts can carry both tensile and compressive forces. Thinner members, such as flexible rods or bars, are only capable of withstanding tension. The individual truss members are made up of various iron or steel shapes, such as angles, channels, plates, I–beams, and rods. Greater rigidity is obtained when these shapes are combined by means of

rivets, lacing bars, lattice bars, or batten plates. Figure 49 shows the basic elements that make up a metal truss bridge.

*Distribution*

Metal truss spans first appeared on Texas roadways in the 1870s and 1880s, after the large railroads of the Midwest and East penetrated Texas and began expanding their lines across the state. By the early 1900s, truss spans were found in virtually every comer of the state. The demand for wider and more durable bridges has led to the disappearance of many early metal truss bridges, reflecting increased vehicular loads, traffic volume, and safety needs. Of the approximately 1,200 trusses extant at the time of TxDOT's 1995 metal truss bridge inventory, approximately 154 are under inspection for vehicular use. (This census figure does not include trusses by-passed or relocated for pedestrian use.)

Bridges in this property type are most commonly found in a broad central corridor of the state that extends east to Tyler and west to San Angelo. This region is crossed by several major watersheds and was the site of the state's earliest and most intensive rural settlement. While the extreme eastern portion of the state was also the site of early agricultural development, the easy available of timber precluded a more extensive use of short span metal truss bridges in this region. A few metal truss bridges are scattered throughout the more populated areas of the state, with several THD spans serving as gateways to communities and cities.

*Materials*

The materials used in truss construction changed over the centuries, beginning with timber and shifting to cast and wrought iron composite construction, wrought iron, and steel. By the early 1870s, wrought iron had generally surpassed timber as the preferred material for truss bridges.[797] The first metal truss bridges were shipped to Texas in the 1870s, and most subsequent spans erected during the following two decades were built of wrought iron. While steel manufacturing plants were established in the U.S. by the 1860s, cost and reliability factors prevented widespread use of steel until the 1890s. The last decade of the nineteenth century is generally regarded as a transitional period, with bridge fabricators employing steel and wrought-iron members depending on cost and structural considerations.[798] Because the rolling mills produced the same shapes and forms for the two materials, wrought iron and steel trusses appear very similar and, in many cases, are virtually identical. By 1900, steel had become the dominant material for metal truss bridge construction in the country.

*Connection Methods*

The connection methods used in truss construction have also changed over time, reflecting advances in engineering technology and the need for more rigid and durable structures. Most metal truss bridges built between 1860 and 1945 exhibit either pinning or riveting connection methods (refer to Figure 50). Typically, when a fabricator received an order for a truss, they would shop-rivet the composite members together and then ship the bridge

[797] Indiana, however, continued to construct timber truss (covered) bridges into the 1920s. See Brown, Mark M. and Matt Reckard "Cataract Falls Bridge, Spanning Mill Creek" Historic American Engineering Record, Survey No. IN-104, 2002, 7.
[798] Van Trump, James D. "Smithfield Street Bridge, Spanning Monongahela River on Smithfield Street, Pittsburgh, Allegheny County, PA," Historic American Engineering Record, Survey No. PA-2, 1974, 22. (Author of the HAER report, Jamie Van Trump, quoting an article written by engineer Gustav Lindenthal.)

components to the site, where the bridges were assembled using one of the connection methods. Pinning, the older method, was popular during the late nineteenth and early twentieth centuries. An advantage of the pin-connected (or pin and eyebar) truss was that it could be easily erected on the site or readily disassembled in the event of bridge relocation, a common practice in late-nineteenth and early-twentieth-century Texas. The lack of rigidity of the pin connections was a major downfall, however, since it increased bridge vibrations and led to increased wear around the joints. From about 1900 to 1915, a number of bridge builders in the state used an intermediate form of connection that combined shop-riveting with pins. Improvements in portable pneumatic riveting equipment at the turn of the century brought about a greater use of field riveting, initially for short spans and eventually for longer trusses as well. Typically, the individual bridge members would be shipped to the site, and the members would then be riveted in the field using connection or gusset plates. While the first all-riveted trusses in Texas date from the early 1900s, field riveting was not standard practice in Texas until about 1920. Bolts were used for field connection of both pinned and riveted trusses before the widespread use of field rivets.[799] These traditional connection technologies were largely replaced after World War II by arc welding and high-tensile bolts, introduced in the late 1940s and 1950s, respectively.

*Truss Configurations*

The basic truss pattern occurs in segments called panels that can be repeated as needed to provide the desired overall span length.[800] There are three configurations of truss panels, based on their relationship with the roadway. A metal truss bridge is usually constructed as a pony truss for lengths of 30 to 90 feet, with the deck attached to the bottom chord and the two sections of the truss rising above the roadway level. Because this type of truss is relatively short and rigid, no overhead lateral bracing is required to maintain the alignment of the trusses. The preferred choice for spans of 90 feet and longer is the through truss, which is essentially a pony truss with taller web members and overhead lateral bracing joining the top chords. A much less common configuration in Texas was the deck truss, such as the West Lancaster Avenue Bridge in Fort Worth (TxDOT Structure No. 02-220-0-ZL13-80-001). In rare cases, when a crossing was deep enough to accommodate the main web underneath the roadway level, the trusses were erected below the deck. Figure 51 illustrates the three different roadway configurations.

*Truss Patterns and Subtypes*

The arrangement of the main members in a truss determines the specific truss form or subtype, such as Warren, Pratt, Parker, and others. Most truss subtypes are named after the inventor or patent holder of that specific truss configuration. See Figure 52 for a visual inventory of the truss patterns currently in vehicular use in Texas. Specific descriptive information on each subtype is provided in Section 2.B(2) below.

*Locally Built Truss Bridges*

Virtually all of the metal truss bridges constructed in Texas prior to 1917, and most of the locally built structures dating after 1917, were designed and erected by bridge fabricators. In almost all cases, these bridges were

---

[799] Healey, John, "North Village Bridge Spanning the French River on North Main Street, Webster, Worcester County, Massachusetts, Historic American Engineering Record, Survey No. MA-99, 1990, 2.
[800] On the conceptual development of truss panels, see Tom F. Peters, "Bridge Technology and Historical Scholarship," Proceedings of the First International Congress on Construction History (Madrid, 2003), 63-64.

constructed without regulations or supervision from governmental entities or consulting engineers. With only vague standards and specifications guiding the bridge selection process, most bridge companies developed stock spans that they marketed throughout the state. These spans were typically lightweight structures made up of slender members, such as paired angles and thin plates, connected by pins or a loose pattern of rivets. While the bridges designed by the various companies are very similar in character, the fabricators often developed unique solutions for completing the portal bracing, web members, and gusset plates (if present) of a truss. Many bridge designers also used non-functional decoration, such as bridge plaques, cresting, and finials, to differentiate their trusses from those of other builders.

During this early era of metal truss bridge construction, the bridge's layout and composition were usually dictated by economic factors and the need for expediency in a bridge's construction. Typically, a metal truss span was erected in the middle of a channel and was flanked by a series of timber or I-beam approach spans connecting with the roadway on either side. At longer crossings, metal truss bridges were often built with multiple truss spans (up to 20 feet or more) over the main channel with approaches. In an effort to minimize potential damage by rapid currents and flooding, the metal truss spans were usually placed at a higher grade than the approach spans and the adjoining roadway. In many cases, the bridge was also placed at right angles to the stream with winding approach roadways on either end in lieu of constructing a skewed truss that could cross the stream at an angle. Consequently, skewed trusses dating before 1917 were rare.

While THD bridge engineers were not directly responsible for local bridge activities, they did significantly influence local bridge work. As local engineers became more familiar with THD designs and practices during the 1920s and 1930s, a number of them began to borrow freely from THD plans and specifications and to apply the same standards to local bridge projects. In a few cases, locally built bridges closely resemble THD built structures. In most rural areas, however, the counties continued to purchase stock metal truss spans, although not in the same quantity as they did previously. Beginning in the 1920s, many counties and cities also began to use concrete slabs, girders, and other bridge types at small-to mid-sized crossings. Approximately 150 metal truss bridges survive on city and county roadways in the state.

*THD Truss Bridges*

THD bridges tend to exhibit the standardized characteristics and preferences of the early THD bridge division and the BPR, an agency of the U.S. Department of Agriculture. In contrast with the light-type trusses designed by bridge fabricators, these were large, robust structures comprised of heavy, built-up members connected by substantial gusset plates and rivets. Truss railing typically took the form of simple steel members (angles, channels, H-beams or I-beams) placed in one or two rows across the main truss span(s). In some cases, the railings were supported by additional steel members, such as steel angles or I-beams. From about 1920 to the early 1930s, the most popular standard plan trusses used by the THD were the Warren pony (for spans of 50 to 80 feet), the Pratt through truss (for spans of 100 to 150 feet), and the Parker through truss (for spans of 120 to 250 feet). The push for standardization was one of the THD's most important and lasting contributions to the broad patterns of transportation statewide.

In addition to the main truss, most THD bridges also include large, permanent-type approach spans, concrete decking and curbing, and prominent concrete or steel approach railings. By the late 1920s, THD bridge engineers were emphasizing overall simplicity, including the use of rolled wide-flange beams as members rather than built-up fabricated members and their elaborate parts. THD engineers also recognized the need to provide harmonious treatment of railings, bridge-ends, and substructure. Many of the trusses and other bridge elements (e.g., substructure, railings, approaches) constructed by the THD conformed to standard plans. In some cases, however,

custom design features, such as special railing or pier designs, were also used to address unusual engineering or aesthetic concerns. While THD bridges typically do not exhibit architectural details or special decorative elements, exceptions were made for bridges readily visible to the public, such as locations adjacent to parks and railroad lines. In cases where visibility was a factor, THD bridge engineers created visually pleasing and harmonious designs, often applying special decorative details and ornamentation to a bridge's piers, railings, and approaches.[801]

The bridges erected by the THD reflect a more sophisticated engineering approach than that employed by earlier bridge builders in the state. The THD bridge design and selection process resulted from an analysis of a wide range of factors, such as soil conditions, hydraulics, flooding, drift, navigational requirements, and other elements. THD bridges were designed to be large enough to accommodate floodwaters in an entire floodplain without any overflow on the approach roadways. In almost all cases, THD bridges were built at the same grade (or virtually the same grade) as the approach roadways. For large crossings, the solution was usually one or more large metal truss spans flanked by a series of relatively short concrete or metal approach spans. Alternatively, smaller structures were constructed across relief channels that help accommodate rising floodwater. In some cases, long approaches were avoided by filling in part of the floodplain; occasionally, relief structures were built in combination with a filled-in section in order to accommodate water overflow in peak seasons. The THD also continually improved its design and construction practices. For example, by the mid-1920s the THD had discontinued the use of pin connections in favor of riveting methods and had replaced suspended floor-beam designs with more rigid decking systems that framed the floor beams into the bottom chord.

Over the years the THD's design preferences evolved largely eliminating the Warren pony and Pratt throughs. By the mid-1930s the THD was using I-beams and girders for most shorter spans. The average span of the 385 extant pre-1936 steel girder bridges is 42 feet. For the 791 extant concrete girder bridges built pre-1936 the average span is 32 feet. By comparison, the 50 extant pre-1936 Warren Ponies average 58 feet and the 17 extant pre-1936 Pratt throughs average 126 feet. The THD continued to erect Parker through truss spans at mid-to longer-sized crossings through the late 1940s.

In addition to the simpler truss subtypes discussed thus far, the THD's bridge division designed several cantilever trusses beginning in the early 1920s and continuing through the 1950s; the latest cantilever truss erected in the state dates from 1970. Another truss type the THD bridge division employed for longer spans was the continuous truss, which has a chord and web configuration that continues uninterrupted over one or more intermediate supports or piers.

From the 1920s to the early 1940s, the THD was responsible for designing and completing several hundred metal truss bridges on the state highway system. Many of the more modest examples have since been removed. Only about 24 metal truss bridges remain in the state are products of THD design and construction.

*Truss Bridge Substructure*

Although the superstructure is often the most prominent aspect of a metal truss bridge, the substructure is also important. Most of the early bridges in this property type had timber pile abutments with plank end walls. Other early abutments were constructed of stone or consisted of steel piles with sheet steel end walls. Piers were used for

[801] The 2012 resurvey of the metal truss bridges in vehicular use identified few examples of this aesthetic treatment other than the SH 16 at Llano River (Roy Inks) (TxDOT Structure No.14-150-0-0290-01-023) and the Loop 481 at South Llano River (TxDOT Structure No. 07-134-0-0142-16-031) bridges.

longer bridges that included a main truss span(s) and approaches. The early approaches usually consisted of timber or steel I-beam trestle spans. The most common pier type used for truss spans in the late nineteenth and early twentieth centuries consisted of concrete-filled tubular caissons built from riveted iron or steel plates. Another common pier type for truss spans were simple metal pile bents built from channels or composite members. In Texas, concrete was not used extensively for substructures until about 1910. Typical THD construction featured concrete piers arranged in a dumbbell configuration, with battered cylindrical columns connected by a solid diaphragm or web wall. Alternatively, columns were squared. The THD developed a series of standards for dumbbell piers that were used for most metal truss bridge construction. In addition, non-standard pier designs included solid piers with rounded, squared or, less typically, pointed (cutwater) ends.

*Typical Alterations/Conditions*

The conditions of the bridges in this property type vary greatly depending on the level of maintenance, vehicular loads, materials, inherent properties of the design, and local climatic conditions. Metal truss bridges on the state highway system receive regular maintenance and are generally in good repair. In many cases, these bridges survive with few non-historic alterations evident. The most obvious modifications found on THD bridges are large singular guardrails affixed to the thinner historic railings and rebuilt portal bracing or web members. Most of the bridges on local roadways have not fared as well as the highway structures. Without paint and regular maintenance, many local bridges are in a deteriorated condition. The narrow widths and winding approaches that are commonly associated with these bridges make them very susceptible to vehicular collisions. Their unstable piers and low elevations above the streambed also make them vulnerable to washouts and flooding damage. On the other hand, local bridges sometimes retain integrity compared to equivalent bridges on the state highway system because of their relative isolation and reduced traffic volume.

### *(b) Significance*

This section refines the significance and eligibility requirements that apply to all bridges to specific conditions of the metal truss bridge type. Additional considerations for specific subtypes are found in individual discussions, below. While truss bridges are generally significant under *Criterion C* for engineering, there are certain circumstances when they can be significant under *Criterion A.*

*Criterion A Significance*

A metal truss bridge may be eligible for listing on the National Register for association with the broad patterns of history. As detailed below, in Texas a riveted parallel chord Warren pony truss can be significant under Criterion A for association with locally funded transportation networks.

*Criterion C Significance*

The following discussion of significance applies to all metal trusses unless specified otherwise by the discussions of significance for individual metal truss subtypes. In general, a metal truss bridge in Texas can be significant under *Criterion C* for:

Embodying distinctive characteristics of a type, period, or method of construction

Based on an analysis of extant metal truss bridges in Texas identified through comprehensive survey efforts, all examples of metal truss bridges constructed before 1946 are significant at the local level as embodying distinctive characteristics of a type.

Period or method of construction (including innovations)

*Connection type*
Evolution of connection type reflects changing understanding of structural behavior by engineers, improvements in material quality, and changing fabrication practice. Bridges significant for their connection type are:

- threaded rod connections before 1900
- Pin-connected bridges constructed before 1900
- Rivet-connected bridges constructed before 1917
- Use of all welded connections before 1950
- Use of high-tensile bolts for structural steel members before 1956

Pinned trusses were faster to erect, especially before wide availability of pneumatic powered riveting systems in the field. Early rivets sometimes became brittle after they cooled. Further, Gilded Age engineers conceptualized pins as very large rivets with known shear strength. They also saw pinned connections as statically determinate hinges. During this era, stresses were much more difficult to determine for the more rigid riveted connections than for pins.[802] Consequently, pin connected trusses constructed before 1900 are significant for association with these conditions. Field observations in Texas indicate that the transition from pin connections to all rivet connections was made by 1905 for Warren pony trusses by bridge companies. For larger trusses, the transition took longer. The THD, for example, developed standardized versions of pin connected Pratt and Parker through trusses in 1919 and 1921, respectively. It is also clear that the THD was simultaneously developing all riveted versions of Pratt and Parker through trusses. Thus, all riveted trusses fabricated before the creation of the THD in 1917 represent examples of technological innovation. The historic context identifies the use of welded connections as innovative when used before 1950.[803]

*Other fabrication details*
Beside pin connections, Gilded Age engineers also demonstrated their understanding of structural behavior by designing and fabricating details like fish-belly floor beams (deeper at the middle of the deck than at the panel points) to allow for greater bending moment in the middle of a simple beam. Examples include the Lenticular through truss over the San Antonio River in Brackenridge Park, San Antonio (TxDOT Structure No. 15-015-0-B038-25-005) and the Willow Springs Road Bridge over Cummins Creek, a Pratt through truss in Fayette County (TxDOT Structure No. 13-076-0-AA03-98-005). While not character-defining, these features may be considered when assessing a bridge's design significance.

---

[802] "Parker Bridge, Spanning Verdigris River, Coffeyville vicinity, Montgomery County, Kansas," Historic American Engineering Record KS-7, 5.
[803] The historic context also identifies high-tensile bolts as an innovative feature when used before 1956. The 2012 fieldwork was not expecting, and did not identify, any truss bridges designed for high-tensile bolt connections. It did find many trusses where rivets were repaired with high-tensile bolts.

*Material*
As noted in the context, the significant transition from wrought iron to steel in metal trusses was largely completed by 1900. Wrought iron is a defining characteristic of the American Standard truss and as such is significant. A bridge may be significant for its material if it was constructed of:

- Wrought and cast-iron regardless of construction date
- Wrought iron regardless of construction date, or
- Steel if constructed before 1900

*Exceptional main span length for type*
Exceptional main span length illustrates the variation within a class of bridges and signals significant engineering achievement. Generally, longer main span lengths signal more difficult engineering complexity. Guidance is provided in its subtype discussion below.

*Number of truss spans*
Exceptional structure length illustrates the variation within a class of bridges and signals a distinctive engineering achievement. This MPS uses the number of truss spans as an easy to apply proxy for overall length. While important, the somewhat iterative nature of adding another span is generally not as challenging as designing an exceptionally long main span and is therefore less important as a marker of engineering significance. A metal truss bridge constructed in Texas before 1945 with three or more truss spans meets the threshold for distinctive engineering complexity. In order to be NRHP eligible under *Criterion C* in the area of *Engineering*, however, a bridge that meets this threshold should also possess an additional distinctive engineering achievement.[804]

Representing the work of a master

A bridge can be a distinctive engineering achievement for embodying work of an engineer, designer, fabricator, or builder with national or state importance. As noted in the NRHP Bulletin *How to Apply the National Register Criteria for Evaluation*, a property should be considered important within a body of work to be considered significant as the work of a master. To be judged significant as a work of a master, a bridge should be:

- Documented as having been designed one of the engineers specifically listed in Section E of this MPS. Supervision of the engineer(s) performing the calculations, reviewing, or otherwise checking drawings or other related work is not sufficient to qualify a metal truss as a work of a master. For example, a truss identified as being constructed by Flinn-Moyer or *personally designed* by George G. Wickline qualifies as the work of a master. In contrast, a bridge designed *under Wickline's supervision*, or *a standard design* by Austin Bridge Company of Dallas, Texas, is not the work of a master.

[804] There are numerous precedents for requiring more than a particular overall length to establish a bridge's significance. Tennessee awards 1 point for 3 or more spans (Cooper, p. 13). California awards between 2 and 8 points depending on the number of truss spans. Further, the Texas SHPO endorsed a parallel methodological philosophy for assessing engineering complexity of bridges constructed between 1945 and 1965. In a similar vein, overall bridge length is just one of several potential elements contributing to NR eligibility under the non-truss methodology. See the non- truss and the 1945- 1965 methodologies elsewhere in this document.

On the list of individuals included in Appendix F – Texas Master Builders of the *Final Evaluation Methodology: Texas Historic Bridge Inventory, Evaluation of 1945-1965 Bridges*., or

- Identified in the scholarly or professional literature as a major work of an engineer, designer, fabricator, or builder with national or state importance. For example, the SH 87 Bridge at the Neches River (commonly known as the Rainbow Bridge, TxDOT Structure No. 20124030603015) was identified by the Historic American Engineering Record as the work of an important engineer.[805]

In order to be NRHP eligible under *Criterion C: Engineering*, however, a bridge that meets this threshold must embody an additional distinctive engineering achievement. Being solely a work of a master is not sufficient for a metal truss to be significant under *Criterion C*.[806]

Possessing high artistic values

Trusses possessing high artistic value are important for their expression of an aesthetic ideal. Since this determination is particularly subjective, a bridge must receive recognition under another *Criterion C* category to be significant. To be recognized for high artistic value, a metal truss built in Texas must possess:

- Deliberate ornament such as decorative pedestrian rail, portal, parapet, or lighting fixtures. A fine example of such decoration is found on the Lenticular through truss over the San Antonio River in Brackenridge Park, San Antonio (TxDOT Structure No. 15-015-0-B038-25-005), or
- Deliberate ornament that is documented as an aesthetic feature in engineering, historical, or other appropriate literature; in public records; or via public involvement.

### *(c) Registration Requirements*

In addition to possessing significance under one of the National Register Criteria, a metal truss must also be shown to have historic integrity to be eligible for the NRHP. The National Register bulletin *How to Apply the National Register Criteria for Evaluation* defines historic integrity as "the ability of a property to convey its significance."

*Criterion A registration requirements*

There are no specific *Criterion A* registration requirements specific metal truss bridges under this evaluation methodology. See Section 2.A(3), General Bridge Registration Requirements, above.

---

[805] George Wickline of the Texas Highway Department's Bridge Division produced the preliminary design and oversaw the bridge's construction while on leave from his regular duties as State Bridge Engineer. See Gruen, *Rainbow Bridge.* Historic American Engineering Record, Survey No. TX-43. 1996, rev. 1998.

[806] There are numerous precedents for requiring more than documentation that a bridge was designed by a significant engineer to establish a bridge's significance. Tennessee awards 3 points toward significance for a "known, unusual, or significant builder" (Cooper, p. 13). California awards between 12 and 6 points towards significance for major and minor (respectively) examples by a significant builder/designer. Further, the Texas SHPO endorsed a parallel methodological philosophy for assessing bridge constructed between 1945- and 1965. See the 1945- 1965 methodology elsewhere in this document.

*Criterion C Registration Requirements*

Introduction

To be eligible under *Criterion C* for *Engineering*, a metal truss bridge should possess significance as discussed above and should retain its character-defining features and historic integrity with particular emphasis of retention of integrity of design, workmanship, and materials. Since *Criterion C* relates to the engineering significance of trusses, integrity of design, workmanship, and materials are typically more important because they allow a structure to convey its physical features and characterize the type, period, or method of its construction. For this reason, these aspects of integrity are heavily weighed. Major alterations relating to these integrity aspects significantly compromises integrity. Major alterations to a bridge's design, workmanship, or materials will result in a determination that a bridge is no longer eligible despite its engineering significance. Thresholds for what constitutes a major alteration are defined below for each subtype.

Integrity Considerations under *Criterion C*

*Location*
Alterations to a truss's location do not result in the same level of diminished integrity under *Criterion C*, since trusses were designed and constructed of prefabricated parts that allowed for relatively easy relocation as traffic needs evolved. Local decisions to recycle and relocate bridges to new crossings were a routine occurrence especially for locally constructed and locally owned bridges. THD records of the 1930s provide evidence that THD bridge engineers often salvaged old trusses and reused them at locations with lesser traffic requirements. Indeed, relocation in the historic period could constitute an additional significant date in its own right. Changes to location can result in different degrees of integrity loss under *Criterion C* depending upon any physical alterations that occurred after the relocation of the bridge. For example:

- A bridge in its original location, where original location is defined by most recent period of significance, would retain integrity of location.
    - *Example:* The main span of the CR 337 at Colorado River Bridge (TxDOT Structure No. 08-168-0-AA01-42-002) in Mitchell County was relocated to its present location sometime after the historic period, perhaps the 1950s.
- A bridge that has been relocated after the historic period and retains character-defining features at its new location would retain integrity of location.
    - *Example:* The c. 1895 Forest Brook Drive at Red Oak Creek Bridge (TxDOT Structure No. 18-071-0 BB00-80-002) is a pin connected Pratt half-hip pony truss moved to its current location about 1968.
- A bridge that has been relocated and does not retain its character-defining features would not retain integrity of location.

A bridge that does not retain its character-defining features after relocation experiences compromised integrity sufficient to preclude eligibility, while a bridge that retains its character-defining features after relocation experiences minor loss of integrity that would be insufficient on its own to preclude eligibility.

*Design*

While integrity of design is important for conveying a bridge's engineering significance, greater alterations to its historic design may be permissible if the bridge is an example of an extremely uncommon subtype. Alteration, repair, or complete replacement of bearings, floor beams, stringers, or travel surfaces do not impact integrity of design as these are not character-defining features of metal truss bridges. These features were typically designed for ongoing maintenance and replacement. Character-defining characteristics can be found in the subtype descriptions.

Truss deck systems are subject to high wear and were intended to be periodically repaired or replaced. Consequently, they are excluded in assessing integrity since the deck systems of few metal truss bridges retain high integrity of design, materials, or workmanship.

In assessing integrity under *Criterion C*, it is constructive to consider the physical components of a metal truss bridge in terms of character and non-character-defining features. A subtype's character-defining features should be present and sufficiently intact to possess integrity of design. Non-character-defining features include features that are both historic-age, such as a fish-belly floor beam, and non-historic-age, such as aluminum guard rail. As an example, the US 87 at Llano River Bridge (TxDOT Structure No. 14-157-0-0071-04-018) consists of two polygonal top chord Warren through trusses with 12 concrete girder and two steel I-beam approach spans, and concrete rail. Polygonal top chord Warren through trusses are an uncommon type that demonstrate variety within the truss subtype. The approach spans should be individually evaluated in their own right, but are of substantially lesser importance. As non-character-defining features, severe losses or alterations to the US 87 approaches would rarely preclude NRHP eligibility due to design and materials integrity. Similarly, demolition and complete reconstruction of the steel I-beam and concrete deck SH 203 Salt Fork of the Red River Bridge's (TxDOT Structure No. 14-227-0-0700-03-004) approach span did not create a false sense of history and did not impact the character-defining Parker through trusses.

Rehabilitation of a metal truss done according to the *Secretary of the Interior's Standards for Rehabilitation (codified in 36 CFR 67)* can replace up to a majority (not counting the deck system) of the original metal elements in kind. In kind refers to similar structural and decorative shapes as found on the historic bridge. Introduction of new elements, such as transition blocks between new and historic elements, are subject to further integrity assessment under the *Secretary's Standards*.

Severe alterations resulting in extensive changes to the original design diminish a metal truss's historic character and could render it ineligible due to integrity loss. Severe alterations also result from multiple major and minor alterations such adding new members, alterations to character-defining features, and removing features, such as knee braces. Examples of severe alterations include:

- Widening
- Narrowing roadway surface by a lane or more
- Changing the character-defining pattern of the truss web
- Otherwise reengineering the truss when done outside the historic period
- Catastrophic failure.

Examples of severe alterations include:

- The removal of one of three lanes from the North Presa Street at San Antonio River Bridge (TxDOT Structure No. 15-015-0-B279-95-001) severely impacted the bridge's design integrity.
- A vehicle collision with the Toll Bridge Road over Lampasas River, near Salado (TxDOT Structure No. 09-014-0-D004-72002) resulted in complete integrity loss when it collapsed.

However, an example of alteration not affecting integrity is the Murphy-Whipple through truss that carries CR 3112 over the North Bosque River (TxDOT Structure No. 09-018-0-AA03-33-001), which did not lose design integrity as widening was done during the historic period.

Major design alterations resulting in substantial loss to qualities that define the truss's engineering significance under *Criterion C* include extensive reinforcement of character-defining features such as top chords and compression members with welded plates as on the Smothers Creek Bridge on County Road (CR) 183 in Lavaca County (TxDOT Structure No. 13-143-0-AA01-02-004); or when the main span no longer behaves as a truss. Another example is the Lavaca River Bridge on Lavaca CR 260 (TxDOT Structure No. 13-143-0-AA01-69-001), where the original deck system has been replaced and the trusses rendered redundant by reinforced concrete box-girders. The system propping up the no longer extant CR 228 at Briar Creek bedstead truss in Young County was not, however, a major design alteration for two reasons, as the NPS bulletins provide for more relaxed integrity standards for rare examples[807] and because removing the supports could have been done with minor damage to character-defining features.

Minor alterations represent a minimal loss of design integrity under *Criterion C*. Examples include removal of "knee braces" and sympathetic reengineering of portal and sway bracing. These are common solutions to certain vertical and horizontal clearance issues and can extend the service period of metal trusses. Knee braces were removed, for example, from the FM 601 at Hubbard Creek in Shackelford County (TxDOT Structure No. 08-209-0-0107-03-012) before rehabilitated to the *Secretary of the Interior's Standards.* Alteration or loss of original rail not possessing high artistic value is also considered minor. While bridge rails have become increasingly important safety features, they rarely contribute to the significance of metal truss bridges constructed before 1945. The pedestrian rail of the North Fifteenth Street at Pin Oak Creek bedstead truss (TxDOT Structure No. 18-175-0-B010-45-001), however, has historically derived finials and pointed arch ornament that contributes to design significance. Alteration or loss of its original rail could be major.

While alteration to or loss of original rail may be considered a minor alteration, TxDOT has designed and crash tested two rails specifically for THD designed through trusses.[808] One was coordinated with the State Historic Preservation Office (SHPO) and installed on the SH 16 at Llano River (Roy Inks) Bridge (TxDOT Structure No.14-150-0-0290-01-023). The second was developed for the US 281 at Brazos River Bridge in Palo Pinto County (TxDOT Structure No. 02-182-0-0250-02-018). Use of either of these *particular* rails on THD-designed through trusses does not impact integrity of design unless attaching them would require reengineering character-defining aspects of truss members. These rails are made of steel, a material visually compatible with metal trusses, are small

[807] "The rarity and poor condition, however, of other extant examples of the type may justify accepting a greater degree of alteration or fewer features, provided that enough of the property survives for it to be a significant resource"; *How to Apply the National Register Criteria for Evaluation*, 47.
[808] C. Eugene Buth, William F. Williams, Wanda L. Menges, Rebecca R. Haug, *Retrofit Railings for Truss Bridges, Report No. FHWA/TX-05/0-4419-5* (College Station, Texas: Texas Transportation Institute, October 2005).

when compared to the scale of THD designed through trusses, and minimize the impacts to a bridge's character-defining features when compared to other crash tested rail systems such as solid concrete or "Jersey" barriers.

Non-truss approach spans are frequently part of the design of a truss bridge, but generally do not impact integrity of design for the overall bridge. While such approach spans could be significant in their own right, they generally are not. The appropriate non-truss evaluation methodology should be used when there is uncertainty or controversy. When non-truss approach spans are not significant in their own right, they should be considered *historic-age*, as opposed to character-defining features of the design. Consequently alterations to contributing approach spans rarely impact integrity of design.

Gilded Age refinements, such as fish-belly floor beams or original rail fasteners, as found on the Willow Springs Road Bridge in Fayette County (TxDOT Structure No. 13-076-0-AA03-98-005), may be unimportant (as opposed to character-defining) design features. As such, they are worth considering when developing a maintenance or preservation plan.

*Setting*

A truss loses integrity of setting only when it can be documented that specific aspects of the setting contributed to a truss bridge's design beyond common adaptations to site and location, such as channel and crossing length, skew, and foundation conditions. Therefore, changes to a bridge's physical environment and setting generally do not result in a loss of integrity under *Criterion C*. Professional judgment may be required to accurately assess integrity of setting, in the rare cases where setting specifically contributes to a bridge's engineering significance. Construction of a new bridge or a low-water crossing as a bypass next to an existing truss bridge, such as at the CR 422 Bridge at Dockum Creek in Dickens County (TxDOT Structure No. 25-063-0-AA01-04-001), rarely requires alterations to the character-defining features of a truss bridge and thus rarely compromises integrity of setting. In contrast, excavation of part of a cliff face directly responsible for the bridge's site-specific design and location, as occurred when the CR 207 Bridge at the Salt Fork of the Brazos River (TxDOT Structure No. 08-217-0-AA02-07-001, HAER TX-66) was bypassed, may result in a loss of integrity of setting. Such rare occasions require professional judgment to assess whether the change represents impacts integrity of setting.

*Materials*

Rehabilitation of a metal truss done according to the *Secretary of the Interior's Standards for Rehabilitation* can replace in-kind up to a majority (not counting the deck system) of the original metal elements. For example, the deck surface of the SH 203 at the Salt Fork of the Red River Bridge in Collingsworth County (TxDOT Structure No. 25-044-0-0230-01-006) was replaced, selective repairs were made to the floor beams, and the entire historic-age steel I-beam approach span was fully reconstructed using in-kind design and materials. The bridge was considered to retain integrity of materials.

Minor alterations resulting in a minimal loss of the original materials not diminishing the truss's ability to convey engineering significance under *Criterion C.* For example, the removal of "knee" bracing from the FM 601 at Hubbard Creek Bridge (TxDOT Structure No. 08-209-0-0107-03-012).

Major alterations resulting in substantial loss of the original material diminishing the truss's ability to convey its engineering significance under *Criterion C* include extensive changes to connections replacement and wholesale

replacement of major members as at the SH 290 at the Pecos River Bridge (TxDOT Structure No. 07-053-0-0140-08-051).

Severe alterations resulting in extensive loss to the original material diminishing the truss's historic character under *Criterion C* includes welding a metal plate to the top chord of the Good Hope Road at Atascosa River Bridge (TxDOT Structure No. 16-149-0-AA02-10-001)

*Workmanship*

Workmanship is the physical evidence of crafts of a particular culture or people during any period in history or prehistory.[809] Workmanship for metal trusses is strongly evidenced by specialized construction and fabrication skills. Wrought iron trusses fabricated before 1890, for example, required highly specialized skills such as blacksmithing. Workmanship for metal truss bridges became less of an integrity consideration as use of steel and concrete increased in the twentieth century. One exception is the 1938 Rainbow Bridge (SH 87 Bridge at the Neches River, TxDOT Structure No. 20-124-0-0306-03-015) in Jefferson and Orange counties, which required uncommon skill in its construction.

Alterations resulting in a minimal loss of the original workmanship not diminishing a truss's ability to convey engineering significance under *Criterion C* are considered minor. Examples of minor alterations include noticeable, but sympathetic, use of welding on character-defining features and poorly executed repairs to, or replication of, visually prominent decorative elements.

Major alterations to workmanship are those that result in substantial loss of the original material and diminish the truss's ability to convey its engineering significance under *Criterion C*. For example, replacement of the distinctively formed and textured wrought-iron eyebars on Berlin Iron Bridge Company lenticular truss bridges in San Antonio (TxDOT Structure Nos. 15-015-0-B002-75-001, 15-015-0-B038-25-002, 15-015-0-B075-05-009, 15-015-0-B156-65-001) in a way that is visible to the general public, or extensive and noticeable welded repairs to an example of a common truss type, are examples of major alterations to workmanship. The SH 290 at the Pecos River Bridge (TxDOT Structure No. 07-053-0-0140-08-051) has major workmanship integrity losses from extensive welded repairs in the upper latter bracing and numerous welded battens on a replacement web vertical.

A truss bridge rehabilitated according to the *Secretary of the Interior's Standards for Rehabilitation* retains integrity of workmanship. Examples include the SH 203 at the Salt Fork of the Red River (TxDOT Structure No. 25-044-0-0230-01-006) and Loop 481 at South Llano River bridges (TxDOT Structure No. 07-134-0-0142-16-031) where alterations and repairs to character-defining features were minimal given the size of the trusses and were critical to continued vehicular use.

*Feeling and Association*

Changes to a truss bridge's integrity of feeling and association only rarely impact its ability to convey its engineering significance. The visual impressions of a particular period of truss design, such as the Gilded Age of the late nineteenth century, derive from its engineering, available materials, and in some cases, the aesthetic theories of the period. For metal truss bridges under the *Criterion C: Engineering* context, integrity of feeling and

[809] *How to Apply the National Register Criteria for Evaluation*, 46.

association are therefore most strongly tied to integrity of design, materials, and workmanship and, as such, are best assessed in conjunction with those respective standards.

### (2) Metal Truss Subtypes

This section provides descriptions, significance statements, and registration requirement specific to each of the metal truss subtypes.

#### *(a) Pratt and Pratt Variants*

*Pratt*

Description
While there are many subtypes of the Pratt truss, this description applies only to parallel chord Pratt trusses. The Pratt truss is defined by its use of vertical web members in compression and diagonal web members. Typically, vertical members of a Pratt truss are thicker and act in compression, while diagonal members are thinner and are placed in tension. The top chord is horizontal and is parallel to the bottom chord except at the endposts, which are inclined. A Pratt through truss has bracing (portal, struts, lateral, and sway) located above the roadway connecting the trusses.

Significance
Developed in the 1840s, the Pratt truss became the dominant metal truss type for spans less than 250 feet during the latter half of the nineteenth century. Material efficiencies from shorter compression members and longer tension members were critical to this success. This is because geometry requires that compression members use substantially more metal per linear foot in order to resist buckling than required by tension members to resist tensile forces. (A Howe truss has the opposite arrangement of compression and tension in the web and thus uses metal less efficiently.) In addition, pinned connections simplified certain aspects of the engineering calculations and facilitated erection given Gilded Age understanding of structural behavior. Surviving examples of pin-connected wrought iron Pratt trusses in Texas are particularly significant for their association with the rise of the Post Bellum American Standard truss. That most Pratt trusses will be significant under several areas (uncommon type, pin connections, early date, and use of wrought iron) is a reflection of the subtype's overall importance in Texas and American bridge history.

The Pratt pony subtype is the lighter load version of the Pratt through truss. It served a similar role as Warren pony trusses prior to the latter's transition to riveted connections around 1900.

Individual bridge fabrication companies executed details, such as connections, differently. Such refinements demonstrate the variation possible within this subtype and can sometimes be diagnostic of the fabricator. However, these fabricator-specific details do not necessarily denote significance, particularly given the significance of most Pratt trusses for other reasons, such as uncommon type.

THD engineers developed standardized designs for both Pratt through and pony trusses, but none are known to survive. Similarly, the THD developed 35-, 40-, and 45-foot Pratt pony truss designs between 1918 and 1920, but no examples are known to remain extant. Any documented example of a THD standard Pratt truss, particularly a Pratt through truss, would be significant as an indication of the THD's standardization initiatives, of the longevity of the subtype, and its eclipse by the Parker truss and non-truss bridges.

Registration Requirements
To be eligible under *Criterion C* in the area of *Engineering*, a Pratt truss should possess engineering significance as defined above (pp. 219-222) and should also possess the following character-defining features to retain integrity:

- Verticals in compression
- Diagonals, slanting down and in towards center, in tension connecting only one panel
- Parallel top and bottom chords[810]
- For Pratt through trusses: Through truss configuration (struts, sway bracing, and lateral bracing above roadway)
- For Pratt pony trusses: Pony truss configuration (no upper bracing)
- Inclined endposts

In addition, the following typical features are common for Pratt through trusses:

- Diagonal counters on some examples (character-defining if part of original design)
- Portal bracing or struts on some through truss examples (character-defining if part of original design)
- Bottom lateral bracing (not character-defining)
- Floor beams (not character-defining)
- Stringers (not character-defining)

There are no other registration requirements specific to this subtype. Use the registration requirements common to all metal truss subtypes for assessing significance and integrity, and situations not identified herein.

*Pratt Half-hip*

Description
The Pratt half-hip truss, commonly used for spans of 60 feet or less, eliminates the hip verticals (the verticals closest to the endposts) and instead features endposts that are more inclined. Visually, the inclined endposts do not horizontally extend across the full length of the end panels. This is the character defining feature that separates it from other Pratt variants.

Significance
For this subtype, refer to the significance discussion common to all metal truss bridges. (pp.219-222)

Registration Requirements
For this subtype, use the registration requirements common to all metal truss bridges. (pp. 222-228)

[810] Subsets of the Pratt truss type often have polygonal top chords (e.g., Camelback and Parker trusses). These subsets have separate defining features.

*Truss Leg Bedstead*

Description
The truss leg bedstead's distinguishing and character defining features are vertical endposts that extend below the lower truss chord to serve as a pier or abutment support.

Significance
For this subtype, refer to the significance discussion common to all metal truss bridges. (pp.219-222)

Registration Requirements
For this subtype, use the registration requirements common to all metal truss bridges.

*Parker*

Description
A Parker truss is a Pratt truss (diagonals in tension, verticals in compression) with a polygonal top chord of more than five segments. The top chord is composed of inclined straight members with the angle of inclination changing at the panel points. By arching the top chord, the Parker provides greater strength than the Pratt and could be used for longer span lengths, usually up to 250 feet or more.

Significance
The Parker truss was developed in Boston in the 1870s as a means to build longer spans and to make more efficient use of materials compared to an equivalent-length Murphy-Whipple design (a type of Pratt truss popular in the 1880s and 1890s, described below).[811] Unlike parallel chord Pratt trusses, but like bowstring trusses, Parkers have more metal concentrated in the middle of the span. This concentration is a more efficient use of material as the forces are greatest at the middle. Standardized designs reduce the labor and fabrication costs associated with the Parker truss's increased variation in member sizes. Parkers have two advantages over the bowstring truss: the inclined endposts can be readily modified for minor changes in span length and the end panels are more durable under heavy concentrated moving loads.[812]

In Texas, standard Parker through truss designs were extensively developed by the THD during the 1920s and continued to be used into the 1940s. The THD built Parker through truss spans in lengths of 120 to 250 feet with roadway widths ranging from 16 to 24 feet. THD bridge engineer George Wickline clearly showed a preference for the Parker through truss; thus, it became the THD's predominant longer-span bridge type at an early date.[813] THD standard designs began a shift towards rolled-section webbing and struts beginning in late 1929.

Registration Requirements
To be eligible under *Criterion C* in the area of *Engineering*, a Parker truss should possess engineering significance as defined above and should also possess the following character-defining features to retain integrity:

- Pratt truss web configuration (verticals in compression, diagonals in tension)

---

[811] James Cooper, *Iron Monuments to Distant Prosperity: Indiana's Metal Bridges, 1870-1930*. n.p., 1987, 62-63, 76-77.
[812] Darnell, "The National Bridge and Iron Works and the Original Parker Truss," 11-12.
[813] Stocklin, E-37.

- Polygonal top chord with more than five slopes
- Inclined endposts
- For Parker through trusses: Through truss configuration (struts, sway bracing, and lateral bracing above roadway)

In addition, the following typical features are common for Parker trusses:

- Diagonal counters on some examples (character-defining if part of original design)
- Portal bracing or struts on some examples (character-defining if part of original design)
- Bottom lateral bracing (not character-defining)
- Floor beams (not character-defining)
- Stringers (not character-defining)

There are no other registration requirements specific to this subtype. Use the registration requirements common to all metal truss subtypes for assessing significance and integrity, and situations not identified herein.

*Camelback*

Description
The Camelback truss is a variant of the Parker truss with a polygonal top chord having a total of exactly five segments, including the inclined endposts. The center section of the top chord is parallel to the bottom chord. Character-defining features are:

- Pratt truss web pattern (verticals in compression, diagonals in tension)
- Top chord with exactly 5 segments (including inclined endposts)
- Center section of top chord is parallel to bottom chord[814]

Other typical features of Camelback trusses are:

- Diagonal counters on some examples (can be character-defining if part of original design)
- Portal bracing or struts on some examples (can be character-defining if part of original design)
- Lateral bracing (not character-defining)
- Floor beams (not character-defining)
- Stringers (not character-defining)

Significance
Polygonal top chord trusses exploit the efficiency of concentrating metal towards the middle of the span where bending is greatest. The slope could be varied to increase the height of the truss. The higher the truss, the longer the span can be.[815] Cooper suggests the Camelback replaced the Murphy-Whipple truss "for spans too long to be a simple Pratt."[816] Likewise, they may be used for spans too short for efficient use of the Parker truss. The THD

[814] James Cooper, *Iron Monuments to Distant Prosperity: Indiana's Metal Bridges, 1870-1930*. n.p., 1987, 75.
[815] Martha Carver, 300-301.
[816] James Cooper, *Iron Monuments to Distant Prosperity: Indiana's Metal Bridges, 1870-1930*. n.p., 1987, 74.

designed only one Camelback standard design, the T22-110. No examples of this 1932 riveted design are known to survive. Camelbacks are a rare subtype in Texas.

Registration Requirements
There are no registration requirements specific to this subtype. For this subtype, use the registration requirements common to all metal truss bridges. (pp. 222-228)

*Pennsylvania*

Description
The Pennsylvania truss is a variant of the Parker truss with character defining polygonal top chord and subdivided panels, in which diagonals are braced at their midpoint with sub-diagonals and vertical struts.

Significance
Pennsylvania trusses are a rare subtype in Texas. For this subtype, refer to the significance discussion common to all metal truss bridges. (pp. 219-222)

Registration Requirements
For this subtype, use the registration requirements common to all metal truss bridges. (pp.222-228)

*K-truss*

Description
The K-truss is a variant of the Parker truss developed in the early twentieth century. It is distinguished by subdivided panels with a vertical and two diagonals forming a K shape in each panel. The design is meant to afford greater span length and strength. The sole extant K-truss example in Texas, the NRHP-listed SH 78 Bridge at the Red River in Fannin County (TxDOT Structure No. 01-075-0-0279-02-024), connects Texas and Oklahoma and was primarily designed by engineers of the Oklahoma Highway Commission.

Significance
For this subtype, refer to the significance discussion common to all metal truss bridges. (pp. 219-222)

Registration Requirements
For this subtype, use the registration requirements common to all metal truss bridges. (pp.222-228)

*Murphy-Whipple*

Description
The Murphy-Whipple truss is an all wrought iron Pratt truss with parallel chords and with diagonals extending over two pin-connected panels. These are character defining features. The type is sometimes also termed a double-intersection Pratt truss due to the diagonal configuration. The Hays Street Bridge (TxDOT Structure No. 15-015-0-

B156-65-001) in San Antonio is also termed a Murphy-Whipple truss as its cast iron is limited to connection blocks and decorative features.[817]

Significance
The Murphy-Whipple is a rare subtype in Texas. For this subtype, refer to the significance discussion common to all metal truss bridges. (pp.219-222)

Registration Requirements
For this subtype, use the registration requirements common to all metal truss bridges. (pp.222-228)

*Lenticular*

Description
Lenticular trusses' character defining features are pin-connected curved top and bottom chords, forming a lens shape, supported by vertical endposts. Most, including all Texas examples, use the Pratt configuration webbing.

Significance
Lenticulars are a rare subtype in Texas. For this subtype, refer to the significance discussion common to all metal truss bridges. (pp.219-222)

Registration Requirements
For this subtype, use the registration requirements common to all metal truss bridges. (pp.222-228)

***(b) Warren and Warren Variants***

A Warren truss has a zig-zag (/\/\/\/\) web pattern with the triangular shapes of the truss forming equilateral triangles. The Warren's relatively rigid diagonals function both in tension and compression and can be supplemented by thinner vertical members that act primarily as braces or secondary members. A Warren truss can have one or two sets of these verticals. One set braces the top chord against buckling under compression while the other set supports intermediate floor beam connections. As is the case with most trusses, the top chords and endposts are usually in compression while the lower chord remains in tension.

Warren trusses may have parallel top chords (i.e., the top chords are parallel to the bottom chord) or may have polygonal top chords. Warren trusses were used in pony, through, and deck configurations in Texas. The Warren parallel top chord pony truss with riveted connections was the most common truss subtype in Texas during the early and mid-twentieth century. While the Warren configuration was also used for through spans, this version was not common in Texas. Another Warren variant found in Texas is the double-intersection Warren, which has a second triangular web system superimposed onto the original Warren design. An example of this truss web pattern is found on the approach span of the CR 366 Bridge over the San Gabriel River in Williamson County (TxDOT Structure No. 14-246-0-AA04-74-001).

More information regarding the various Warren subtypes and configurations is provided below.

[817] *Historic Context for Common Historic Bridge Types*, 3-28, 3-29.

*Warren Parallel Top Chord Pony*

Description
The parallel chord Warren pony truss is a half through truss with zig-zag (/\/\/\/\) pattern to the web members. The top chord is parallel to the bottom chord except at the endposts, which are inclined. Variants of the basic design include one or two sets of verticals. The verticals either brace the top chord against buckling under compression or support intermediate floor beam connections.

Significance
The Warren truss was patented in England in 1848 with contributions from Italian, Belgian, and English engineers.[818] Its diagonals are subject to both compression and tension under moving loads. Diagonals were thus usually identical and designed for both types of stresses. The load reversal is greater at the center of the span, however, and this created substantial wear on center span connections.[819] This wear was problematic given the extensive use of pin connections by nineteenth-century American bridge companies. Consequently, pin-connected Warren ponies are rare in Texas as they were not successful designs.

The Warren pony truss began to gain popularity during the early 1900s, at the same time field riveting was coming into practice in the U.S. By providing a simplified truss configuration and eliminating all redundant members, the Warren was easy to design and fabricate, and was particularly suited to the new field riveting technology. In Texas, the transition to riveted connections was largely completed by 1905 and the riveted Warren parallel top chord pony truss became the state's most numerous truss subtype during the twentieth century. From about 1905 through the 1930s, hundreds and perhaps several thousand riveted-connected Warren pony trusses were erected throughout Texas. They were extensively used on moderately traveled rural roads.[820] The THD's first standard truss design was a Warren Pony.[821] Because the Warren pony was most adaptable to lengths of 30 to 90 feet, the Pratt through continued to be the preferred type for longer crossings of 90 to 150 feet. The current population of riveted Warren ponies far exceeds all other truss types, proving its versatility and inherent durability.

The engineering challenges associated with Warren pony design were comparatively minor once the problems associated with pinned connections were addressed with the widespread adoption of riveted connections. As smooth wagon and automobile passage became a greater concern for local road traffic in the early twentieth century, the need for inexpensive low volume shorter span crossings increased. Warren pony trusses, and to a much smaller extent Pratt ponies, became a standard solution in the decades before the creation of the THD. As such, the primary significance of the Warren pony was its contribution to the development of the rural road network by counties and local governments. The absence of bridge engineering skills at the local level and the funding mechanisms provided by the legislature meant that the local governments turned to bridge companies. As noted elsewhere, most of these companies were from out of state. Each tended to solve the same design and fabrication problems slightly differently. This variation within a theme can be seen in the extant pre-1917 population.

The THD's first standardized trusses were Warren ponies developed between 1918 and 1925. Generally through the 1920s, diagonals were fabricated of laced or battened angles and top chords were laced or battened with

---

[818] David Guise, "The Evolution of the Warren, or Triangular Truss," *IA: The Journal of the Society for Industrial Archeology* 32 No. 2 (2006), 23-40.
[819] James Cooper, James, *Iron Monuments to Distant Prosperity: Indiana's Metal Bridges, 1870-1930*. n.p., 1987, 84.
[820] James Cooper, *Iron Monuments to Distant Prosperity: Indiana's Metal Bridges, 1870-1930*. n.p., 1987, 87.
[821] Stocklin, E-31.

channels and cover plates. THD Warren pony standard designs followed this fabrication approach and are strongly associated with the shift to centralized funding given the limited engineering effort required to design them.[822]

The late 1920s and 1930s saw the THD increasingly discontinue development of shorter truss spans (primarily Warren pony and Pratt through) in favor of simple I-beams, as well as continuous and cantilever-suspended steel I-beam units. These trends were largely made possible by longer I-beam sections available from the rolling mills.[823] A few all-welded versions of the Warren pony were constructed after World War II.

Registration Requirements
The following character-defining features must be present for all parallel-chord Warren pony trusses to retain integrity for eligibility under *Criterion C*:

- Diagonals carrying both compression and tension
- Parallel chords
- Inclined endposts
- Half-through or pony roadway configuration
- Variants with one or two sets of verticals

In addition, the following typical features are common for Warren parallel top chord pony trusses:

- External sway braces (can be character-defining if part of original design)
- Floor beams (not character-defining)
- Stringers (not character-defining)

There are no other registration requirements specific to this subtype. Use the registration requirements common to all metal truss subtypes for assessing significance and integrity. (pp.222-228)

*Warren polygonal top chord pony*

Description
This subtype differs from the more common Warren Parallel Chord pony with its polygonal top chord having at least three slopes. Other *character-defining* features for this subtype are:

- Warren web configuration: diagonals carry both compression and tension
- Polygonal top chord
- Inclined endposts
- Half-through/pony deck configuration
- Variants with one or two sets of verticals

[822] Not all the post 1917 Warren ponies used fabricated top chords. An alternate tradition developed using rolled sections. This is probably tied to changes in shop fabrication methods and availability from structural steel rolling mills. Additional research might clarify whether the rolled-section top chord was an incremental change or a substantive innovation.
[823] Stocklin, E-40.

Other *typical* features for this subtype are:

- Riveted connections
- Floor beams (not character-defining)
- Stringers (not character-defining)

Significance
The material efficiencies of this subtype's polygonal top chord allows for longer spans and heavier loads in the pony configuration when compared to the more common parallel chord version. Examples in San Antonio are also wider and of much heavier construction. Never as common in Texas as parallel chord Warrens, polygonal Warren ponies are significant as an uncommon type. For reasons yet unclear, the extant polygonal Warren pony trusses form geographical concentrations in San Antonio and in the greater Hallettsville area. The THD developed two standard plans for this subtype in 1930 with 80-foot spans. One was 20 feet wide and the other was 22 feet wide. No examples of these THD designs are known to survive. In 2003, TxDOT designed and constructed a 100-foot span, 28-foot wide, Warren polygonal truss fabricated of self-weathering steel (TxDOT Structure No. 13-062-0-AA01-39-001, CR 119, Von Haffen Road over Unnamed Tributary of Deer Creek, DeWitt County). It was an experiment in the economics of constructing metal trusses capable of carrying modern loads.

Registration Requirements
For this subtype, use the registration requirements common to all metal truss bridges. (pp.222-228)

*Warren Through*

Description
A Warren through truss has both the zig-zag (/\/\/\/\) web pattern and the top bracing and struts of the through deck arrangement. Warren through trusses in Texas were designed by THD engineers and have both sets of verticals. Excepting only the US 87 at Llano River (TxDOT Structure No. 14-157-0-0071-04-018), extant Warren through trusses in Texas were designed as continuous spans.

Significance
For this subtype, refer to the significance discussion common to all metal truss bridges. (pp. 219-222)

Registration Requirements
For this subtype, use the registration requirements common to all metal truss bridges. (pp.222-228)

***(c) Bowstring***

Description
The bowstring truss has a curved shape resembling a bow or arch with a curved or polygonal top chord in compression tied by a horizontal lower chord in tension. The deck is carried by a series of verticals and diagonals in the truss web that are all placed under tension. The bowstring was one of the earliest metal truss forms that bridge builders brought to Texas. Threaded rod connections can be character-defining. Due to washouts and bridge replacements, however, few examples of this truss type remain in the state.

Significance
For this subtype is rare in Texas. Refer to the significance discussion common to all metal truss bridges. (pp. 219-222)

Registration Requirements
For this subtype, use the registration requirements common to all metal truss bridges. (pp. 222-228)

***(d) Continuous***

Description
The continuous truss is not a specific subtype in terms of a distinct truss web pattern. Instead, the term describes how the truss spans relate to the substructure. In a continuous truss, the chords and web configuration continue uninterrupted over one or more intermediate supports or piers. In Texas, trusses with this configuration are usually simply categorized as continuous trusses, for purposes of bridge inspection and evaluation. However, these trusses also have a web pattern as described below. Extant continuous-span trusses in Texas were constructed by the THD in the 1930s and later and are most accurately described as continuous Warren trusses.

Some continuous trusses have a top chord that is parallel to the bottom chord, such as the Brazos River Bridge on SH 6 in Knox County (TxDOT Structure No. 25-138-0-0098-05-036). In other examples, the top chord is bowed or shaped like a catenary curve, such as the South Llano River Bridge on SL 481 in Kimble County (TxDOT Structure No. 07-134-0-0142-16-031). In Texas, continuous spans were erected both as through and deck trusses.

Significance
For this subtype, refer to the significance discussion common to all metal truss bridges. (pp. 219-222)

Registration Requirements
For this subtype, use the registration requirements common to all metal truss bridges. (pp. 222-228)

## C. Suspension Bridges

### (1) Description

Suspension bridges are cable-supported structures with towers, cables, generally level decks, and anchorages. Two subtypes of suspension bridges were constructed in Texas: catenary and the cable-stayed. In the catenary (also known as parabolic) subtype, the deck is hung from vertical suspenders attached to cables. The suspenders and cables are in tension while the towers that support them are in compression. Decks are frequently stiffened with trusses. Heavy anchorages counter the tensile forces in the cables. See Figure 53. In the cable-stayed subtype, the suspenders and the catenary are replaced with cables that directly connect the towers and the deck.

Table 8 lists Texas suspension bridges documented in HAER documentation:

**Table 8. Texas Suspension Bridges Documented in HAER Documentation**

| Bridge | HAER No. | Location | Builder | Type | Clear span (feet) | Year |
|---|---|---|---|---|---|---|
| Waco | TX-13 | Over the Brazos River, Waco, McLennan County | Thomas M. Griffith | Parabolic with stays | 475 | 1870; rebuilt 1914 |
| Barton Creek Bridge | TX-87 | Off CR 119, Erath County | Runyon Bridge Co., Weatherford, Texas | Cable-stayed | 100 | 1890 |
| Bluff Dale Suspension Bridge | TX-36 | CR149 over the Paluxy River, Bluff Dale, Erath County | Runyon Bridge Co., Weatherford, Texas | Cable-stayed | 140 | 1891; moved 1935 |
| Clear Fork of the Brazos Suspension Bridge | TX-64 | CR179 over Clear Fork of the Brazos River, Shackelford County | Flinn-Moyer Co., Weatherford, Texas | Parabolic probably with stays | 140 | 1896 |
| Beveridge Bridge | TX-46 | CR 112 over the San Saba River, San Saba County | Flinn-Moyer Co., Weatherford, Texas | Parabolic with stays | 140 | 1896 |
| Choctaw Creek Bridge | TX-85 | Over Choctaw Creek, Grayson County | William Greer, Sherman, Texas | Parabolic | 120 | ca. 1915 |
| Rock Church Bridge | TX-81 | Over the Paluxy River, near Tolar, Hood County | Unknown | Parabolic with stays | 110 | ca. 1917 |
| Roma-Miguel Alemán (formerly San Pedro) International Bridge | - | Over the Rio Grande, Roma, Starr County, and Ciudad Alemán, Mexico | George E. Cole, Engineer | Parabolic | 630 | 1928 |
| Regency Suspension Bridge | TX-61 | Over the Colorado River, near Goldthwaite, San Saba-Mills Counties | Austin Bridge Company | Parabolic | 340 | 1939 |

*Sources: County Bridge Files, Environmental Affairs Division, TxDOT, Austin, Texas; HAER reports.*

## (2) Significance

### *(a) Criterion A*

For significance of suspension bridges under *Criterion A*, refer to the significance discussion common to all bridges. (pp 208-212)

### *(b) Criterion C*

Prior to 1940, several 100-to 140-foot-span suspension bridges were built in the north central region of Texas. This concentration represents a regional adaptation to environmental conditions as well as a tradition of inventive design by vernacular builders.

The short-span, wire-supported bridges of Mitchell, Runyon, Flinn, Greer, and other builders not yet documented represent a remarkable body of inventive bridges built in response to a strong demand by a public with very modest governmental resources. These inventors responded with solutions outside the learned traditions of academic engineers and more within that of covered bridge builders and of James Finley. In 1808 Finley, a prosperous farmer and jurist living in Western Pennsylvania, patented a chain-link suspension bridge with a level roadway and a truss-stiffened deck that is generally considered the first modern suspension bridge. Texas inventors shared other similarities with Finley besides broad formal characteristics of their bridges. Both Finley and the Texans sought financially profitable designs for often remote areas that could be simply constructed without the need for sophisticated mathematics. Because the Texas inventors were less prominent individuals than Finley, and because they did not publish their work or findings save as patents, little direct knowledge exists of their design methods. Whether they worked with drawings, models, or small-scale construction, however, these designers were both liberated by their apparent unfamiliarity with academic traditions and hindered by their limited conceptual knowledge of structural behavior. The results were a fascinating range of variations on an ancient theme.

*Parabolic or Catenary Suspension Bridges*

Besides validating the value and potential of suspension bridges, the Waco suspension bridge set several precedents. It was a parabolic, or catenary, suspension bridge with inclined stays and a stiffening truss. While these features would become standard or, as in the case of inclined stays, fairly common on subsequent Texas suspension bridges, the Waco bridge used pre-manufactured wire ropes. In contrast, most Texas suspension bridge builders would fabricate their in-situ cables.

*Cable-Stayed Suspension Bridges*

Runyon's work in particular foreshadowed the international development of cable-stayed bridges after 1950.[824]

[824] For a brief elaboration on this point see David P. Billington and Aly Nazmy, "History and Aesthetics of Cable-Stayed Bridges," *(ASCE) Journal of Structural Engineering* 117, no. 10 (October 1991), 3103-3134.

### *(c) Registration Requirements*

In addition to possessing significance under one of the National Register Criteria, a suspension bridge must also be shown to have historic integrity to be eligible for the NRHP. The National Register bulletin *How to Apply the National Register Criteria for Evaluation* defines historic integrity as "the ability of a property to convey its significance."

*Criterion A*

For evaluation of suspension bridges under *Criterion A*, use the registration requirements common to all bridges. (pp 212-214)

*Criterion C*

Most of the suspension bridges in Texas were not designed or constructed by professionally trained engineers. Combined with their small-scale and often remote locations this means that they are fragile and were frequently repaired. Integrity requirements for suspension bridges take these factors into consideration along with the de facto thresholds set by SHPO during coordination of the rehabilitation of the Regency (TxDOT Structure No. 02-073-0-AA01-49-002) and Beveridge Bridge (TxDOT Structure No. 23-206-0-AA01-12-001) rehabilitations in 1997 and 2009, respectively.

For *Criterion C*, a suspension bridge must possess historical significance as discussed above and must retain integrity of:

- Location

A bridge should remain in the same location as it was located during its period of significance. For example the NRHP listed Bluff Dale Bridge (HAER TX-36) was relocated in 1934 yet it retains integrity of location.

- Design

A suspension bridge must retain 1) anchorages, towers, a wire support system, and a minimal deck system and 2) be recognizable as a vehicular bridge in order to retain integrity of design. For example, the Regency Bridge (TxDOT Structure No. 23-167-0-AA01-27-001) is in still in vehicular service and the Beveridge Bridge (TxDOT Structure No. 23-206-0-AA01-12-001) retains a deck wide enough for vehicles. The Barton Creek Bridge (HAER TX-87, however has deteriorated to the point it is little more than a web of twisted wire cables. The Choctaw Creek Bridge (HAER TX-85) may now be in a similar condition.

- Materials and Workmanship

Rehabilitation of a suspension done according to the Secretary of the Interior's Standards for Rehabilitation can be quite extensive and still retain integrity of materials and workmanship. For example the 2005 Beveridge Bridge (TxDOT Structure No. 23-206-0-AA01-12-001) rehabilitation installed new anchorages, replaced the wire cables

and floor beams, and re-engineered the tower foundations. All that remains of the original bridge are the towers, a builder's plaque, and the no longer in use anchorages.[825]

- Setting

Integrity of setting and workmanship are not as important for *Criterion C* eligibility of suspension bridges as the type is capable spanning much longer distances than ever tried in Texas. Further, the NRHP listed Waco Suspension Bridge retains its eligibility despite the dramatic changes to its setting and the city since its 1869 construction.

- Feeling and association.

Changes to a suspension bridge's integrity of feeling and association only rarely impact its ability to convey its engineering significance. The historic character of a pre WW II suspension bridge is largely dependent on its design. Alterations that kept them in use have created complicated aesthetics and limited historic sense of particular periods of time.

*Criterion D*

By their nature, suspension bridges have greater information potential when compared to other bridge types. For example, abandoned anchorages at the SH 16 at Colorado River and at FM 4 at Brazos River crossings have the potential to reveal information about a character defining element of Texas wire-supported bridges not available by other means. Further, the ruinous Barton Creek Bridge has revealed sufficient important information about E. E. Runyon's patented connections and about materials and design elements once present at the NRHP listed Bluff Dale Bridge to be NRHP eligible under Criterion D in its own right.

Professional judgment, based on the literature, is required in assessing eligibility under Criterion D.

## D. Non-truss/Non-suspension Bridges

### (1) Introduction

This section contains the methodologies for 1) the pre-1950 survey of bridges types that are neither metal trusses nor suspension bridges and 2) the survey of all bridges types constructed between 1945 and 1965.[826] Both focus on the mainstream development of reinforced concrete and steel beam technologies. Several forms of pre-stressed concrete were developed and extensively used after WWII. A few arches, primarily reinforced concrete before 1945 and steel after 1945, are also included in this section

[825] The integrity of the hangers currently at Beveridge is not clear at this time.
[826] A few bridges constructed after 1945, but before 1950, were not surveyed due to an oversight.

## (2) Description

### *(a) Reinforced Concrete Bridge Types*

*Concrete Slab and Tee-beam Bridges*

Concrete Slab

Broadly speaking, a concrete slab bridge consists of a flat sheet of concrete, usually several inches in thickness, encasing a matrix of steel reinforcement bars. Within this general type are several variants reflecting the type's evolution over time. The reinforced concrete slab bridge (termed "flat slab" in TxDOT's *Coding Guide*) emerged in the second decade of the twentieth century as an economical bridge for small to medium spans. Minnesota engineer C. A. P. Turner introduced the reinforced continuous slab to the U.S. in the early 1900s with a system that improved slab design by thickening the pier caps and placing additional reinforcement at the juncture of the slab and support. Dubbed the "Mushroom System" because of the pier's distinctive shape, Turner's slab innovation was soon adapted by railroad engineers for short span structures. Before Turner's system became an accepted practice with highway engineers, early slab structures consisted of steel I-beams embedded in a concrete slab. This reinforcement method proved impractical, as it was often difficult to secure a bond between the concrete and steel, and if successful, the bridge tended to be exceedingly heavy having to carry the weight of the beams, concrete floor, and traffic load. A few short span structures of this type were constructed in Texas, with the practice being generally abandoned after 1920.

As confidence grew in metal bar reinforcement systems, the flat slab became increasingly utilized for short-span highway bridges. The first reinforced concrete slab bridges in Texas were small structures, having thick slabs and integral parapet railing. With improved methods of calculating the amount of reinforcing bar needed to carry loads evenly, the bridge type became part of the THD's standard plan designs in 1918. During the 1920s, the THD used reinforced concrete slabs almost exclusively for short spans. The majority of bridges from this time period featured spans measuring 20 feet or less and supported on reinforced concrete bents. Although the concrete slab was considered a rudimentary form, a few examples incorporated aesthetic design principles.

Following World War II, the concrete slab was one of the THD's main bridge types used during the 1945-1965 period, and hundreds of reinforced concrete slab bridges remain in Texas. Although some simple flat slab spans were built during the immediate post-World War II period, their use was nearly completely eclipsed by a new slab span type, the FS slab, designed by the THD for specific use on the new farm-to-market road system.[827] The FS slab design had raised structural curbs that were monolithically poured with the slab; the integrated curbs provided strength that allowed for thinner slab depth and greater overall economy. The monolithically poured curbs acted as small girders and were the main difference between the pre-1944 designed flat slabs and the FS slab. Typically, the high curbs served as railing on the bridge and no added handrails were used. The FS slab proved to be easy to construct and ideal for short crossings on THD roadways.

[827] Texas Department of Transportation, *Bridge Design Manual*, Section 7-16.

In the 1930s, the continuous slab was introduced nationally with a single slab extending across several spans, with use of continuous concrete slabs beginning in Texas around 1936.[828] Spans of 20 to 30 feet were typical, with occasional interior spans of up to 40 feet.[829] Their use in Texas continued through the 1960s.

The THD developed numerous standards for simple flat slabs, simple FS slabs, continuous flat slabs, and continuous FS slabs. As noted above, the THD developed standard designs for concrete slabs as early as 1918. The CB-6 design was a common slab design of the early THD period, utilized widely across the state for spans 8 to 20 feet in length. Even though the THD had numerous standard designs for simple flat slabs by the 1940s, they created new standards for these bridges after World War II, capable of handling H-15 and H-20 loads. After constructing a successful test of an FS Slab bridge in Henderson County, the THD also developed a series of standard details for the FS Slabs. The earliest FS Slab standards are dated 1945 and have 8-inch-high curbs, with span lengths of 15, 20, and 25 feet and design loads of H-10 and H-15. Although the THD built these bridges in significant numbers for the farm-to-market road system, fewer than a dozen standards are known to have been issued with the latest dated 1954.

Continuous slab spans include continuous flat slabs and continuous FS slabs. A review of THD standard plans created between 1944 and 1956 reveals that the THD established many more standard plans for continuous flat slab bridges than they did for continuous FS slabs. Standards for 90-and 100-foot continuous FS slab units were developed with an H-15 design load, with the first standard issued in 1945. Research also shows that the THD issued several standard plans for continuous flat slabs between 1944 and 1956. These standards had continuous units measuring up to 110 feet with design loads up to HS-20.

Substructure standards for simple and continuous spans were also issued for these bridges. They specified two-column, spill-through type bridge abutments and three-pile bent piers using a cast-in-place concrete cap on precast concrete, steel, or timber piles, or two-column reinforced concrete framed bents on individual footings.[830]

Concrete Tee-beam

A Tee beam structure features concrete “T-shaped” beams supporting an integral deck slab or a cast-in-place concrete deck that is used for the roadway surface. Steel rods are concentrated in the bottom of the web and in the top flange steel rods are laid perpendicular to the web. When the tee beam and deck are integrated together, steel reinforcing in the Tee beam’s web and reinforcing in the deck are usually tied together by U-shaped hangers.[831] By doing this, the slab and beams become unified structural components, which increases the bridge’s strength and allows greater span lengths. With typical spans ranging from 30 to 50 feet, Tee beams were often more economical than slabs for lengths exceeding 25 feet.[832]

---

[828] PAC Spero & Company and Louis Berger & Associates, *Historic Highway Bridges in Maryland: 1631-1960: Historic Context Report*, Rev. ed. (Baltimore, Mar.: October 1995), 145.
[829] Texas Department of Transportation, *Bridge Design Manual*, 7-19.
[830] "Texas 1946 Secondary Road Program Established New Construction Record," *Engineering News-Record*, 101-102.
[831] Parsons Brinckerhoff and Engineering and Industrial Heritage, *A Context for Common Historic Bridge Types, NCHRP Project 25-25, Task 15*, 3-88.
[832] Parsons Brinckerhoff and Engineering and Industrial Heritage, *A Context for Common Historic Bridge Types, NCHRP Project 25-25, Task 15*, 3-88.

Introduced in the 1910s, concrete Tee beams were already prevalent in the U.S. prior to World War II. While simple spans were most common in Texas during the postwar period, continuous spans were also built.[833] Although continuous concrete Tee beams were introduced nationally in the 1930s, this variant was not used in Texas until the 1950s. Use of continuous concrete tee beams in Texas ended in the 1960s.[834]

The THD produced standard plans for simple span Tee-beams in 1951 and 1956. The standard plans had span lengths of 35, 40, and 48 feet. Depending upon their deck width, they had design loads of H-15 and H-20. The THD issued standards for continuous spans in 1956 for units 190 and 230 feet long, with H-15 and H-20 design loads. The last standard design for a concrete Tee beam was issued in 1956 for use on interstate crossovers in select districts. In the early 1960s engineers began building Tee beam bridges with prestressed steel wires rather than steel reinforcing bars. Although quite common on Texas highways in the 1920s and 1930s, reinforced concrete Tee beam bridges were largely superseded by pan-formed girders after World War II.

Concrete Slab and Tee-beam – Variable Depth

Reinforced concrete variable depth bridges have been used in the U.S. since the 1930s. In the 1950s THD engineers built variable depth slab bridges and variable depth Tee beam bridges as grade separation structures. These bridges are designed with the same principles as reinforced concrete bridges that have consistent depths; however, variable depth slabs and tee beam bridges concentrate the reinforcing steel bars over the piers with less rebar (and concrete) at mid-span. Although the bridges still function as slabs and Tee beams respectively, they resemble parabolic arch bridges. In modifying slabs and tee beams in this way, engineers can achieve longer spans. TxDOT's *Bridge Design Manual* notes that variable depth slab interior spans could measure up to 60 feet; however, former Waco bridge engineers Richard Casbeer and Ron Koester recalled in an interview that continuous variable depth slab spans could reach 80 feet.[835] Koester noted that variable depth Tee beam spans could reach 90 feet long.

While examples of these bridge types are scattered throughout the state, the Waco District built many of these bridges. The Waco District bridge designers pushed for the use of these bridge types for grade separation structures, particularly for use on IH 35. The Waco District preferred using variable depth reinforced concrete slabs and variable depth reinforced concrete Tee beams for many crossings that required long spans.[836] While the Waco District's use of variable depth continuous reinforced concrete bridges is well known and documented, the Abilene, Fort Worth, and Houston Districts also used this bridge type for their grade separation structures. Similarly, variable depth continuous reinforced concrete slabs were used over IH 10 in Houston according to Ed Suchiki, a former Houston Urban Expressway Office bridge engineer. However, many of these structures are no longer extant and only a small pool of these bridges remains.

Although few simple variable depth flat slabs and variable depth tee beams are extant in Texas, the continuous spans are more plentiful, with more than 250 continuous variable depth slabs and over 100 continuous variable depth tee beams extant in 2009.

---

[833] *Safety Inspection of In-Service Bridges: Participant Notebook*, vol. 1-2 ([McLean, Va.]: U.S. Dept. of Transportation, Federal Highway Administration, National Highway Institute, January 1992), 8.3.3.
[834] Texas Department of Transportation, *Bridge Design Manual*, 7-22, 7-34.
[835] Texas Department of Transportation, *Bridge Design Manual*, 7-16, 7-19; Dick Casbeer, Ron Koester, and Frank Leos, Interview by Mead & Hunt, Inc. and TxDOT Bridge Division, Texas Department of Transportation, digital audio and visual recording, Waco District Bridge Office, Waco, Texas, October 16, 2006.
[836] Casbeer, Koester, and Leos, interview by Mead & Hunt, Inc. and TxDOT Bridge Division, Texas Department of Transportation.

Double Tee-beam

This bridge type consists of reinforced concrete members that look similar to Tee beams; however, rather than the members being T-shaped, the beams look like two T's (TT) directly adjacent to each other. Reinforced concrete double tee beam bridges are very rare in Texas. Only one extant example of this bridge type built during the 1945-1965 period was identified in a 2009 inventory. Careful inspection of the seams between the beams indicates whether the beams are channel beams or double Tee beams, as the double Tee beam has wide flanges on either side of the webs. The only known extant reinforced double tee beam in Texas was built in 1950 and has one span that is 27 feet long.

*Concrete Girder Bridges*

Concrete Girder – Simple and Cantilever

Early reinforced concrete girder bridges consisted of steel I-beams encased in concrete beams. This primitive reinforcement system was short lived, as the concrete had a tendency to crack and peel away from the I-beams. A few examples of this formative girder technology exist in Texas, including the 1928 Dry Comal Creek Bridge, on Landa Street (BS 46) in New Braunfels (TxDOT Structure No. 15-046-0-0215-02-013). The girder-and-floorbeam is another example of an early reinforced girder form that had limited use in Texas. In the girder-and-floorbeam bridge, the reinforced concrete floorbeams are arranged perpendicular to the girder and slab floor system. The only known example of this bridge type is a four-span structure located on Stone Bridge Drive at Turtle Creek, in Dallas (TxDOT Structure No. 18-057-0-9S76-60-001). The earliest reinforced concrete girder structures date from the 1910s and consist of relatively short spans with solid parapet railing. Typical of these designs is a short span located in Navarro County (TxDOT Structure No. 18-175-0-AA02-73-001) carrying CR NE 1040 over the Tupelo Branch. This 43-foot-long bridge is composed of four concrete girders reinforced with twisted steel bars. The construction of reinforced concrete girders increased dramatically after the organization of the THD in 1917. The bridge type became a building block in the expansion of the state highway system, reaching its greatest popularity in the 1930s. The longest intact concrete girder bridge of this period is the Tunis Creek Bridge (TxDOT Structure No. 06-186-0-0140-03-021), located on the original alignment of SH 27 (now IH 10 SB frontage road) in Pecos County. The 741-foot-long bridge consists of 26 spans of standard reinforced girder supported on concrete bents and outlined with THD Type K standard railing.

The cantilever reinforced concrete girder bridge made a brief appearance in the 1920s and 1930s as an alternative to concrete arch construction. Employing essentially the same technology as the cantilever-suspended span steel bridge, the cantilever girder could produce a longer span than a non-continuous type and be used where unsatisfactory foundation conditions would prohibit a true arch. The State Highway Department built the first cantilever concrete girder bridge in 1922 along the Old Spanish Trail (FM 1579) at the East Navidad River in Fayette County (TxDOT Structure No. 13-076-0-1498-01-002). Designed by Bridge Division engineer A. T. Granger, this graceful crossing features three curved cantilever girder and pier units elaborated with incised geometric panels. This bridge was followed in 1930 by a 472-foot-long concrete cantilever girder bridge carrying South Oakes Street over the North Concho River (TxDOT Structure No.07-226-0-B023-10-002). The THD used the form again in the early 1930s to construct two bridges over the Trinity River on US 377 (East Belknap Street) (TxDOT Structure No. 02-220-0-0081-01-001) and the West Fork of the Trinity River on SH 199 (TxDOT Structure No. 02-220-0-0171-05-017), both in Fort Worth. In both situations, the bridge designers utilized the cantilever reinforced concrete girder form to give the artistic effect of an arch.

The continued use of concrete girders during the 1945-1965 period was sparse and mainly confined to off-system roads. Review of bridge inspection files and site visits conducted for a 2009 bridge inventory revealed six extant post-World War II reinforced concrete girder bridges.

Concrete Box Girder

The concrete box girder uses hollow boxes as its main supporting members. A box girder bridge is a fixed bridge consisting of various "box-shaped" sections used to support the deck. The first reinforced concrete box girders were built in the western U.S. in the late 1930s.[837] The box girder design was improved in the 1950s when designers began using prestressed steel wires rather than reinforcing steel bars to strengthen the box girders. The THD's use of the concrete box girder bridge form was restricted.[838] Variations identified in TxDOT's *Bridge Design Manual* include multiple, single, or spread. Multiple box girders indicate that the girders were built directly adjacent to each other and often tied together, creating an instant driving surface or an instant surface for the deck to be poured. Spread box girders indicate that the girders were spread apart from each other and the girders were tied to the deck and the substructure rather than to each other. Research reveals that no standard plans for this bridge type were issued by the THD. These bridges may have been used more widely on a national level since the BPR had standard specifications for them in 1957.

Concrete Pan-formed Girder

The concrete pan-formed girder was a reinforced concrete bridge type developed by the THD immediately after World War II specifically for use on the newly created farm-to-market road system.[839] The THD's design was developed by Charles S. Matlock and E.A. Jelinek, under the supervision of state bridge engineer James P. Exum.[840] B.A. Trice may have also been involved in the development of the design of the pan-formed girder. It was an economic alternative for short crossings where steel I-beams or concrete girders were previously used.[841] The pan-formed girder bridges had typical spans of 30-and 40-foot lengths, and combined the strength of girder construction with the simplicity of slab construction.[842]

The cross section of the deck was a series of repeating arches on 3-foot centers. This design made maximum use of concrete and reinforcing steel. These bridges were economical because they were built by placing reinforcing steel bars in and atop modular steel forms and pouring the concrete directly into the forms. These steel forms were constructed from rolled sheet steel that were identical, interchangeable, and reusable.[843] Since no formwork and very little falsework were required, the forms were self-supporting. In this way, these concrete cast-in-place bridges could be cheaply constructed in quick succession.

---

[837] California Division of Highways, *Manual of Bridge Design Practice*, 2nd ed. ([Sacramento, Calif.]: State of California Highway Transportation Agency, Department of Public Works, Division of Highway, Bridge Department, 1963), 48.
[838] Texas Department of Transportation, *Bridge Inspection Database*, n.p.
[839] Texas Department of Transportation, *Bridge Design Manual*, 7-27.
[840] B. A. Trice, "Low Cost Concrete Bridge," *Roads and Streets* 91, no. 10 (October 1948), 85.
[841] Texas Department of Transportation, *Bridge Design Manual*, 6-18.
[842] Perrin, "Low Cost Bridge: Design Capitalized in a Texas County Road Program," *Roads and Streets*, 39.
[843] Trice, 83.

Pan-formed girders were initially created and designed for the light H-10 and H-15 loading requirements on farm-to-market roads.[844] The load capacity for these designs increased during the early 1950s, with designs of H-15 and H-20, and by 1955, the THD had standard designs for pan-formed girders with HS-20 design loads. THD engineers modified the design to make this type stronger as load requirements increased due to increasing truck size. Additionally, the design loads of these economical bridges were also increased so they could be used on other roadway types that had higher load capacity requirements, such as U.S. and state highways.

Pan-formed girders were so widely used in Texas because they were easy to design and construct, and they employed reusable forms. The main reason for the type's success was the use of standard plans to build these bridges. Research reveals that between 1945 and 1965 the THD designed more standard plan sets for pan-formed girder bridges than any other bridge type. In 1948, the THD issued its first set of standard plans for pan-formed girders, which had a design load of H-10. The original design accommodated a 30-foot span length with 20-inch-wide caps and no skew, but this developed into a basic span length of 30 feet, 4 inches to accommodate a 24-inch cap width.[845] Several 30-foot, 4-inch pan-formed girder standard designs were issued by the THD in the early 1950s. In 1956, a design for 40 feet was introduced, and in the early 1960s, standard drawings were distributed for both 30 feet, 4 inches and 40-foot span lengths for five roadway widths and five different skew angles.[846] Standard plans for a 42-foot, 3-inch span length were introduced in 1958, and at a mere 2.25 feet longer than the 40-foot span, it offered the longest standard span for a reinforced concrete pan-formed girder designed between 1945 and 1965. THD engineers also found that the pan-formed girder spans could also be used to build long bridges where short, repeating spans were acceptable.

Pan-formed bridges were built in great numbers in the decades following World War II for the reasons outlined above. The THD pan-formed girder is most strongly associated with state-system roadways, particularly farm-to-market roads. In a 2009 survey of bridges constructed between 1945 and 1965, only 12 percent of the extant pan-formed girder bridges were located on county or city roads.[847] The 2009 survey also revealed that concrete pan-formed girders constituted approximately 25 percent of the total number of extant bridges statewide from the period.[848]

Although the pan-formed concrete girder was widely used during the 1945-1965 period, some districts used the type sparingly and abandoned it after the period. According to TxDOT's *Bridge Design Manual*, pan-formed girder bridges were prematurely deteriorating in salty environments, and as a result the THD searched for an alternative design.[849] Perhaps this is the reason that lower percentages of pan-formed girders are found in the Gulf Coast districts of Corpus Christi, Houston, Pharr, and Yoakum than other places in the state.[850] The pan-formed concrete girder was one of the most economical bridge designs of this period, but prestressed concrete beams later

---

[844] The load requirements of the subject period were based on the number of axels and weight of trucks. Load designation with an H indicated a two axel truck and HS indicated three or more axel truck, with numbers following the H or HS signifying the tonnage the truck carried.
[845] Texas Department of Transportation, *Bridge Design Manual*, 7-27.
[846] Texas Department of Transportation, *Bridge Design Manual*, 7-27.
[847] Texas Department of Transportation, *Bridge Inspection Database*, n.p.
[848] Texas Department of Transportation, *Bridge Inspection Database*, n.p.
[849] Texas Department of Transportation, *Bridge Design Manual*, 7-53. The alternative design that THD found to replace pan-formed girders in the Gulf Coast region was the prestressed concrete box girder.
[850] Texas Department of Transportation, *Bridge Inspection Database*, n.p.

became more economical for longer crossings.[851] Nevertheless, this bridge type was used extensively by the THD during the 1945-1965 period and over 2,000 examples built between 1945 and 1965 remained as of 2009.[852]

Concrete Channel Beam

Reinforced concrete channel beams have been used in the U.S. since 1910. The use of the bridge type continued into the 1945-1965 period, with a few examples still extant on Texas roadways. Channel beams look similar to Tee beams as they have a vertical web and a horizontal flange. However, channel beams have two vertical webs extending from the flange, forming a flattened U-shaped beam. These were usually precast beams that generally have span lengths of less than 50 feet.[853]

Concrete Slab Beam

Little information is known about reinforced concrete slab beam bridges. This bridge type, which consisted of a solid slab superstructure, was very rare, with only one extant example in Texas. The extant bridge of this type was built in 1960, has a span length of 19 feet, and an overall structure length of 40 feet.

*Concrete Arch Bridges*

This bridge type converts the downward force of its own weight, and of any weight pressing down on top of it, into an outward force along its sides and base. It has typical span ranges from 40 to 150 feet. The earliest concrete bridges constructed in Texas were closed-spandrel arches, which essentially mimicked stone masonry arch construction. One of the first documented reinforced concrete bridges in the state is the 1908 Euclid Avenue Bridge crossing a tributary of Turtle Creek in Highland Park (TxDOT Structure No. 18-057-0-9HP2-30-001). This short bridge is composed of one closed-spandrel arch ornamented with decorative railing and depressed geometric panels. Not only is the bridge exemplary design, it is also typical of many small closed spandrel arches constructed across the state during the first quarter of the twentieth century. Other representative examples include the 1910 Main Street (FM 51) Bridge at Town Creek in Weatherford (TxDOT Structure No. 02-184-0-0313-02-008), and a 1915 arch located on the Austin to San Antonio Post Road (now named Kyle Crossing Street) crossing the Bunton Branch in Kyle in Hays County (TxDOT Structure No. 14-106-0-C000-57-001). Closed-spandrel arches were also a component of city improvement programs operating in Texas in the 1910s and 1920s. Few closed-spandrel bridges appeared after the 1920s. One notable exception is the 1935 Spur 536 Bridge at the San Antonio River in San Antonio (TxDOT Structure No. 15-015-0-0253-06-029).

While the closed-spandrel bridge relied on spandrel walls to retain fill, the open-spandrel arch revolutionized the design by replacing the solid walls with individual members. Opening the spandrel walls gave the bridge a lighter appearance, making it an ideal medium for architectural treatment. The open-spandrel form was used to construct two large concrete bridges over Buffalo Bayou in Houston in 1914. The 1,273-foot-long Main Street Bridge at Buffalo Bayou (TxDOT Structure No. 12-102-0-B416-97-003) consists of one concrete arch barrel reinforced by the "Kahn System" of reinforcement.[854]

---

[851] Texas Department of Transportation, *Bridge Design Manual*, 7-27.
[852] Texas Department of Transportation, *Bridge Inspection Database*, n.p.
[853] Parsons Brinckerhoff and Engineering and Industrial Heritage, *A Context for Common Historic Bridge Types, NCHRP Project 25-25, Task 15*, 3-91.
[854] Steiger.

The THD occasionally employed the open-spandrel design to create gateway bridges along highways entering cities. The THD achieved its highest artistic expression with the 1934 Guadalupe River Bridge on the original alignment of SH 2 (now BI 35), in New Braunfels (TxDOT Structure No. 15-046-0-0016-11-016). This 818-foot-long bridge is composed of five open-spandrel arches with classically detailed spandrel columns and Art Deco pilasters. The open-spandrel arch was constructed up until the 1940s, when the last bridge of this type, the Lamar Avenue Bridge at the Colorado River (TxDOT Structure No. 14-227-0-0113-12-065) in Austin opened for traffic in 1943. Other noteworthy examples of open-spandrel construction include the 1923 Comal River Bridge on San Antonio Street in New Braunfels (TxDOT Structure No. 15-046-0-B015-50-001) and the Henderson Street Bridge (SH 199) at the Clear Fork of the Trinity River in Fort Worth (TxDOT Structure No. 02-220-0-0171-05-018).

Although arch bridges were commonly built on U.S. roads since 1910, the bridge type was not as popular in Texas as it was in other locations, particularly following World War II. Only one extant reinforced concrete arch bridge is known to have been built in Texas between 1945 and 1965—the Speedway Street Bridge over West Waller Creek in Austin (TxDOT Structure No. 14-227-0-B013-81-002). This 1946 closed spandrel arch is located on the University of Texas at Austin campus.

*Concrete Rigid-frame Bridges*

Arthur G. Hayden introduced the rigid-frame bridge to the United States in the early 1920s, for the development of a system of parkways in Westchester County, New York. Based on European experiments, the rigid-frame is unique in that the superstructure and substructure are poured monolithically as a single unit. This method of construction allowed the thick shoulder joints of the bridge to absorb the load normally carried by the deck, permitting a thinner deck floor. Their slender proportions and narrow, flat arches made the bridge well suited for projects where architectural design and a clear span were important. For these reasons, rigid-frame bridges were a popular choice for short span bridges in urban areas, parks, underpasses, and railroad grade separations.

During the early 1930s, Texas was at the forefront of rigid-frame construction in the U.S. San Antonio engineer J.W. Beretta, who designed at least four rigid-frame structures in the area, championed Texas's use of the bridge form in a 1934 article in the *Journal of the American Concrete Institute*. Erected in 1931, Beretta's design for the Lincoln-Garden Street Bridge over the Comal River (TxDOT Structure No. 15-046-0-B005-90-001) in New Braunfels utilized continuous girders in rigid-frame continuity with the piers. Another rigid-frame bridge receiving attention in engineering journals was the Upper Shoal Creek Bridge on Shoal Creek Blvd in Austin (TxDOT Structure No. 14-227-0-B013-56-006). The one-span bridge consists of a reinforced rigid-frame design with hinged footings and is noteworthy for its chrome-plated steel rod and ornamental concrete post railing system. Constructed in 1934, the bridge was built as part of a project to develop a park and boulevard system along Shoal Creek. The THD used the rigid-frame on a limited basis for grade separations and railroad bridges. The North Main Street Overpass at US 77 in Schulenburg (TxDOT Structure No. 13-076-0-0269-01-036) is the only surviving example of a vehicular overpass designed by the THD using a rigid-frame design prior to World War II.

Three types of rigid-frame bridges were used in Texas during post-World War II period: plain rigid-frames, rigid-frame concrete slabs, and rigid-frame Tee beams. All three bridge types were inexpensive, easy to construct, and

aesthetically appealing for use on urban roadways.[855] They were commonly used for highway and freeway bridge construction and generally had an arched profile. The extant rigid frame bridges from the 1945-1965 period are found in Texas's urban areas of Austin, Dallas, Fort Worth, and San Antonio.

Rigid-frame bridges were mainly used as grade separation structures in urban locations following World War II and had spans ranging from 40 to 120 feet.[856] Since the deck and abutments act as a uniform system, these bridges carried the entire load with little help from a foundation, and were used where logistics, setting, and/or cost prevented the construction of a substantial foundation. Although these bridges were a well-established bridge type, the THD could still be innovative in their construction, such as in the example of the Saunders Avenue and Fleishel Avenue bridges, both of which span SH 31 in Tyler (TxDOT Structure Nos. 10-212-0-0424-01-030 and 10-212-0-0424-01-031). The superstructure portion of the bridge was poured at the Saunders Avenue ground level and the SH 31 roadway was dug under the Saunders Avenue superstructure. The abutment walls and foundation were then put into place. Constructing the bridge in this way, the contractor did not have to use falsework under the bridge, which is a major expense in the construction of these structures.

In situations where substantial foundations could be built to resist lateral loads, engineers built a modified version of the rigid-frame, the rigid-frame concrete slab. Like plain rigid-frame bridges, the rigid-frame concrete slabs' superstructure is tied into the abutments; however, in the concrete slab variation, the superstructure is only integrated with the substructure cap. Therefore, the continuous form only extends a few feet onto the top of the abutment and the bridge relies on the foundation (rather than integrated superstructure and substructure) to resist the lateral loads. There are several reasons that engineers built rigid-frame concrete slab bridges rather than the plain rigid-frame bridges. First, since the superstructure was only integral with the substructure cap, column-type piers could be easily built placed between travel lanes. Plain rigid-frame bridges had such substantial substructures that multiple spans were not easy to construct. Rigid-frame concrete slab bridges were also less expensive to build than plain-rigid frames since they required less reinforcing material and less concrete, while still providing the elegant arched form for urban roads. Furthermore, the thin superstructure of the rigid-frame concrete slabs made them an ideal choice where vertical clearance issues were a concern. One disadvantage to the rigid-frame concrete slab bridges may have been their maximum span length. According to TxDOT's BID, the rigid-frame concrete slab bridges built in the state had spans less than 70 feet long.

The rigid-frame Tee beam bridge was another type of rigid-frame used during the 1945-1965 period. This bridge type had Tee beam superstructure elements that are monolithically formed with the substructure, creating a series of arching beams. Since the Tee beam form was carried through to the substructure, engineers could easily construct multiple spans, like the rigid-frame concrete slabs, and place the piers where needed. Rigid-frame Tee beams' spans were longer than the rigid-frame slabs, with the longest rigid-frame Tee beam span in the state, measuring 82 feet. However, with the long span range came a deeper superstructure, and the rigid-frame Tee beams could not be used where vertical clearance was a concern.

---

[855] Parsons Brinckerhoff and Engineering and Industrial Heritage, *A Context for Common Historic Bridge Types, NCHRP Project 25-25, Task 15* ([Washington, D.C.]: National Cooperative Highway Research Program, Transportation Research Board, October 2005), 3-96.
[856] Parsons Brinckerhoff and Engineering and Industrial Heritage, *A Context for Common Historic Bridge Types, NCHRP Project 25-25, Task 15*, 3-96.

Rigid-frame designs declined in popularity when the new prestressed concrete designs of the 1950s proved to be less labor intensive and more economical.[857]

### *(b) Prestressed Concrete Bridge Types*

*Prestressed Concrete Beam*

Prestressed concrete beams consist of tensioned reinforcing wires termed "strands" that are covered by high-strength concrete. Once the concrete has cured, the forms are removed, allowing the tensioning in the reinforcement to be transferred to the concrete. This creates a positive camber (or upward curve) and increases the compressive strength of the concrete. The prestressing allows the beam to withstand greater loads without, or with very little, deflection. To provide an adequate anchorage bearing for the pre-tensioned or post-tensioned steel at the end of each beam, fabricators increased the beam web width, which resembled a block. These features, called "end blocks," are present on prestressed concrete beams built during the 1945-1965 period, although the practice was discontinued later.

The THD developed a group of standard precast, pre-tensioned concrete beams in 1956 and 1957. In 1956, THD Bridge Division engineer James Graves designed a pre-tensioned, precast, prestressed concrete beam bridge for FM 237 at Coleto Creek in Victoria County (TxDOT Structure No. 13-235-0-0941-04-007). As a result, in 1956, he created the THD prestressed concrete beam standard shapes: the A, B, and C beams.[858] These standards were developed independent of the AASHO standard beam shapes.[859] The THD's initial designs were successful as the standards and these beams have changed very little since the 1950s.[860]

Prestressed concrete beams were used for medium-span stream crossings and grade separations in place of steel beam bridges, which had slow delivery periods and were very expensive.[861] Like other state highway departments, the THD soon found that precast, pre-tensioned concrete beams proved to be the most economical bridge type for medium-span length bridges.[862] In 1962, AASHO and the PCI published recommendations for standard shapes of prestressed concrete I-beams, piling, slabs, and box beams. By the early 1960s, prestressed concrete girders were found largely to be economical and practical for span ranges of 40 to 100 feet, but were generally not cost-

---

[857] Parsons Brinckerhoff and Engineering and Industrial Heritage, *A Context for Common Historic Bridge Types, NCHRP Project 25-25, Task 15*, 3-96, 3-97.
[858] Robert L. Reed, n.p.
[859] The May 2004 *Slab, Beam & Girder Bridges in Oregon: Historic Context Statement* notes that AASHO developed its first prestressed concrete beam standard in 1956. Mead & Hunt's research in Nebraska points to that state issuing standards for prestressed concrete beams in 1958. Ohio's 2004 historic context for 1951-1961 bridges states that Ohio did not issue standards for prestressed concrete beams until 1960. With THD engineers reviewing information from California, Florida, and Tennessee regarding their use of prestressed concrete, it is assumed that these states may have pre-1956 standards. Therefore, it appears that the THD's development of prestressed concrete beam standards is neither particularly early nor late compared with other states and AASHO.
[860] Texas State Department of Highways and Public Transportation, *Bridge Design Guide*, 5-69.
[861] Texas Department of Transportation, *Bridge Design Manual*, 6-18.
[862] Texas Department of Transportation, *Bridge Design Manual*, 1-4.

competitive for spans below 30 feet.[863] With advances in technology, use of precast, prestressed concrete became more common in Texas and the nation.

In the 1950s, most states were constructing bridges that used simply supported beams. The use of prestressed concrete beams for continuous construction was limited to only a few states, and very few continuous prestressed concrete beams were built on Texas roads through the mid-1960s.[864]

Although rare, cantilevered prestressed concrete girder bridges were built during the late 1950s and early 1960s. These bridges have short superstructure members that are tied into the pier caps and extend out over the pier, and the ends of the specially designed prestressed concrete girders rest on the cantilevered extensions. By cantilevering the prestressed concrete girders, the engineers were able to maximize the span length of the structure while maintaining the cost savings of using a prestressed concrete beam.

Although several small bridge projects in Texas used prestressed concrete in the early and mid-1950s, the first major project in the state that employed prestressed concrete was the Corpus Christi Harbor Bridge (1959) constructed in Nueces County (TxDOT Structure No.: 16-178-0-0101-06-041). Special precast and post-tensioned concrete beam shapes were used for this extant bridge's 2,000 feet of 40-and 60-foot prestressed concrete I-beam approach spans.[865] Special shapes were also developed for the Buena Vista and Commerce Street overpasses in San Antonio (TxDOT Structure Nos. 15-015-0-B046-95-002 and 15-015-0-B075-10-004, respectively). Constructed in 1957, the bridges had parallel 1,600-foot spans carrying city streets over a series of railroad tracks.

*Prestressed Concrete Pan-formed Girder*

Two types of prestressed concrete pan-formed girder bridges were built during the post-World War II period. The first type resembles the repeating arch-shaped pan-formed girder that is usually strengthened with steel reinforcing bars. The prestressed pan-formed concrete girder was the first prestressed concrete bridge type used in Texas. Although the THD used the pan-formed girder to build its first prestressed concrete bridge, the type was very rarely employed.

Since the agency had been using the pan-formed girder design for several years, they tried their first attempt at a prestressed concrete bridge with a pan-formed shape. The THD first built a prestressed concrete pan-formed girder on the SH 60 Bridge (1952) across the San Bernard River between Austin and Wharton counties.[866] The San Bernard River Bridge was extant in 2009 (TxDOT Structure No. 13-008-0-0240-01-008).

The second type of prestressed pan-formed girder bridge is a post-tensioned, precast bridge that had a slab and the vertical girders integrated together. Although cast in a steel form, these prestressed bridges do not have the repeating-arch shape at the top of the girders as those noted above. A bridge of this type is the extant Pine Street

---

[863] Norman L. Scott, "Suggestions for Reducing Costs in Prestressed Concrete Bridges," in *Highway Research Record Number 34: Bridge Design, Analysis, and Costs* (Washington, D.C.: Highway Research Board, 1963), 117.
[864] Based on the article, Florida is assumed to be one of the states that were using precast, prestressed concrete beams of continuous construction. The other states are not identified. W. E. Dean, "Continuous and Cantilever Bridges with Precast-Prestressed Concrete Beams," in *Proceedings Convention Committee Meeting Papers, New York, New York, October 5-7, 1965* (Washington, D.C.: American Association of State Highway Officials, General Offices, 1965), 267-268.
[865] Texas Department of Transportation, *Bridge Design Manual*, 7-72.
[866] Texas Department of Transportation, *Bridge Design Manual*, 7-44.

Overpass (1956) on a section of the Dallas Expressway, now designated as US 175 (TxDOT Structure No. 18-057-0-0092-01-053). It contains three, 58-foot, simply supported, post-tensioned, concrete pan-formed spans. Another example of the use of this type is the extant Lavaca Bay Causeway Bridge (1959) on SH 35 in Calhoun County (TxDOT Structure No. 13-029-0-0179-10-061).[867] As the longest bridge built in Texas during the 1945-1965 period, most of the bridge is comprised of these prestressed concrete pan-formed girders. This type was ideal for the crossing since the slab and girder were integrated together and an instant working surface was available once they were laid in place. This bridge used so much prestressed concrete that a plant was built adjacent to the bridge just to build the approach spans for the structure.

*Prestressed Concrete Slab*

Prestressed concrete slabs are cast-in-place post-tensioned bridges, few of which were built during the post-World War II period. These complex bridges were built in rare cases where structure depth was critical or where aesthetic design was a consideration.[868] TxDOT's *Bridge Design Manual* notes that this bridge type was rarely used and that several problems were experienced when constructing the bridge.[869] Only one prestressed concrete slab bridge is known to be extant, and it is a continuous prestressed concrete slab located in the San Antonio District. It carries West Martin Street over Alazan Creek (TxDOT Structure No. 15-015-0-B219-85-011).

*Prestressed Concrete Box Girder*

Prestressed concrete box girders are precast, box-shaped girders that are strengthened with pre-tensioned steel wires. From their initial use in the 1950s until 1965, the majority of these girders were placed in a row with individual boxes directly adjacent to each other. A pedestrian bridge over Memorial Drive in Houston (TxDOT Structure No. 12-102-0-B441-85-016) is the only prestressed concrete box girder bridge built prior to 1965 that uses a single girder.

Prestressed concrete box girders were first used in the state by a local contractor in Victoria named Herman Baass. Baass, who was not a trained engineer, began experimenting with prestressed concrete for county road bridges in the early 1950s.[870] Baass indicated that he began building prestressed concrete box girders because he could place the girders directly adjacent to each other and tie them together. This created an instant wearing surface, and an asphalt or concrete deck did not have to be built atop the box girders. This produced cost and time savings to the county governments, and Baass built several of these bridges throughout eastern Texas.

The THD did not build prestressed concrete box beams until the late 1960s.[871] Hearing of Baass's successful prestressed concrete box girder design in the Gulf Coast region, the THD adopted the premise of his design as a standard and as an alternative to pan-formed girders that were performing poorly in salty environments.[872]

---

[867] Texas Department of Transportation, *Bridge Design Manual*, 7-43.
[868] Texas Department of Transportation, *Bridge Design Manual*, 7-40.
[869] Texas Department of Transportation, *Bridge Design Manual*, 7-40.
[870] Baass, Interview with Mead & Hunt, Inc. and TxDOT Bridge Division, Texas Department of Transportation.
[871] Texas State Department of Highways and Public Transportation, *Bridge Design Guide*, First ed. ([Austin, Texas]: [Texas State Department of Highways and Public Transportation], 1990), 5-39.
[872] Charlie Covill, Interview by Mead & Hunt, Inc. and TxDOT Bridge Division, Texas Department of Transportation, digital audio and video recordings, Travel Division Studio, Riverside Campus Building 150, Austin, Texas, August 29, 2006.

Although the THD did not have standard plans for these bridges until the late 1960s, the BPR had standard plans for these bridges in 1956.

*Prestressed Concrete Channel Beam*

Like the reinforced concrete channel beam, prestressed concrete channel beams are precast members that have a flattened inverted U-shaped beam. The majority of the nine extant prestressed concrete channel beams were built by the City of El Paso. The earliest bridge of this type was built in 1960. Main span lengths for the type range from 29 to 65 feet. Of the nine extant Texas bridges of this type, only one has multiple spans, and its structure length is 309 feet.

*Prestressed Concrete Tee-beam*

Although the THD developed standard drawings for prestressed concrete Tee beam superstructures, this type was very rarely used. It represented an advance in materials from the reinforced concrete Tee beam developed in the 1910s. The prestressed concrete Tee beam design, referred to as the Lin Tee, was available in Texas in the early 1960s. The Lin Tee was introduced in 1962 and named after its inventor, T.Y. Lin. The El Paso District developed standard designs and drawings for a precast, prestressed single Tee beam bridge. During the 1945-1965 period, the El Paso District built some of these bridges as pedestrian structures in the city of El Paso. They also used this design for the twin bridges on IH 10 near Van Horn in 1968.[873] One prestressed concrete Tee beam was built in 1965 by the City of Wichita Falls (TxDOT Structure No. 03-039-0-3429-01-001). It carries FM 2606 over Lake Arrowhead Spillway in Clay County. The THD Bridge Division developed standard drawings for a prestressed concrete Tee beam in 1969 that were never used.[874] A 2009 bridge inventory identified five extant prestressed concrete Tee beam bridges, with the earliest example built in 1960.

***(c) Steel bridge types***

*Steel Beam – Simple, Continuous, Cantilever*

Steel I-beam bridges take their name from the structural elements of which they are composed. An I-beam is a joist or girder fabricated of rolled steel that has short flanges (or protruding edges) and a cross section formed like the letter "I." A steel I-beam bridge may also be referred to as a steel stringer. It was one of the leading twentieth-century bridge types in Texas, and many are extant, including simple spans and continuous and cantilevered variants.

Steel I-beam bridges have been used in Texas since the 1910s. The earliest steel I-beam bridges in the state were based on standards developed by the BPR, and the THD developed its own standard designs for steel I-beam bridges in 1919.[875] Prior to 1925, the length of these bridges was restricted to single spans of 20 to 50 feet because rolling mills could not produce longer beams.[876] The strength and size of I-beams increased in the 1930s, and continuous and cantilevered I-beam spans began to appear in Texas during this period. By the late 1930s,

---

[873] Texas Department of Transportation, *Bridge Design Manual*, 7-65.
[874] Texas Department of Transportation, *Bridge Design Manual*, 7-65.
[875] Texas Department of Transportation, *Bridge Design Manual*, 7-108.
[876] Texas Department of Transportation, "Texas Historic Bridge Inventory: Survey of Non-Truss Structures," 21.

continuous steel I-beams could be produced at lengths of over 200 feet. In 1934, the THD began experimenting with independent steel beams placed between cantilevered arms, projecting beyond the main supports of the bridge. These cantilevered spans allowed for a longer span length with a thinner deck, resulting in a more economical bridge.

By 1945, steel I-beam bridges were a well-established design with which most bridge engineers and fabricators were familiar, but in the late 1940s, long-time THD bridge engineer Percy Pennybacker pushed to dramatically change the way steel I-beams were used.[877] He promoted and initiated the replacement of riveted steel construction with all-welded construction, which allowed for simpler splicing of continuous units. With Pennybacker promoting welded bridge construction, the THD nearly abandoned the use of simple steel I-beam bridges in favor of continuous steel I-beam spans by the 1950s.[878] In the 1950s, the THD used continuous steel I-beam bridges extensively, finding this type to be most economical for spans that ranged from 40 to 90 feet.[879] These continuous bridges were used widely on U.S. and state highways.[880] The continuous steel I-beam bridge was used when long spans were needed, and often utilized in interchanges for these same reasons.

During the post-World War II period, the well-established steel I-beam bridge was utilized by city and county governments in its simple-span form, while the THD used the newly developed, all-welded, continuous-span steel I-beams for long spans, interchanges, and skewed structures.[881] Although popular prior to and during the 1945-1965 period, long delivery times, high steel prices, and the development of prestressed concrete beams in the mid-1950s ended the popularity of the steel I-beam bridge in the early 1960s.[882] Regardless, hundreds of steel I-beam bridges are extant on Texas roads.

As mentioned above, another variation of the steel I-beam bridge is the cantilevered steel I-beam with suspended span. This bridge type, which had been used in Texas since the 1930s, allowed for longer interior spans than continuous steel I-beams. Although first applied to truss construction, cantilever support methods were applied to other bridge types during the post-World War II period, including concrete girders and steel I-beams. Not only do cantilevered spans provide for longer span lengths, but they also can be erected without falsework and without obstructing the channel. These cantilevered steel beams with suspended spans also have interior spans that are suspended from anchored spans that extend over substructure supports. A pin and hanger structural connection joins the suspended span to an anchored span. Due to their complexity, these structures are often an expensive bridge type that was rarely built, and few of these bridges are extant in Texas.

*Steel Plate Girder – Simple, Continuous, Cantilever, Variable Depth*

A plate girder, or fabricated steel girder, consists of built-up riveted or welded angles and plates with a deep web fabricated to form a section that looks like the letter "I." The web lies between the top and bottom flanges, which are fabricated by plate steel placed horizontally over the webs of the girder. With their deep web, plate girders are able to span beyond the length of a standard steel I-beam. Steel I-beams are limited to standard sizes due to

---

[877] Bundy, interview by Mead & Hunt, Inc. and TxDOT Bridge Division.
[878] Texas Department of Transportation, *Bridge Design Manual*, Section 7-108.
[879] Bundy, "Design of Welded Bridge Structures," 132.
[880] Texas Department of Transportation, *Bridge Inspection Database*, n.p.
[881] Texas Department of Transportation, *Bridge Inspection Database*, n.p.
[882] Texas Department of Transportation, *Bridge Design Manual*, 7-108.

physical and economic limitations in the steel mills. A plate girder, on the other hand, can be fabricated to any required depth.

By the late nineteenth century many bridge fabricators were building plate girders for short to intermediate spans. By 1916, the renowned American bridge engineer J.A.L. Waddell noted that the ordinary limit for plate girder spans was about 100 feet, although spans of 120 feet or more were common for swing spans. These girders typically consisted of metal angles and plates riveted together to form relatively large beams.

Transportation difficulties and the preference for light spans prevented a widespread use of girders on Texas roadways until the 1920s and 1930s. Steel fabricated girders never became part of the THD's standard designs. Because of its cost and difficulty in transporting, the fabricated girders were used only in special situations.[883] Good representative fabricated girder bridges include the 1931 through-girder Benton Street Overpass in Big Spring (TxDOT Structure No. 08-115-0-B054-90-001), the 1937 South Main Street overpass of the BNSF railroad in Fort Worth (TxDOT Structure No. 02-220-0-ZM06-70-001), and the 1943 multi-girder overpass on Zang Boulevard (SL 354) at Cedar Creek in Dallas (TxDOT Structure No. 18-057-0-9Z05-40-009).

In post-World War II Texas, fabricated steel was less available than concrete and, as a result, more expensive. The type's relatively high cost and the THD's preference for lighter spans resulted in plate girders being used only in special situations in the state.[884] Approximately 250 known examples remain in Texas that date from the 1945-1965 period, with typical span lengths of 30 to 100 feet.[885] Two basic forms of plate girder bridges built during the 1940s through 1960s are plate girders with floor beam system, which were riveted structures, and a multi-girder system with several parallel girders that do not require floor beams and had welded connections. Although plate girders with floor systems outnumbered the multiple plate girder bridges by 4 to 1 during the 1945-1965 period, the multiple plate girder bridges were more economical than girder bridges with floor systems once welded connections were established.

Another variation of steel plate girder bridges is the variable depth plate girder. Variable depth steel plate girders are multiple plate girder bridges that do not have floor systems. As with variable depth concrete slabs and variable depth concrete girder bridges, when the superstructure members are very deep over the piers and taper to a thinner depth at mid-span, longer spans can be achieved. Like other variable depth bridges, they are generally built in continuous span configurations. Examples of variable depth steel plate girder bridges are the Buffalo Bayou Twin Bridges (1956) on US 90-A in Houston, Harris County (TxDOT Structure Nos.: 12-102-0-0027-10-062 and 12-102-0-0027-10-063).

Steel plate girders with cantilevered, suspended spans are another variation of steel plate girders. Unlike other cantilevered bridges that have a span that projects out from a pier or abutment and is supported at one end by an anchor span, these bridges have a span that is suspended between two cantilevered spans. These bridges are difficult to design and construct, thus making them rare nationally and in Texas. Only one bridge of this type is known to have been built in Texas between 1945 and 1965: the extant US 90 at Devils River bridge (TxDOT Structure No. 22-233-0-0022-09-070).

---

[883] Banks, "Short Spans, About Bridges, Part ITI," 16-17; Banks, "Short Spans About Bridges, Part IV," 26-27; Waddell, 1: 408-409; Condit, *American Building: Materials and Techniques*, 225-226; Cooper, 42-43.
[884] Texas Department of Transportation, "Texas Historic Bridge Inventory: Survey of Non-Truss Structures," 22.
[885] Texas Department of Transportation, *Bridge Design Manual*, 7-112.

*Steel Arch*

Although used in the U.S. since the 1860s, the THD constructed few steel arch bridges prior to 1945, with only one known steel arch built in Texas during the 1945-1965 period. This 1957 bridge carries Dallas' Hampton Road over IH 30 (TxDOT Structure No. 18-057-0-1068-04-109) and features a 192-foot, two-hinged arch that was the first example of an all-welded, box girder type arch rib in the U.S. The two-hinged arch pins the hinges at the base of the arch to limit rotational effects between the structure and the foundation. The two-hinge system also controls abutment movement and allows use of lighter construction materials. The Hampton Road Bridge won an American Institute of Steel Construction award in 1957 for its unique construction. Since steel arches were difficult to fabricate and to erect, these bridges are very rare in Texas and nationwide.

Although metal multi-plate arches or pipes are coded in Texas's BID as metal arch bridges, these bridges are bridge-class culverts and do not have the complex design illustrated in the steel arch described above.

*Other Steel Bridge Types*

Railroad Flat Cars
Eight extant bridges built between 1945 and 1965 have superstructures that are recycled railroad flat cars. The railroad cars are simply placed upon the substructure and a deck is placed on the cars. The earliest extant railroad car built during this period is dated 1951. These bridges' main spans range from 38 to 50 feet long. Two bridges have more than one span, each with a maximum overall structure length of 131 feet.

Truss Girders
Little information is known about truss girder bridges, which are known to have been built during this period in the Abilene District only. These bridges consist of multiple girders that are laid longitudinally under the deck. These girders are built up members with two steel members that are connected with welded, laced steel angles. Three extant bridges of this type were built between 1945 and 1965, although one was widened with new members in 1959. The widened bridge was built in 1945 and the other two bridges were built in 1951. All three bridges have more than one span, have a main span length of 40 feet, and have a maximum overall span length of 140 feet.

***(d) Movable Bridge Types***

A movable bridge is a structure with a span that can be moved to clear a navigation channel when the bridge superstructure has a low clearance. Depending on its height over the water, a movable bridge may allow small craft to pass beneath, while it continues to carry vehicles over the river. When larger vessels approach, the span is moved or opened to provide adequate clearance, and returned to its original closed position after the vessel has passed. Prior to the 1830s, moveable span bridges consisted of crude wooden structures resembling medieval drawbridges or floating pontoons. As railroads spread across the nation, bridge engineers began to search for more permanent moveable bridge forms to span navigable waters, since railroad grades could not readily be elevated for a bridge high enough to provide fixed clearance. Spurred by advances in metal truss technology, engineers fashioned new designs utilizing fabricated steel spans and motorized drive mechanisms. Three basic steel moveable span types evolved during the late nineteenth century: horizontal swing, bascule, and vertical lift spans.

Historically, the majority of movable bridges were located across major rivers and waterways in the eastern part of Texas. All of the major movable span bridges designed by THD before World War II were constructed over the Sabine River separating Louisiana from Texas. A limited number of swing span, bascule, and vertical lift bridges

were built during the post-World War II period. Causeways and elevated roadways were instead preferred since they were easier and cheaper to build and maintain.

*Swing*

Swing bridges are the earliest and simplest forms of movable bridge. In the 1830s and 1840s, these bridges generally consisted of a crude timber truss span pivoted on a central pier. These primitive structures were manually operated with cables or rope, or simply nudged open by the vessel requiring passage. Engineers improved the design of the swing bridge during the latter part of the century by replacing the timber trusses with steel spans and the steam engines with gasoline or, later, electric drives. The bridge could move on a central pivot or pin (known as a center-bearing swing span) or a circular drum with rollers (known as a rim-bearing swing span).[886] When the swing bridge is open, each half is cantilevered over the water. Two channels are cleared for a ship to pass. As ship traffic increased, this bridge type fell out of favor due to the amount of space it occupied in the channel. Swing bridges largely gave way to bascule and lift bridges in the early twentieth century.

The former Sabine River Bridge at Orange was the first swing bridge built over an interstate waterway. Erected in 1927, this 1,020-foot-long bridge facilitated interstate travel between New Orleans and Houston on the Old Spanish Trail (SH 3) until a new fixed span bridge replaced it in 1947.

As noted above, technological advances in vertical lift and bascule forms rendered the swing span virtually obsolete by the late 1920s. In comparison to these bridge types, swing bridges were slow to operate, having to rotate a full 90 degrees to open, and required large piers in the center of the waterway greatly reducing the navigable area of the channel. However, because of their basic economy of materials and simplified construction, the swing bridge was utilized during the Depression for large work-relief bridge projects.

Two horizontal swing bridges were constructed in Texas during the post-World War II period. One of these was built in 1958 and carried SH 82 over the Sabine River in Jefferson County (TxDOT Structure No.: 20-124-0-2367-01-002; removed from service). It features a Pennsylvania truss swing span on a central pivot.[887] The other bridge was built in 1960 on East Round Bunch Road over Cow Bayou in Orange County (TxDOT Structure No.: 20-181-0-AA26-90-006). It has a rim-bearing, 180-foot long, plate girder swing span.

*Vertical Lift*

Introduced in the 1890s, vertical lift bridges typically use beams or trusses to span between two towers. The bridge deck is raised using cables attached to rotating drums in the towers. The deck maintains its horizontal position as cables raise the deck vertically, providing vertical clearance for vessels to pass. The span is then lowered to allow vehicles to cross. Although two known examples of lift bridges were constructed after World War II, only one is extant: the FM 106 bridge over the Arroyo Colorado in Cameron County (TxDOT Structure No.: 21-031-0-0630-02-003). The bridge, which was built in 1953, has riveted connections, is 382 feet long, and has a 145-foot movable span.

---

[886] Parsons Brinckerhoff and Engineering and Industrial Heritage, *A Context for Common Historic Bridge Types, NCHRP Project 25-25, Task 15*, 3-115, 3-118.
[887] Texas Department of Transportation, "Texas Historic Bridge Inventory: Survey of Non-Truss Structures," 42-43.

*Bascule*

Introduced in the 1890s, Bascule bridges utilize a beam or truss deck that can be raised on a pivot point, often a trunnion, to an inclined or vertical position. To clear the waterway, the deck is either raised in a vertical plane or rolls back on a segmental rack. Bascule bridges can be single-leaved with a single movable span unit or double-leaved with a pair of movable units. Types of bascule bridges include simple trunnion, Strauss trunnion, and Scherzer-type rolling lift. Two known examples of bascule bridges are simple trunnion bascule bridges and were constructed after World War II: FM 521 at the Colorado River in Matagorda County (TxDOT Structure No. 13-158-0-0846-03-009) and Seawolf Parkway at Pelican Island Channel in Galveston County (TxDOT Structure No. 12-085-0-B007-90-001). During a 2009 site visit, the FM 521 bridge was being dismantled and had been replaced by another structure. The Pelican Island Bridge, however, was extant in 2009.

### *(e) Timber Stringer*

Timber stringer bridges are simple structures that have been used throughout history and refined with the development of dimensioned lumber. The THD had developed standard designs for short-span timber stringers by 1920. Timber stringers were used extensively in east Texas, where timber was available and economical construction was especially important. The THD's use of timber stringers declined after 1950 as the transportation loads increased and new materials became economical. Furthermore, timber beams could only span about 20 feet and an exposed timber bridge could be expected to last 20 to 30 years, if it was not damaged by fire or flood. Since timber bridges do not generally require complex engineering analysis, these structures were used by county governments for small crossings throughout the late nineteenth and twentieth centuries, particularly in east and central Texas.

### *(f) Stone Masonry*

The use of stone as a structural construction material made an appearance in the early part of the twentieth century as a component of Austin's city beautification program. Considered the most "artistic" choice for small or medium spans, a number of stone arches were constructed on principal streets crossing Shoal Creek and Waller Creek. One of the last surviving examples of one of these arches is the Waller Creek Bridge on East 6th Street (TxDOT Structure No. 14-227-0-B000-17-005). Erected c.1930, the 37-foot-long structure presents a single arch composed of rough-cut limestone blocks, and features masonry parapet railing on the south side of the structure.

The Great Depression spurred labor-intensive projects that often used stone as a building material. The exceptional Possum Kingdom Bridge (TxDOT Structure No. 02-182-0-0362-02-003) over the Brazos River in Palo Pinto County is one of the few bridges built during the Great Depression to feature true masonry arch construction. The WPA erected the 433-foot-long stone bridge in 1942 from 3,830 yards of locally quarried limestone. The project employed around 300 workers and is considered the largest masonry bridge construction project undertaken in Texas.

## (3) Significance

### *(a) Criterion A*

For assessment of non-truss/non-suspension bridge types under *Criterion A*, refer to the significance discussion common to all bridges. (pp 208-212)

### *(b) Criterion C*

According to *National Register Bulletin: How to Apply the National Register Criteria for Evaluation, Criterion C* recognizes bridges that have distinctive design or construction characteristics of a type, period, or method of construction. These distinctive characteristics should illustrate the following: (1) the pattern of features common to a particular class of resources, (2) the individuality or variation of features that occurs within the class, (3) the evolution of that class of resources, and/or (4) the transition between classes of resources. *Criterion C* also recognizes bridges that represent the work of a master or possess high artistic value.

A bridge may be significant for its distinctive design or construction characteristics, as noted below:

- Early use of bridge type – A bridge may be significant as an early example of its type. As noted in NRHP guidance, this characteristic illustrates the evolution of bridge types through an assessment of construction date data.
- Design, fabrication, and construction – The significance of a bridge under *Criterion C* is directly related to its design, fabrication, and construction. Design, fabrication, and construction are evaluated by an examination of length, special features or designs, innovations, and standardizations. A bridge may be significant based on the following indicators:
    - *Exceptional main span length or structure length for type*. As noted in NPS guidance, exceptional main span length or structure length illustrates the variation within a class of bridges and may signal a significant engineering feature.
    - *Uncommon bridge type*. As noted in NPS guidance, rarity of type illustrates the variation of type or method of construction. Bridges are significant as examples of a bridge type or structural form that was not commonly constructed or is now rare in Texas.
    - *Represents innovative designs or features*. As noted in NPS guidance, a special feature or design illustrates the variation within a class of bridges and may signal a distinctive engineering feature. Bridges significant in this category may be important for their engineering response to difficult or unusual site challenges or for representing an innovation or advancement in bridge design or technology. This category also includes bridges illustrating major engineering advancements and significant innovative designs or features, particularly during their early period of use.
    - Significant examples of standard plan bridges. Bridges may be significant as among the most representative or earliest examples of standard plans. The earliest examples of common-type bridges of the 1945-1965 period, such as pan-formed girders, prestressed concrete girders, and FS concrete slabs, illustrate the significant trend of economical design through mass production, as facilitated by THD standardization following World War II. Modifications to previously established or newly established standard plans may also illustrate significant evolution in bridge types.

- Work of a master – A bridge may derive significance as an important work of an engineer, designer, fabricator, or builder with national or state importance. A list of these individuals is included in Section E of this MPS. As noted in the *National Register Bulletin: How to Apply the National Register Criteria for Evaluation*, a property must be considered important within an individual's body of work to be considered significant as the work of a master, such as the first or most technically complex example of the individual's or firm's work in Texas. A bridge should exhibit other distinctive design or construction characteristics as discussed in this section to be considered significant under *Criterion C*. It should be noted that significance is not conveyed by bridges built following standard plans designed by a master; rather, such significance instead resides in individual bridges specifically designed by a master engineer or builder.

- Possess high artistic value – Properties possessing high artistic value are significant for their expression of an aesthetic or design including scale, proportion, balance, detail, ornamentation, and visual relationship to the surrounding environment. However, mere presence of ornamental features or detail in itself does not necessarily denote significance. In addition, bridges built during the 1945-1965 period are not likely to exhibit the design concepts of the classically inspired City Beautiful movement or rustic aesthetic of work-relief bridges of earlier decades. Rather, these post-World War II bridges are likely to have simple, clean lines with little extraneous ornamentation. By itself, presence of ornamental features does not denote significance.

### *(c) Registration Requirements*

*Pre-1945 Bridges*

*Criterion A*
For non-metal truss bridges constructed prior to 1945, use the registration requirements common to all bridges.

*Criterion C*
For non-metal truss bridges constructed prior to 1945, a quantitative rating system is used to assist in evaluation of a structure's relative engineering significance. This system was used to guide eligibility evaluations in TxDOT's *Survey of Non-Truss Structures*, completed in 2001. The rating system was influenced in large part by quantitative methods employed by other states and adapted to the characteristics of bridge types found in Texas. The rating system assigned numerical values in accordance to a bridge's technological significance by comparing every bridge to the pool of all unaltered structures of its type. Like other systems, the quantitative method awarded points for date of construction, overall length, and length of the main span. Unlike other evaluations, this system assigned points to bridges that featured early standard plan railing or special design superstructure or substructure components.

Additional details regarding the methodological approach for survey and evaluation of non-metal truss bridges constructed prior to 1945 is found in Section H of the MPS document. Using this rating system, a cut-off of 62 points represents the separation between technologically significant and insignificant structures. The rating system should not be used as the exclusive measure of a bridge's NRHP eligibility, but rather a method for measuring a structure's relative engineering significance. Many bridges that initially receive a high rating because of overall length may, upon further inspection, be demoted to a lower category because they do not demonstrate real technological merit beyond length. Conversely, a number of shorter bridges may be promoted to a higher category because they represent the last example of a standard plan or feature a rare railing type.

The following is the quantitative rating table and explanation of the quantitative rating system for non-metal truss bridges constructed prior to 1945:

| | | | |
|---|---|---|---|
| **Date of Construction** | | **Special Design** | |
| 1900-1920 | 40 | Decorative elements | 10 |
| 1921-1930 | 30 | Engineering response | 8 |
| 1931-1940 | 20 | Superstructure and substructure | 6 |
| 1941-1944 | 10 | Superstructure only | 4 |
| **Length of Main Span** | | Substructure only | 2 |
| Steel I-beam >65 feet | 20 | **Structural Integrity** | |
| Steel I-beam >50 feet | 10 | Excellent | 8 |
| Concrete girder >45 feet | 20 | *(original design, materials,* | |
| Concrete girder >40 feet | 10 | *workmanship unaltered)* | |
| Concrete slab >30 feet | 20 | Good | 6 |
| Concrete slab >25 feet | 10 | *(minor damage of original design, materials, workmanship)* | |
| **Overall Bridge Length** | | Fair | 4 |
| Steel I-beam >520 feet | 4 | *(some replacement of original design,* | |
| Steel I-beam >340 feet | 2 | *materials, workmanship)* | |
| Concrete girder >420 feet | 4 | **Site Integrity** | |
| Concrete girder >100 feet | 2 | Excellent | 8 |
| Concrete slab >300 feet | 4 | *(original setting, feeling, and* | |
| Concrete slab >200 feet | 2 | *association is unaltered)* | |
| **Rail Type** | | Good | 6 |
| Types A-J | 14 | *(minor alteration of original setting,* | |
| Special Design | 12 | *feeling, and association)* | |
| Type K or Type L | 10 | Fair | 4 |
| Type M | 8 | *(much change to original setting,* | |
| Type P or Type Q | 6 | *feeling, and association)* | |
| Type R-8 or Type R-10 | 4 | **Sufficiency Rating** | |
| Other post-1940 standard rail | 2 | Excellent to good | 8 |
| | | Satisfactory to poor | 6 |
| | | Serious to failed | 4 |

*1945-1965 Bridges*

*Criterion A*
Under *Criterion A*, bridges built between 1945 and 1965 may have significance based on their association with the transportation history of Texas. To be eligible under *Criterion A*, a bridge must have a direct and significant relationship to an important transportation-related initiative. Initiatives identified in the *Historic Context for Texas Bridges, 1945 to 1965* (October 2009) are:

- Initiative to construct three-level and four-level urban interchanges prior to 1960, as part of a significant shift in the previously-established program to construct grade separation structures. Although grade-separation structures were widely used across Texas prior to World War II, the first three-level interchange was built in 1953 and the first four-level interchange was built in 1958. The most significant three-and four-level structures are those built prior to 1960 as the earliest structures associated with this program.
- Initiative to construct international bridges between Texas and Mexico. Bridges built in association with this program were constructed throughout the subject period and were important in expanding transportation networks between the U.S. and Mexico.
- Initiative to construct all-weather durable bridges for improved access along the Texas Gulf Coast. Bridges built in association with this initiative provided reliable, unimpeded vehicular transportation across large navigable bays and inlets while allowing ships unobstructed access to Texas ports. These structures were built throughout the subject period and were important in enhancing transportation to cities, resorts, and recreation areas along the Texas Coast.

The above list represents known events and trends from the subject period, as identified in the *Historic Context for Texas Bridges, 1945 to 1965*. Other significant events or trends associated with the transportation history of Texas may be added to this list as they are discovered. More specific guidance regarding *Criterion A* significance is provided in TxDOT's *Final Evaluation Methodology, Texas Historic Bridge Inventory, Evaluation of 1945-1965 Bridges* (October 2009).

In addition to possessing significance under *Criterion A*, a bridge must also have historic integrity to be eligible for the National Register. Integrity aspects of location, setting, feeling, and association often best illustrate the structure's association with an important transportation-related theme under *Criterion A*. For this reason, deduction of points for these aspects of integrity was heavily weighted in the evaluation system developed for bridges built between 1945 and 1965. Bridges with major alterations to location, setting, feeling, or association are considered not eligible.

While still important under *Criterion A*, alterations to a bridge's design, workmanship, and materials do not result in the same level of diminished integrity under *Criterion A*. A single major alteration to the bridge's design, workmanship, or materials would not necessarily result in loss of integrity to convey significance under *Criterion A*. In contrast, severe alterations to design, workmanship, or materials that result in extensive integrity loss, such as widening, would result in a loss of integrity.

More specific guidance regarding integrity considerations under *Criterion A* is included in *Final Evaluation Methodology, Texas Historic Bridge Inventory, Evaluation of 1945-1965 Bridges* (October 2009).
*Criterion C*
To be eligible under *Criterion C*, a bridge must possess significance for its distinctive design and construction characteristics, as described above. More specific guidance regarding Criterion C significance is provided in

TxDOT's *Final Evaluation Methodology, Texas Historic Bridge Inventory, Evaluation of 1945-1965 Bridges* (October 2009).

In addition to possessing significance under *Criterion C*, a bridge must also be shown to have historic integrity to be eligible for the NRHP.

Since *Criterion C* relates to the engineering and/or architectural significance of a structure, integrity aspects of design, workmanship, and materials are typically more important because they allow a structure to convey its physical features and characterize the type, period, or method of its construction.

For this reason, deduction of points for these aspects of integrity was heavily weighted in the evaluation system developed for bridges built between 1945 and 1965. Widening of a bridge is considered a severe alteration in relation to design, workmanship, and materials. In nearly all cases, such widening renders a bridge unable to convey its significance.

Other major alterations compromise a bridge's integrity of design, workmanship, and materials. However, the significance of a bridge may outweigh the impact of these alterations, depending on the relative significance of the bridge and the number and severity of the alteration. Examples of alterations in this category are:

- Lengthening of a bridge with new approach spans
- Addition of new structural members
- Replacement of original main members with new material
- Removing main members that were integral to the superstructure
- Repairs of structural connections not consistent with original connections
- Removal of original architectural treatments, not including rails or parapets
- Alterations to character-defining features of a bridge type (e.g., removal of monolithic curb on FS concrete slab)

Minor alterations have some impact on a bridge's design, materials, and workmanship, but are generally not sufficient to render a bridge ineligible for registration. Examples of minor alterations are:

- Historic railing removed and replaced with modern railing
- Guard rail installed over historic railing
- New rail installed on bridge that did not historically have railing
- Installation of sidewalk extension

Alterations to a bridge's location do not result in the same level of diminished integrity under *Criterion C*. Changes to location can result in different degrees of integrity loss under *Criterion C* depending upon the physical alterations to character-defining features that occurred after the relocation of the bridge.

Alterations to a bridge's setting, feeling, and association do not detract from a bridge's engineering significance. Therefore, changes relating to these aspects do not result in integrity loss.

More specific guidance regarding integrity considerations under *Criterion C* is included in *Final Evaluation Methodology, Texas Historic Bridge Inventory, Evaluation of 1945-1965 Bridges* (October 2009).

H. Summary of Identification and Evaluation Methodology

## 1. Introduction

This multiple property listing represents a synthesis of several historic bridge and historic roadway inventories and studies conducted by TxDOT from the late 1980s to 2012. A previous multiple property listing for historic bridges in Texas was completed in 1996 as a product of Phase I of the Texas Historic Bridge Inventory. The 1996 listing focused on historic context and registration requirements relating to metal truss vehicular bridges. Later phases of the Texas Historic Bridge Inventory covered additional bridge types and periods of construction. From 2009 to 2012, TxDOT also undertook a study to develop identification, documentation, and evaluation methods for historic roadways. The following discussion provides a synopsis of preceding bridge inventory phases and other studies compiled within this listing.

## 2. Historic Road Corridors

The methodology for identification and evaluation of road corridors within Texas utilized a variety of sources including NRHP Bulletins, NRHP nominations, context studies/survey reports, historic maps and construction plan sheets, topic-specific books and articles, tourist literature, and city and county histories.

Currently, the NPS and THC do not provide guidance for evaluating road corridors. NRHP Bulletins #15 *How to Apply the National Register Criteria for Evaluation*, #16A *How to Complete the National Register Registration Form*, and #16B *How to Complete the National Register Multiple Property Documentation Form* outline general requirements for eligibility and listing of historic properties. NRHP Bulletin #30 *Guidelines for Evaluating and Documenting Rural Historic Landscapes* explains types of historic landscapes (including transportation systems) and the methods for evaluating their significance. While an appropriate general resource, the bulletin lacks a comprehensive analysis of these transportation systems and how road-related resources fit into the overall integrity and significance discussion. *Historic Roads in the National Park System* is an in-depth historical overview and guide for examining the significance of and preserving historic park roads and parkways. Most appropriate for this task is its examination of the road and its road-related resources as interrelated components within a larger system, rather than as individual resources.

Several NRHP nominations also proved helpful in creating a methodology for surveying roadways. Different segments of Route 66 were examined and nominated as multiple property submissions including *Route 66 in Texas, Historic US Route 66 in Arizona, Historic Resources of Route 66 in Kansas, Route 66 and Associated Resources in Oklahoma, and Historic and Architectural Resources of Route 66 through New Mexico,* among others. These nominations use the same standard evaluation criteria for examining the corridor and its extant segments. The criterion translates appropriately into analyzing other potentially historic road corridors (more discussion below).

Context studies/survey reports outline the history of areas with transportation-related resources and some provide guidance for examining these resources and long-term preservation planning. For example, the *Nebraska Historic Buildings Survey Historic Highways in Nebraska* examines selected historic highways within the state and provides registration requirements for listing historic road corridors and segments.

Historic maps and construction plan sheets are also invaluable to determining original road alignments. Maps include Sanborn Insurance maps, those found in the Texas Historic Overlay Map collection and the Portal to Texas History website, and those available at the Texas General Land Office, Texas State Archives, Perry-Castañeda

Library, and local repositories. Construction plan sheets and Record of State Control Numbers, Sections, and Jobs (CSJ) files at TxDOT also provide road alignment and individual construction project information for roadways under state control. County Commission Minutes at county courthouses show the ownership of different segments of the roadway and funding sources for the construction and maintenance of the roads.

Many books and articles provide an overview of road history in the U.S. The works viewed thus far include Howard Preston's *Dirt Roads to Dixie: Accessibility and Modernization in the South* and James Tucker's *The American Road: A Non-Engineering Manual for Practical Road Builders.* Tourist literature including Automobile Blue Books and various promotional pamphlets and brochures at local repositories reflect the popular trends of the era, as well as often providing maps and photographs of transportation-related resources. Finally, county and city histories available at local repositories provide historic context for the different roadways.

### 3. Pre-1945 Metal Truss Inventory (1985-1996)

TxDOT began its statewide Historic Bridge Inventory with documentation and evaluation of about 1,170 metal truss bridges. Primary tasks within this inventory included:

- 1985-1986: Inclusive field survey and documentation for all metal truss and suspension vehicular bridges inspected as part of TxDOT's bridge inspection program.
- 1987-1988: Initial historic context development, providing an overview of Texas transportation trends.
- 1988-1990: Local research using county records and County Historical Commission input.
- 1988 – c.1995: Focused research on bridge builders working in Texas in the late 1800s and early 1900s.
- 1988 – c.1995: Additional contextual research, including focused research using TxDOT records.
- 1988 – 1989: Initial evaluation of metal truss bridges for significance, using a qualitative approach for assessing historical associations under *Criterion A* and *Criterion B* and a separate quantitative approach for assessing engineering and technological significance under *Criterion C*.
- 1989-1994: More detailed analysis of significance and integrity considerations for metal truss bridges with emphasis on the 66 surviving metal truss bridges designed by the THD. More in-depth information regarding evaluation methods used for this inventory phase are found in the internal TxDOT reports *Texas Historic Bridge Inventory* (May 1989), *Summary of Evaluations of Highway Department Designed Metal Truss Bridges for National Register Eligibility Under Criterion C* (March 1994), and Section H of the NRHP multiple property listing *Historic Bridges of Texas 1866-1945* (September 1996).

This inventory phase resulted in preparation of a NRHP multiple property nomination and associated historic context, both titled *Historic Bridges of Texas 1866-1945*. The study period was defined as beginning with the construction of the Waco Suspension Bridge—the earliest example of major bridge construction in Texas—and ending in 1945 to reflect the typical 50-year age rule for NRHP eligibility. The geographic scope of the inventory and the resulting multiple property document encompassed the State of Texas, including bridges at state boundaries and international borders. The 1996 multiple property document included property type discussion and registration requirements for metal truss bridges, with blank placeholders inserted for other bridge types to be evaluated in future inventory phases. Individual nominations were completed for TxDOT-owned metal truss bridges that met criteria for NRHP eligibility using the registration requirements developed for the multiple property document. The individual nominations were submitted with the multiple property nomination. The multiple property document and individual nominations were completed by TxDOT in September 1996 and were accepted by the NPS in October 1996.

The 1996 multiple property document was an important cornerstone for TxDOT's bridge inventory and evaluation program. However, with the passage of time, several shortcomings became evident. As written, it was difficult to understand or replicate the specific reasoning for a bridge's eligibility status using the evaluation system. Some portions of the registration requirements were left open-ended to allow leeway for professional judgment. While sometimes useful, the vagueness also added to subjective and often differing interpretations of a bridge's significance and integrity. Finally, the number of remaining metal truss bridges has greatly diminished since the early 1990s, with only 200 to 210 trusses remaining in vehicular service in 2012. The reduced numbers, combined with evolving ideas on understanding and evaluating the significance of metal truss bridges, pointed to the need for a revised metal truss evaluation system.

### 4. Pre-1945 Metal Truss Re-Evaluation (2011 -2013)

In 2012-2013, TxDOT developed new property type descriptions, significance statements, and registration requirements for National Register eligibility of metal truss bridges under *Criterion C*. At the same time, the historic context of the 1996 multiple property document was revised and reformatted to more clearly differentiate between themes relating to historical associations and those relating to engineering or technological significance. The revised context information is provided in Section E of this document. Property type information and registration requirements are in Section F of the document.

TxDOT commissioned a comprehensive survey of remaining in-service vehicular metal truss bridges. Field investigations took place in fall 2012, with survey and evaluation forms to be completed in August 2013. The trusses were organized by subtypes recognized in the literature, including the Historic American Engineering Record, which in turn is driven by geometry, structural behavior, and developmental history. Registration requirements were based the characteristics that distinguish the sub-types from each other. The threshold for rare/uncommon type was based on the observation of the subtype census numbers between Warren parallel ponies and all other subtypes dramatically breaks around twenty. Integrity standards were drafted based on initial field observations of Pratt through and Warren pony trusses. Further refinements to integrity standards were made with input from field reports and general observations of trusses by the contributors over an extended period.

Of the 208 trusses surveyed 48 are owned by TxDOT (on-system) and the remaining 150 are locally owned by cities and counties (off-system). By sub-type, the survey identified 82 Warren parallel ponies, 21 Pratt throughs, 20 Warren polygonal ponies, 18 Parker throughs, 8, Warren throughs (excluding Warren continuous), 5 Pratt ponies, and 4 Camelback throughs. All other subtypes have populations of 3 or less.

### 5. Suspension Inventory

The few suspension bridges remaining in vehicular service were initially surveyed and evaluated in Phase I of the Texas Historic Bridge Inventory, along with the metal truss bridges. However, no historic context, property type information, or registration requirements were included in the 1996 historic bridge multiple property submission. TxDOT sponsored Historic American Engineering Record documentation of several suspension bridges in 1996 and 2000. This information was used as contextual information, property type analysis, and as a starting point for developing registration requirements for suspension bridges. Criterion C registration requirements were based on the nature and extent of the 1997 and 2009 rehabilitations of the Regency and Beveridge Bridges successfully coordinated with SHPO. See Figure 54 for a location map and elevations.

### 6. Depression-Era Work-Relief Bridges

TxDOT undertook a study of Depression-era road corridors and bridges between 1993 and 2000. The study included substantial historical and archival research, historic context development, field investigations, and NRHP evaluation. The study took place concurrently with a survey and evaluation of TxDOT's Depression-era roadside parks. The focus of both studies was potential *Criterion A* significance of road features for documented and important associations with Depression-era work-relief agencies, and potential *Criterion C* significance for use of stone masonry materials and intensive hand-labor craftsmanship typical of the Rustic style.

TxDOT used district and area office staff to identify and document extant examples of bridges, culverts, and other road-related features within TxDOT right-of-way. The field documentation also extended to bridges with masonry features located on local and county roads. The survey efforts relied on guidance and survey forms developed by historians in TxDOT's Environmental Affairs Division. Using the initial survey and follow-up intensive-level survey when warranted, TxDOT historians evaluated Depression-era bridges and road corridors that contained stone-masonry features. It should be noted that this survey was not mutually exclusive of other bridge inventories. For example, a Depression-era bridge with stone masonry headwalls and substructure was evaluated through this study based on the specific themes noted above, but was also examined as part of the more generalized study of pre-1945 non-truss bridges.

The study did not produce a stand-alone historic context. Historical research conducted in 2009 for this MPS instead identified historic context drafts, registration requirements, and other relevant information in files housed at TxDOT's Environmental Affairs Division. TxDOT anticipates reevaluating these resources in the near future.

### 7. Pre-1945 Slab, Beam, Girder, and Arch Bridges

This second phase of the statewide Historic Bridge Inventory, conducted between 1996 and 2001, evaluated a select group of non-truss bridges constructed before 1950. The pool of bridges was diverse, including a wide range of periods, bridge types, and methods of construction. Bridge types evaluated for the survey included: masonry arch, concrete arch, concrete slab, concrete girder, steel I-beam, fabricated steel girder, and moveable span structures.

The survey and evaluation of the pre-1950 non-truss bridges was completed in three phases. The first phase gathered structural data and performed an initial screening of approximately 40,000 non-truss bridges. The second phase focused on the survey and photo-documentation of 1,032 bridges that were entered in the baseline inventory. The final phase of the project researched and determined the

NRHP eligibility of 467 bridges possessing engineering significance. From this pool, 137 bridges were determined eligible for the NRHP for their engineering significance under *Criterion C* at the state level of significance. Another 102 structures were placed in a reserve group of potentially eligible bridges. These bridges were selected to represent the best examples of each evaluated bridge type and illustrate the distinct periods of bridge building in the first half of the twentieth century in Texas.

### 8. Bridges Constructed Between 1945 and 1965

TxDOT worked with historic preservation consultants to inventory Texas vehicular bridges constructed between 1945 and 1965, regardless of type. A historic context was prepared between 2004 and 2009 with emphases on identifying significant themes under NRHP *Criterion A* in the area of *Transportation* and NRHP *Criterion C* in the

area of *Engineering*. Of particular importance were post-World War II trends in the use of technological innovations and standardization in bridge design and construction.

A preliminary draft context was used in conjunction with TxDOT bridge inspection data, database analysis, and oral interviews to identify bridges that had potential to be eligible for the NRHP. Some types of bridges, such as bridge-class culverts and timber stringer bridges, were categorically determined not eligible and were removed from further study. Widened bridges were also considered categorically not eligible for listing based on severe integrity loss.

An evaluation system was developed to further assess the bridges' significance under *Criterion A* and *Criterion C*, as well as integrity considerations. The evaluation system was primarily quantitative in nature but retained provision for using professional judgment to refine the results of the rating system. The physical condition of the potentially eligible bridges was verified through field survey and documentation, as well as more detailed analysis of bridge inspection files and project construction plans.

A final historic context, evaluation methodology, and project survey forms were completed in late 2009. The revised context information is provided in Section E of this document. Property type information and registration requirements are in Section F of the document.

## I. Bibliography

This bibliography contains a list of sources consulted in the development of this document. Since major portions of this document are taken or adapted from previous TxDOT bridge inventory reports and other studies, including: the existing *Historic Bridges of Texas* Multiple Property Submission (MPS) context developed as part of the 1995 metal truss inventory; the 1999 Depression-era inventory; the 2001 non-truss inventory; and the 2009 inventory of bridges constructed between 1945 and 1965, specific bibliographic information from these previous reports may not be included. Footnotes from the original reports have been included in the text as applicable. Please see the original reports for additional bibliographic information.

Abbe, Donald R. "Hall County," *Handbook of Texas Online*. http://www.tshaonline.org/handbook/online/articles/hch02. Published by the Texas State Historical Association.

-----, "Parmer County," *Handbook of Texas Online.* http://www.tshaonline.org/handbook/online/articles/hcp04. Published by the Texas State Historical Association.

"Abo Road Highway." Drive the Old Spanish Trail website. www.drivetheost.com/abopass.html.

Adams, L.I. *Time Shadows.* Waco, Texas: Davis Brothers Publishing Co., 1971.

"Advances in Design of Superstructure." *Engineering News* 30 (27 July 1893).

"Alamo Iron Works." unpublished brochure. San Antonio: Alamo Iron Works, n.d.

American Association of State Highway Officials. *A Policy on Arterial Highways in Urban Areas.* Washington, D.C.: American Association of State Highway Officials, 1957.

-----. *A Policy on Design Standards: 1-Interstate System, 2-Primary System, 3-Secondary and Feeder Roads.* Washington, D.C.: American Association of State Highway Officials, 1956.

-----. *A Policy on Design Standards: Interstate System.* Washington, D.C.: American Association of State Highway Officials, 1959. Available at McKinney Engineering, University of Texas, Austin, Texas.

-----. *A Policy on Geometric Design of Rural Highways.* Washington, D.C.: American Association of State Highway Officials, 1954.

-----. *A Policy on Grade Separations for Intersecting Highways.* Washington, D.C.: American Association of State Highway Officials, 1944.

-----. *A Story of the Beginning, Purposes, Growth, Activities and Achievements of AASHO.* Washington, D.C.: American Association of State Highway Officials, 1964.

-----. *Historic American Highways*. Washington, D.C.: American Association of State Highway Officials, 1953.

-----. *The History and Accomplishment of Twenty-Five Years of Federal Aid for Highways: An Examination of Policies from State and National Viewpoints.* Washington, D.C.: American Association of State Highway Officials, 1944.

-----. *Map of United States System of Highways Adopted November 11, 1926*. N.p., 1926.

-----. *Standard Specifications for Highway Bridges.* Washington, D.C.: American Association of State Highway Officials, 1957.

Arrowsmith, John. *Map of Texas*. London, 1841.

Atkins, Mark, June Tyler, and Yvonne Jenkins. *Old Alton Bridge.* National Register of Historic Places Registration Form. 1988.

Austerman, Wayne R. *Sharps Rifles and Spanish Mules: The San Antonio–El Paso Main, 1851-1881*. College Station, Texas: Texas A&M University Press, 1985.

Austin Brothers Bridge Company. Archival Photograph Collection, Austin Industries, Dallas., Texas.

-----. "Book of Standard Steel Truss and Beam Span Bridges." Austin Industries, Dallas, Texas.

-----. *Catalog and Handbook for Buyers, Engineers, Builders.* Dallas: Johnston Printing and Advertising Co., 1915.

-----. Contract Records. Austin Industries, Dallas, Texas.

-----. *The Highways.* 1912-1915 issues. Austin Industries, Dallas, Texas.

Austin, Stephen Fuller. *Mapa Original de Texas.* 1829. Texas State Library and Archives Commission. http://www.tsl.state.tx.us/cgi-bin/aris/maps/maplookup.php?mapnum=0917.

-----. *Map of Texas, With Parts of Adjoining States.* Philadelphia, 1833. Texas State Library and Archives Commission. http://www.tsl.state.tx.us/cgi-bin/aris/maps/maplookup.php?mapnum=0409a.

Baker, T. Lindsay. *Building the Lone Star: An Illustrated Guide to Historic Sites.* College Station, Texas: Texas A&M University Press, 1986.

Banks, Ralph K. "An Historical Overview: National Defense and the National System of Interstate and Defense Highways." *Public Works,* (June 1984), 74-80.

-----. "A History of the Bridge Division." N.p., c.1991. Available at Bridge Division, Texas Department of Transportation, Austin, Texas.

-----. "Road to Creation of the Department Not a Smooth One." *Transportation News,* September 1986.

-----. "Short Spans About Bridges, Part III." *County Progress Magazine,* November 1994, 16-17.

-----. "Short Spans About Bridges, Part IV." *County Progress Magazine,* January 1995, 26-27.

Barr, James W. "Interstate Progress Report." *Texas Highways* 6, no. 1 (January 1959): 2-3. Available at Photo Library, Texas Department of Transportation, Austin, Texas.

Bates, Ed F. *History and Reminiscences of Denton County.* Denton, Texas: McNitzky Printing Company, 1918 (reprinted 1976).

Beaumont, Penny, et.al. *Anywhere to Everywhere: The Development of the Interstate Highway System in Texas.* Available from the Texas Transportation Institute at http://tti.tamu.edu/documents/TTI-2006-8.pdf.

Bell County. County Commissioners' Court Minutes. Belton, Texas.

Bell, Wendell. *Fort Griffin Brazos River Bridge.* National Register of Historic Places Registration Form. 1979.

Berlin Iron Bridge Company. *The Berlin Iron Bridge Company: Engineers, Architects and Builders in Iron and Steel.* Hartford: Conn.: Press of Plimpton Manufacturing Co.

Bexar County Highway League. *Bexar County Highway League's Official Log Book for Texas 1914-1915*. San Antonio, Texas: D.E. Colp, 1914.

Bigelow, Lawrence N. "Fifty-Year Development -Construction of Steel Truss Bridges." *ASCE Journal of the Construction Division* 101 (June 1975): 239-257.

Billington, Ray Allen and Martin Ridge. *Westward Expansion: A History of the American Frontier*. New York: University of New Mexico Press, 2001.

"Bills Due This Week to Spend 30 Millions of State Surplus." *The Dallas Morning News.* 12 January 1949.

"The Birth and Growth of History's Most Exciting Building Material," *Civil Engineering* (October 1977),118-120.

"Black Milestones for Neglected Federal Aid Roads." *Municipal Journal* 44, no. 11 (March 16, 1918): 230. Available at books.google.com.

"Bluebonnet Circle Village," City of Fort Worth, Texas website. www.fortworthgov.org/planninganddevelopment/urbanvillages/default.aspx?id=12444.

Bowen, S.W. "The Design and Construction of Four Reinforced Concrete Viaducts at Fort Worth, Texas." *American Society of Civil Engineers Transactions*, Paper no. 1329, 1914.

"Bridge Designers Looking Ahead," *Roads and Streets* 88, no. 7 (July 1945), 100-102.

"Bridge Division Began in 1918." *Highway News* 11, no. 4 (May 1957): 3. Available at Photo Library, Texas Department of Transportation, Austin, Texas.

Britton, Morris L. "Military Road." *Handbook of Texas Online*. http://www.tshaonline.org/handbook/online/articles/exm02. Published by the Texas State Historical Association.

Brosius, Herman. *Bird's Eye View of the City of Dallas Texas 1872.*

Brown, Frank. *Annals of Travis County and of the City of Austin from the Earliest Times to the Close of 1875*. Center for American History, University of Texas at Austin. (Typewritten.)

Brown, Mark. *Bone Crossing Bridge*. Historic American Engineering Record Number TX-29. 1996. Digital images. http://hdl.loc.gov/loc.pnp/hhh.tx0755.

-----. *Broad Street Bridge.* Historic American Engineering Record Number TX-45. 1996. Digital images. http://hdl.loc.gov/loc.pnp/hhh.tx0772.

-----. *Cataract Falls Bridge, Spanning Mill Creek.* Historic American Engineering Record IN-104. 2002.

-----. *Kelley Creek Bridge.* Historic American Engineering Record Number TX-31. 1996. Digital images. http://hdl.loc.gov/loc.pnp/hhh.tx0757.

-----. *Oriana Bridge.* Historic American Engineering Record Number TX-66. 1996. Digital images. http://hdl.loc.gov/loc.pnp/hhh.tx0798.

-----. *South Fork of Hill Creek Bridge.* Historic American Engineering Record Number TX-30. 1996, rev. 1998. Digital images. http://hdl.loc.gov/loc.pnp/hhh.tx0756.

-----. *Texas Suspension Bridges.* Historic American Engineering Record Number TX-98. 2000.

------. *Waters Bluff Bridge.* Historic American Engineering Record Number TX-65. 1996. Digital images. http://hdl.loc.gov/loc.pnp/hhh.tx0797.

Bruce, Arthur G. and John Clarkeson. *Highway Design and Construction.* 3rd ed. Scranton, Penn.: International Textbook Company, 2004. Available at Center for Transportation Research, Austin, Texas.

Bryan, Lieutenant F.T. *Reconnoissances of Routes from San Antonio de Bexar to El Paso Del Norte*. Philadelphia: P.S. Duval's Lithographic Steam Press, 1849.

Bryson, Conrey. "McGinty Club." *Handbook of Texas Online*. http://www.tshaonline.org/handbook/online/articles/vqm01. Published by the Texas State Historical Association.

"Building Bridges Costs Texas Less." *Highway News* 17, no. 9 (September 1963): 6. Available at Photo Library, Texas Department of Transportation, Austin, Texas.

*Burke's Texas Almanac and Immigrant's Hand Book for 1879.* Houston, Texas: N.p., 1879. Available at Texas Department of Transportation Environmental Affairs Division.

Buth, C. Eugene, William F. Williams, Wanda L. Menges, and Rebecca R. Haug. *Retrofit Railings for Truss Bridges, Report No. FHWA/TX-05/0-4419-5*. College Station, Texas: Texas Transportation Institute, October 2005.

Butler, John L. *First Highways of America*. Iola, WI, Krause Publications, 1994.

Bygone Byways. http://home.comcast.net/~bygonebyways/.

California Department of Transportation. *State Highway Bridges of California,* Sacramento, Cal., 1990.

California Division of Highways. *Manual of Bridge Design Practice*, 2nd ed. [Sacramento, Calif.]: State of California Highway Transportation Agency, Department of Public Works, Division of Highway, Bridge Department, 1963.

Caldwell County. County Commissioners' Court Minutes. Lockhart, Texas.

Calvert, Robert A. "Texas Since World War II." *Handbook of Texas Online*. http://www.tshaonline.org/handbook/online/articles/npt02. Published by the Texas State Historical Association.

Calvert, Robert A. and Arnoldo De Leon. *The History of Texas.* Arlington Heights, Ill.: Harlan Davidson, Inc., 1990.

Campbell, Randolph B. *Gone to Texas: A History of the Lone Star State*. New York: Oxford University Press, 2003.

Canion, J.R. *The Historical Background and Development of Road Building in Texas.* Master's Thesis at the University of Texas at Austin, 1936.

Carroll, B.H., ed. *Standard History of Houston, Texas.* Knoxville, Ten.: H.W. Crew & Co., 1912.

Carroll, H. Bailey. "Santa Fe Trail." *Handbook of Texas Online*. http://www.tshaonline.org/handbook/online/articles/SS/exs3.html. Published by the Texas State Historical Association.

Carter, O.K. "The biggest reason for Arlington's decades-long boom." *Fort Worth Star-Telegram*. 30 August 2007: B-2.

Carver, George L. "The Interstate System Survey," in *Proceedings of the Twenty-Third Annual Short Course in Highway Engineering*, ed. Fred J. Benson. College Station, Texas: Texas Engineering Experiment Station, A&M College of Texas, 1949.

Carver, M. "Driving the Dixie: The Development of the Dixie Highway Corridor." *SCA Journal* 13, no. 1 (1994-95, Fall-Winter).

Carver, Martha. *Tennessee's Survey Report for Historic Highway Bridges.* Prepared for the Tennessee Department of Transportation. Nashville, Tenn.: Ambrose Printing Company, 2008.

Casbeer, Dick, Ron Koester, and Frank Leos. Interviews by Mead & Hunt, Inc. and TxDOT Bridge Division, Texas Department of Transportation. Waco District Bridge Office, Waco, Texas. 16 October 2006.

Cassity, Michael. *Route 66 Corridor National Historic Context Study*. Prepared for the Route 66 Corridor Preservation Program, National Park Service. 2004.

"Celebration At Liberty On Completion Of Concrete Highway Shows Magnitude of East Texas Highway Development." *Texas Highway Bulletin* 7, no. 2 (July 1927).

"Central National Road." *Handbook of Texas Online*. http://www.tshaonline.org/handbook/online/articles/CC/erc1.html. Published by the Texas State Historical Association.

Chilton, F.B. *Latest Map of Texas*. Immigration Bureau of the State of Texas, 1888.

Chung, Estella M. *Brushy Creek Bridge*. Historic Engineering Record Number TX-59. 1996, rev. 1998. Digital images. http://hdl.loc.gov/loc.pnp/hhh.tx0791.

-----. *Bryant Station Bridge*. Historic Engineering Record Number TX-60. 1996. Digital images. http://hdl.loc.gov/loc.pnp/hhh.tx0792.

-----. *Fort Griffin Iron Truss Bridge.* Historic Engineering Record Number TX-63. 1996, rev. 1998 by Justin M. Spivey. Digital images. http://hdl.loc.gov/loc.pnp/hhh.tx0795.

-----. *Jimmie's Creek Bridge.* Historic Engineering Record Number TX-54. 1996, rev. 1998 by Barbara Stocklin. Digital images. http://www.loc.gov/pictures/item/TX0785/.

-----. *Stephenville Crossing Bridge.* Historic Engineering Record Number TX-57. 1996, rev. 1998 by Barbara Stocklin. Digital images. http://hdl.loc.gov/loc.pnp/hhh.tx0789.

------. *Sycamore Creek Bridge*. Historic Engineering Record Number TX-58. 1996, rev. 1998. Digital images. http://hdl.loc.gov/loc.pnp/hhh.tx079.

------. *Ward Brazos River Bridge.* Historic Engineering Record Number TX-67. 1996, rev. 1998 by Justin M. Spivey. Digital images. http://hdl.loc.gov/loc.pnp/hhh.tx0799.

Church, D.W. "Wrought Iron Bridges Built by Wrought Iron Bridge Co." Pamphlet, Canton, Ohio, 1995.

Clark, Victor S. *History of Manufactures in the United States, 1860-1914.* Washington, D.C.: Carnegie Institution of Washington, 1928.

*Clason's Guide Map: Texas and Northern Mexico*. Chicago: Clason Map Co., 1924.

*Clason's Texas Guide Map to Texas and Northern Mexico*. Chicago: Clason Map Co., 1931.

Cleeland, Teri. *Historic US Route 66 in Arizona*. National Register of Historic Places Multiple Property Documentation Form. Washington, D.C.: National Register of Historic Places, National Park Service, 1988.

Clouette, Bruce and Matthew Roth. *Connecticut's Historic Highway Bridges.* Hartford, Conn.: Connecticut Department of Transportation, 1991.

Cockrell, Frank M. "History of Early Dallas." 1944 reprint of article published in *Dallas News*, 1932.

Colorado County Historical Commission, comp. *Colorado County Chronicles.* Austin, Texas: Nortex Press, 1986.

*Colton's New Map of the State of Texas*. New York: J.H. Colton, 1858.

*Colton's Texas*. New York City: G.W. and C.B. Colton & Co., 1871.

"Commission Approves Third Interstate Phase." *Highway News* 11, no. 1 (February 1957): 2. Available at Photo Library, Texas Department of Transportation, Austin, Texas.

Commission of Control for Texas Centennial Celebrations. *Monuments Erected by the State of Texas to Commemorate the Centenary of Texas Independence*. Austin: The Steck Company, 1939.

Committee on History and Heritage of American Civil Engineering, ed. *American Wooden Bridges*. New York: American Society of Civil Engineers, 1976.

Commonwealth of Pennsylvania. *Historic Highway Bridges in Pennsylvania.* Published by the Pennsylvania Historical and Museum Commission and the Pennsylvania Department of Transportation, 1986.

"Compromise Sought on State Tax Bill." *The Dallas Morning News.* 13 May 1951.

Comp, T. Allan and Donald Jackson. "Bridge Truss Types: A Guide to Dating and Identifying." *History News* 32, no. 5 (May 1977).

Condit, Carl. *American Building Art: The Nineteenth Century.* New York: Oxford University Press, 1960.

--------. *American Building Art: The Twentieth Century.* New York: Oxford University Press, 1960.

--------. *American Building: Materials and Techniques from the Beginning of the Colonial Settlements to the Present.* Chicago: University of Chicago Press, 1968.

Cook, Richard J. *The Beauty of Railroad Bridges.* San Marino, Calif.: Golden West Books, 1987.

Cooper, James L. *Artistry and Ingenuity in Artificial Stone: Indiana's Concrete Bridges, 1900-1942*. Greencastle, Ind.: J.L. Cooper, 1997.

-----. *Iron Monuments to Distant Prosperity: Indiana's Metal Bridges, 1870-1930.* n.p., 1987.

Cooper, Theodore. *American Railroad Bridges.* New York: Engineering News Publishing Company, c. 1890.

*Correct Map of Texas.* St. Louis, Mo.: Woodward, Tiernan, & Hale, 1878.

"County Road News." *Texas Highway Bulletin* 3, no. 6 (June 1923).

"County Road News." *Texas Highway Bulletin* 4, no. 8 (August 1924).

"County Road News." *Texas Highway Bulletin* 4, no. 10 (October 1924).

"County Road News." *Texas Highway Bulletin* 4, no. 11 (November 1924).

"County Road News." *Texas Highway Bulletin* 8, no. 2 (February 1928).

"County Road News," *Texas Highway Bulletin* 8, no. 4 (April 1928).

Creuzbauer, Robert. *J. De Cordova's Map of the State of Texas.* N.p.: J. De Cordova, 1851.

-----. *A Map to Illustrate the Most Advantageous Communication from the Gulf of Mexico and the Mississippi Valley to California.* New York: Mayer & Karff, 1849.

Cushman, Gregory T. "Environmental Therapy for Soil and Social Erosion: Landscape Architecture and Depression-Era Highway Construction in Texas," in *Environmentalism in Landscape Architecture*, Michel Conan, ed., 45-70. Washington, D.C.: Dumbarton Oaks, 2000.

Dallas County Heritage Society and the Dallas Historical Society. "A Transportation Time Line." *Legacies: A History Journal for Dallas and North Central Texas* vol. 1 (Spring 1995).

"Dallas – Fort Worth Turnpike." *Texas Highways* 4, no. 12 (December 1957): 22. Available at Photo Library, Texas Department of Transportation, Austin, Texas.

Dallek, Robert. *Lyndon B. Johnson: Portrait of a President*. New York: Oxford University Press, 2004.

Darnell, Victor C. *Directory of American Bridge-Building Companies, 1840-1900.* Washington, D.C.: Society for Industrial Archeology, 1984.

-----. "The National Bridge and Iron Works and the Original Parker Truss." *Journal of the Society for Industrial Archeology* 24(2), 1998.

Dase, Amy E. *Brazoria Bridge*. National Register of Historic Places Registration Form. 1991.

Dean, W. E. "Continuous and Cantilever Bridges with Precast-Prestressed Concrete Beams," in *Proceedings Convention Committee Meeting Papers, New York, New York, October 5-7, 1965*. Washington, D.C.: American Association of State Highway Officials, General Offices, 1965.

DeLony, Eric. *Landmark American Bridges.* New York: American Society of Civil Engineers, 1993.

Department of Agriculture and Bureau of Public Roads. *The Federal Aid Highway System – Progress Map – North Central Texas*. N.p., 1931.

Department of Economic Development. "State's top community development projects honored." 12 April 2011. http://web.archive.org/web/20040503212353/http://pio.neded.org/press/2001/01rel21.htm.

*Description of Best Route from Austin to San Antonio, Texas*. N.p: 1865[?]. Texas State Archives Map Number 1004e. Texas State Library and Archives Commission. http://www.tsl.state.tx.us/cgi-bin/aris/maps/maplookup.php?mapnum=1004e.

"The Developments of the Nineteenth Century in Bridge Design and Construction." *Engineering News* 44 (December 13, 1900).

DeWitt Carlock Greer Collection, Center for American History, University of Texas at Austin.

"Dixie Overland Highway." *American Roads*. http://www.americanroads.us/autotrails/dixieoverland.html.

Draffin, Jasper O. "A Brief History of Lime, Cement, Concrete and Reinforced Concrete." *Journal of the Western Society of Engineers* 48, no. 1 (March 1943), 14-47.

Dunn, Jeff. "The Development of Automobile Roads in Dallas County, 1905-1926." *Legacies: A History Journal for Dallas and North Central Texas* XII, no. 1 (Spring 2000): 13-28.

Ecker, Pam S. "The Historic Context of the Dixie Highway." U.S. Highways – U.S. 1 to (U.S. 830). http://www.us-highways.com/tzimm/ecker.htm.

Edwards, Nathaniel Llewellyn. "The Evolution of Early American Bridges." Abstract of paper read at Craxton Hall, Westminster, England, March 15, 1933.

-----. *A Record of History and Evolution of Early American Bridges.* Orono, Maine: University Press, 1959.

*El Camino Real de los Tejas National Historic Trail* Association. 2009. http://www.elcaminorealdelostejas.org/.

*EI Paso City Directory, 1920.* EI Paso: Hudspeth Directory Co., 1920.

Eppinger, J. and F.C. Baker. *Map of Texas Compiled from Surveys Recorded in the General Land Office*. 1851.

Erlichman, Howard J. *Camino del Norte: How a Series of Watering Holes, Fords, and Dirt Trails Evolved into Interstate 35 in Texas*. College Station, Texas: Texas A&M University Press, 2006.

"Federal Aid: Fiscal Years 1928-1944." Unpublished notes. Located in Depression-era Files, Texas Department of Transportation, Environmental Affairs Division.

Federal Highway Administration. "The Dwight D. Eisenhower National System of Interstate and Defense Highways." http://www.fhwa.dot.gov/reports/routefinder/.

-----. "Historic Roads." http://www.environment.fhwa.dot.gov/histpres/roads.asp

-----. "Highway Statistics Summary 1995, Section IV: Highway Finance." http://www.fhwa.dot.gov/ohim/summary95/text/hf.html.

-----. "Right of Passage: The Controversy Over Vertical Clearance on the Interstate System." http://www.fhwa.dot.gov/infrastructure/50vertical.cfm

-----. "The Trail Blazers: Brief History of the Direct Federal Highway Construction Program." http://www.fhwa.dot.gov/infrastructure/blazer01.cfm.

-----. "U.S. 82." http://www.fhwa.dot.gov/highwayhistory/us82.cfm.

Fehrenbach, T.R. *Lone Star: A History of Texas and the Texans.* New York: Macmillan Publishing Co., 1968.

Ferris, Herbert W., compiler. *Historical Record, Dimensions and Properties of Rolled Shapes, and Steel and Wrought Iron Beams and Columns.* New York: American Institute of Steel, 1953.

Fidler, T. Claxton. *A Practical Treatise on Bridge Construction.* London: Charles Griffin and Company, 1887.

Findlayson, J. *Mexico and Internal Provinces*. 1820. Texas State Library and Archives Commission. http://www.tsl.state.tx.us/cgi-bin/aris/maps/maplookup.php?mapnum=0360.

Flook, Jerry. "History of the Bankhead Highway: Presented in the Context of Experience of Garland, Texas, a City on Its Route." *Douglas Athas | City Council District 1 Representative and Mayor Pro Tem Garland, Texas*. 2009. http://douglasathas.net/blogs/index.php/2009/08/16/bankhead_flook4.

"The FM Program for 1965." *Texas Highways* 12, no. 7 (July 1965): 11. Available at Photo Library, Texas Department of Transportation, Austin, Texas.

"Ford and Neighbors Trail." *Handbook of Texas Online*. http://www.tshaonline.org/handbook/online/articles/exf01. Published by the Texas State Historical Association.

Fossey, Will. "Old Spanish Trail." *Handbook of Texas Online*. http://www.tshaonline.org/handbook/online/articles/OO/ero1.html. Published by the Texas State Historical Association.

Fowler, Charles Evan. "American Bridge Shop Methods." *Cassier's Magazine* 17 (January 1900).

Fraser, Clayton B. *Highway Bridges of Colorado*. National Register of Historic Places Multiple Property Documentation Form. 2000.

-----. *Vehicular Bridges in Arizona 1880-1964*. National Register of Historic Places Multiple Property Documentation Form. 2008.

*Gallup's Map of Texas*. Kansas City, Mo.: F.E. Gallup Map Company, 1920.

"The Galveston County (Texas) Highway Bridge." *Engineering News* 31 (8 March 1894).

Gammel, H.P.N. *The Laws of Texas.* vol. VIII. Houston: Gammel Publishing Co., 1874.

-----. *The Laws of Texas.* vol. IX. Houston: Gammel Publishing Co., 1898.

-----. *The Laws of Texas, 1822-1897, Volume X*. Austin, Texas: The Gammel Book Company, 1898.

Gard, Wayne. "Shawnee Trail." *Handbook of Texas Online*. http://www.tshaonline.org/handbook/online/articles/SS/ays2.html. Published by the Texas State Historical Association.

*General Laws of the State of Texas.* Austin, Texas: Von Boeckmann-Jones Co., 1907.

"Giant Step in Interstate Progress." *Texas Highways* 11, no. 1 (January 1964): 10-11. Available at Photo Library, Texas Department of Transportation, Austin, Texas.

Gilchrist, Gibb. *Texas Highway Department 1927-1937.* N.p., 1937. Available at Photo Library, Texas Department of Transportation, Austin, Texas.

Gliddon, Reverdy T. *Texas Highway Administration*. Master's Thesis at the University of Texas at Austin, 1951.

"Golden Anniversary, Texas Highway Department, 1917-1967." *Texas Highways* 14, no. 9 (September 1967). Available at Environmental Affairs Division, Texas Department of Transportation, Austin, Texas.

Goode, Preston C. *The Texas Farm to Market Road Program in Perspective, 1945-1970.* Austin, Texas: N.p., April 1971. Available at Reference Documents Collection, Texas State Library, Austin, Texas.

Goujon, J. *A Map of Louisiana and Mexico.* 1820. Texas State Library and Archives Commission. http://www.tsl.state.tx.us/cgi-bin/aris/maps/maplookup.php?mapnum=1024.

Greene, A.C. *900 Miles on the Butterfield Trail*. Denton, Texas: University of North Texas Press, 1994.

"Greer Addresses Road Federation." *Texas Highways* 12, no. 6 (June 1965): 10-12. Available at Photo Library, Texas Department of Transportation, Austin, Texas.

Greer, Dewitt C. "Access Control One Way of Restoring Traffic Stability." *Better Roads*. October 1956.

-----. Administrative Circular No. 32-44, 8 July 1944. Administrative Circulars – Texas Highway Department Correspondence.

-----. "Expressways." *Texas Highways* (n.d.): 8-11. Available at Photo Library, Texas Department of Transportation, Austin, Texas.

-----. "The Future of Highways and Highway Transportation." *Texas Highways* 8, no. 3 (March 1961): 14-17. Available at Photo Library, Texas Department of Transportation, Austin, Texas.

-----. *History of the Texas Highway Department*. Austin, Texas: Texas Highway Department, 1959.

-----. "Subject: Design Standards for Farm to Market Roads." *Administrative Circular No. 23-62.* 7 February 1962.

-----. "Subject: Culvert Standards." *Administrative Circular 123-64.* 17 November 1964.

Gruen, J. Philip. *Canadian River Wagon Bridge.* Historic Engineering Record Number TX-41. 1996. Digital images. http://hdl.loc.gov/loc.pnp/hhh.tx0767.

-----. *Coryell County Historic Bridge.* Historic Engineering Record Number TX-55. 1996, rev. 1998. Digital images. http://hdl.loc.gov/loc.pnp/hhh.tx0786.

----. *Rainbow Bridge.* Historic Engineering Record Number TX-43. 1996, rev. 1998. Digital images. http://hdl.loc.gov/loc.pnp/hhh.tx0769.

Guise, David. "The Evolution of the Warren, or Triangular Truss." *IA: The Journal of the Society for Industrial Archeology* 32, no. 2 (2006).

Hagan, Hilton. *An Informal History of the Texas Department of Transportation.* [Rev.] ed. [Austin, Texas]: Texas Department of Transportation, Public Information Office, 1991. Available at Reference Documents Collection, Texas State Library, Austin, Texas.

Hannaford, Jean T. "Old Preston Road." *Handbook of Texas Online*. http://www.tshaonline.org/handbook/online/articles/OO/exo3.html. Published by the Texas State Historical Association.

Hardman, Peggy. *Keller-Haslet Road Bridge.* Historic Engineering Record Number TX-86. 1996. Digital images. http://hdl.loc.gov/loc.pnp/hhh.tx0954.

----. *Maury Maverick Bridge.* Historic Engineering Record Number TX-82. 2000. Digital images. http://hdl.loc.gov/loc.pnp/hhh.tx0950.

Harper, Robert. "Roads for Defense." *County Progress,* August 1940.

Hart, Lisa. "Defining Historic Road Corridors: The Texas Perspective." Presented at Preserving the Historic Road 2008. Albuquerque, New Mexico. 2008.

Havins, Thomas R. *Something about Brown (A History of Brown County, Texas).* Brownwood, Texas: Banner Printing Company, 1958.

Hayden, Martin. *The Book of Bridges: the History, Technology and Romance of Bridges and Their Builders.* New York: Galahad Books, 1976.

Haywood, Robert C. "Jones and Plummer Trail." *Handbook of Texas Online*. http://www.tshaonline.org/handbook/online/articles/JJ/exj1.html. Published by the Texas State Historical Association.

-----. "Potter-Blocker Trail." *Handbook of Texas Online*. http://www.tshaonline.org/handbook/online/articles/PP/ayp1.html. Published by the Texas State Historical Association.

-----. "Tascosa-Dodge City Trail." *Handbook of Texas Online*. http://www.tshaonline.org/handbook/online/articles/TT/ext4.html. Published by the Texas State Historical Association.

-----. *Trails South: The Wagon-Road Economy in the Dodge City–Panhandle Region.* Norman, Okla.: University of Oklahoma Press, 1986.

Hempill, Hugh. "Early Automobiles in San Antonio: 1899-1916." Texas Transportation Museum, http://www.txtransportationmuseum.org/ECH.htm.

Hess, Jeffrey A. "Final Report of the Minnesota Historic Bridge Survey: Part 2." Prepared for Minnesota Historical Society and Minnesota Department of Transportation, St. Paul, Minn., August 1988.

Hewes, Laurence I. and Clarkson H. Oglesby. *Highway Engineering*. New York: John Wiley & Sons, Inc., 1954.

HHM, Inc. *Preliminary Guidelines for Assessing NRHP Eligibility for Texas Roadside Parks*. Prepared for Texas Department of Transportation, 2005.

Hill, J. Rutledge. "Problems of the Postwar Contractor." *Roads and Streets,* (May 1945).

*Highway Map of Texas*. Austin, Texas: Texas State Highway Department, 1919.

*Highway Map of the State of Texas*. Austin, Texas: Texas State Highway Department, c.1922.

"Highways." *Encyclopedia of Oklahoma History and Culture*. http://digital.library.okstate.edu/encyclopedia/entries/H/HI004.html.

HNTB Corporation, *Selected Historic Context for Hwy 20 (Alameda from Glenwood to Loop 375)*, prepared for the Texas Department of Transportation, 2006.

Historic Roads. http://www.historicroads.org/

Hofsommer, Donovan L. "Missouri-Kansas-Texas Railroad," *Handbook of Texas Online* http://www.tshaonline.org/handbook/online/articles/eqm08. Published by the Texas State Historical Association.

Hool, George A. and W.S. Kinne, eds. *Movable and Long-Span Steel Bridges.* 2d ed. New York: McGraw-Hill Book Company, Inc., 1943.

Hosen, Frederick E. *The Great Depression and the New Deal.* Jefferson, N.C.: McFarland & Company, Inc., Publishers, 1992.

Houston, Major D.C. *Department of the Gulf Map No. 14: Eastern and Central Texas.* N.p., Feb. 1864.

Huddleston, John David. *Good Roads for Texas: A History of the Texas Highway Department, 1917-1947*. College Station, Texas: Doctoral Dissertation at the Graduate College of Texas A&M University, 1981.

"Hug-The-Coast Highway Picturesque Route." *Texas Highway Bulletin* 8, no. 2 (February 1928).

Humble Oil and Refining Company. *Highways of Texas*. Houston: Humble Oil and Refining Co., 1924.

Hunt, William R. "Roscoe, Snyder and Pacific Railway," *Handbook of Texas Online*. http://www.tshaonline.org/handbook/online/articles/eqr13. Published by the Texas State Historical Association.

-----, "Roscoe, TX," *Handbook of Texas Online*. http://www.tshaonline.org/handbook/online/articles/hjr13.. Published by the Texas State Historical Association.

Imberman, Eli Woodruff. "The Formative Years of the Chicago Bridge and Iron Company." Ph.D. dissertation, University of Chicago, 1973.

Ingalls, Marlin R. *Iowa's Historic Automobile Roads: A National Register Study of Pre-1948 Arterial Highways.* Project Completion Report 32, no. 16. Prepared for Iowa Department of Transportation. Iowa City, Iowa: Highway Archaeology Program, University of Iowa, 2009.

International & Gt. Northern Railroad Co. *Correct Map of Texas*. St. Louis: Woodward, Tiernan & Hale, 1878.

"The International Meridian Highway – U.S. Highway No. 81 Bulletin, June 9, 1927." Available in the collection of the F.A. Long Papers (Manuscript collection of the Nebraska State Historical Society, Lincoln, Neb.).

Jackson, Donald C. *Great American Bridges and Dams.* Washington, D.C.: The Preservation Press, 1988.

-----. "Railroads, Truss Bridges, and the Rise of the Civil Engineer." *Civil Engineering* 47, no. 10 (October 1977).

Jackson, Robert W. *Choctaw Bottoms Road Bridge.* Historic Engineering Record Number TX-56. 1996. Digital images. http://hdl.loc.gov/loc.pnp/hhh.tx0788.

-----. *Iron Ore Creek Bridge.* Historic Engineering Record Number TX-38. 1996. Digital images. http://hdl.loc.gov/loc.pnp/hhh.tx0764.

-----. *Little Mineral Creek Bridge.* Historic Engineering Record Number TX-39. 1996. Digital images. http://hdl.loc.gov/loc.pnp/hhh.tx0765.

-----. *Stinnett Road Bridge.* Historic Engineering Record Number TX-42. 1996. Digital images. http://hdl.loc.gov/loc.pnp/hhh.tx0768.

-----. *West Lancaster Street Bridge.* Historic Engineering Record Number TX-48. 1996. Digital images. http://www.loc.gov/pictures/item/TX0775/.

-----. *Yegua Creek Bridge.* Historic Engineering Record Number TX-53. 1997. Digital images. http://hdl.loc.gov/loc.pnp/hhh.tx0784.

Jasinski, Laurie E. "Cherokee Trace." *Handbook of Texas Online.* http://www.tshaonline.org/handbook/online/articles/CC/exc6.html. Published by the Texas State Historical Association.

JeffersonHighway.com. *Jefferson Highway History, Maps, News, Merchandise*. 2009. http://maps.bc.ca/jeffhwy/index2.htm.

Jenkins, James T. "The Story of Roads." Reprint from *American Road Builder*, September 1967.

Johnson, A. E., ed. *Published on the Occasion of the Golden Anniversary American Association of State Highway Officials: A Story of the Beginning, Purposes, Growth, Activities and Achievements of AASHO.* Washington, D.C.: The American Association of State Highway Officials, 1965. Available at Science Libraries Shelving Facility, University of Wisconsin, Madison, Wis.

Jones, Dixie L. "Old Military Road." *Handbook of Texas Online.* http://www.tshaonline.org/handbook/online/articles/OO/exo2.html. Published by the Texas State Historical Association.

Jones, W. Dwayne. *Bankhead Highway Historic District*. National Register of Historic Places Multiple Property Documentation Form. 1998. Available at Texas Historical Commission, Austin, Texas.

-----. *Old Austin to San Antonio Post Road.* National Register of Historic Places Registration Form. 2006. Available at Texas Department of Transportation Environmental Affairs Division, Austin, Texas.

Jordan, Terry G. *Texas: A Geography.* Boulder, Colo.: Westview Press, 1984.

*John F. Worley and Company's Dallas Directory for 1902.* Dallas: John F. Worley, 1902.

*John F. Worley and Company's Dallas Directory for 1903.* Dallas: John F. Worley, 1903.

*John F. Worley and Company's Dallas Directory for 1904.* Dallas: John F. Worley, 1904.

*John F. Worley Directory Company's San Antonio City Directory,* 1927-8. Dallas: John F. Worley Directory Co., 1928.

*John F. Worley Directory Company's San Antonio City Directory, 1929-30.* Dallas: John F. Worley Directory Co., 1930.

*Jules A. Appler's City Directory of Greater San Antonio,* 1914. San-Antonio: J.A. Appler, 1914.

*Jules A. Appler's City Directory of Greater San Antonio,* 1916. San Antonio: J.A. Appler, 1916.

*Jules A. Appler's General Directory of San Antonio, Texas, 1901/1902.* San Antonio: J.A. Appler, 1901.

Karnes, Thomas L. *Asphalt and Politics: A History of the American Highway System*. Jefferson, N.C.: McFarland & Co., 2009.

*Karte des Staates Texas [Map of the State of Texas]*. Weisbaden, Hesse, 1851.

Kaszynski, William. *The American Highway: The History and Culture of Roads in the United States*. Jefferson, N.C.: McFarland & Co., 2000.

Keane, Melissa and J. Simon Bruder. *Good Roads Everywhere: A History of Road Building in Arizona*. Prepared for the Arizona Department of Transportation, 2004.

Kemp, L.W. "Atascosita Road." *Handbook of Texas Online*. http://www.tshaonline.org/handbook/online/articles/AA/exa2.html. Published by the Texas State Historical Association.

Killebrew, Tom. "The Creation of the Modern Freeway in Dallas, Texas, 1911-1949: the Story of North Central Expressway." *Legacies: A History Journal for Dallas and North Central Texas* XIV, no. 1 (Spring 2002).

King, Joseph E. *A Historical Overview of Texas Transportation, Emphasizing Roads and Bridges.* Austin, Texas: Texas State Department of Highways and Public Transportation, 1988. Available at Bridge Division, Texas Department of Transportation, Austin, Texas.

Kirby, Richard Shelton; Withington, Sidney; Darling, Arthur Burr; and Kilgour, Frederick Gridley. *Engineering in History.* New York: Dover Publications, Inc., 1990.

Kirschbraun, Lester, Philip F. Sharples, and Charles Carroll Brown. "The Design of Asphaltic Concrete and Bituminous Macadam Pavements." *Municipal Engineering*. Vol. 52, no.3 (March 1917): 104-110.

Kite, Kirk. "Highway Development." *Handbook of Texas Online*. http://www.tshaonline.org/handbook/online/articles/HH/erh2.html. Published by the Texas State Historical Association.

-----. *A History of the Texas State Department of Highways and Public Transportation – 1917-1980.* Ph.D. dissertation at the University of New Mexico, 1981. Available at Photo Library, Texas Department of Transportation, Austin, Texas.

Knight & Associates, Inc. *Historic Documentation of the Gruene Bridge, Gruene, Comal County, Texas*. Prepared for the Texas Department of Transportation, 2004.

-----. *Old Austin to San Antonio Post Road Historic District Draft National Register of Historic Places Nomination*. 2007.

-----. *Reconnaissance Level Survey of Multiple Intersections in the Houston District for ADA Curb Ramp Improvements*. TxDOT, 2011.

-----. *Survey Report for the 5000 Block and 5100 Block of Broadway Avenue, Galveston, Galveston County, TX*. TxDOT, 2003.

Koch, Augustus. *Austin, State Capital of Texas*, 1887.

-----. *Bird's Eye View of El Paso, El Paso County Texas*, 1886.

-----. *Bird's Eye View of the City of Austin Travis County Texas 1873*. Madison, Wis.: J. J. Stoner, 1873.

-----. *Bird's Eye View Of the City of Houston, Texas 1873*. Madison, Wis.: J. J. Stoner, 1873.

Koster, George E. *A Story of Highway Development in Nebraska*. Lincoln, Nebr.: Department of Roads, 1997.

Krim, Arthur. "Ozark Trails – Mother Road." *SCA Journal* (spring 1996).

"La Bahia Road." *Handbook of Texas Online*. http://www.tshaonline.org/handbook/online/articles/LL/exl1.html. Published by the Texas State Historical Association.

Landrum, Graham, and Allan Smith. *Grayson County: An Illustrated History*. Fort Worth: Historical Publishers, 1967.

Lauderdale, Regina A. *State Highway 78 Bridge at the Red River*. National Register of Historic Places Registration Form. 1996.

"La Salle County Highway to be Built," *Texas Highway Bulletin* 8, no. 4 (April 1928).

Lewis, Tom. *Divided Highways*. New York: Viking, 1997.

Limmer, E.A., Jr., ed. *Story of Bell County, Texas*. vol. I. Austin, Texas: Eakin Press, 1988.

Livermore, Captain W.R. *Military Map of the Rio Grande Frontier*. N.p., 1883.

Loutzenheiser, Donald W. "New Concepts for Urban Freeway Interchanges." *Journal of the Highway Division: Proceedings of the American Society of Civil Engineers* 88, no. HW1.

MacCorkle, Stuart A. and Dick Smith. "Highway Administration." *Texas Government*. New York: McGraw Hill Book Company, 1964.

Magnolia Petroleum Company. *Motoring Through Texas in 1934*. New York: General Drafting Co., 1934.

Mantor, Ruth. "Taylor, TX," *Handbook of Texas Online* http://www.tshaonline.org/handbook/online/articles/het01. Published by the Texas State Historical Association.

"The Manufacture of Structural Steel in the United States." *Cassier's Magazine* 17 (February 1900).

"Map Collection." *Texas State Library and Archives Commission*. http://www.tsl.state.tx.us/cgi-bin/aris/maps/maplookup.php?mapnum=0942.

*Map of Texas*. Printed in the *New York Herald*. New York City: 1863.

*Map of Texas to Accompany Grange's Southern and Western Texas Guide*. Chicago: Rand McNally, 1878.

*A Map of Texas Showing the State Parks and the Municipal Parks.* Texas Planning Board, 1936.

*Map of the Location of Iron Ore Deposits, Blast Furnaces, Lignite Mines in Operation and Producing Oil Fields in East Texas.* Austin, Texas: University of Texas Bureau of Economic Geology and Technology, 1912.

Marcy, Capt. R.B. *Map of the Country Between the Frontiers of Arkansas and New Mexico.* New York: H. Lawrence, 1852.

Martin, Howard N. "Coushatta Trace." *Handbook of Texas Online*. http://www.tshaonline.org/handbook/online/articles/CC/exc5.html. Published by the Texas State Historical Association.

-----. "Liberty-Nacogdoches Road." *Handbook of Texas Online*. http://www.tshaonline.org/handbook/online/articles/LL/bpl4.html. Published by the Texas State Historical Association.

Mayfield, Bernard. "Nacogdoches-Neches Saline Road." *Handbook of Texas Online*. http://www.tshaonline.org/handbook/online/articles/NN/exn2.html. Published by the Texas State Historical Association.

McCahon, Mary, et al. National Cooperative Highway Research Program. *Web-Only Document 189: Design and Management of Historic Roads*. Transportation Research Board. January 2012.

McComb, David. G. *Texas: An Illustrated History.* New York: Oxford University Press, 1995.

McCullough, C.B. *Economics of Highway Bridge Types.* Chicago: Gillespie Publishing Co., 1929.

McDaniel, Bernice. *Highway Administration in Grayson County, Texas*. Master's Thesis at the University of Texas at Austin, 1929.

McGraw, A. Joachim, John W. Clark, Jr., and Elizabeth A. Robbins, eds. *A Texas Legacy, the Old San Antonio Road and the Caminos Reales*. Austin, Texas: Texas Department of Transportation, 1998.

McMillan, Thomas E. *County Unit Road Administration in Texas.* Austin, Texas: Institute of Public Affairs, University of Texas, 1954.

McMillen, Kathryn Smith. *The San Antonio-San Diego Mail Line in Texas, 1857-1861*. Master's Thesis at the University of Texas at Austin, Texas, 1960.

McNaughton, G.A. *The Meridian Road in Texas, 1916*. San Antonio, Tex: International Road Association Texas Division, 1916.

McNichol, Dan. *The Roads that Built America*. New York: Barnes and Noble, 2003.

McWhorter, Eugene W. "Longview, TX (Gregg County)." *Handbook of Texas Online.* http://www.tshaonline.org/handbook/online/articles/hdl03. Published by the Texas State Historical Association.

-----. *Traditions of the Land: The History of Gregg County, Texas.* Longview, Texas: The Gregg County Historical Foundation, 1989.

Mead & Hunt, Inc. *Historic Context for Texas Bridges, 1945-1965*. Prepared for the Texas Department of Transportation, 2009.

-----. *Indiana Bridges Historic Context Study, 1830s-1965*. Prepared for the Indiana Department of Transportation, 2007.

-----. *Lost Pine Lake Property Evaluation*. Prepared for the Texas Department of Transportation, 2004.

-----. *Historic Context and Comparative Analysis Report: Statewide Study of Bedstead Truss Bridges.* Prepared for the Texas Department of Transportation, July 2009.

Mead & Hunt, Inc. and Heritage Research, Ltd. *Nebraska Historic Highway Survey*. Prepared for the Nebraska State Historical Society and the Nebraska Department of Roads, 2002.

Mead & Hunt, Inc. *US Highway 66 in California Multiple Property National Register Nomination.* September 2011.

Meridian Highway Constitution and by-laws in the collection of the F.A. Long Papers (Manuscript collection of the Nebraska State Historical Society, Lincoln, Neb.).

"Meridian Highway History." *Texas Oil News*. N.p., c.1920. Available at Nebraska State Historical Society, Nebraska State Historic Preservation Office, Lincoln, Neb.

*Midget Map of the Transcontinental Trails of the United States*. Chicago: Clason Map Co., 1923. http://www.fhwa.dot.gov/infrastructure/midgetmap.cfm.

*Military Map of Southwest Texas*. N.p., 1881.

*Military Map of Western Texas*. N.p., 1884.

Miller, John D. *Map Showing Proposed System of State Highways as Adopted June 1917*. Austin, Tex: State Highway Department, 1917.

Mittendorfer, M.Y. *A.R. Roessler's Latest Map of the State of Texas*. New York City: A.R. Roessler, 1874.

Morehead, Richard M. *Dewitt C. Greer: King of the Highway Builders.* First Edition ed. *Distinguished Texans Series.* Austin, Texas: Eakin Press, 1984.

-----. "Gas Tax Bill Passes House." *The Dallas Morning News.* 11 April 1951.

-----. "Legislative Conferees Break Taxes Deadlock." *The Dallas Morning News.* 5 June 1951.

-----. "New Plan to Block More Taxes Drafted in State Legislature." *The Dallas Morning News.* 4 February 1951.

Miller, Shannon. *Austin Bridge Company and Associated Companies: The First 50 Years, 1918-1968.* Dallas: Taylor Publishing Company, 1974.

Morris, John Miller. "Exploration." *Handbook of Texas Online*. http://www.tshaonline.org/handbook/online/articles/EE/uzeuj.html. Published by the Texas State Historical Association.

*Morrison and Fourmy's Directory of the City of Fort Worth 1899-1900.* Galveston: Morrison and Fourmy, 1899.

*Morrison and Fourmy's General Directory, Fort Worth, Texas,* 1896-1897. Galveston: Morrison and Fourmy, 1896.

Mosher Steel Company. "The Story of Mosher Steel." Seventy Fifth Anniversary Brochure, 1960. Dallas Public Library, Dallas.

Muller, Samuel A. *A Study of the Public Road System in Texas.* Master's Thesis at the University of Texas at Austin, 1955.

Murphy, J.P. and Charles Bolanz. *Revised Edition of Murphy and Bolanz Official Map of the City of Dallas and Suburbs.* Dallas, Texas, 1891.

Nation, Carol. "Covered Bridges in Texas." *Texas Highways*, May 1964.

National Archives. Works Progress Administration, Texas, Project Folders, Project 10273. Microfilm rolls of WPA projects available at Texas Department of Transportation, Environmental Affairs Division, Austin, Texas.

National Park Service, U.S. Department of the Interior. *National Register of Historic Places Multiple Property Documentation Form for Highway Bridges in Nebraska, 1870 -1942*, 1992.

Neville, A. W. *The History of Lamar County.* Paris, Texas: The North Texas Publishing Co., 1937 (reprinted 1986).

*New Commercial Map of Texas*. Chicago: George F. Cram, 1900.

*A New Map of Texas, Oregon, and California*. Philadelphia: S. Augustus Mitchell, 1846.

Newlan, Ralph. *Richmond Bridge.* Historic Engineering Record Number TX-11. 1989. Digital images. http://hdl.loc.gov/loc.pnp/hhh.tx0598

Nixon, Nina L. "Pinta Trail." *Handbook of Texas Online*. http://www.tshaonline.org/handbook/online/articles/PP/ayp2.html. Published by the Texas State Historical Association.

North American Auto Trails. http://academic.marion.ohio-state.edu/schul/trails/trails.html.

*Official Map of the Highway System in Texas*. Austin, Texas: State Highway Commission, 1933.

*Official Map of the Highway System of Texas: Federal Aid System.* Austin, Texas: Texas State Highway Department, 1935.

Oklahoma Department of Transportation. *Historic Bridge Survey, Phase IO: A Re-Evaluation of "Spans of Time: Oklahoma Historic Highway Bridges,"* (www.okladot.state.ok.us/memorial/pdfs/pln_span-of-time_survey-phase-1.pdf), accessed on April 7, 2014.

"Old San Antonio Road." *Handbook of Texas Online*. http://www.tshaonline.org/handbook/online/articles/OO/exo4.html. Published by the Texas State Historical Association.

Old San Antonio Road. http://www.texandesigns.com/kingshwy/.

"The Old San Antonio Road/Kings Highway/El Camino Real." http://www.texandesigns.com/kingshwy/history.htm.

"The Old Spanish Trail: Building the Shortest Highway in the Longest Amount of Time." *Drive the Old Spanish Trail*. http://www.drivetheost.com/index.html.

Old Spanish Trail Centennial. http://www.oldspanishtrailcentennial.com.

*Old Spanish Trail System of Highways, Service Map and Travel Information, East Texas, Orange-San Antonio*. San Antonio: Old Spanish Trail Association, April 1923. www.oldspanishtrailcentennial.com/Travel%20logs/1923-1/Cover%20Part%201.htm.

*Old Spanish Trail System of Highways, Service Map and Travel Information, West Texas, San Antonio-El Paso*. San Antonio: Old Spanish Trail Association, April 1923. www.oldspanishtrailcentennial.com/Travel%20logs/1923-2/Cover%20Part%201.htm.

*Old Spanish Trail Travelog, March 1929, The National Trunk Line through the Southern Borderlands*, http://www.oldspanishtrailcentennial.com/Travel%20logs/1929-1/1929-1%20Travel%20log%20index.htm.

Olien, Roger M. "Oil and Gas Industry." *Handbook of Texas Online* (http://www.tshaonline.org/handbook/online/articles/doogz). Published by the Texas State Historical Association.

PAC Spero & Company and Louis Berger & Associates. *Historic Highway Bridges in Maryland: 1631-1960: Historic Context Report*, Rev. ed. Baltimore: October 1995.

Papademetriou, Peter C. *Transportation and Urban Development in Houston, 1830-1980.* Houston, Texas: Metropolitan Transit Authority of Harris County, 1982.

Parsons Brinckerhoff Quade & Douglas, Inc. *Small Structures on Maryland's Roadways Historic Context Report.* Prepared for the Maryland State Highway Administration, 1997.

"Pat Neff Highway – State Highway No. 2." *Texas Highway Bulletin* 4, no. 7 (July 1924).

Patton, Phil. *Open Road: A Celebration of the American Highway.* New York: Simon and Schuster, 1986.

Payne, Darwin. *Dallas: An Illustrated History.* Woodland Hills, Calif.: Windson Publications, 1982.

"The Pecos Viaduct." *Engineering News* 29 (5 January 1893).

Penick, Monica and Gregory Smith. *Route 66 in Texas MPS*. National Register Multiple Property Documentation Form. 2003. Available at Texas Historical Commission, Austin, Texas.

Perrin, Frank W. "Low Cost Bridge: Design Capitalized in a Texas County Road Program." *Roads and Streets* 93, no. 6 (June 1950): 39-40, 42. Available at Wendt Library, University of Wisconsin, Madison, Wis.

Perry, Suzanne. "Gregg County." *Handbook of Texas Online.* http://www.tshaonline.org/handbook/online/articles/hcg10. Published by the Texas State Historical Association.

Pevehouse, Henry M. *An Economic Analysis of Highway Construction: A Study of the Location, Financing, and Building of the Post Road from Austin to San Antonio*. Master of Arts thesis, University of Texas at Austin, June 1930.

Pierce, Richard. "Interstate: More Than the Sum of Its Parts." *Texas Highways* 11, no. 2 (February 1964): 12-15. Available at Photo Library, Texas Department of Transportation, Austin, Texas.

Pike, Captain Zebulon Montgomery. *A Map of the Internal Provinces of New Spain*. 1807. *Texas State Library and Archives Commission*. http://www.tsl.state.tx.us/cgi-bin/aris/maps/maplookup.php?mapnum=1438

Pirtle, Jack L. "Trammel's Trace." *Handbook of Texas Online*. http://www.tshaonline.org/handbook/online/articles/TT/ext3.html. Published by the Texas State Historical Association.

Pressler, Charles W. *Traveller's Map of the State of Texas*. New York City: N.p., 1867.

Preston, Howard Lawrence. *Dirt Roads to Dixie: Accessibility and Modernization in the South, 1885-1935.* Knoxville: University of Tennessee Press, 1991.

Procter, Ben H. "World War II." *Handbook of Texas Online*. http://www.tshaonline.org/handbook/online/articles/npwnj. Published by the Texas State Historical Association.

Purcell, Brian. *The Texas Highway Man Pages*. http://www.texashighwayman.com/index.shtml.

Raffetto, Francis. "Taxes Go up Today." *The Dallas Morning News.* 6 September 1955.

Raitz, Karl. "The US 40 Roadside." *The National Road*. Baltimore, Md.: The Johns Hopkins University Press, 1996.

Raines, Caldwell Walton. *Analytical Index to the Laws of Texas, 1823-1905.* Littleton, Colo.: Fred B. Rothman & Co., 1987.

Ramsdell, Charles. *San Antonio: A Historical and Pictorial Guide.* Austin, Texas: University of Texas Press, 1959.

*Rand McNally Junior Auto Trails Map, Texas*. Chicago: Rand McNally & Co., 1923

*Rand McNally Main Highway Map of Texas*. Chicago: Rand McNally & Co., c.1923.

*Rand McNally New Commercial Atlas Map of Texas*. Chicago: Rand McNally & Co., 1930.

*Rand McNally Official Auto Trails Map*. Chicago: Rand McNally & Co., 1925.

*Rand McNally Official Auto Trails Map of Texas, Arkansas, Louisiana, Southern Oklahoma, and Western Mississippi, District 18*. Chicago: Rand McNally & Co., 1923.

Reed, Robert L. "Elastomeric Bearings for Texas Highway Bridges." San Antonio, Texas: The 2nd World Congress on Joint Sealing & Bearing Systems for Concrete Structures, 2 October 1986.

Reed, S.G. *A History of Texas Railroads.* Houston, Texas: St. Clair Publishing Co., 1941.

*Revised Map of the State of Texas*. N.p., 1876.

*Richardson's New Map of the State of Texas*. New York City: G.W. & C.B. Colton & Co.'s Map Establishment, 1870.

Richardson, Rupert N. "Butterfield Overland Mail." *Handbook of Texas Online*. http://www.tshaonline.org/handbook/online/articles/BB/egb1.html. Published by the Texas State Historical Association.

Richardson, Rupert N. *Texas: the Lone Star State.* Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1958.

Richardson, Rupert N., Ernest Wallace and Adrian N. Anderson. *Texas: the Lone Star State.* Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1970.

Ritter, L.J. and R.J. Paquette. *Highway Engineering.* New York: The Ronald Press Company, 1951.

Roeser, C., Jr. *Post Route Map of the State of Texas*. N.p.: U.S. Post Office Department, 1891.

Rose, Mark H. *Interstate: Express Highway Politics, 1939-1989.* Knoxville, Tenn.: University of Tennessee Press, 1990.

*Safety Inspection of In-Service Bridges: Participant Notebook*, vol. 1-2. [McLean, Va.]: U.S. Dept. of Transportation, Federal Highway Administration, National Highway Institute, January 1992.

*Sanborn's Fire Insurance Map, San Antonio, Texas*, 1911 (revised), vol. 1, sheet 55. New York: Sanborn Map Company, 1911 [revisions to 1951].

*Sanborn's Fire Insurance Map, San Antonio, Texas*, 1912 New York: Sanborn Map Company, 1912.

Scoggin, Robert W. "Roads and Highways." *Encyclopedia of Arkansas History and Culture*. http://www.encyclopediaofarkansas.net/encyclopedia/entry-detail.aspx?entryID=4209.

Scott, Norman L. "Suggestions for Reducing Costs in Prestressed Concrete Bridges," in *Highway Research Record Number 34: Bridge Design, Analysis, and Costs.* Washington, D.C.: Highway Research Board, 1963.

Seely, Bruce. *Building the American Highway System: Engineers as Policy Makers*. Philadelphia: Temple University Press, 1987.

Senex, John. *A Map of Louisiana and the River Mississippi.* 1721. Texas State Library and Archives Commission. http://www.tsl.state.tx.us/cgi-bin/aris/maps/maplookup.php?mapnum=0362.

Simmons, David A. "Bridge Building on a National Scale; The King Iron Bridge and Manufacturing Company." The *Journal of the Society for Industrial Archeology* 15 (1989).

Simons, Charles E. "Progress." *Texas Parade*. April 1938.

Simons, Helen and Catherine A. Hoyt, eds. *Hispanic Texas: A Historical Guide.* Austin, Texas: University of Texas Press, 1992.

*Sinclair Road Map of Texas*. Chicago: Rand McNally & Co, 1941.

*Situations-Plan der Stadt New Braunfels und der dabei angekauften Landereien*, N.p.: Karl, Prinzen zu Solms-Braunfels, 1846. Texas State Archives Map Number 2198. Texas State Library and Archives Commission. www.tsl.state.tx.us/cgi-bin/aris/maps/maplookup.php?mapnum=2198.

Skaggs, Jimmy M. *The Cattle-Trailing Industry: Between Supply and Demand, 1866-1890*. Wichita, Kans.: The University Press of Kansas, 1973.

-----. "Western Trail." *Handbook of Texas Online*. http://www.tshaonline.org/handbook/online/articles/WW/ayw2.html. Published by the Texas State Historical Association.

Slotboom, Erik. *Houston Freeways: A Historical and Visual Journey.* Cincinnati, Ohio: C.J. Krehbiel, 2003.

"State Highway Construction." *Texas Highway Bulletin* 8, no. 4 (April 1928).

State Highway Department of Texas. *First Biennial Report, 1917-1918.* Austin, Texas: Von Boeckmann-Jones Co., 1919. Available at Photo Library, Texas Department of Transportation, Austin, Texas

-----. *Second Biennial Report, 1918-1920.* Austin, Texas: Von Boeckmann-Jones Co., 1921. Available at Photo Library, Texas Department of Transportation, Austin, Texas.

-----. *Third Biennial Report, 1920-1922.* Austin, Texas: Von Boeckmann-Jones Co., 1923. Available at Photo Library, Texas Department of Transportation, Austin, Texas.

-----. *Fourth Biennial Report, 1922-1924.* Austin, Texas: Von Boeckmann-Jones Co., 1925. Available at Photo Library, Texas Department of Transportation, Austin, Texas.

-----. *Fifth Biennial Report, 1924-1926.* Austin, Texas: A.C. Baldwin & Son, 1927. Available at Photo Library, Texas Department of Transportation, Austin, Texas.

-----. *Sixth Biennial Report, 1926-1928.* San Antonio, Texas: Eagle Publishing Co., 1929. Available at Photo Library, Texas Department of Transportation, Austin, Texas.

-----. *Seventh Biennial Report, 1928-1930.* Austin, Texas: State Highway Department of Texas, 1930. Available at Photo Library, Texas Department of Transportation, Austin, Texas.

-----. *Eighth Biennial Report, 1930-1932.* Austin, Texas: State Highway Department of Texas, 1932. Available at Photo Library, Texas Department of Transportation, Austin, Texas.

-----. *Ninth Biennial Report, 1932-1934.* Austin, Texas: State Highway Department of Texas, 1934. Available at Photo Library, Texas Department of Transportation, Austin, Texas.

-----. *Tenth Biennial Report, 1934-1936.* Austin, Texas: State Highway Department of Texas, 1936. Available at Photo Library, Texas Department of Transportation, Austin, Texas.

-----. *Eleventh Biennial Report, 1936-1938.* Austin, Texas: State Highway Department of Texas, 1939. Available at Photo Library, Texas Department of Transportation, Austin, Texas.

-----. *Twelfth Biennial Report, 1938-1940.* Austin, Texas: State Highway Department of Texas, 1941. Available at Photo Library, Texas Department of Transportation, Austin, Texas.

-----. *Thirteenth Biennial Report, 1940-1942.* Austin, Texas: State Highway Department of Texas, 1943. Available at Photo Library, Texas Department of Transportation, Austin, Texas.

-----. *Fourteenth Biennial Report, 1942-1944.* Austin, Texas: State Highway Department of Texas, 1945. Available at Photo Library, Texas Department of Transportation, Austin, Texas.

-----. *Fifteenth Biennial Report, 1944-1946.* Austin, Texas: State Highway Department of Texas, 1947. Available at Photo Library, Texas Department of Transportation, Austin, Texas.

-----. *Eighteenth Biennial Report, 1950-1952*. Austin, Texas: State Highway Department of Texas, 1953. Available at Photo Library, Texas Department of Transportation, Austin, Texas.

-----. *Twentieth Biennial Report, 1954-1956*. Austin, Texas: State Highway Department of Texas, 1957. Available at Photo Library, Texas Department of Transportation, Austin, Texas.

State Department of Highways and Public Transportation, *General Highway Map, Kimble County, Texas*. 1963, revised to 1985.

"State Highway No. 3." *Texas Highway Bulletin* 4, no. 8 (August 1924).

Steely, Jim. "Public Works of the Depression Era. *Texas Architect* (May-June, 1986).

Steiger, Richard W. "The Kahn Reinforcing Bar." *Concrete Construction*. May 1990. www.concreteconstruction.net/images (accessed 28 March 2013).

Steinman, David B. and Sara Ruth Watson. *Bridges and their Builders*. New York: G.P. Putnam's Sons, 1941.

Stephens, A. Ray, and William M. Holmes. *Historical Atlas of Texas*. Norman, Okla.: University of Oklahoma Press. 1989.

Stever, Rex H. "Stagecoach Lines." *Handbook of Texas Online*. http://www.tshaonline.org/handbook/online/articles/SS/ers1.html. Published by the Texas State Historical Association.

Stewart, Frank M. *The Development of State Control of Highways in Texas*. Reprinted from *The Southwestern Social Sciences* Quarterly XIII, no. 3. Austin, Texas: N.p., 1932.

Stocklin, Barbara. *Historic Bridges of Texas, 1866-1945*. National Register of Historic Places Multiple Property Documentation Form. 1996. Available at Texas Department of Transportation Environmental Affairs Division, Austin, Texas.

"Suspended in Time." *Waco Tribune-Harold*, 7 January 1995.

Taylor, Tory Laughlin. *Colorado River Bridge at Bastrop*. National Register of Historic Places Registration Form. 1990.

Taylor, T.U. "County Roads." *University of Texas Bulletin No. 54*. Austin, Tex: University of Texas, 1890.

*Texas*. New York: J.H. Colton & Co, 1834.

*Texas*. Austin, Texas: General Land Office. n.d.

"Texas 1946 Secondary Road Program Established New Construction Record." *Engineering News-Record* 138, no. 4 (23 January 1947): 99-102. Available at Wendt Library, University of Wisconsin, Madison, Wis.

*Texas Almanac 1956-1957*. Dallas, Texas: A.H. Belo Corporation. 1955.

*Texas Almanac and State Industrial Guide 1970-1971*. Dallas, Texas: A.H. Belo Corporation, 1969.

*Texas Automobile Road Map*. Rand McNally & Co., c.1917.

"Texas Centennial." *Handbook of Texas Online*. http://www.tshaonline.org/handbook/online/articles/lkt01. Published by the Texas State Historical Association.

Texas Department of Transportation. *A Guide to the Research and Documentation of Historic Bridges in Texas*. 2004.

-----. Bridge articles binder. Available at Texas Department of Transportation Environmental Affairs Division, Austin Texas.

-----. *Bridge Design Manual*. [Austin, Texas]: [Texas Department of Transportation], December 2001. Available at Texas Department of Transportation, Austin, Texas.

-----. *Construction and Maintenance Bulletin*. No. 27 (September 1953).

-----. County history binders. Available at Texas Department of Transportation Environmental Affairs Division, Austin, Texas.

-----. Depression-era corridor files. Available at Texas Department of Transportation Environmental Affairs Division, Austin, Texas.

-----. Depression-era research files. Available at Texas Department of Transportation Environmental Affairs Division, Austin, Texas.

-----. Depression-era binder. Available at Texas Department of Transportation Environmental Affairs Division, Austin, Texas.

-----. Highway Designation File, Business Interstate Highway No. 35-H. http://www.dot.state.tx.us/tpp/hwy/bi/bi0035h.htm.

-----. Highway Designation File, Farm to Market Road No. 1009. http://www.dot.state.tx.us/tpp/hwy/fm1000/fm1009.htm.

-----. Highway Designation File, Farm to Market Road No. 1102. http://www.dot.state.tx.us/tpp/hwy/fm/fm1102.htm.

-----. Highway Designation File, Ranch to Market Road No. 1674. http://www.dot.state.tx.us/tpp/hwy/rm/rm1674.htm.

-----. Highway Designation File, State Highway Loop No. 481. http://www.dot.state.tx.us/tpp/hwy/sl/sl0481.htm.

-----. Highway Designation File, U.S. Highway No. 290. http://www.dot.state.tx.us/tpp/hwy/us/us0290.htm.

-----. Historic bridge database. 2008. Available at Texas Department of Transportation Environmental Affairs Division, Austin, Texas.

-----. Historic bridge documentation report binders. Available at Texas Department of Transportation Environmental Affairs Division, Austin, Texas.

-----. Historic bridge standard plan files. Available at Texas Department of Transportation Environmental Affairs Division, Austin, Texas.

-----. "IH 30 Corridor." Texas Department of Transportation website. http://www.dot.state.tx.us/ftw/mis/ih30/history.htm.

-----. Road progress binder. Available at Texas Department of Transportation Environmental Affairs Division, Austin, Texas.

-----. *Texas Highway Bulletin*. Various years. Available at Texas Department of Transportation Environmental Affairs Division, Austin, Texas.

-----. Texas Highway Department histories files. Available at Texas Department of Transportation Environmental Affairs Division, Austin, Texas.

-----. *Texas Historic Bridge Inventory, Survey of Non-Truss Structures*, 2001. Available at Texas Department of Transportation Environmental Affairs Division, Austin, Texas.

*TexasEscapes.com*. http://www.texasescapes.com.

Texas Good Roads Association and Austin Automobile Club. *Texas State Highway Guide*. Austin, Texas: Forum Publishing Company, 1918.

Texas Highway Department. *F.M. Highway No. 1582, Frio, LaSalle & McMullen Counties, Project Nos. R1500-1-4, R1500-2-1, R1500-3-1, Plans of Proposed Grading, Structures, Base & Surfacing*. 6 December 1961. Available at Texas Department of Transportation, General Services Division, Records Management Division.

-----. *General Information on Texas Highways, September 1919*. Austin, Texas: Von Boeckmann-Jones Co., 1919.

-----. "Golden Anniversary, Texas Highway Department, 1917-1967." Special issue, *Texas Highways* 14, no. 9 (September 1967).

-----. *Record of State Control Numbers, Sections and Jobs, Control No. 16, Sec. 4*. Available at Texas Department of Transportation Environmental Affairs Division, Austin, Texas.

-----. *Record of State Control Numbers, Sections and Jobs, Control No. 18, Sec. 1*. Available at Texas Department of Transportation Environmental Affairs Division, Austin, Texas.

-----. *Record of State Control Numbers, Sections and Jobs, Control No. 28, Sec. 5*. Available at Texas Department of Transportation Environmental Affairs Division, Austin, Texas.

-----. *Record of State Control Numbers, Sections and Jobs, Control No. 53, Sec. 12*. Available at Texas Department of Transportation Environmental Affairs Division, Austin, Texas.

-----. *Record of State Control Numbers, Sections and Jobs, Control No. 96, Sec. 6*. Available at Texas Department of Transportation Environmental Affairs Division, Austin, Texas.

-----. *Record of State Control Numbers, Sections and Jobs, Control No. 105, Sec. 1*. Available at Texas Department of Transportation Environmental Affairs Division, Austin, Texas.

-----. *Record of State Control Numbers, Sections and Jobs, Control No. 141, Sec. 9*. Available at Texas Department of Transportation Environmental Affairs Division, Austin, Texas.

-----. *Record of State Control Numbers, Sections and Jobs, Control No. 141, Sec. 18*. Available at Texas Department of Transportation Environmental Affairs Division, Austin, Texas.

-----. *Record of State Control Numbers, Sections and Jobs, Control No. 142, Sec. 1*. Available at Texas Department of Transportation Environmental Affairs Division, Austin, Texas.

-----. *Record of State Control Numbers, Sections and Jobs, Control No. 142, Sec. 16*. Available at Texas Department of Transportation Environmental Affairs Division, Austin, Texas.

-----. *Record of State Control Numbers, Sections and Jobs, Control No. 168, Sec. 1*. Available at Texas Department of Transportation Environmental Affairs Division, Austin, Texas.

-----. *Record of State Control Numbers, Sections and Jobs, Control No. 320, Sec. 3*. Available at Texas Department of Transportation Environmental Affairs Division, Austin, Texas.

-----. *Record of State Control Numbers, Sections and Jobs, Control No. 1273, Sec. 1*. Available at Texas Department of Transportation Environmental Affairs Division, Austin, Texas.

-----. *Road, Street, and Highway Finance in Texas*. Austin, Tex: Texas Highway Department, 1952.

-----. *Texas Expressways*. Austin, Texas: Texas Highway Department, 1954.

-----. *The Texas Farm to Market Road Program in Perspective*. Austin, Texas: Texas Highway Department, April 1971.

-----. *The Texas Highway System as Related to National Defense Transportation*. Austin, Texas: Texas Highway Department, December 1940.

*Texas Highway Department Official Map*. Austin, Texas: Texas Highway Department, 1945.

*Texas Highway Department Official Map*. Austin, Texas: Texas Highway Department, 1949.

*Texas Highway Map*. Austin, Texas: Texas Highway Department, 1921.

*Texas Highway Map*. Austin, Texas: Texas Highway Department, 1937-1939.

*Texas Highway Map*. Austin, Texas: Texas Highway Department, 1941.

*Texas Highway Map*. Austin, Texas: Texas Highway Department, 1942.

Texas Historic Sites Atlas. http://atlas.thc.state.tx.us/.

"Texas Holds Road-Building Lead in U.S." *Dallas Times*. 1 January 1964. Available at Center for American History, Roads Scrapbook 1918-1964, University of Texas, Austin, Texas.

*Texas in Doubleday Page & Co Geographic Manual and New Atlas*. New York: Doubleday, Page & Co, 1918.

Texas Legislative Council. *Texas Roads and Highways*. Staff Research Report No. 52-3. Austin, Texas: Texas Legislative Council, 1952.

*Texas Parade*. 1936 to 1952. Available at Texas Department of Transportation Travel Division.

Texas Parks and Wildlife Department. Greenways Program. "Fact Sheet for the Paris to Farmersville Branch of the Chaparral Railroad Company." 1995.

Texas Research League. *A Program for Texas Highways*. Austin, Texas: Texas Research League, 1957.

-----. *The Texas Farm to Market Road Program*. Austin, Texas: Texas Research League, 1957.

Texas State Department of Highways and Public Transportation. Bridge Division. *Bridge Design Guide*. Austin, Texas, 1990.

Texas State Highway Commission. *Texas: A Guide to the Lone Star State.* New York: Hastings House, 1940. Reprinted with introduction by Don Graham. Austin, Texas: Texas Monthly Press, 1986.

Texas State Highway Department. *General Highway Map, Comal County, Texas*. 1936, revised to 1940.

-----. *General Highway Map, Comal County, Texas*. 1959.

-----. *General Highway Map, Dimmit County, La Salle County, Texas*. 1936, revised to 1940.

-----. *General Highway Map, Gregg County, Texas.* 1955, revised to 1961.

-----. *General Highway Map, Hall County, Texas.* 1936, revised to 1940.

-----. *General Highway Map, Kimble County, Texas*. 1936, revised to 1940.

-----. *General Highway Map, Kimble County, Texas*. 1958, revised to 1961.

-----. *General Highway Map, La Salle County, Texas*. 1959, revised to 1961.

-----. *General Highway Map, Liberty County, Texas*. 1936, revised to 1940.

-----. *General Highway Map, Liberty County, Texas*. 1958, revised to 1961.

-----. *General Highway Map, Nolan County, Texas.* 1936, revised to 1940.

-----. *General Highway Map, Nolan County, Texas.* 1955, revised to 1961.

-----. *General Highway Map, Parmer County, Texas.* 1936, revised to 1940.

-----. *General Highway Map, Parmer County, Texas.* 1959, revised to 1961.

-----. *General Highway Map, Upshur County, Gregg County.* 1936, revised to 1939.

-----. *Manual of Instructions for the Making of Surveys and Preparation of Plans, Specifications and Estimates for Construction.* Austin, Texas, 1930.

-----. *Report on Toll Bridges and Ferries Across the Rio Grande.* Austin, Texas, November 1937.

-----. *Specifications: Roads and Bridges.* Revised Edition. Austin, Texas, 1920.

-----. *Texas Highway Department*, 1927-1937. Austin, Texas, 1937.

-----. *Texas Highway Facts: A Preliminary Report.* Austin, Texas, 1940.

*Texas State Highway Guide*. Austin, Texas: Forum Publishing Company, 1918.

Texas State Library & Archives Commission. "The King's Highway." http://www.tsl.state.tx.us/treasures/flagsandmaps/kings-hwy.html.

Texas Transportation Museum. "Texas Road Transportation History." *TTM web*. http://www.txtransportationmuseum.org/TIMELINE3.htm.

Texas Turnpike Authority. "Contract No. D-FW 86, Toll Plazas, Entrance and Exit Ramps at North Fielder Road, Arlington, Dallas – Fort Worth Turnpike." Project Plans. 8 July 1962. Available at Texas Department of Transportation Environmental Affairs Division.

-----. "Contract No. D-FW 93, Toll Plaza Buildings, Toll Plaza at Handley Interchange, Dallas – Fort Worth Turnpike." Project Plans. 7 February 1963. Available at Texas Department of Transportation Environmental Affairs Division.

"Texas Urban Expressways Being Designed from Center Out." *Roads and Streets* 88, no. 11 (November 1945): 65-68.

Thomason, Philip and Teresa Douglas. *Route 66, SH 207 to Interstate 40*. National Register of Historic Places Registration Form. 2007. Available at Texas Historical Commission, Austin, Texas.

Tobin, Peggy. "Bandera Pass." *Handbook of Texas Online*. http://www.tshaonline.org/handbook/online/articles/BB/rkb1.html. Published by the Texas State Historical Association.

"The Trail." CARTA: El Camino Real de Tierra Adentro Trail Association website. http://www.caminorealcarta.org/trailInfo.htm.

*Transcontinental Highways of the United States in Auto Trails and Commercial Survey of the United States*. New York: George F. Cram Co., 1918.

Trice, B. A. "Low Cost Concrete Bridge." *Roads and Streets* 91, no. 10 (October 1948).

Tucker, James I. *The American Road, A Non-Engineering Manual for Practical Road Builders*. Norman, Oklahoma, 1916.

Tyson, Lueise. *U.S. Route 66 – Sixth Street Historic District*. National Register of Historic Places Registration Form. 1993. Available at Texas Historical Commission, Austin, Texas.

University of Texas -Bureau of Business Research. *Atlas of Texas*. Austin, Texas: The University of Texas, 1976.

U.S. Army Corps of Engineers. *Beaumont(, Texas)*. 1:125,000 scale topographic quadrangle tactical map. N.p.: 1911.

-----. *Beaumont(, Texas)*. 1:125,000 scale topographic quadrangle tactical map. N.p.: 1922.

-----. *Hunter, Texas*. 1:62,500 topographic quadrangle progressive military map. San Antonio, Texas: Eighth Corps Area Engineer Reproduction Plant, 1916, reprinted in 1927.

-----. *Hunter, Texas*. 1:62,500 topographic quadrangle tactical map. N.p.:1932.

-----. *Liberty(, Texas)*. 1:125,000 scale topographic quadrangle tactical map. N.p.: 1911.

-----. *Liberty(, Texas)*. 1:125,000 scale topographic quadrangle tactical map. N.p.: 1922.

-----. *New Braunfels, Texas*. 1:62,500 topographic quadrangle progressive military map. San Antonio, Texas: Eighth Corps Area Engineer Reproduction Plant, 1916, reprinted in 1922.

-----. *Webb(, Texas)*. 1:125,000 scale topographic quadrangle tactical map. N.p.: 1916.

U.S. Department of Agriculture, "Standard Specifications for Steel Highway Bridges." *Department Bulletin* No. 1259 (October 9, 1924).

U.S. Department of Agriculture Bureau of Public Roads. "U.S. Route 80 from Savannah, Georgia to San Diego, California." 1931. http://www.fhwa.dot.gov/infrastructure/us80sb.cfm.

U.S. Geological Survey. *Granger, Texas* 1:24,000 topographic quadrangle map. Washington, D.C.: U.S. Geological Survey, 1964.

-----. *New Braunfels, Texas* 1:62,500 topographic quadrangle map. Washington, D.C.: U.S. Geological Survey, 1925.

-----. *Taylor, Texas* 1:125,000 topographic quadrangle map. Washington, D.C.: U.S. Geological Survey, 1885.

"U.S. Highways: From U.S. 1 to (U.S. 830)." http://www.us-highways.com/.

U.S. Department of the Interior, National Park Service. *National Register Bulletin: How to Apply the National Register Criteria for Evaluation.* http://www.nps.gov/nr/publications/bulletins/nrb15/.

U.S. Department of Transportation, Federal Highway Administration. *America's Highways,* 1776-1976: *A History of the Federal-Aid Program.* Washington, D.C.: U.S. Government Printing Office, 1976.

Van Citters, Karen. *Historic Context and National Register Evaluation of New Mexico Department of Transportation Bridges*. Prepared for the New Mexico Department of Transportation, 2003.

Von Haake, A. *Post Route Map of the State of Texas.* N.p.: U.S. Post Office Department, 1907.

Waddell, J .A.L. *Bridge Engineering* 2 vols. New York: John Wiley & Sons, Inc., 1916.

--------. "Suitability of the Various types of Bridges for the Different Conditions Encountered at Crossings." Reprinted from the *Journal of the Western Society of Engineers* 32, no. 9 (October 1927).

Wallace, Laurel T. *Historic Highways in the NMDOT System*. NMDOT Cultural Resource Technical Series 2004-1. Prepared for the New Mexico Department of Transportation, 2004.

Webb, Walter Prescott, ed. *The Handbook of Texas*, 3 vols. Austin, Texas: Texas State Historical Association, 1952-1976.

Weingroff, Richard F. "Designating the Urban Interstates." http://wwwcf.fhwa.dot.gov/infrastructure/fairbank.cfm.

-----. "Federal-Aid Highway Act of 1956: Creating the Interstate System." *Public Roads* 60, no. 1 (summer 1996). http://wwwcf.fhwa.dot.gov/infrastructure/rw96e.cfm.

-----. "Federal Aid Road Act of 1916: Building the Foundation." *Public Roads* 60, no. 1 (summer 1996). http://wwwcf.fhwa.dot.gov/infrastructure/rw96a.cfm.

-----. "From 1916 to 1939: The Federal-State Partnership at Work." *Public Roads* 60, no. 1 (summer 1996). http://wwwcf.fhwa.dot.gov/infrastructure/rw96c.cfm.

-----. "From Names to Numbers: The Origins of the U.S. Numbered Highway System." http://wwwcf.fhwa.dot.gov/infrastructure/numbers.cfm.

-----. "Jefferson Davis Memorial Highway." http://www.fhwa.dot.gov/infrastructure/jdavis.cfm.

-----. "U.S. Route 80 – The Dixie Overland Highway." http://www.fhwa.dot.gov/infrastructure/us80.cfm.

Werner, George C. "Railroads." *Handbook of Texas Online*. http://www.tshaonline.org/handbook/online/articles/eqr01. Published by the Texas State Historical Association.

Westyard, A.L. (attributed). *Houston, Texas. (Looking South.) 1891*. Chicago: D.W. Ensign, Jr., 1891.

Whitney, Charles S. *Bridges: A Study in Their Art, Science and Evolution.* New York: William Edwin Rudge, 1929.

Wickline, George G. "Bridge Problems in Texas." *Texas Highway Bulletin* 2 (September 1922): 9-10.

----. "Texas Bridges Under Construction." *Texas Highway Bulletin* 4, no. 11 (November 1924).

Williams, Claire. "Commemorating Texas History: The Historical Marker Program." Unpublished manuscript. N.p., 1986. Available at Texas Historical Commission, History Programs Division, Austin, Texas.

*Wilson County Camelback Bridge.* Historic Engineering Record Number TX-68. N.d. Digital images. http://hdl.loc.gov/loc.pnp/hhh.tx0800.

Wisconsin Historical Society. "Federal Aid Highway Act of 1921." http://www.wisconsinhistory.org/archstories/late_roads/fed_hwy_act.asp.

Woods, Randall B. *LBJ: Architect of American Ambition*. New York: Free Press, 2006.

Worcester, Donald E. "Chisholm Trail." *Handbook of Texas Online*. http://www.tshaonline.org/handbook/online/articles/CC/ayc2.html. Published by the Texas State Historical Association.

Works Project Administration, comp. *Houston: A History and Guide.* Houston: The Anson Jones Press, 1942.

*Worley's Directory of Dallas, Texas,* 1913. Dallas: John F. Worley, 1913.

*Worley's Directory of Dallas, Texas,* 1912. Dallas: John F. Worley, 1912.

*Worley's Directory of El Paso, Texas, 1909.* Dallas: John F. Worley, 1909.

*Worley's Directory of El Paso, Texas,* 1913. Dallas: John F. Worley, 1913.

*Worley's General Directory of Greater Dallas, Texas, 1908.* Dallas: John F. Worley, 1908.

Young, J.H. *A New Map of Texas with the Contiguous American and Mexican States.* Samuel Augustus Mitchell, Philadelphia: 1836. Texas State Library and Archives Commission. http://www.tsl.state.tx.us/cgi-bin/aris/maps/maplookup.php?mapnum=0023a.

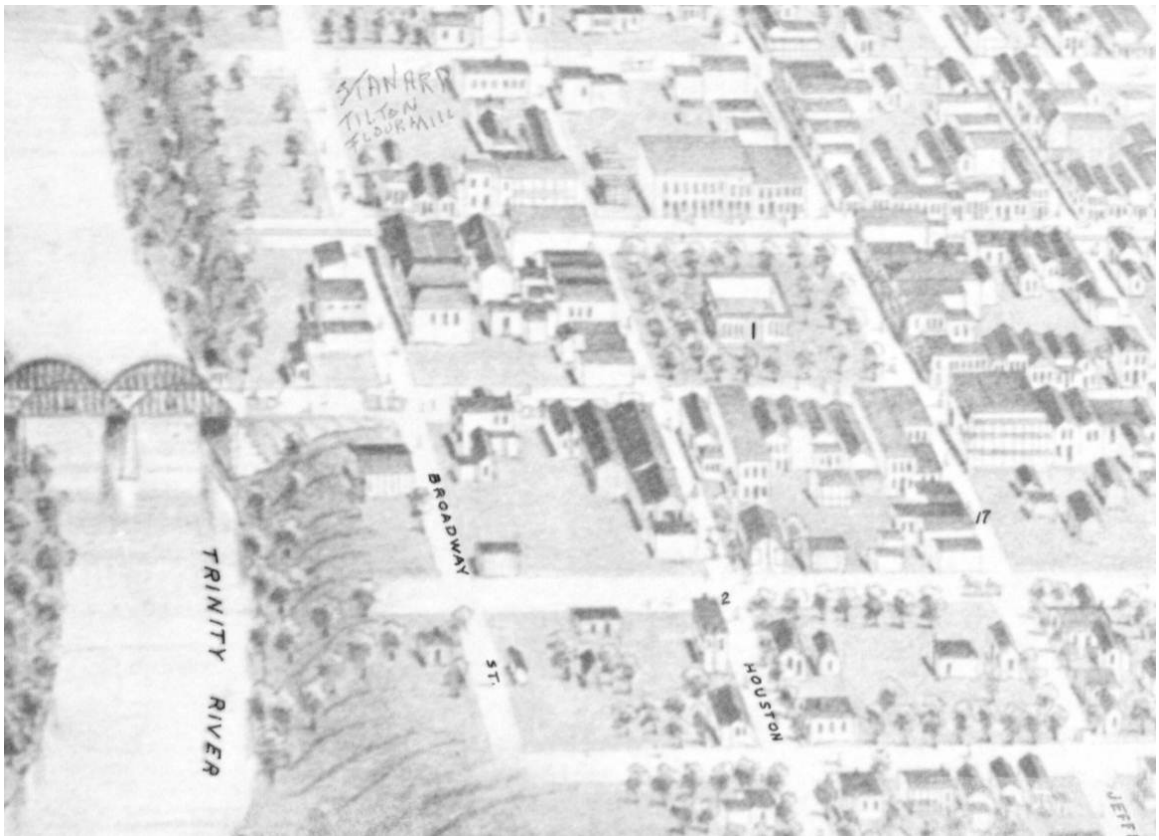



*Figure 1. 1872 birds' eye view of Commerce Street Bridge in Dallas, showing bridge's relationship to the city's growing commercial district.*

*(Source: Texas/Dallas History and Archives Division, Dallas, Texas)*

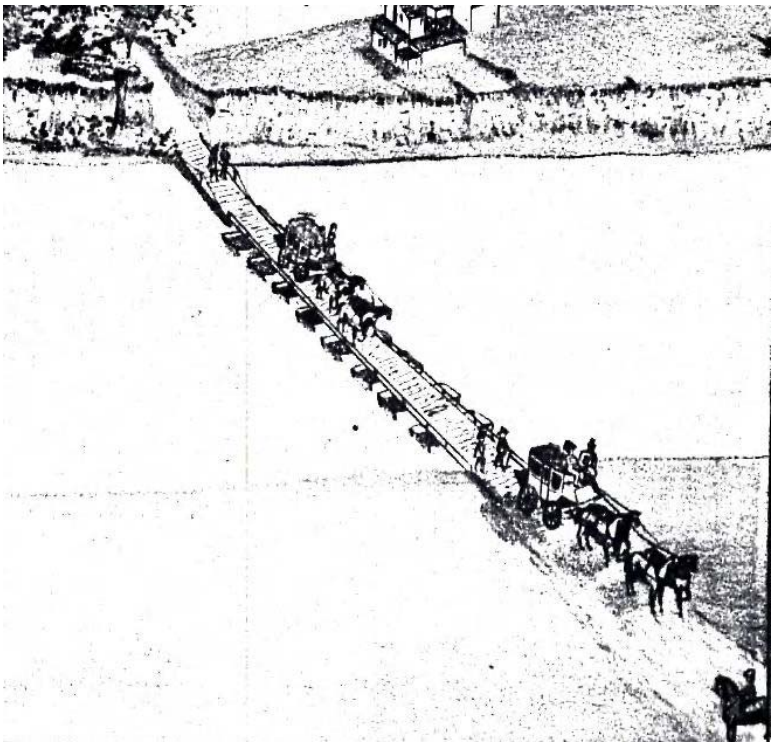


*Figure 2. Pontoon Bridge over the Colorado River in Austin, 1874.*
*(Source: Texas State Library and Archives Map Collection)*

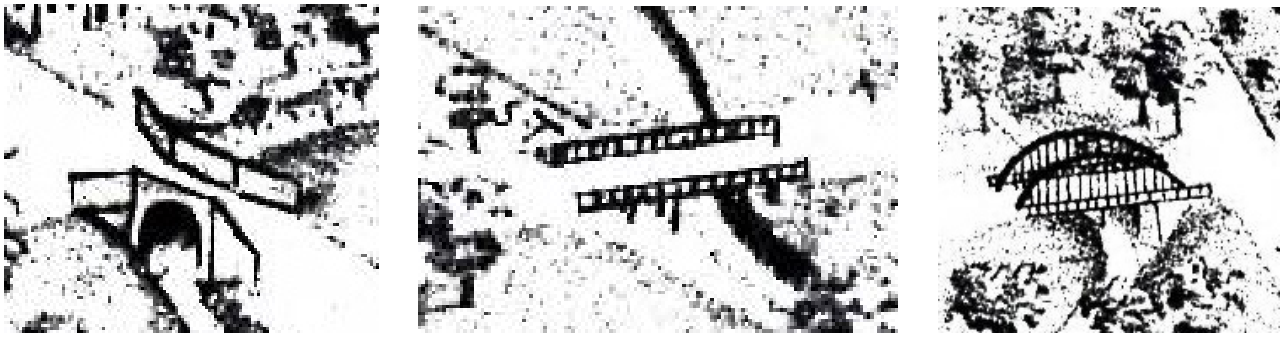


*Figure 3. Examples of urban bridges over small crossings, Austin 1874.*
*(Source: Texas State Library and Archives Map Collection)*

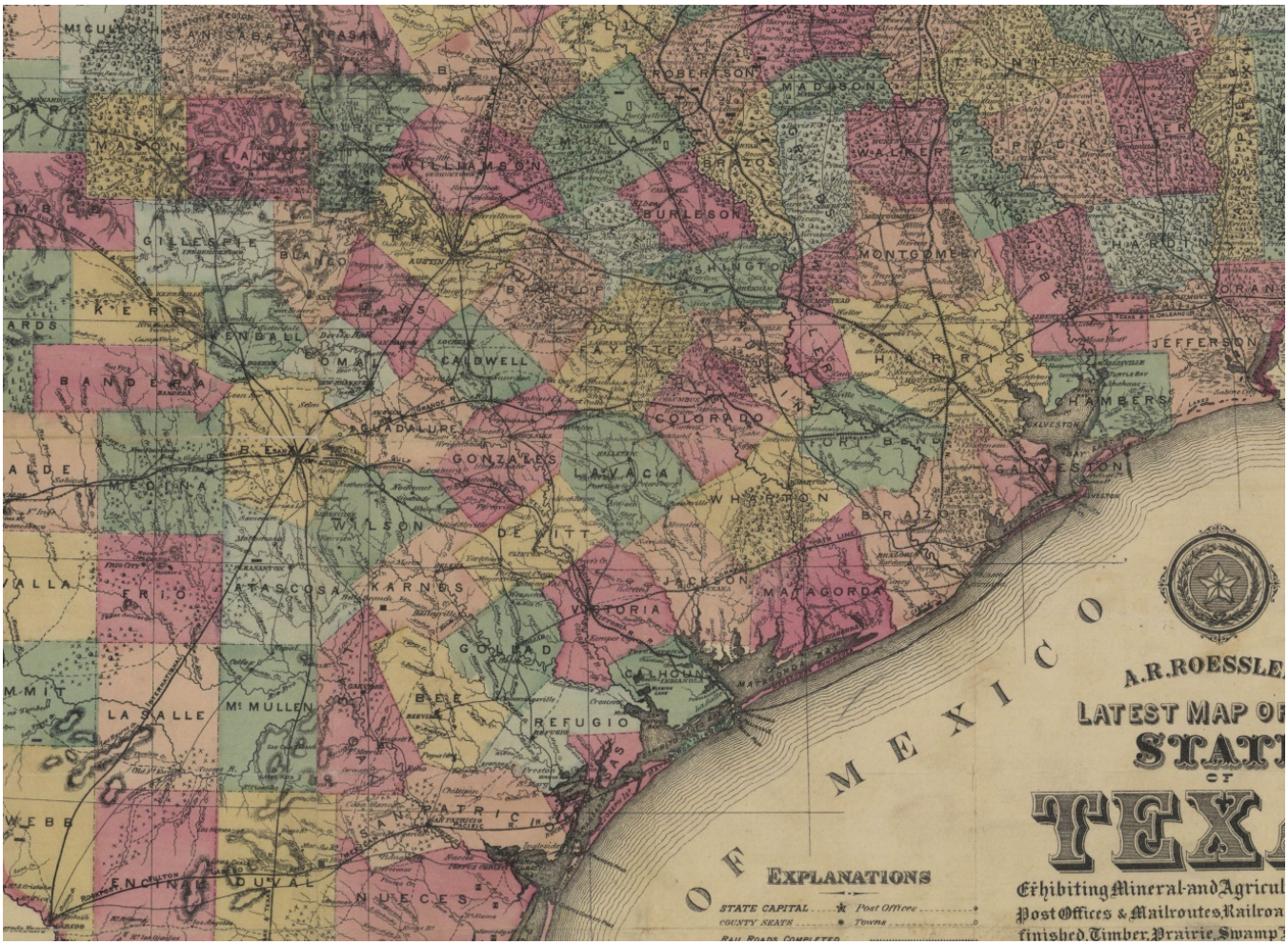



*Figure 4. 1874 map of Texas, showing development of railroad and road networks in central and southeast Texas. (Source: Texas State Library and Archives Map Collection)*

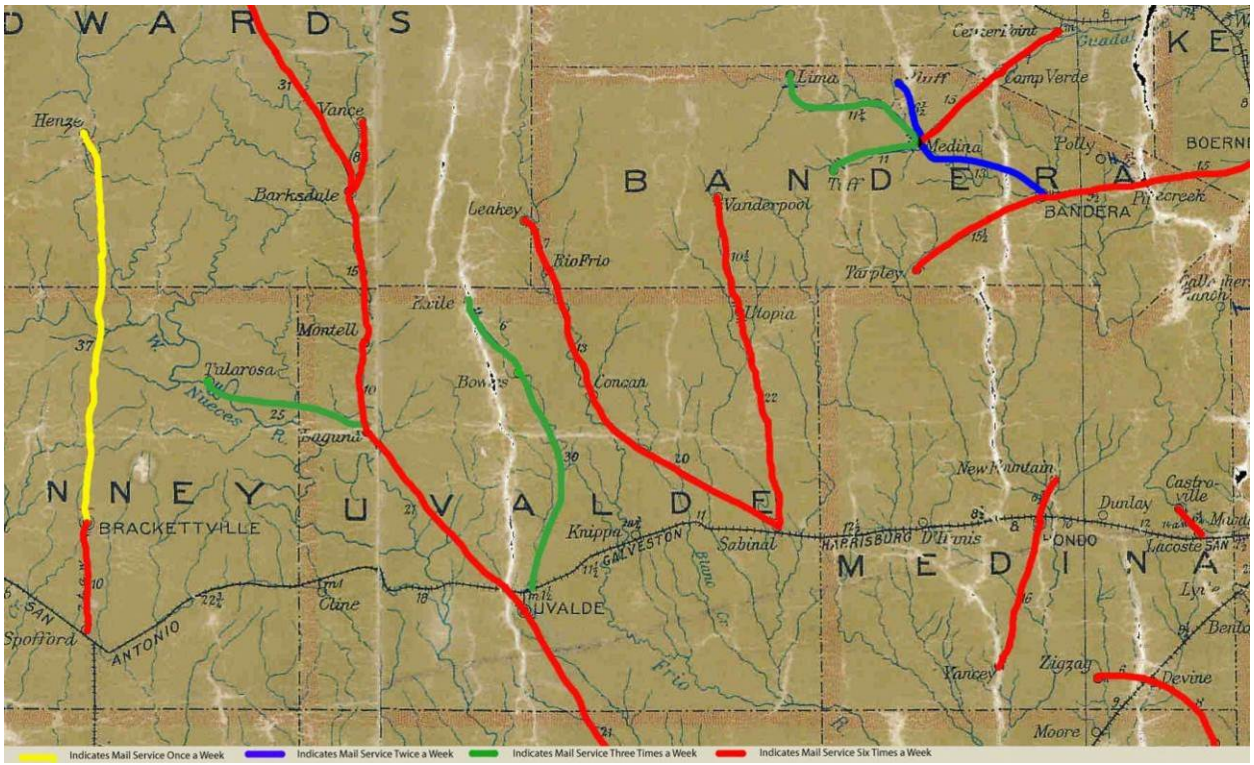



*Figure 5. 1907 post routes in west-central Texas, illustrating the extent of mail service and relationship of roads to rail lines. (Source: Texas State Library and Archives Map Collection)*

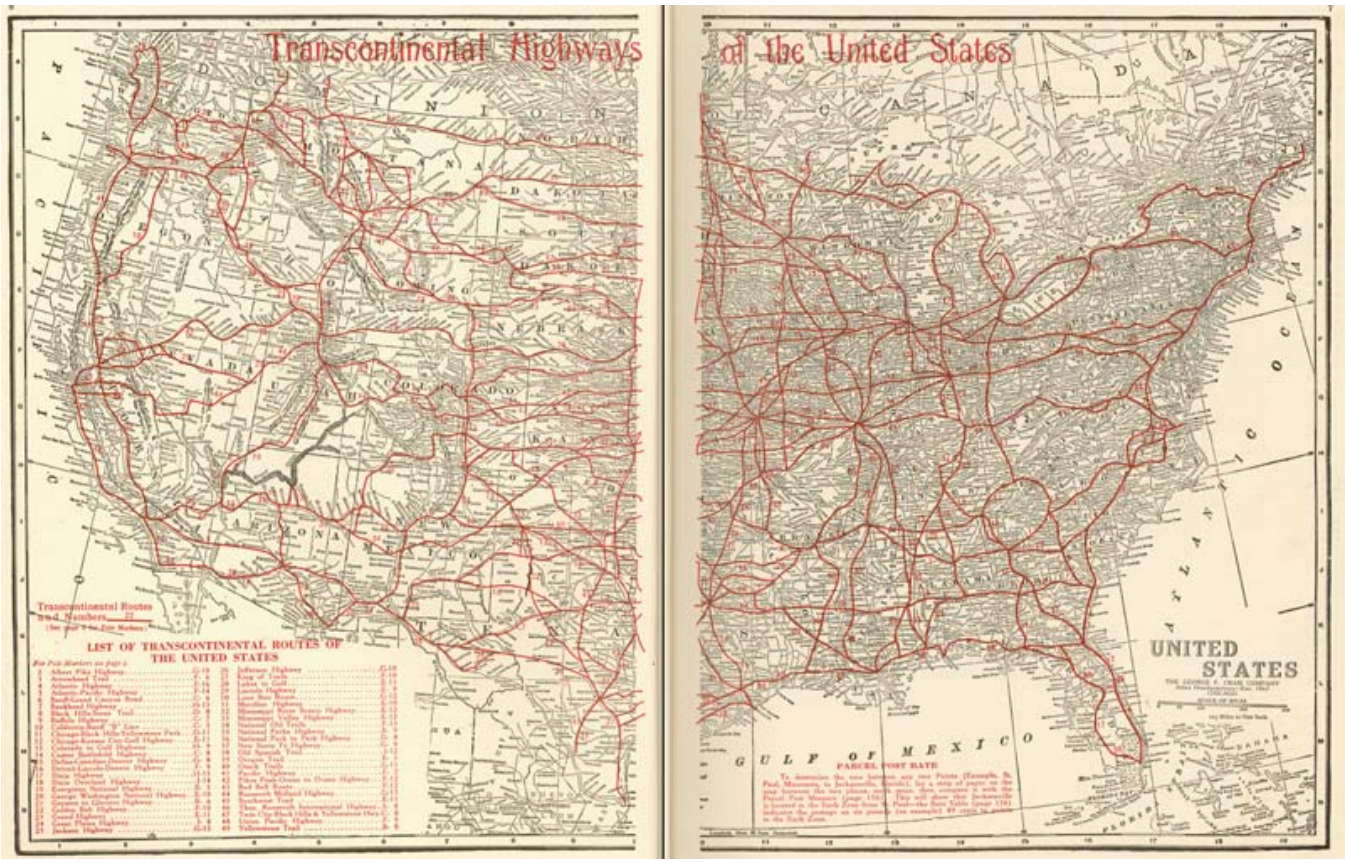
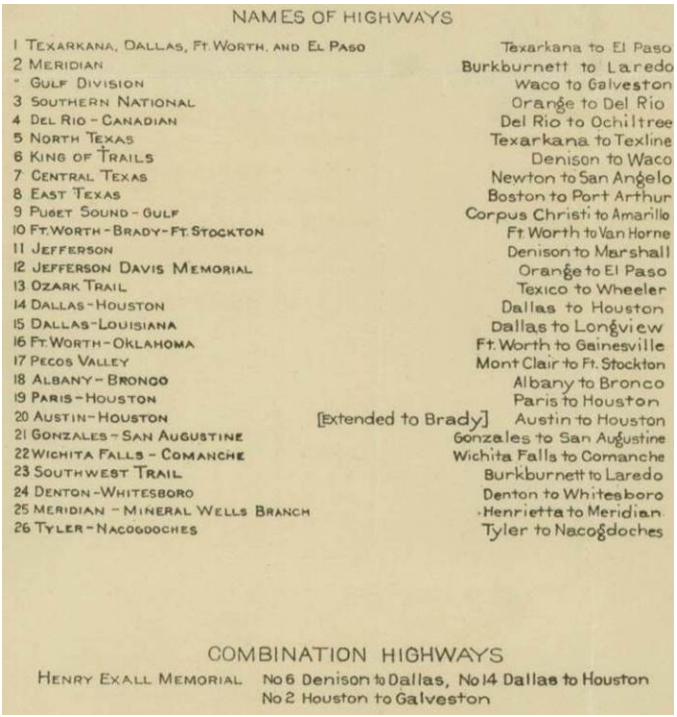



*Figure 6. 1918 map of transcontinental highways in the U.S.*
*(Source: Texas State Library and Archives Map Collection)*



NAMES OF HIGHWAYS

| | |
|---|---|
| 1 TEXARKANA, DALLAS, FT. WORTH, AND EL PASO | Texarkana to El Paso |
| 2 MERIDIAN | Burkburnett to Laredo |
| " GULF DIVISION | Waco to Galveston |
| 3 SOUTHERN NATIONAL | Orange to Del Rio |
| 4 DEL RIO - CANADIAN | Del Rio to Ochiltree |
| 5 NORTH TEXAS | Texarkana to Texline |
| 6 KING OF TRAILS | Denison to Waco |
| 7 CENTRAL TEXAS | Newton to San Angelo |
| 8 EAST TEXAS | Boston to Port Arthur |
| 9 PUGET SOUND - GULF | Corpus Christi to Amarillo |
| 10 FT. WORTH - BRADY - FT. STOCKTON | Ft Worth to Van Horne |
| 11 JEFFERSON | Denison to Marshall |
| 12 JEFFERSON DAVIS MEMORIAL | Orange to El Paso |
| 13 OZARK TRAIL | Texico to Wheeler |
| 14 DALLAS - HOUSTON | Dallas to Houston |
| 15 DALLAS - LOUISIANA | Dallas to Longview |
| 16 FT. WORTH - OKLAHOMA | Ft. Worth to Gainesville |
| 17 PECOS VALLEY | Mont Clair to Ft. Stockton |
| 18 ALBANY - BRONCO | Albany to Bronco |
| 19 PARIS - HOUSTON | Paris to Houston |
| 20 AUSTIN - HOUSTON | [Extended to Brady] Austin to Houston |
| 21 GONZALES - SAN AUGUSTINE | Gonzales to San Augustine |
| 22 WICHITA FALLS - COMANCHE | Wichita Falls to Comanche |
| 23 SOUTHWEST TRAIL | Burkburnett to Laredo |
| 24 DENTON - WHITESBORO | Denton to Whitesboro |
| 25 MERIDIAN - MINERAL WELLS BRANCH | Henrietta to Meridian |
| 26 TYLER - NACOGDOCHES | Tyler to Nacogdoches |

COMBINATION HIGHWAYS

HENRY EXALL MEMORIAL No 6 Denison to Dallas, No 14 Dallas to Houston
No 2 Houston to Galveston

*Figure 7. Named Highways in Texas, 1917.*
*(Source: Texas State Library and Archives Map Collection)*

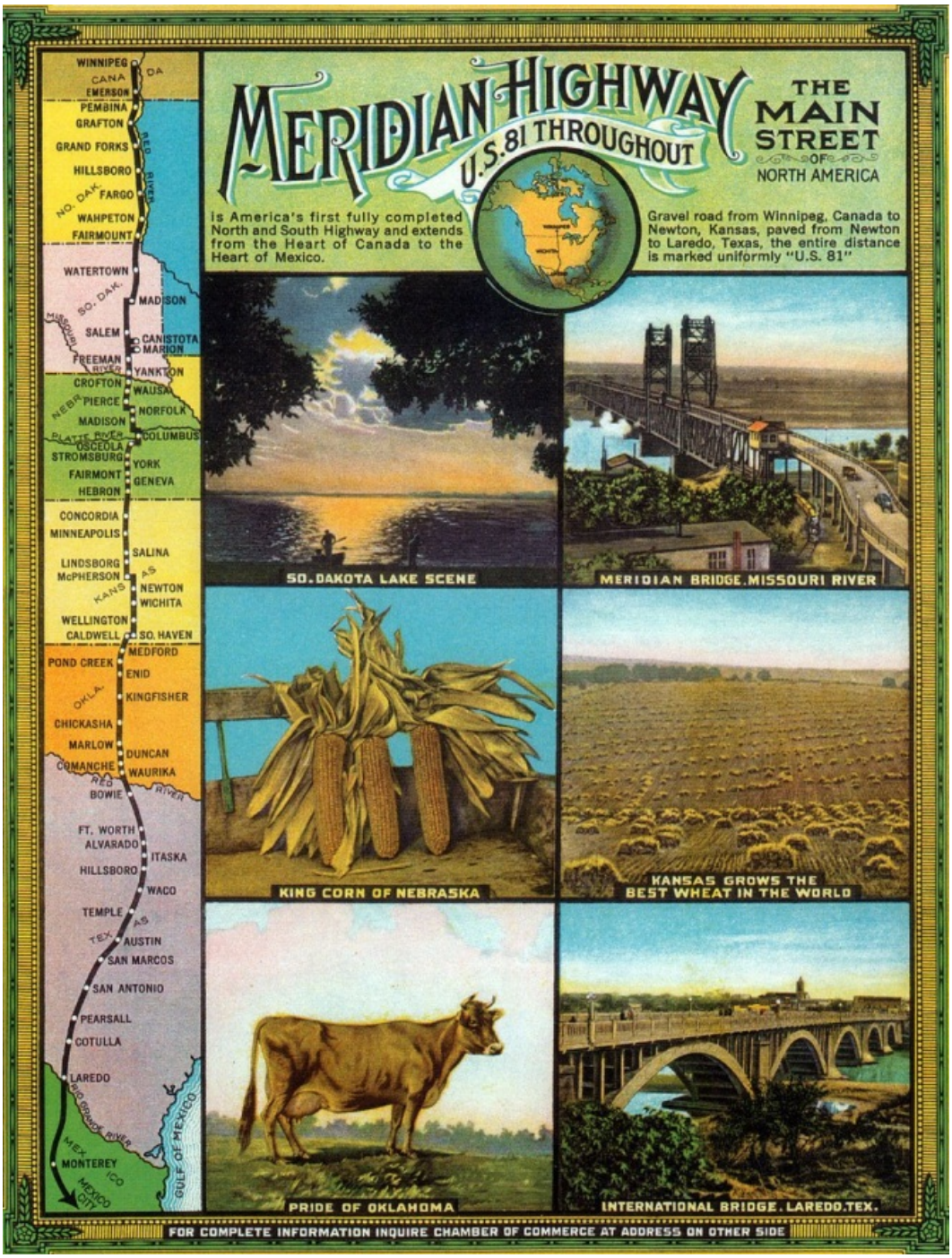



*Figure 8. Meridian Highway brochure.*
*(Source: Mead & Hunt, Inc. private collection)*

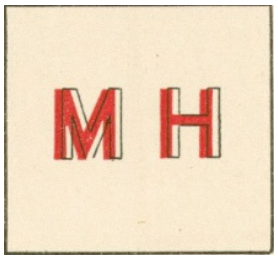



*Figure 9. Meridian Highway pole marker.*
*(Source: Texas General Land Office)*

*Figure 10. Dixie Overland Highway marker.*
*(Source: Texas General Land Office)*

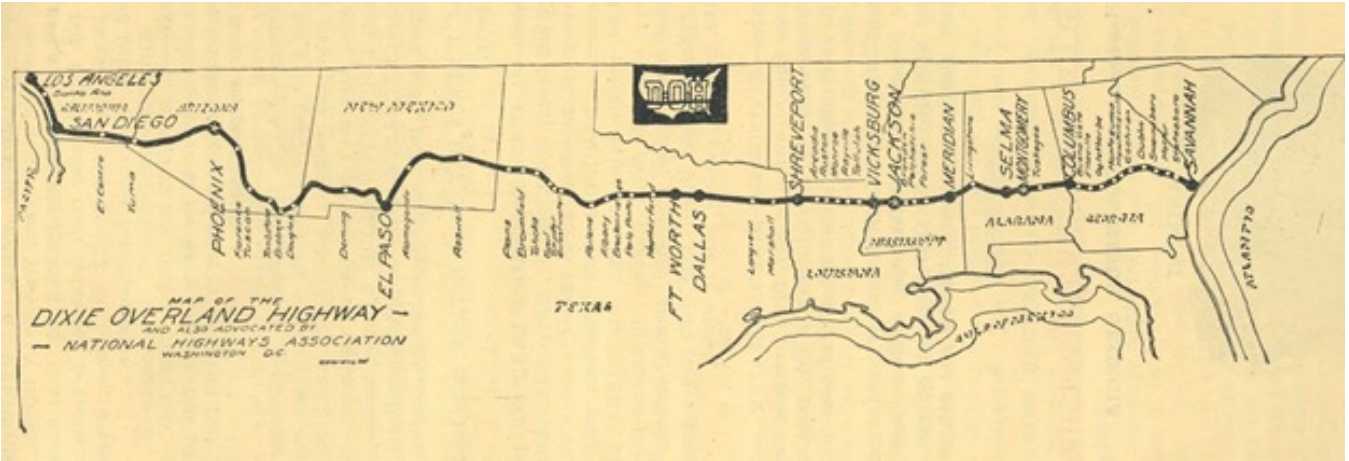



*Figure 11. Dixie Overland Highway map.*
*(Source: http://www.fhwa.dot.gov/infrastructure/us80map2.cfm)*

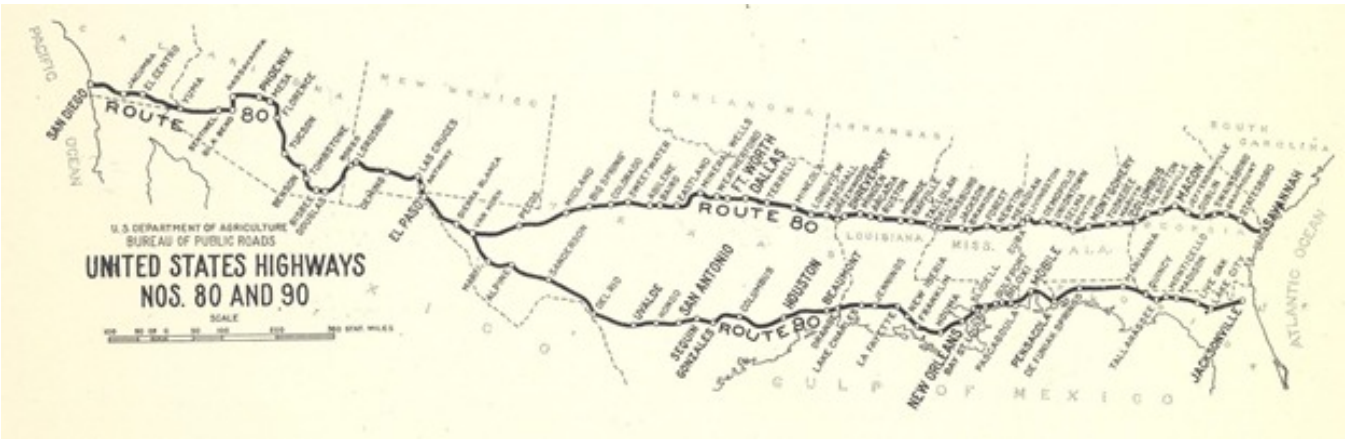



*Figure 12. US 80 map.*
*(Source: http://www.fhwa.dot.gov/infrastructure/us80map1.cfm)*

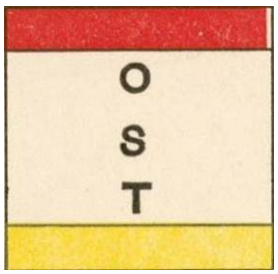



*Figure 13. Old Spanish Trail marker.*
*(Source: Texas General Land Office)*

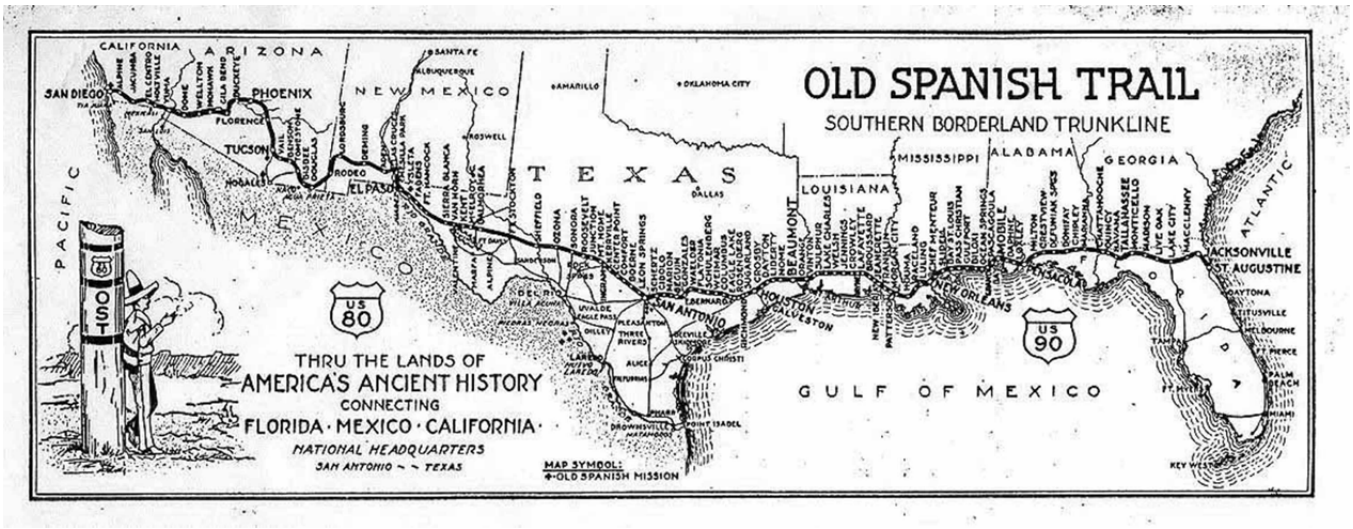



*Figure 14. Old Spanish Trail map.*
*(Source: http://www.drivetheost.com/map.html)*

*Figure 15. Concrete obelisk on former Ozark Trail alignment in downtown Tulia.*
*(Source: Mead & Hunt, Inc.)*

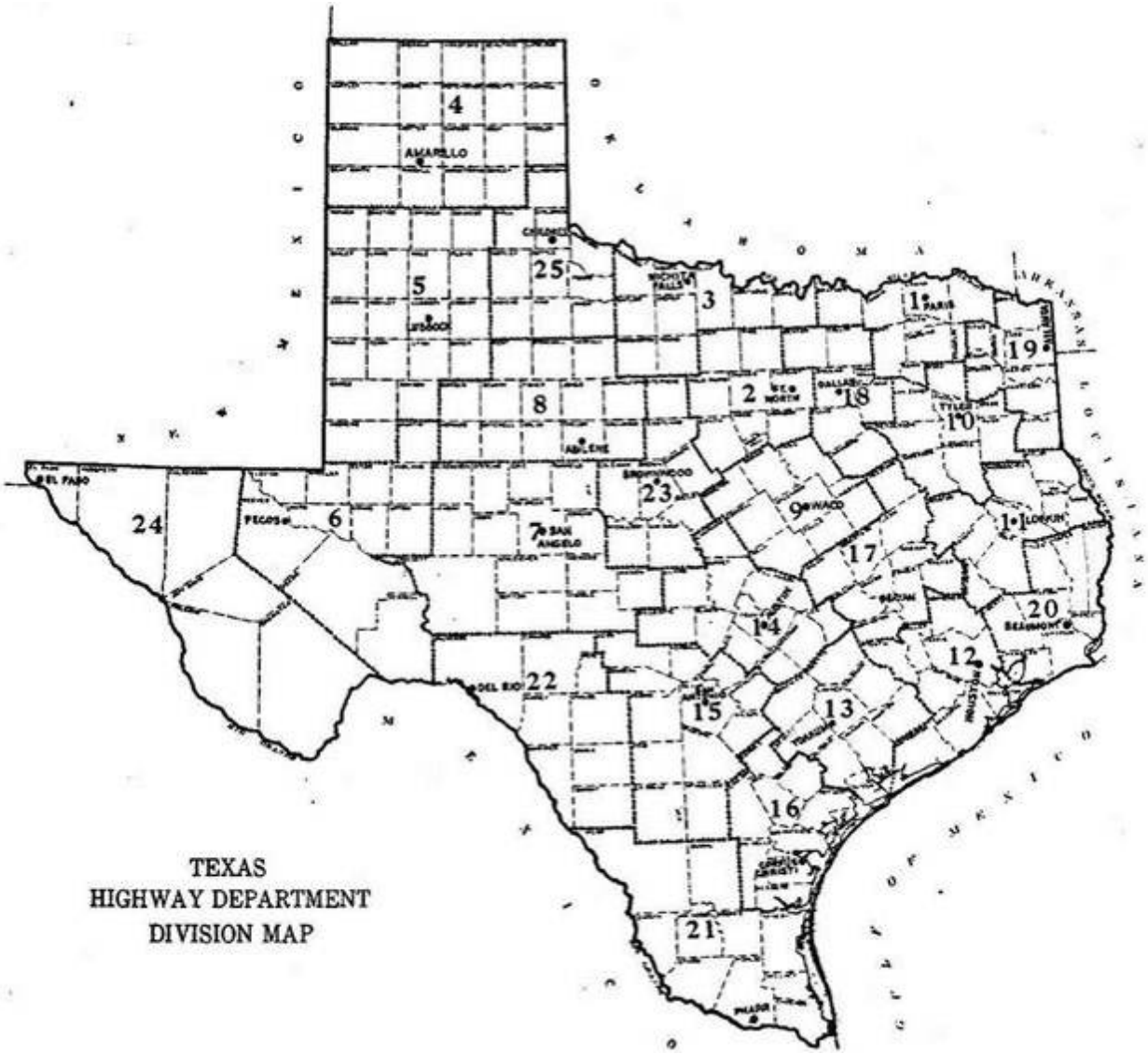



*Figure 16. 1937 Texas Highway Division Map, showing the state's 25 districts. (source: Gibb Gilchrist, Texas Highway Department 1927-1937, 6).*

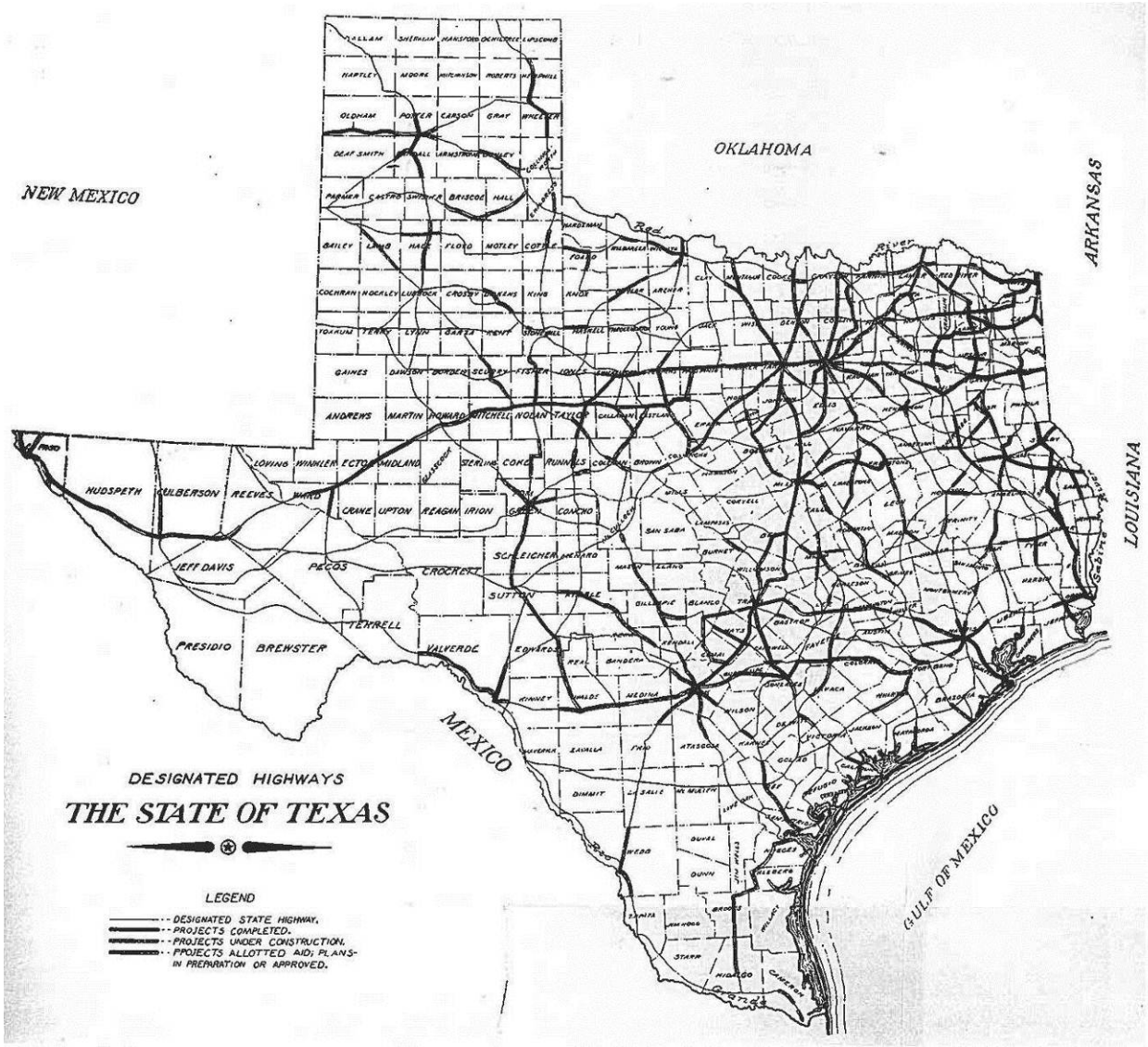



*Figure 17. 1921 Second Biennial Report Designated Highways Map*
*(Source: Texas Department of Transportation)*

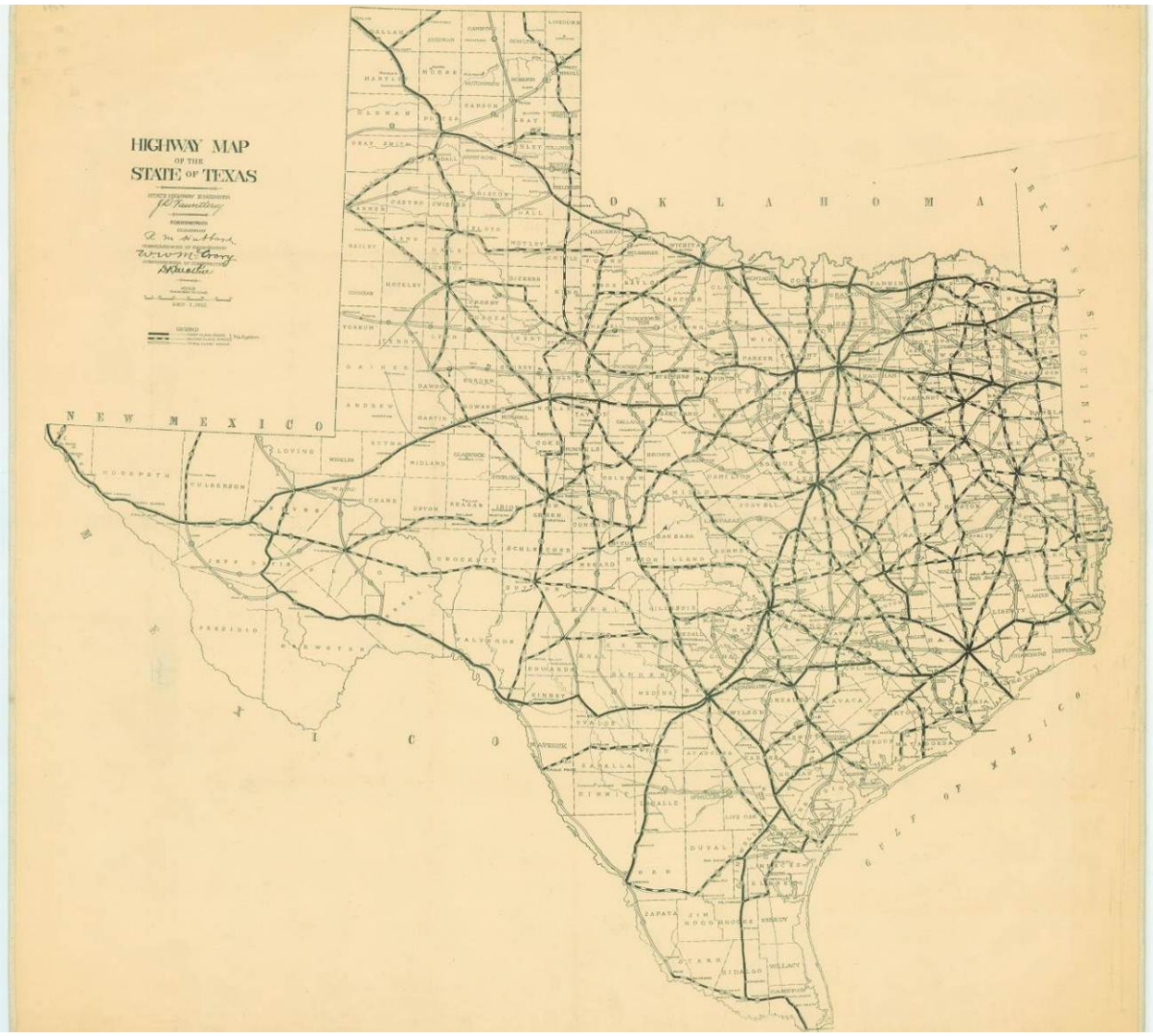



*Figure 18. 1922 Highway Map of the State of Texas.*
*(Source: Texas State Library and Archives Map Collection)*

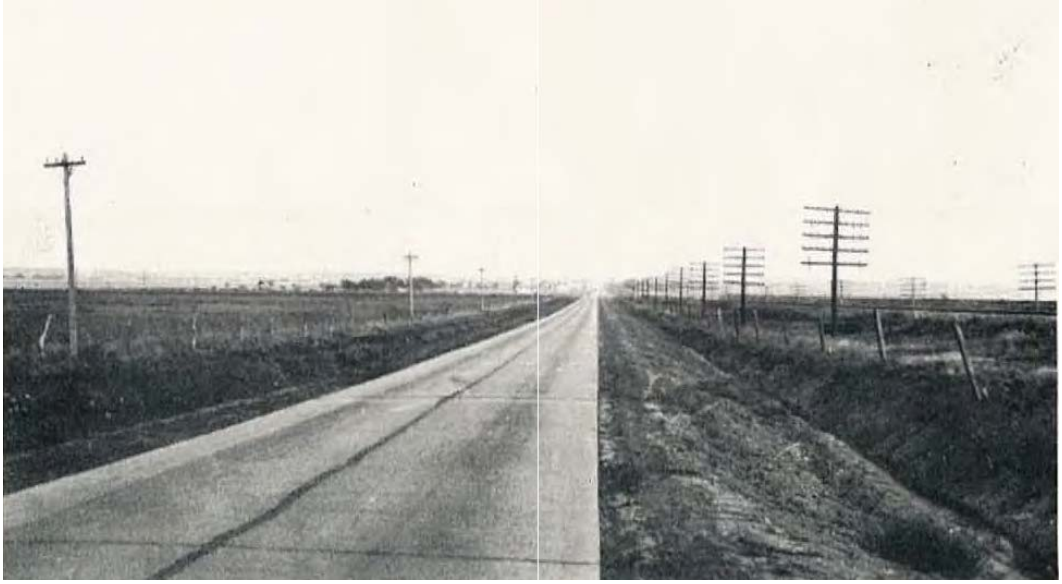


*Figure 19. Typical highway section, 1926.*
*(Source: Gibb Gilchrist, Texas Highway Department 1927-1937, 46)*

*Figure 20. Photo of a culvert from the early 1920s.*
*(Source: Texas Department of Transportation Photo Library)*

*Figure 21. Highway signage in Montague County showing state and federal designations on same roadway, c. late 1920s or 1930s.*

*(Source: Texas Department of Transportation Photo Library)*

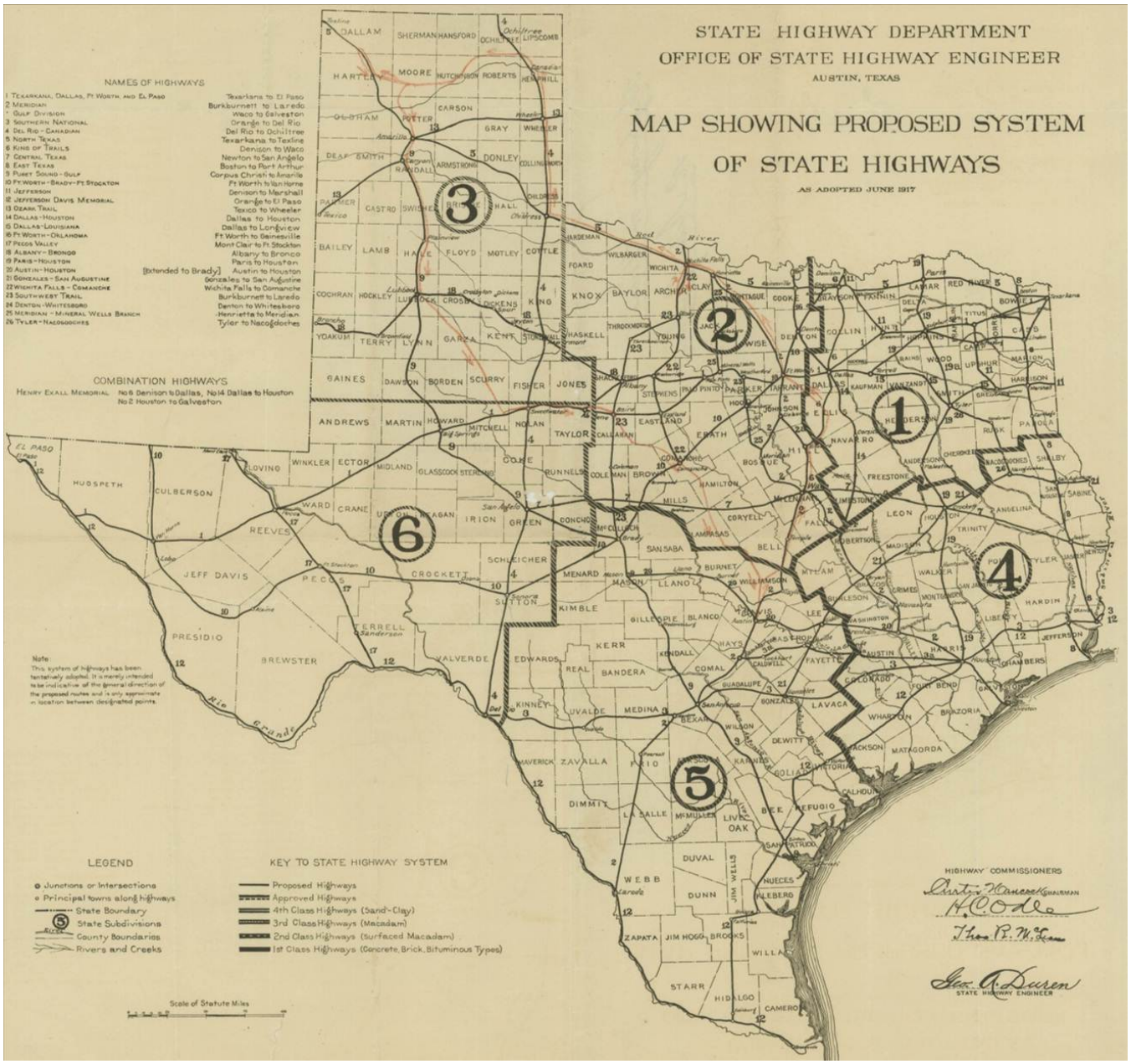



*Figure 22. 1917 map of proposed system of state highways in Texas.*
*(Source: Texas State Library and Archives Map Collection)*

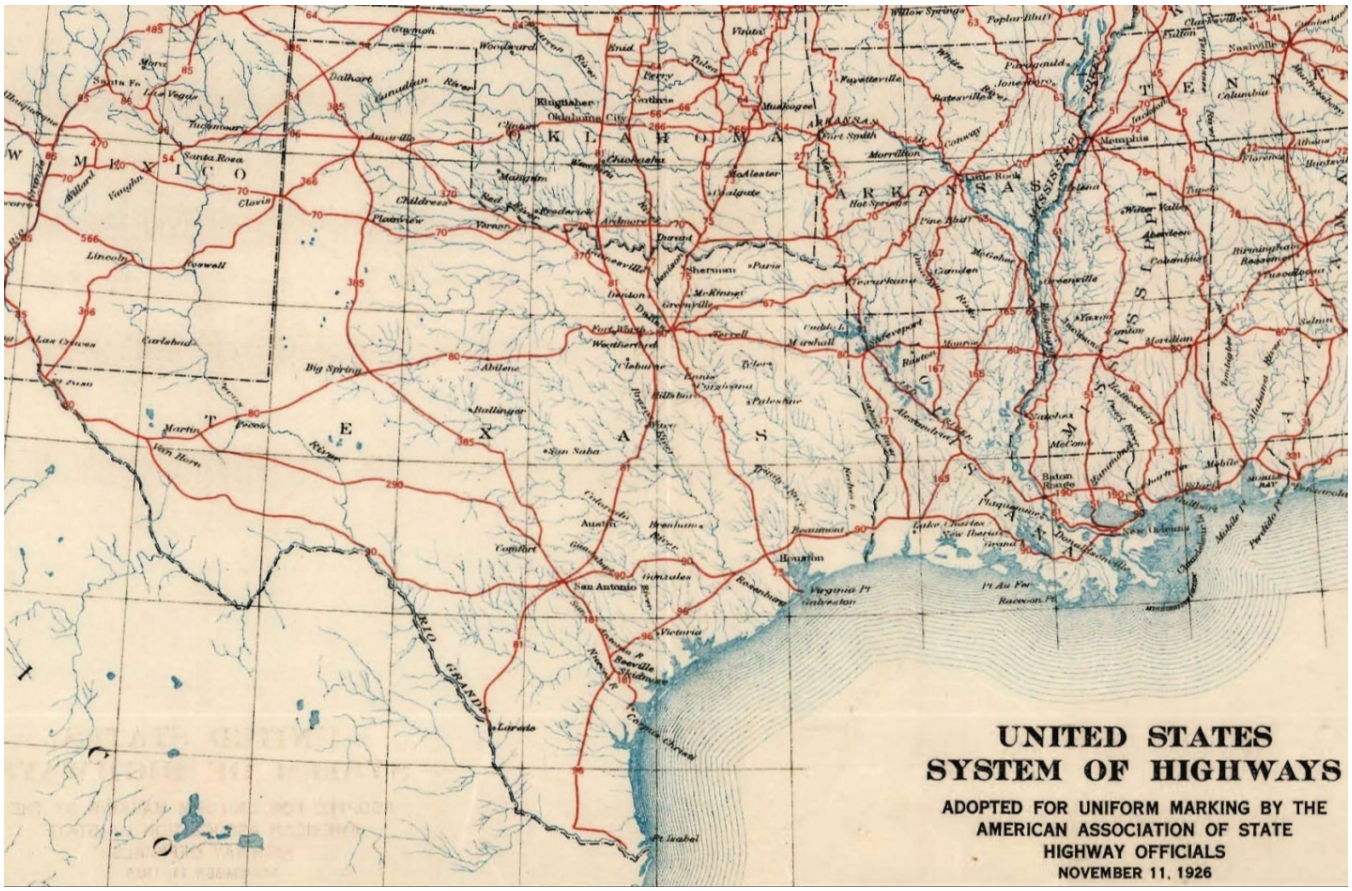



*Figure 23. 1926 map of approved U.S. Highway system.*
*(Source: http://www.okladot.state.ok.us/hqdiv/p-r-div/maps/misc-maps/1926us.pdf)*

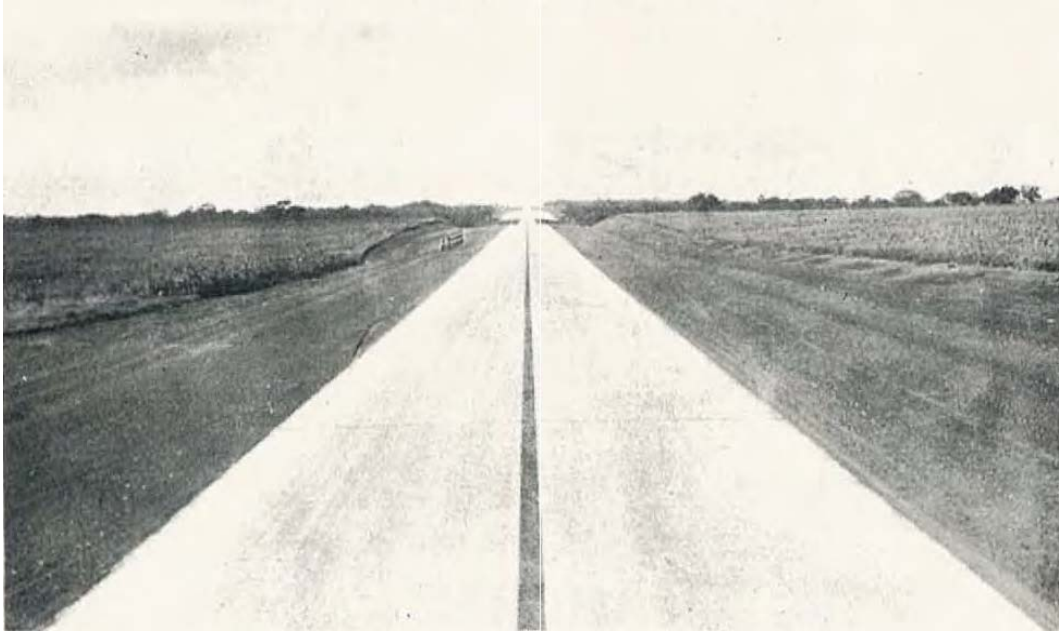


*Figure 24. Typical highway section, 1937*
*(Source: Gibb Gilchrist, Texas Highway Department 1927-1937, 46)*

*Figure 25. Wichita County highway 1931.*
*(Source: Texas Department of Transportation Photo Library)*

*Figure 26. Red River Bridge on SH 2 in Montague County, completed 1931.*
*(Source: Gibb Gilchrist, Texas Highway Department 1927-1937, 109)*

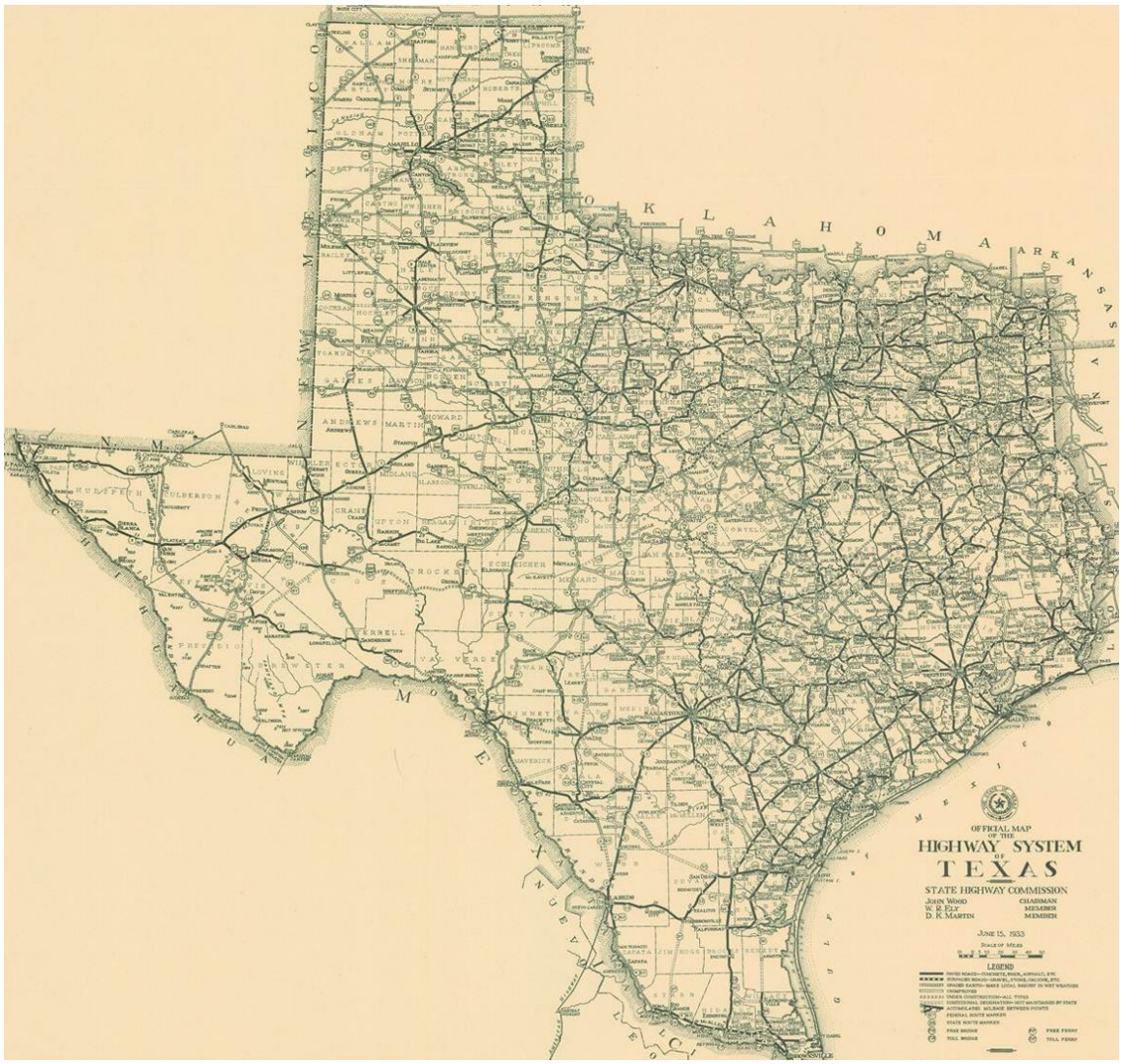



*Figure 27. 1933 map of state highway system.*
*(Source: Texas State Library and Archives Map Collection)*

*Figure 28. THD urban road and underpass construction in DeWitt County, 1936-37.*
*(Source: Texas Department of Transportation Photo Library)*

*Figure 29. Use of stone masonry on THD project in Erath County, late 1930s.*
*(Source: Texas Department of Transportation Photo Library)*

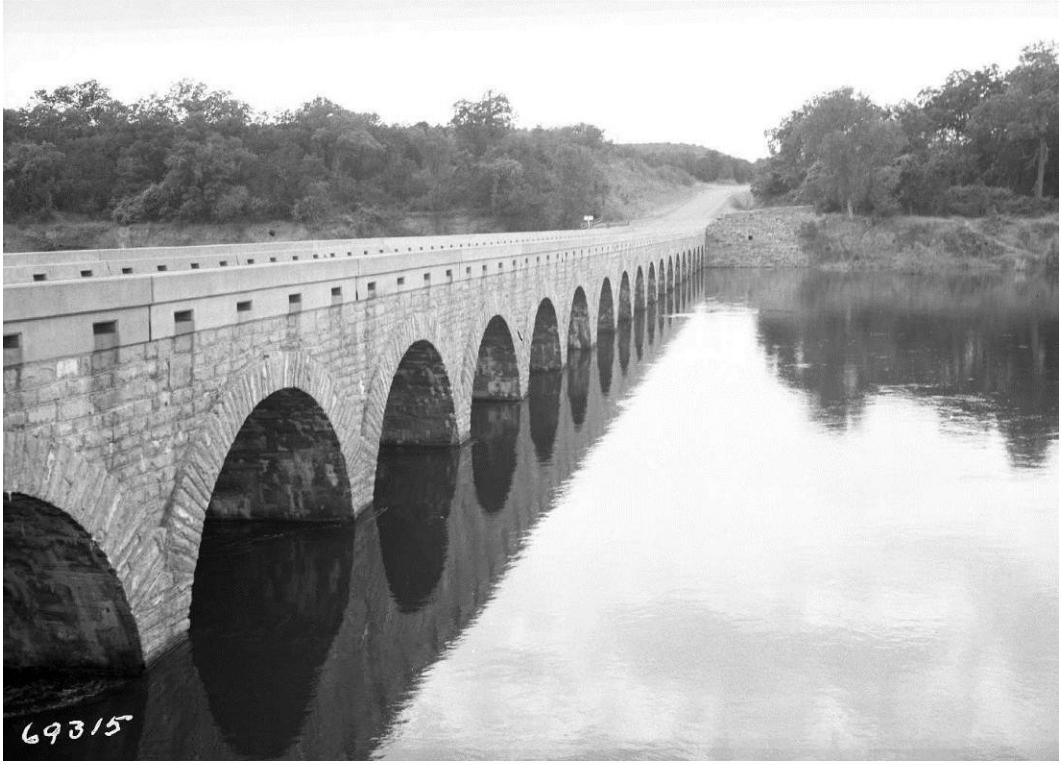



*Figure 30. Possum Kingdom Bridge at the Brazos River, early 1940s.*
*(Source: Texas Department of Transportation Photo Library)*

*Figure 31. Joint THD/NYA roadside park construction project*
*(Source: Texas Department of Transportation Photo Library)*

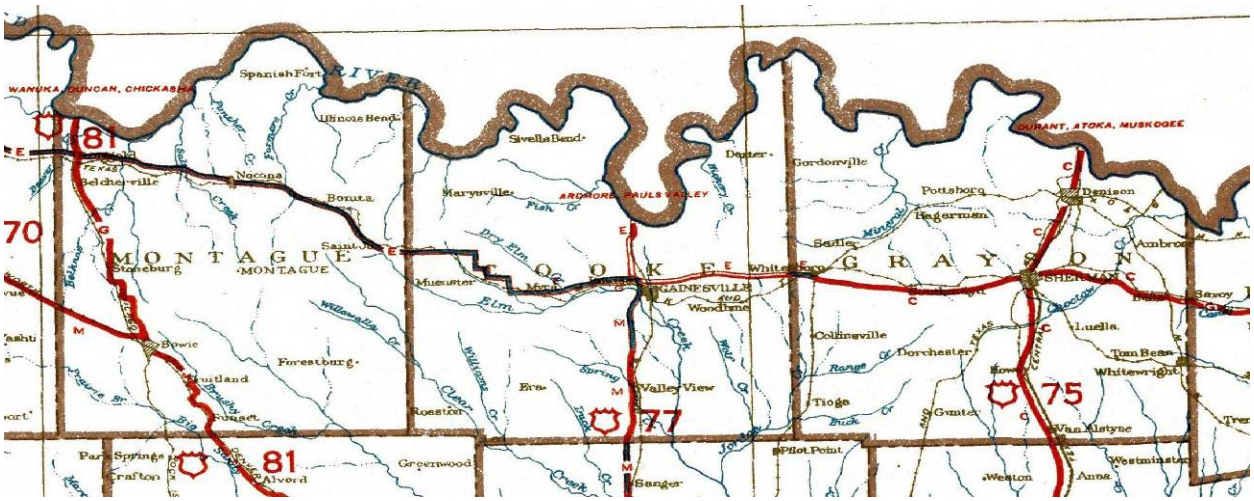



*Figure 32. Portion of 1931 Bureau of Public Roads map, showing federal-aid highways in Montague, Cooke, and Grayson Counties, 1931.*
*(Source: Texas State Library and Archives Map Collection)*

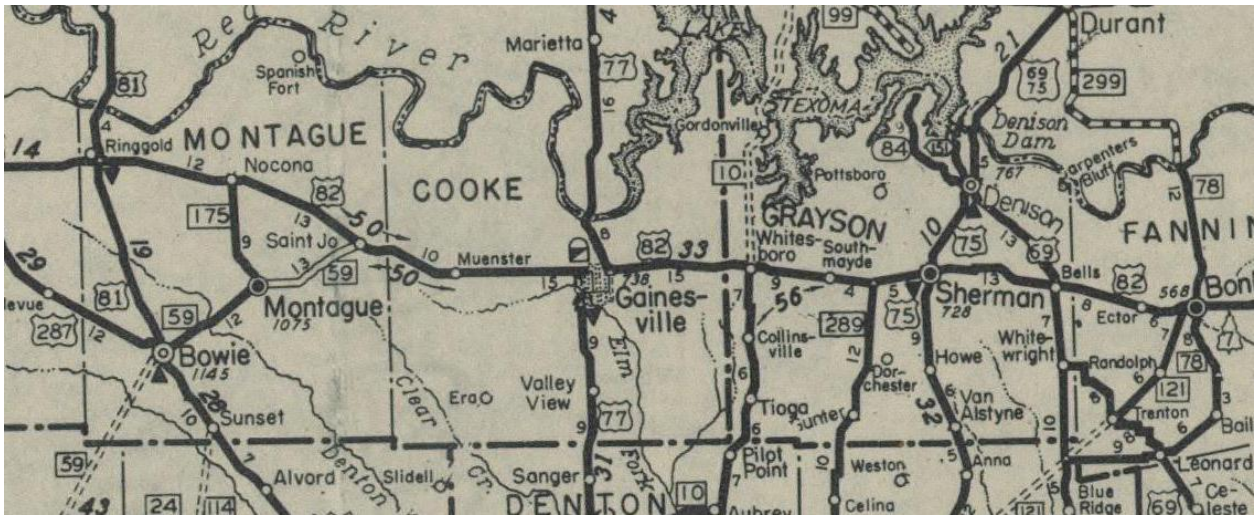



*Figure 33. Portion of 1941 THD State Highway Map, showing highway development in Montague, Cooke, and Grayson Counties.*

*(Source: Texas State Library and Archives Map Collection)*

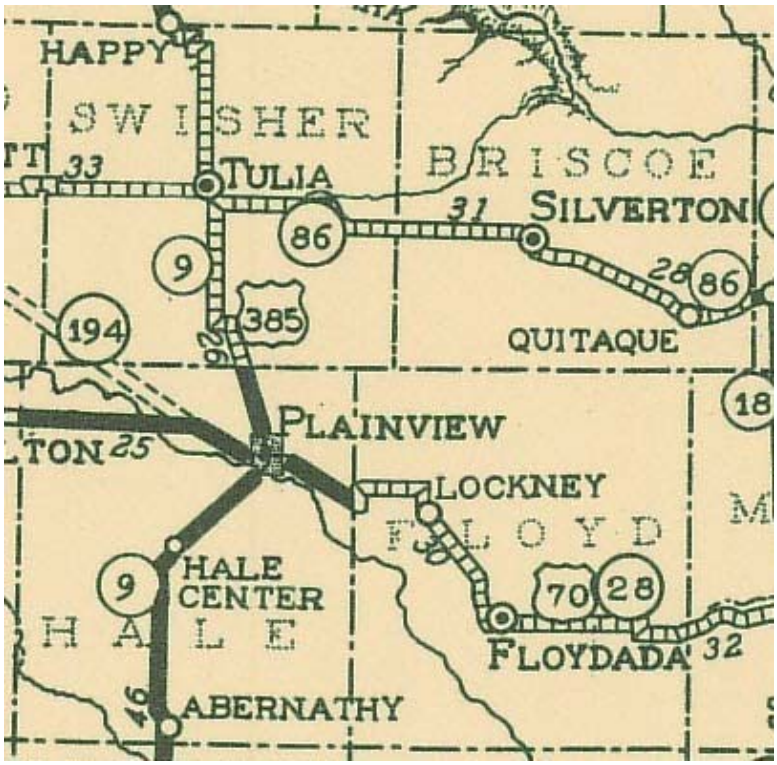



*Figure 34. Portion of 1933 THD State Highway Map showing highways in the Texas Panhandle.*

*(Source: Texas State Library and Archives Map Collection)*

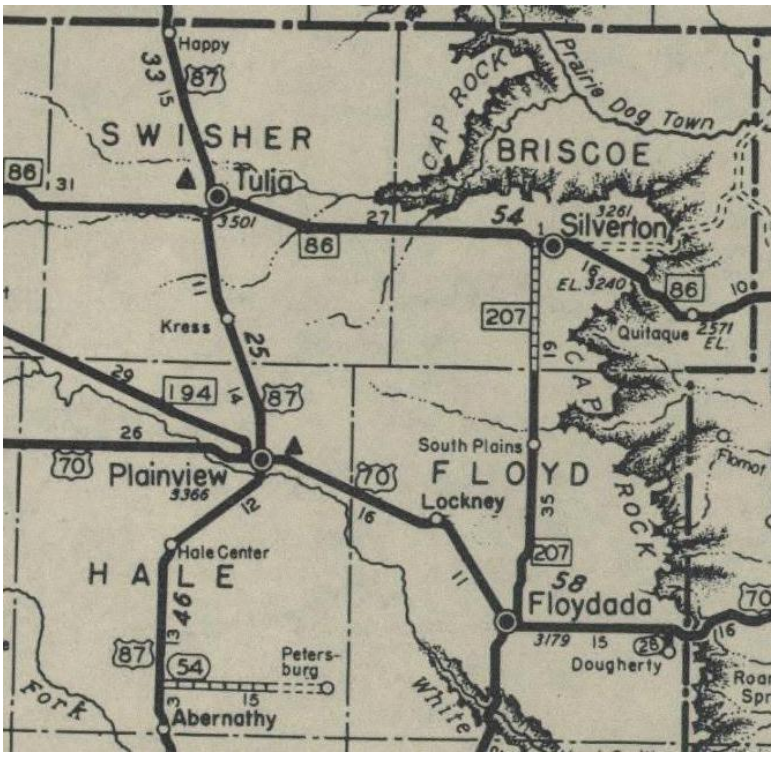



*Figure 35. Portion of 1945 THD State Highway Map, showing highways in Texas Panhandle. (Source: Texas State Library and Archives Map Collection)*

*Figure 36. Installing brick pavement on US 180 in Parker and Palo Pinto Counties, 1938. At the time, the roadway was designated as Alternate US 80 and roughly followed the historic alignment of the Bankhead Highway route. (Source: Texas Department of Transportation Photo Library)*

*Figure 37. Recently completed grade separation structure, US 81 in Montague County, November 1936. (Source: Texas Department of Transportation Photo Library)*

*Figure 38. FM 155 in Fayette County before improvement.*
*(Source: TxDOT Library)*

*Figure 39. FM 155 in Fayette County after improvement.*
*(Source: TxDOT Library)*

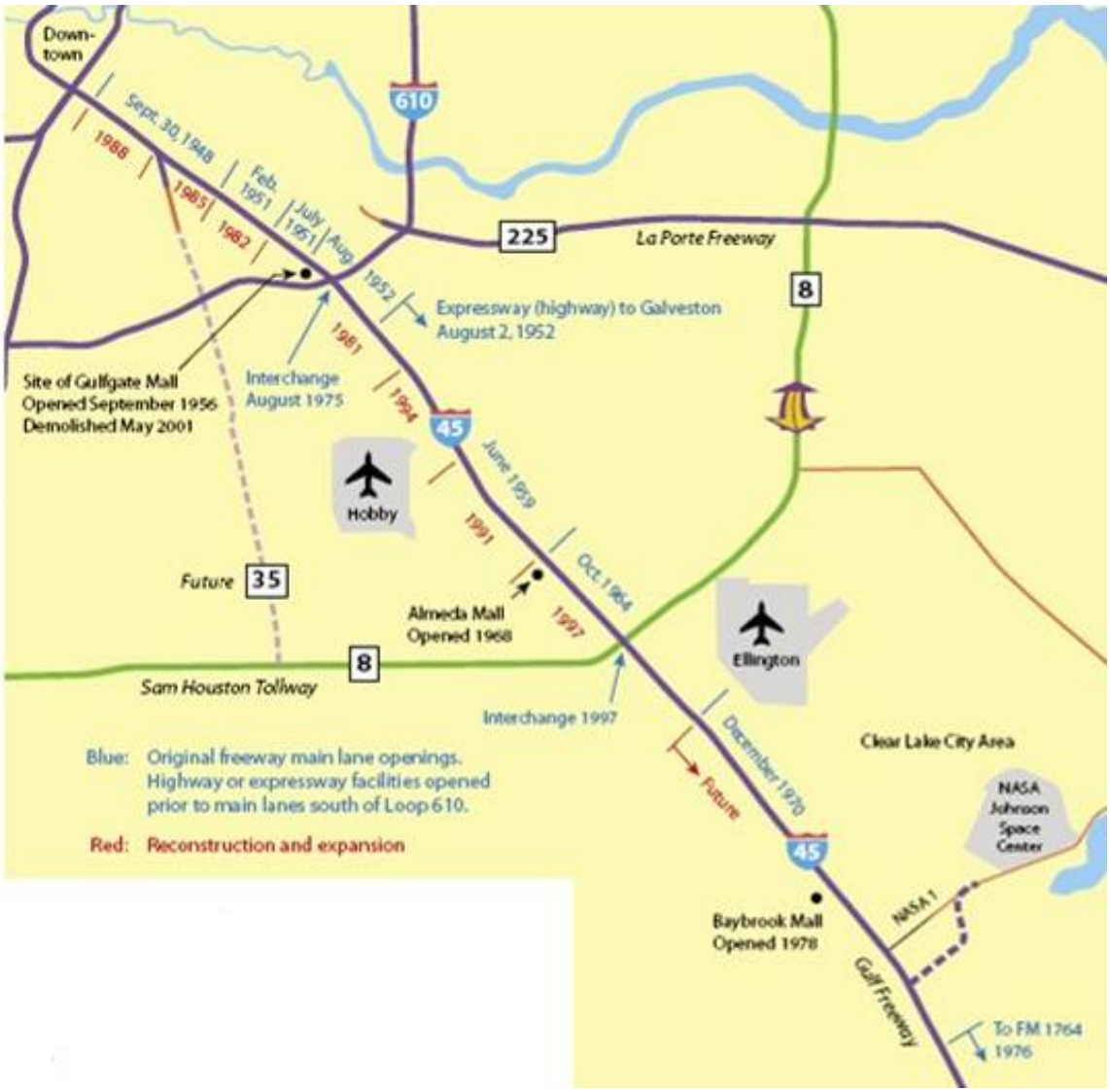



*Figure 40. Map of Gulf Freeway showing construction history.*
*(Source: Erik Slotboom, Houston Freeways: A Historical and Visual Journey, 2003, 145)*

*Figure 41. 1950s aerial view of the Gulf Freeway looking toward downtown Houston and illustrating the use of the frontage road*

*(Source: Erik Slotboom, Houston Freeways: A Historical and Visual Journey, 2003, 150)*

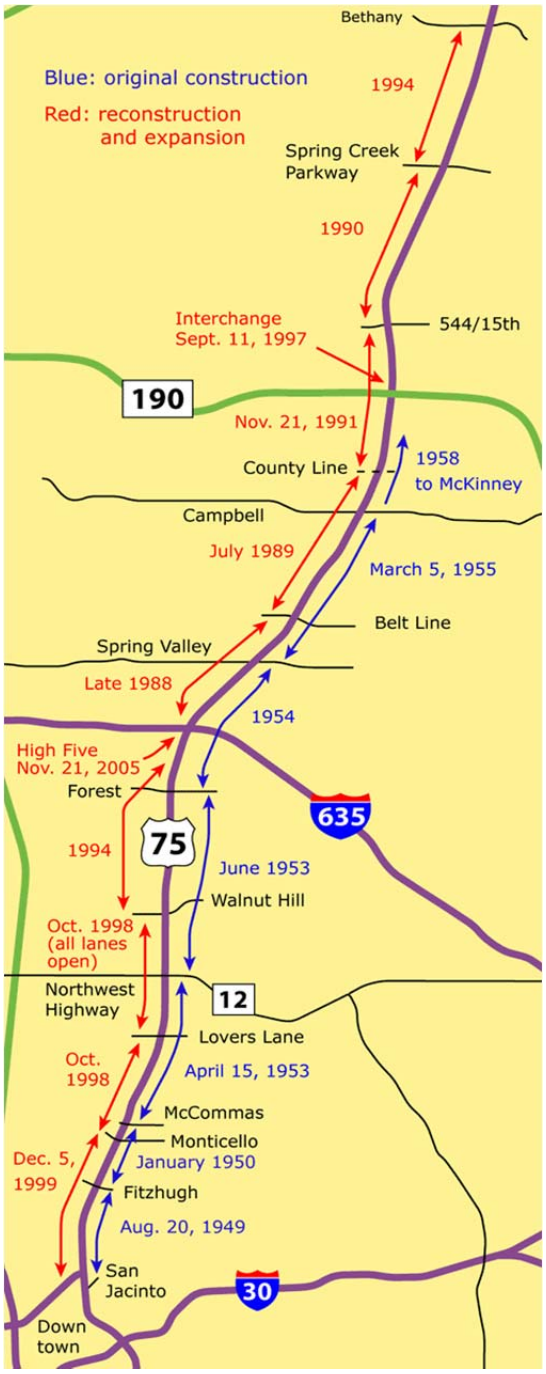



*Figure 42. Map of the North Central Expressway showing construction history. (Source: "US 75: Central Freeway," DFW Freeways, www.dfwfreeways.info/pages/highwayInfo/highwayInfoHome.aspx?highway=75n)*

*Figure 43. Early photograph (c.1955) of North Central Expressway with traffic heading downtown. (Source: Tom Killebrew, "The Creation of the Modern Freeway in Dallas, Texas, 1911-1949: the Story of North Central Expressway," Legacies: A History Journal for Dallas and North Central Texas, XIV, no 1 [Spring 2002]: 50)*

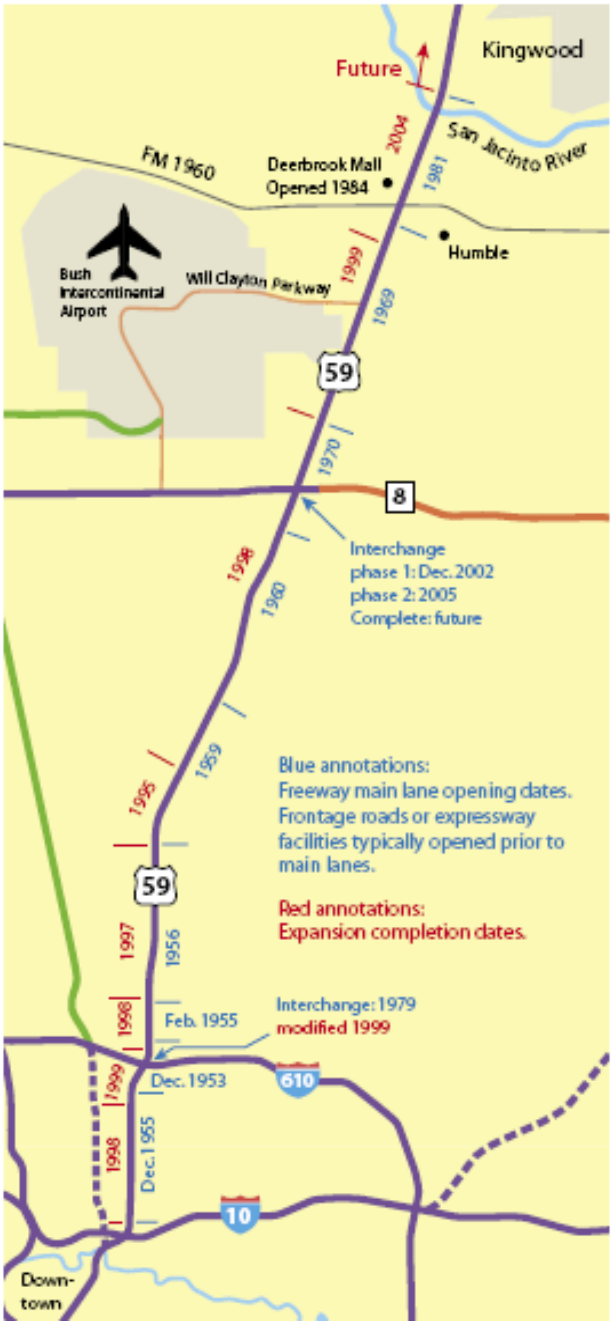



*Figure 44. Map of the Eastex freeway showing construction history.*
*(Source: Erik Slotboom, Houston Freeways: A Historical and Visual Journey, 2003, 226)*

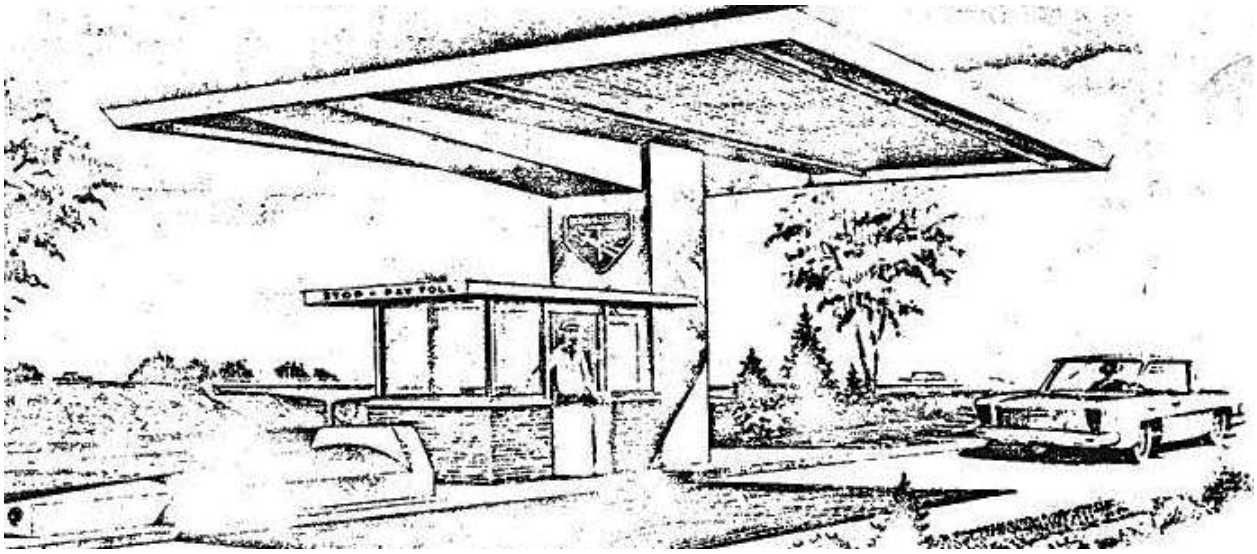



*Figure 45. Drawing of Dallas-Fort Worth Turnpike tollbooth from 1962 construction plans. (Source: Texas Department of Transportation.)*

*Figure 46. Dallas-Fort Worth Turnpike (now IH 30) interchange at Watson Road (now SH 360), 1957. (Source: www.texasfreeway.com.)*

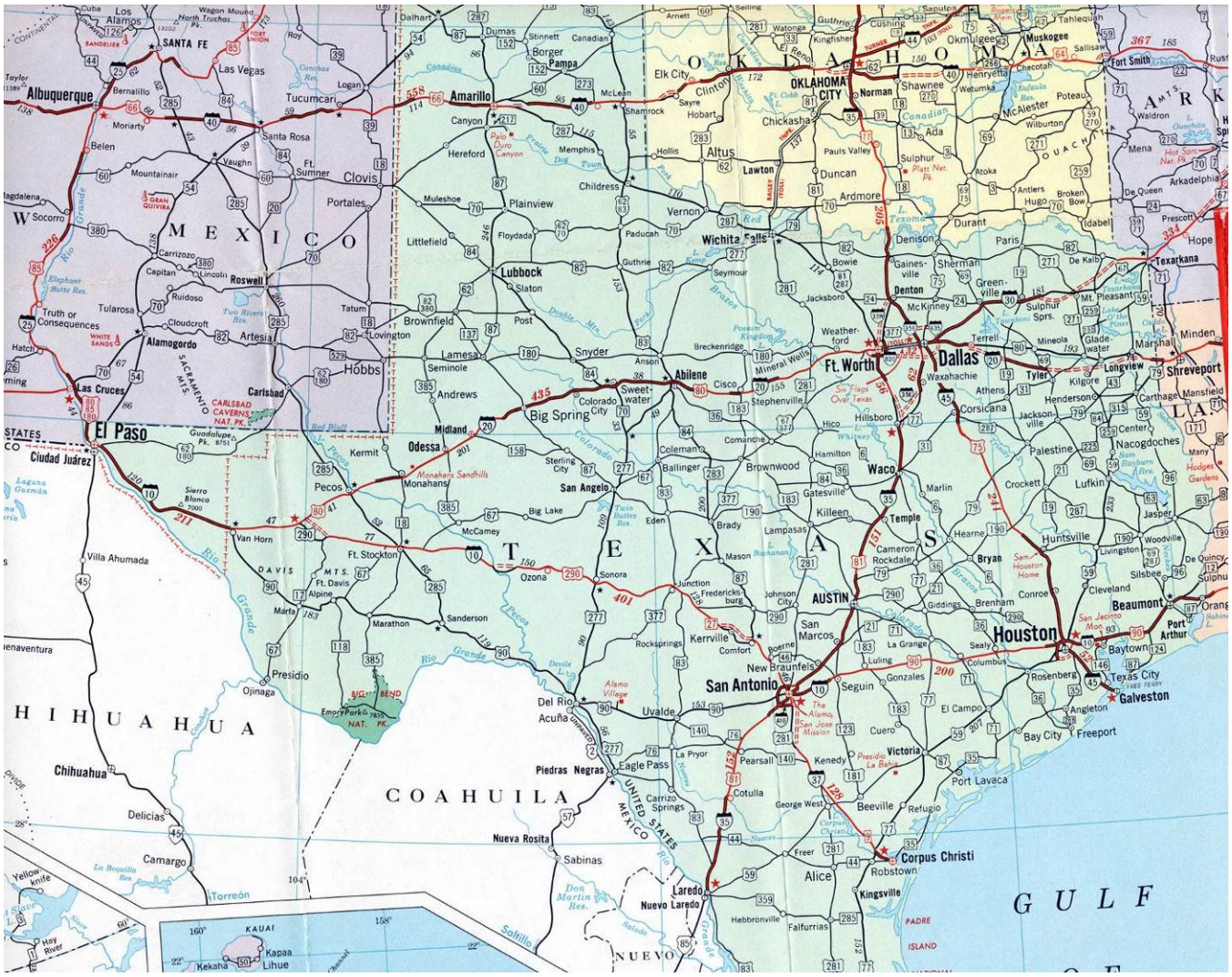



*Figure 47. Interstate map of Texas from 1965.*

*(Source: Esso, U.S. Happy Motoring Guide: The Interstate Highway System, Spring 1965)*

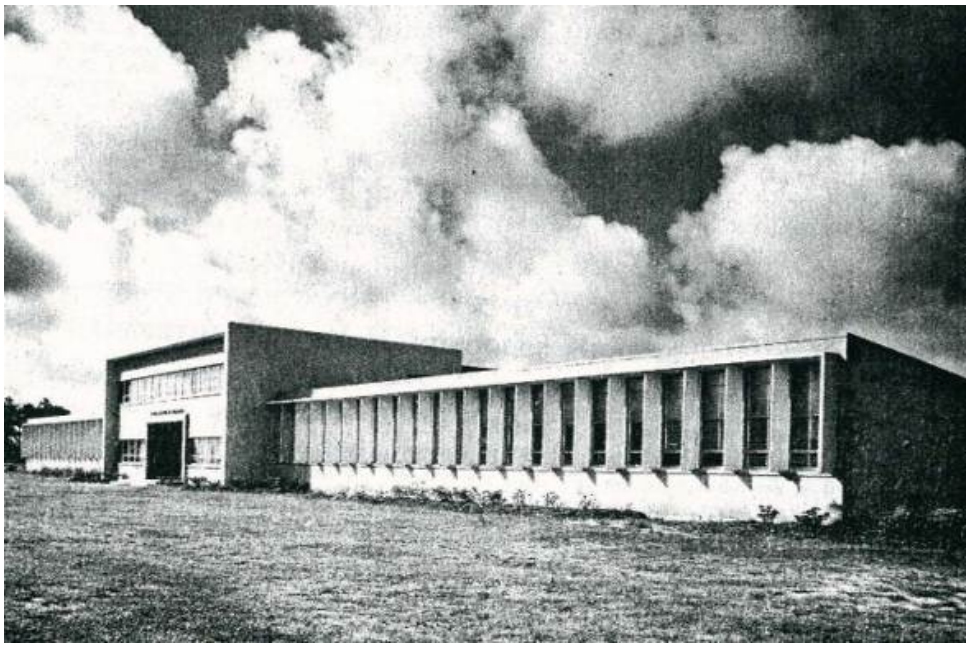


*Figure 48. View of Houston District headquarters office, 1953.*
*(Source: Texas Highway Department, Construction and Maintenance Bulletin No. 27, September 1953.)*

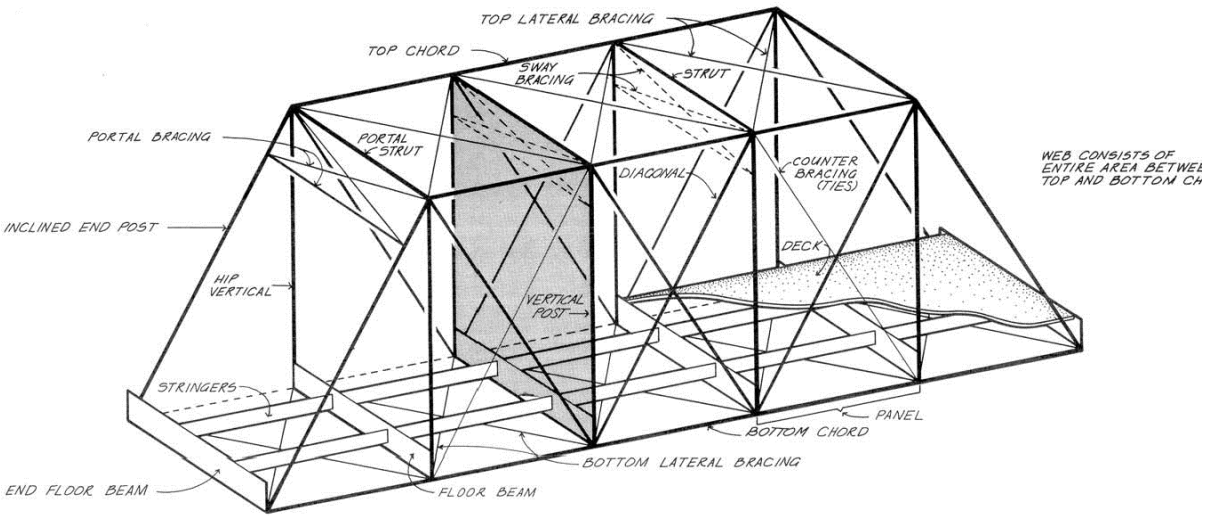



*Figure 49.*

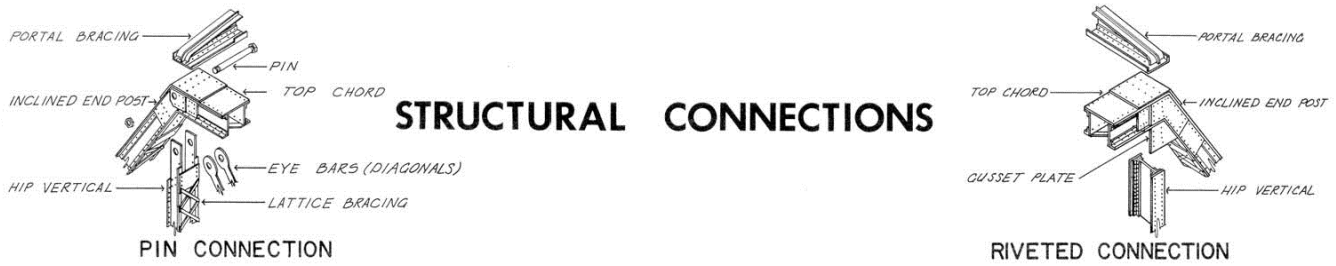



*Figure 50.*

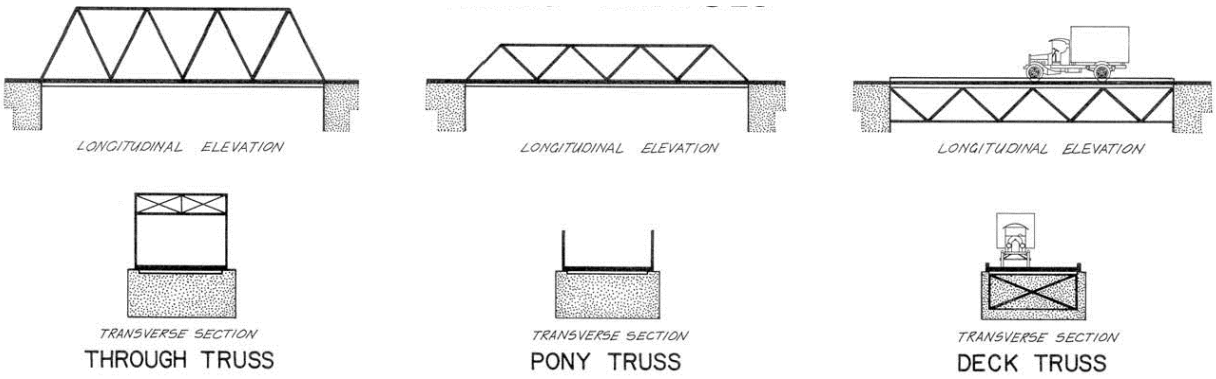



*Figure 51.*

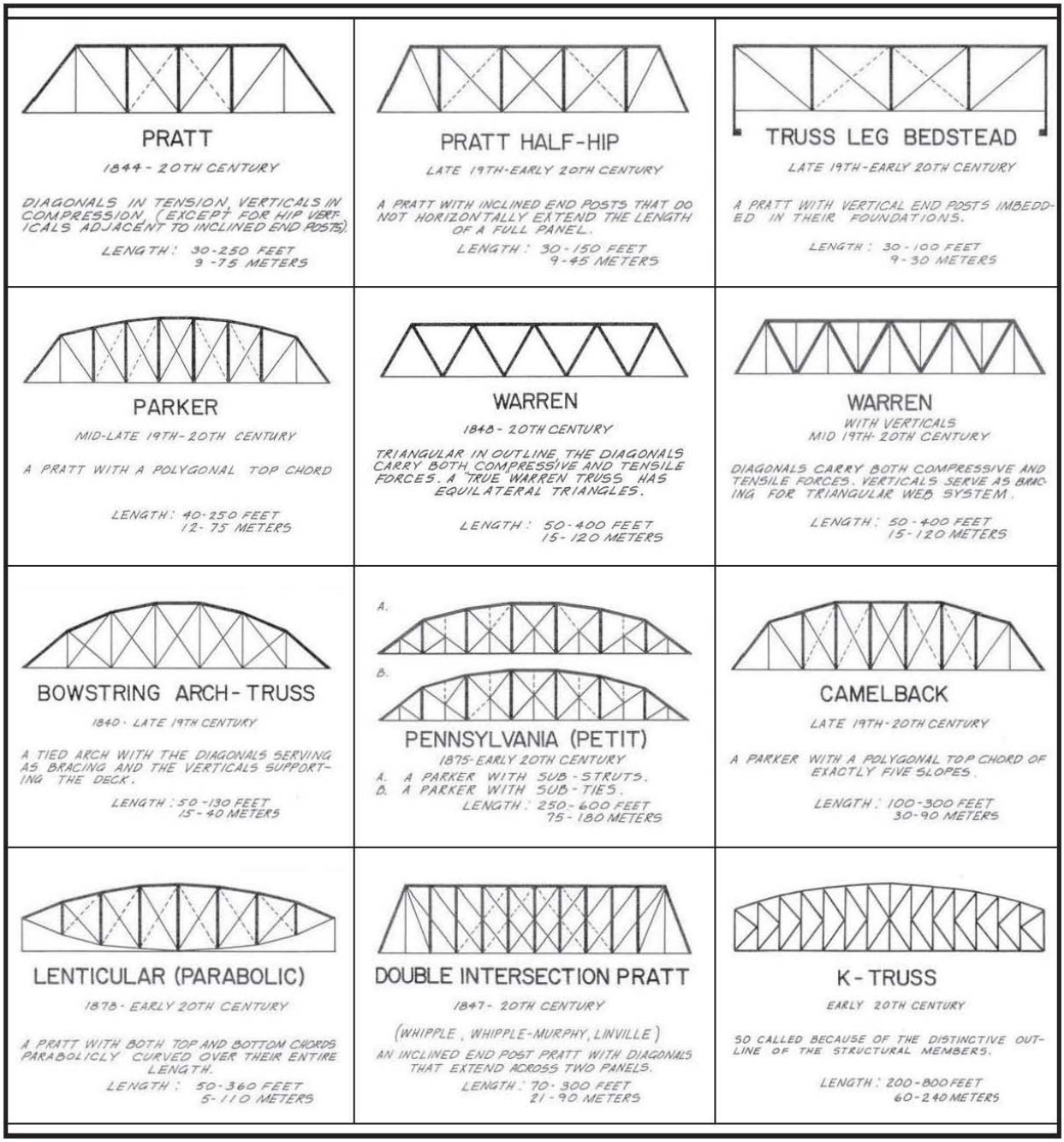

PRATT
1844 - 20TH CENTURY
DIAGONALS IN TENSION, VERTICALS IN COMPRESSION, (EXCEPT FOR HIP VERTICALS ADJACENT TO INCLINED END POSTS).
LENGTH: 30-250 FEET
9-75 METERS
PRATT HALF-HIP
LATE 19TH-EARLY 20TH CENTURY
A PRATT WITH INCLINED END POSTS THAT DO NOT HORIZONTALLY EXTEND THE LENGTH OF A FULL PANEL.
LENGTH: 30-150 FEET
9-45 METERS
TRUSS LEG BEDSTEAD
LATE 19TH-EARLY 20TH CENTURY
A PRATT WITH VERTICAL END POSTS IMBEDDED IN THEIR FOUNDATIONS.
LENGTH: 30-100 FEET
9-30 METERS
PARKER
MID-LATE 19TH-20TH CENTURY
A PRATT WITH A POLYGONAL TOP CHORD
LENGTH: 40-250 FEET
12-75 METERS
WARREN
1848 - 20TH CENTURY
TRIANGULAR IN OUTLINE, THE DIAGONALS CARRY BOTH COMPRESSIVE AND TENSILE FORCES. A "TRUE WARREN TRUSS HAS EQUILATERAL TRIANGLES.
LENGTH: 50-400 FEET
15-120 METERS
WARREN
WITH VERTICALS
MID 19TH-20TH CENTURY
DIAGONALS CARRY BOTH COMPRESSIVE AND TENSILE FORCES. VERTICALS SERVE AS BRACING FOR TRIANGULAR WEB SYSTEM.
LENGTH: 50-400 FEET
15-120 METERS
BOWSTRING ARCH-TRUSS
1840 - LATE 19TH CENTURY
A TIED ARCH WITH THE DIAGONALS SERVING AS BRACING AND THE VERTICALS SUPPORTING THE DECK.
LENGTH: 50-130 FEET
15-40 METERS
A.
B.
PENNSYLVANIA (PETIT)
1875-EARLY 20TH CENTURY
A. A PARKER WITH SUB-STRUTS.
B. A PARKER WITH SUB-TIES.
LENGTH: 250-600 FEET
75-180 METERS
CAMELBACK
LATE 19TH-20TH CENTURY
A PARKER WITH A POLYGONAL TOP CHORD OF EXACTLY FIVE SLOPES.
LENGTH: 100-300 FEET
30-90 METERS
LENTICULAR (PARABOLIC)
1878 - EARLY 20TH CENTURY
A PRATT WITH BOTH TOP AND BOTTOM CHORDS PARABOLICLY CURVED OVER THEIR ENTIRE LENGTH.
LENGTH: 50-360 FEET
5-110 METERS
DOUBLE INTERSECTION PRATT
1847 - 20TH CENTURY
(WHIPPLE, WHIPPLE-MURPHY, LINVILLE)
AN INCLINED END POST PRATT WITH DIAGONALS THAT EXTEND ACROSS TWO PANELS.
LENGTH: 70-300 FEET
21-90 METERS
K-TRUSS
EARLY 20TH CENTURY
SO CALLED BECAUSE OF THE DISTINCTIVE OUTLINE OF THE STRUCTURAL MEMBERS.
LENGTH: 200-800 FEET
60-240 METERS

*Figure 52.*

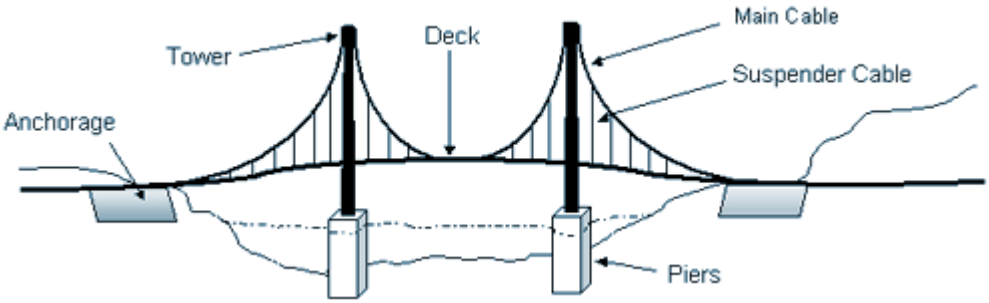



*Figure 53*

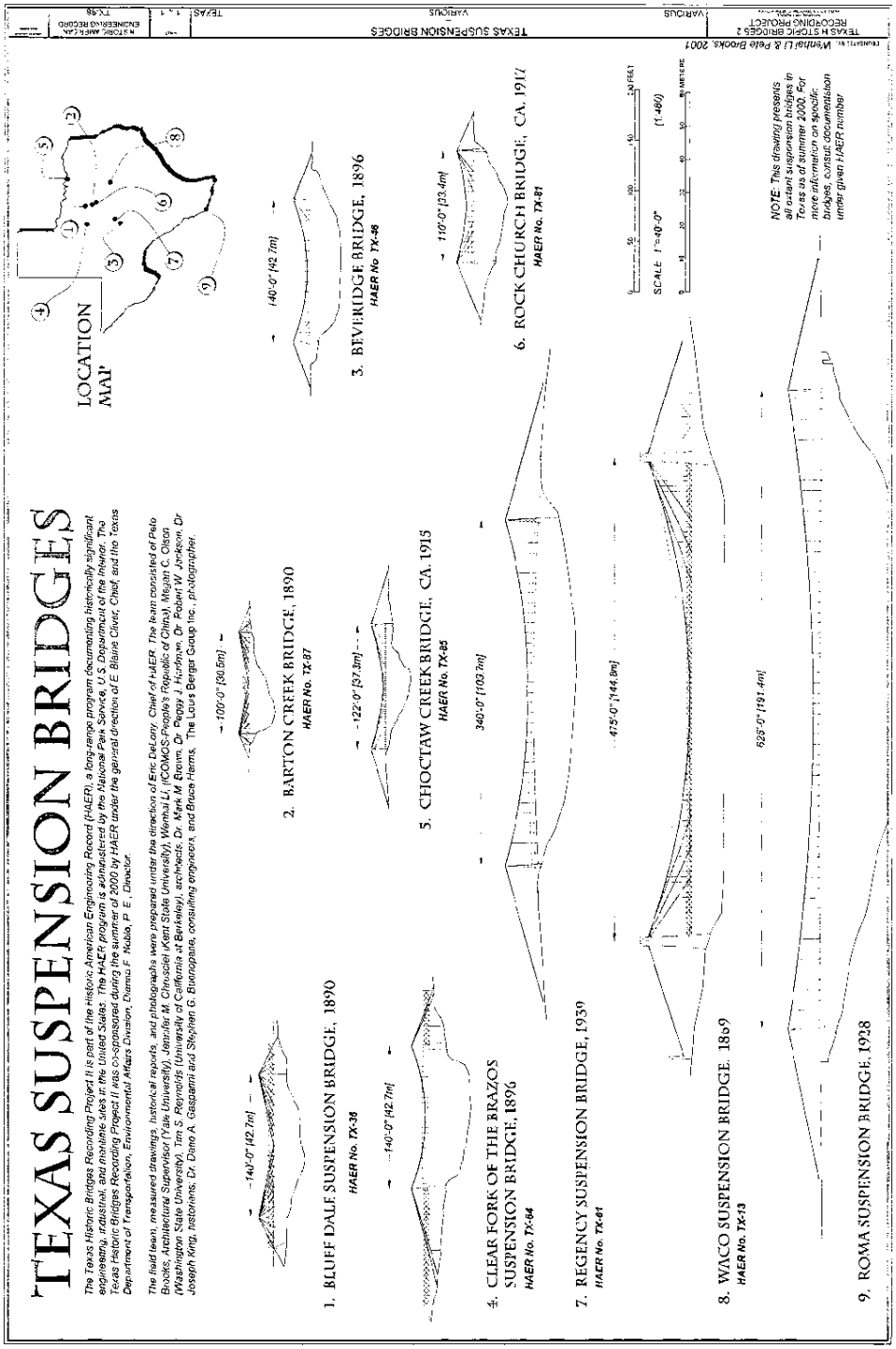

TEXAS SUSPENSION BRIDGES
LOCATION MAP
1. BLUFF DALE SUSPENSION BRIDGE, 1890
HAER No. TX-38
140'-0" [42.7m]
2. BARTON CREEK BRIDGE, 1890
HAER No. TX-87
100'-0" [30.5m]
3. BEVERIDGE BRIDGE, 1896
HAER No. TX-48
140'-0" [42.7m]
4. CLEAR FORK OF THE BRAZOS SUSPENSION BRIDGE, 1896
HAER No. TX-64
140'-0" [42.7m]
5. CHOCTAW CREEK BRIDGE, CA. 1915
HAER No. TX-85
122'-0" [37.3m]
6. ROCK CHURCH BRIDGE, CA. 1917
HAER No. TX-81
110'-0" [33.4m]
7. REGENCY SUSPENSION BRIDGE, 1939
HAER No. TX-61
340'-0" [103.7m]
8. WACO SUSPENSION BRIDGE, 1869
HAER No. TX-13
475'-0" [144.8m]
9. ROMA SUSPENSION BRIDGE, 1928
625'-0" [191.4m]
SCALE 1"=40'-0"
(1:480)
NOTE: This drawing presents all extant suspension bridges in Texas as of summer 2000. For more information on specific bridges, consult documentation under given HAER number
TEXAS SUSPENSION BRIDGES
VARIOUS
TEXAS HISTORIC BRIDGES 2 RECORDING PROJECT
VARIOUS
TEXAS
TX-98
HISTORIC AMERICAN ENGINEERING RECORD
Wenhar L.L. & Pete Brooks, 2001

*Figure 54*