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SPECIFICATIONS FOR DESIGN OF STRUCTURES

October 1935

TEXAS DEPARTMENT OF TRANSPORTATION

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SPECIFICATIONS FOR DESIGN OF STRUCTURES

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SPECIFICATIONS FOR DESIGN

OF

STRUCTURES

WATERWAY

0. DETERMINATION OF WATERWAY AREA. For the determination of the waterway area to be provided by any drainage structure, a careful study shall be made of local conditions, including flood height and flow, size and performance of other openings in the vicinity carrying the same stream, characteristics of the channel and of the watershed area, climatic conditions, available rainfall records and any other information pertinent to the problem and likely to affect the safety or economy of the structure.

For culverts and small bridges, waterway formulas or drainage tables may be used to assist in fixing the proper size of opening. The use of such formulas or tables is justified only to the extent that they are known to fit local conditions. However, their use shall serve merely as a guide and shall not obviate the need for careful field observation and the exercise of intelligent judgment.

In general, the waterway provided shall be sufficient to insure the discharge of flood waters without undue backwater head and at a velocity which will not increase the erosive action of the stream to such an extent as to endanger the structure.

1. RESTRICTED WATERWAYS. When it is necessary to restrict the waterway to such an extent that the stream will be discharged at erosive velocities, protection against damage due to scour shall be afforded by deep foundations, curtain or cut-off walls, rip-rap, stream bed paving, or other suitable means. Likewise, embankment slopes adjacent to all structures subject to erosion shall be adequately protected by rip-rap, brush mattresses, tree retards, wing dams, or other suitable construction.

2. CHANNEL OPENINGS. The channel openings shall conform in width, height and location to all Federal, State and local requirements. Particular attention is directed to the Federal laws governing the bridging of navigable waters and to the fact that the U. S. War Department exercises control over all the navigable waters of the United States.

The clear width of all openings and the clear vertical distance between the superstructure and flood water elevation shall be sufficient for the passage, without damage to the structure, of the largest drift or debris which may be expected. The minimum distance from low part of superstructure to flood water elevation shall preferably be about three feet.

1369

3. PIER SPACING AND LOCATION. Piers shall be located in such manner as to meet the above specified requirements for channel openings. They shall be located so as to afford the minimum restriction of the waterway, especially in the main stream channel. In general, piers shall be placed as nearly parallel with the direction of the stream current as is practicable, due consideration being given to the velocity and direction of current at both ordinary and highwater stages, so as to avoid such deflections of the current as might prove destructive to the foundations of the structure or to the adjacent stream banks.

The spacing of piers shall be such as to reduce the cost of the whole structure to a minimum consistent with the above conditions.

4. SIZE OF CULVERT OPENINGS. In general, culverts shall be proportioned to carry the maximum flood discharge without head. If the maximum flood discharge occurs only at rare intervals, culverts may be designed to carry it under slight head, provided they are protected against undermining by means of adequate pavements and apron or cut-off walls and that adjacent embankments are protected from erosion by rip-rap or other suitable means.

ROADWAY

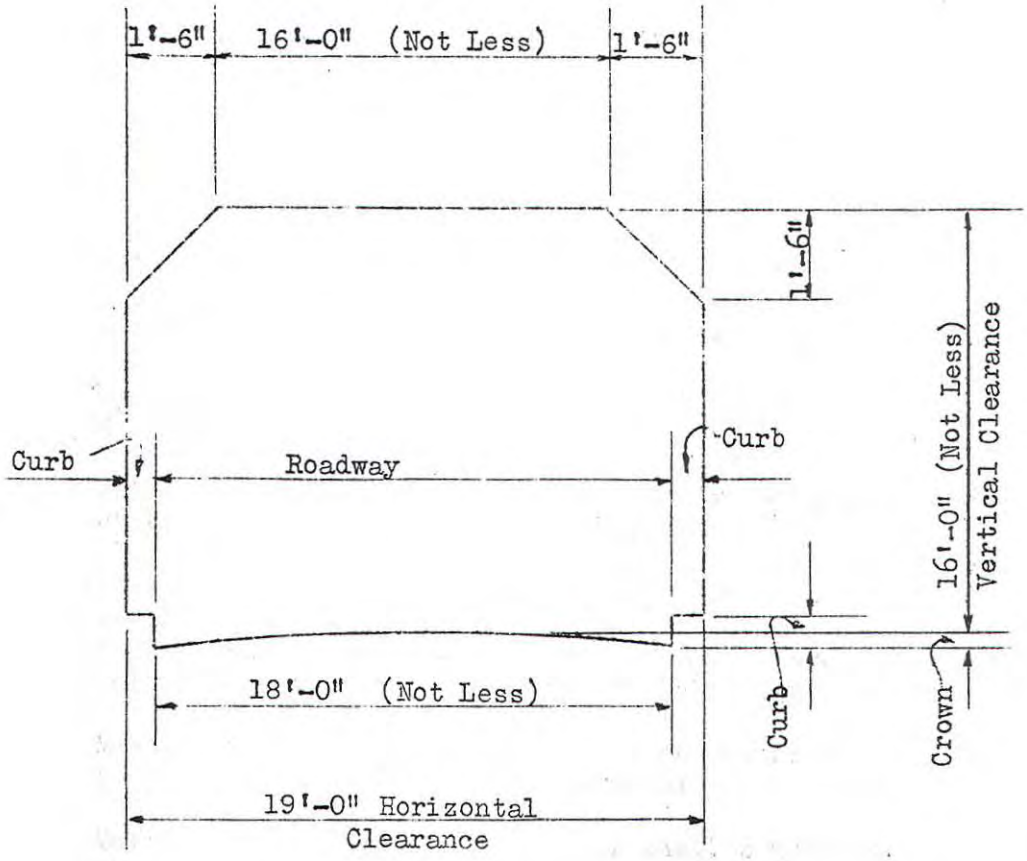
5. WIDTH OF ROADWAY AND SIDEWALK. The width of roadway shall be the clear width measured at right angles to the longitudinal center line of the bridge between the tops of curbs or guard timbers, if these exist; otherwise, it shall be the clear width inside to inside of the handrails or other fencelike protections paralleling the sides of the structures.

Upon structures having a sidewalk, the clear width of side walk shall be measured at right angles to the curb or guard timber and from the face thereof to the extreme inside portion of the handrail. For structures having trusses, girders or parapet walls adjacent to the curbs, the width of sidewalk shall be measured from their extreme outside portions to the inside of the handrail.

6. LENGTH OF CULVERTS. The length of culverts shall be sufficient to provide the full required width of roadway or width at the top of embankment. The assumed slope of the embankment shall be suitable for the particular filling material involved and shall be such as to eliminate any tendency for the embankment slopes to slip or slide.

7. CLEARANCES. The clearance width shall be the clear width available, and the clearance height shall be the clear height available, for the passage of vehicular traffic, as shown on the clearance diagrams, Fig. 1.

Unless otherwise provided the several parts of the structure shall be constructed to secure the following limiting dimensions or clearances for traffic.



CLEARANCE DIAGRAM

TWO WAY HIGHWAY TRAFFIC

Figure No.1

10-35-1311
Sheet 3

Bridges constructed for the use of two-way highway traffic shall have a roadway clearance not less than that shown in Figure 1. The roadway width shall be increased at least 9 feet for each additional lane of traffic.

8. CURBS. The projection of the curb, measured from that portion of the rail nearest the roadway, shall not be less than 6 inches and preferably shall be not less than 9 inches. The curb height shall be not less than 9 inches above the adjacent finished roadway surface.

Concrete curbs shall be designed to resist a lateral force of not less than 500 pounds per linear foot of curb, applied at the top of the curb.

9. RAILINGS. Substantial railings shall be provided along each side of the bridge for the protection of traffic. Preferably, the top of railing shall be not less than 3'-0" above the finished surface of the roadway adjacent to the curb, and, when on a sidewalk, shall be not less than 3'0" above the sidewalk floor.

In general, railings shall be of two classes as follows:

1. Railings for the protection of pedestrians on bridges in cities and villages.

2. Railings suitable for use on country bridges which are not subject to general pedestrian traffic.

Metal Railings. Metal railings shall be designed to resist a horizontal force of not less than 500 pounds per linear foot, for Federal Aid projects and 150 pounds for State projects, applied at the top of rail, and a vertical force of not less than 100 pounds per linear foot.

Metal railings of the second class may consist of not less than two lines of horizontal rails of approved section.

Metal railings of the first class shall consist of an upper and a lower horizontal rail connected by a suitable web. The clear distance between the top of curb or sidewalk and the lower rail shall not exceed 6 inches.

All connections to posts, truss members, etc., shall contain not less than two rivets or bolts each. Ample provision shall be made for movement due to temperature.

Concrete Railings. Concrete railings shall be designed to resist a horizontal force of not less than 500 pounds per linear foot for Federal Aid projects and 150 pounds per linear foot for State projects, applied at the top of the rail, and a vertical force of not less than 100 pounds per linear foot.

Openings in concrete railings of the first class shall be proportioned with due regard to the safety of persons using the structure.

Provision shall be made for the expansion and contraction of concrete railings at intervals consistent with the design.

10. DRAINAGE. The transverse drainage of roadways shall be secured by means of a suitable crown in the roadway surface. Longitudinal drainage shall be secured by means of scuppers or drains of ample size, constructed in the gutters or curbs at suitable intervals. The details of floor drains shall be such as to prevent the discharge of drainage water against any portion of the structure. Overhanging details in concrete and timber floors preferably shall be provided with drip beads.

11. BLAST PROTECTION. On bridges over railroad tracks, metal likely to be injured by locomotive gases shall be protected by blast plates located over the centerline of the track. The plates shall be not less than 5/16 inch thick and shall be so supported that they may be replaced readily. Pockets which will hold locomotive gases shall be avoided if practicable.

TYPES OF STRUCTURES AND GOVERNING SPAN LENGTHS

Preferably, the type of bridge to be used for various span lengths shall be as follows, though special conditions may warrant a deviation therefrom.

12. STEEL STRUCTURES.

Rolled beams, up to	60 feet
Plate girders	30 to 100 "
Low riveted trusses	45 to 100 "
Riveted trusses	90 to 150 "
Riveted or pin-connected trusses above	150 "

13. CONCRETE STRUCTURES:

Slab spans or box culverts up to	24 feet
Simple girder spans	18 to 60 "
Arches	All span lengths

14. CLASSIFICATION OF BRIDGES. The classification of bridges with reference to traffic shall be as follows:

Class "AA". Bridges for specially heavy traffic units in locations where the passage of such loads is frequent.

Class "A". Bridges for normally heavy traffic units and the occasional passage of specially heavy loads.

Class "B". Bridges for light traffic units and the occasional passage of normally heavy loads. Class "B" bridges shall be considered as temporary or semi-temporary structures.

LOADS

15. LOADS. Structures shall be proportioned for the following

loads and forces:

(a) Dead Load.
(b) Live Load.
(c) Impact or dynamic effect of the live load.
(d) Lateral forces.
(e) Other forces, when they exist, as follows: Longitudinal force; centrifugal force; and thermal forces.

Members shall be proportioned for the combination of loads and forces producing the maximum total stress, except as otherwise provided herein.

Upon the stress sheets a diagram of the assumed live loads shall be shown and the stresses due to the various loads shall be shown separately.

16. DEAD LOAD. The dead load shall consist of the weight of the structure complete, including the roadway, sidewalks, pipes, conduits, cables and other public utility services.

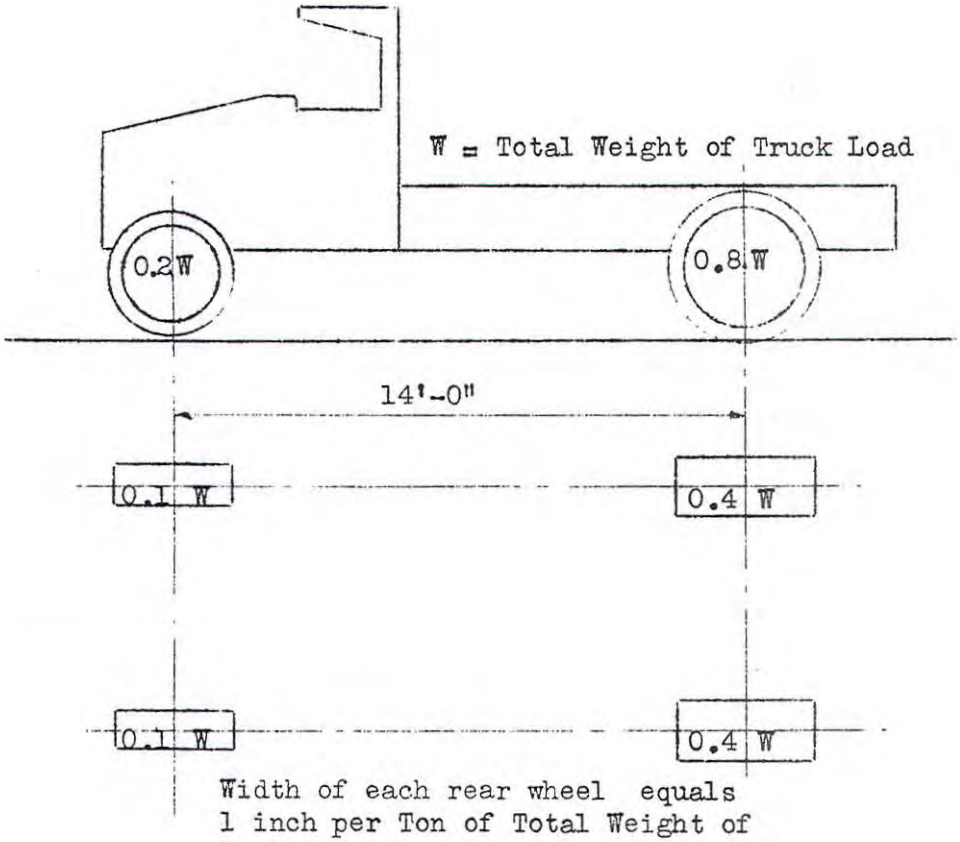
The snow and ice load is considered to be offset by an accompanying decrease in live load and impact and shall not be included except under special conditions.

In the case of structures having concrete slab floors, an adequate allowance shall be made in the design dead load to provide for the weight of a wearing surface. This allowance will depend upon the type of wearing surface contemplated; it shall be in addition to the weight of any monolithically placed concrete wearing surface; and shall be not less than 15 lb. per square foot of roadway.

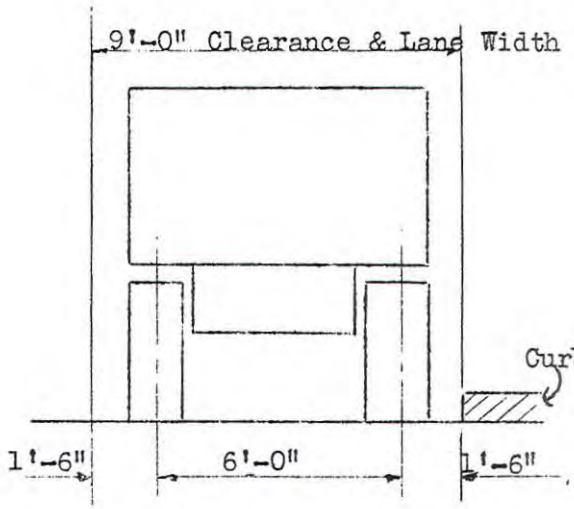
The following weights are to be used in computing the dead load;

	Weight per cubic foot pounds
Steel	490
Cast Iron	450
Timber (treated or untreated)	60
Concrete, plain or reinforced	150
Loose sand and earth	100
Rammed sand or gravel, and ballast	120
Macadam or gravel, rolled	140
Cinder filling	60
Pavement, other than wood block	
Railway rails and fastenings	150 per lin. ft. of track.

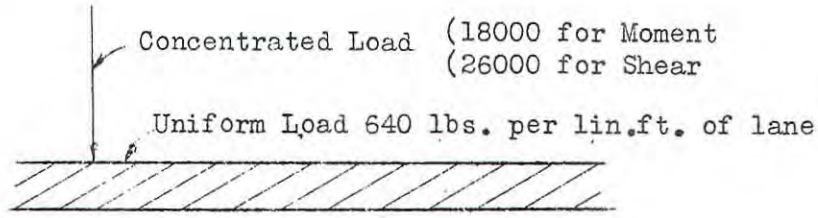
17. LIVE LOAD. The live load shall consist of the weight of the applied moving load of vehicles, cars and pedestrians.



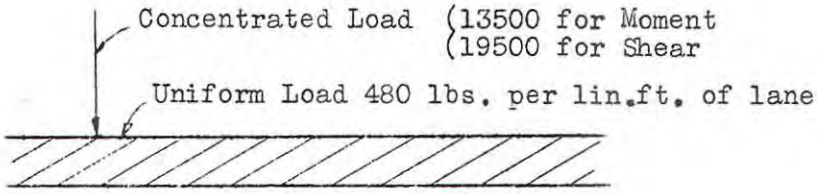
Width of each rear wheel equals
1 inch per Ton of Total Weight of
Loaded Truck



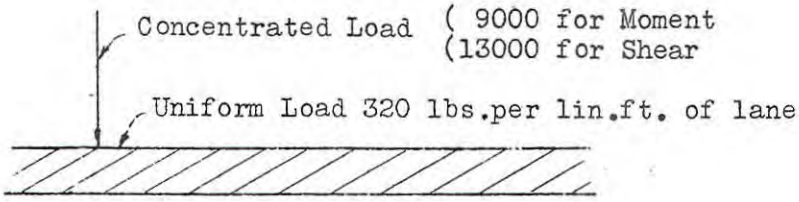
TRUCK
Figure No.2



H 20 LOADING



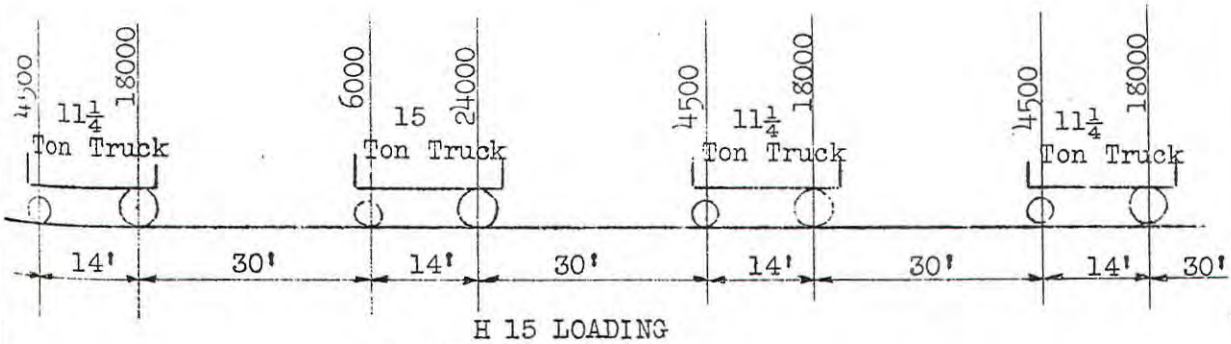
H 15 LOADING



H 10 LOADING

EQUIVALENT LOADING

Figure No. 3



H 15 LOADING

TRUCK TRAIN LOADING

Figure No.4

H-20 & H-15 loading shall be spaced as above and the loads increased or decreased proportionately corresponding to the truck train loading used.

18. HIGHWAY LIVE LOADS. The highway live load on the roadway portion of the bridge shall consist of trains of motor trucks, or equivalent loads, as hereinafter specified. Each loading is designated by the letter "H", followed by a numeral indicating the gross weight in tons of the heaviest loaded truck in the train.

19. TRAFFIC LANES. The truck trains or equivalent loads shall be assumed to occupy traffic lanes, each having a width of 9 feet corresponding to the standard truck clearance width. Within the curb to curb width of the roadway, the traffic lanes shall be assumed to occupy any position which will produce the maximum stress, but which will not involve overlapping of adjacent lanes, nor place the center of the lane nearer than 4 feet 6 inches to the roadway face of the curb.

20. TRUCKS. The wheel spacing, weight distribution, and clearance of the trucks used for design purposes shall be as shown in Fig. 2.

21. HIGHWAY LOADING. The highway loading shall be of three classes, namely, H20, H15, and H10, and may be either truck train loadings or equivalent loadings. Loadings H15 and H10 are 75 per cent and 50 per cent, respectively, of Loading H20.

(a) Truck Train Loadings. The truck train loading shall be as shown in Fig. 4 and shall be used for loaded lengths of less than 60 ft. It shall consist of one truck of the gross weight indicated by the loading class followed by, or preceded by, or both followed and preceded by, a line of trucks of indefinite length, each of the following or preceding trucks having a gross weight of three-fourths of the gross weight indicated by the loading class.

Trucks in adjacent lanes shall be considered as headed in the same direction.

(b) Equivalent Loading. Rhe equivalent loading shall be as shown in Fig. 3, and shall be used only for loaded lengths of 60 feet or greater. It shall consist of a uniform load per linear foot of traffic lane combined with a single concentrated load so placed on the span as to produce maximum stress. The concentrated load shall be considered as uniformly distributed across the lane on a line normal to the centerline of the lane. For the computation of moments and shears, different concentrated loads shall be used as indicated in Fig. 3.

22. SELECTION OF LOADINGS. Bridges of the different classes shall be designed for the loadings as follows:

Class of Bridge	Loading
"AA"	H20
"A"	H15
"B"	H10

23. APPLICATION OF LOADINGS. The loadings shall be applied

by that one of the following methods which produces the greater maximum stress in the member considered, due allowance being made for the reduced load intensities hereinafter specified for roadways having loaded widths in excess of 18 feet.

(1) Each traffic lane loading shall be considered as a unit, and the number and position of the loaded lanes shall be such as will produce maximum stress.

(2) The roadway shall be considered as loaded over its entire width with a load per foot of width equal to one-ninth of the load of one traffic lane.

24. REDUCTION IN LOAD INTENSITY. If the loaded width of the roadway exceeds 18 feet, the specified loads shall be reduced one per cent for each foot of loaded roadway width in excess of 18 feet with a maximum reduction of twenty-five per cent, corresponding to a loaded roadway width of 43 feet. If the loads are lane loads, the loaded width of the roadway shall be the aggregate width of the lanes considered; if the loads are distributed over the entire width of the roadway, the loaded width of the roadway shall be the full width of roadway between curbs.

25. SIDEWALK AND FOOT BRIDGE LOADING. Sidewalk floors, stringers, and their immediate supports shall be designed for a live load of not less than 100 lb. per square foot of sidewalk area.

Girders or trusses of bridges with sidewalks shall be designed for a sidewalk live load determined by the following formula:

$$P = \left(40 + \frac{3000}{L}\right)\left(\frac{55 - W}{50}\right), \text{ in which:}$$

P = Live load in lb. per square foot of sidewalk area, but not to exceed 100 lb. per square ft.
L = Loaded length of sidewalk in feet.
W = Width of sidewalk in feet.

In calculating stresses in structures which support cantilevered sidewalks, the sidewalk shall be considered as fully loaded on only one side of the structure if this condition produces maximum stress.

All parts of foot bridges shall be designed for a live load of not less than 100 pounds per square foot.

26. IMPACT. Live Load stresses, except those due to sidewalk loads and centrifugal, tractive, and wind forces, shall be increased by an allowance for dynamic vibratory, and impact effects.

The amount of this allowance or imcrement is expressed as a fraction of the live load stress, and shall be determined by the formula:

$$I = \frac{50}{L + 125}$$, in which:

I = Impact fraction.
L = The length in feet of the portion of the span which is loaded to produce the maximum stress in the member considered.

A maximum of 25% impact for concrete spans and 30% for steel spans shall be used.

27. LONGITUDINAL FORCE. Provision shall be made for the effect of a longitudinal force of 10 per cent of the live load on the structure, acting 4 feet above the floor.

28. LATERAL FORCES. (a) The wind force on the structure shall be assumed as a moving horizontal load equal to 30 lb. per square foot on $1\frac{1}{2}$ times the area of the structure as seen in elevation including the floor system and railings and on one-half the area of all trusses or girders in excess of two in the span.

(b) The lateral force due to the moving live load and the wind pressure against it, shall be considered as acting 6 feet above the roadway and shall be as follows:

Highway bridges, 200 lb. per linear foot.

(c) The total assumed wind force shall be not less than 300 lb. per linear foot in the plane of the loaded chord and 150 lb. per linear foot in the plane of the unloaded chord on truss spans, and not less than 300 lb. per linear foot on girder spans.

(d) In calculating the uplift, due to the foregoing lateral forces, in the posts and anchorages of viaduct towers, highway viaducts shall be considered as loaded on the leeward traffic lane with a uniform load of 400 lb. per linear foot of lane.

(e) A wind pressure of 50 lb. per square foot on the unloaded structure, applied as specified above in paragraph (a), shall be used if it produces greater stresses than the combined wind and lateral forces of paragraphs (a) and (b).

29. FORCES OF STREAM CURRENT, FLOATING ICE AND DRIFT. All piers and other portions of structures which are subject to the force of flowing water, floating ice, or drift shall be designed to resist the maximum stresses induced thereby.

The force due to stream current shall be determined by the formula:

$$P = 1\tfrac{1}{2} V^2$$

V = Velocity in feet per sec.
P = Lbs. per square ft. of cross-section exposed to current.

30. PRESSURE FROM RETAINED MATERIAL. Structures designed to retain fills shall be proportioned to withstand pressures as given by Rankine's formula, provided, however, that no structure shall be designed for an equivalent fluid pressure of less than 30 pounds per cubic foot. The above dead load pressure shall be increased to provide for any live load surcharge which may exist.

All designs shall provide for the thorough drainage of back filling material by means of weep holes with French drains, or other suitable means.

31. THERMAL FORCES. Expansion. In all statically determinate structures, provision shall be made for expansion due to an extreme variation in temperature of from -- 40 degrees to + 120 degrees Fahrenheit.

Thermal Stresses. In all statically indeterminate structures, provision shall be made for the stresses resulting from the following variations in temperature:

Metal structures: From 0 degrees to + 120 degrees Fahr., the rise and fall in temperature shall be figured from an assumed mean temperature,

	Temp. Rise	Tem. Drop
Concrete Structures.	30 deg. F.	40 deg. F.

UNIT STRESSES

32. GENERAL. Except as otherwise provided herein, the several parts of a structure shall be so proportioned that the unit stresses will not exceed the following. Unless otherwise noted, all unit stresses are given in pounds per square inch.

STEEL STRUCTURES

33. STRUCTURAL GRADE AND RIVET STEEL:

Tension:

Axial tension, structural members, net section 16,000
Rivets in tension, where permitted--50% of single shear values.
Bolts, area at root of thread 10,000

Axial Compression:

Axial compression, gross section ..... 15,000-50 L/R
but not to exceed 13,500.
L = length of member, in inches.
R = least radius of gyration, in inches

Bending on Extreme Fiber:

Rolled shapes, built sections and girders, net section 16,000

Pins 24,000

Shear:

Girder webs, gross section 10,000
Pins and shop driven rivets 12,000
Power driven field rivets and turned bolts ... 10,000
Hand driven rivets and unfinished bolts 7,500

Bearing:

Pins, steel parts in contact and shop driven rivets 24,000
Power driven field rivets and turned bolts ... 20,000
Hand driven rivets and unfinished bolts 15,000
Expansion rollers, pounds per linear inch 600d
Where d = diameter of roller in inches

Countersunk Rivets:

In metal 3/8 inch thick and over, half the depth of countersink shall be omitted in calculating bearing area.
In metal less than 3/8 inch thick, countersunk rivets shall not be assumed to carry stress.

Diagonal Tension:

In webs of girders and rolled beams, at sections where maximum shear and bending occur simultaneously 16,000

34. OTHER METALS:

Axial Tension:

Wrought-iron 12,000

Bending on Extreme Fiber:

Cast Steel 12,000
Cast iron 3,000

Shear:

Cast steel 10,000
Cast iron 3,000

Bearing:

Cast steel 14,000
Cast iron 10,000
Bronze sliding expansion bearings 3,000

35. BEARING ON BRIDGE SEATS:

Bearing on concrete masonry, limestone masonry and better 500

CONCRETE STRUCTURES

36. CONCRETE:

Direct Compression:

Columns reinforced with longitudinal bars and separate

Lateral ties	600-15 L/D
But not to exceed	450
Where L = unsupported length of column	
D = least diameter of column	
Piers and pedestals	450
Compression Due to Bending:	
Beams and slabs	650
Arch rings, including temperature and rib shortening	800
Tension	ZERO
Shear (Diagonal Tension):	
Beams without shear reinforcement, Longitudinal bars not anchored.....	40
Longitudinal bars anchored	60
Beams with shear reinforcement	120
Punching Shear	120

37. REINFORCEMENT:

Tension:

Beams and slabs	16,000
Arch rings, including temperature and rib shortening	20,000

Compression--15 times stress in surrounding concrete.

Bond:	
Bars not anchored	80
Bars adequately anchored by hooks or otherwise	120

(NOTE: The above allowable unit stress values for concrete and for bond on reinforcement are based on an ultimate compressive strength value of 2200 pounds per square inch at the age of 28 days when tested in accordance with the Tentative Standard Methods of Sampling and Testing of the American Association of State Highway Officials.

When the aggregates used and the laboratory and field control of concrete mixtures are such that a uniformly higher ultimate compressive strength is insured, then the above unit stresses may be increased by a maximum of 15% for concrete having an ultimate strength of 2,800 pounds per square inch or more at the age of 28 days and proportionally for intermediate values of ultimate strength, except that the stress due to bending in arch ribs when the effects of temperature and rib shortening are included, shall in no case exceed 800 pounds per square inch.

When economy may be obtained by the use of aggregates which will result in concrete having a lower ultimate strength than 2,200 pounds per square inch at the age of 28 days, the above unit stresses shall be reduced in the proportion that the lower ultimate strength in pounds per square inch bears to 2,200).

38. BEARING POWER OF SOILS. For the designs of foundations, the following unit bearing values may be assumed in the absence of definite information as to the actual bearing power of the foundation in question. In this tabulation it is intended to cover only broad basic groups of materials and to specify for these a maximum range in bearing power. These groups may be further subdivided to provide for special conditions.

Materials.	Tons per Sq. Ft.
Alluvial earth and loam, confined	.0 to 0.5
Soft clay, dry earth and loam ..... confined	0.5 to 1.5
Ordinary clay and sand clay, confined	1.5 to 2.0
Dry clay and fine sand, firm, confined	2.0 to 3.0
Hard clay, coarse sand, and uncemented gravel compacted	3.0 to 5.0
Gravel and coarse sand, cemented	5.0 to 7.0
Soft rock, cleaned to solid bed	7.0 to 10.0
Ordinary rock, cleaned to solid rock	10.0 to 15.0
Hard bed rock	15.0 to 25.0

These pressures are based on the assumption that the materials are in mass and not simply in thin layers. Generally foundation pressures for culverts shall not exceed 1.5 and for small bridges shall not exceed 2.0 tons per square foot.

If tests are made, the test load shall be one and one-half times the proposed pressure. The test load shall remain for 48 hours during which time it shall show no settlement.

The most unfavorable conditions of buoyancy shall be assumed in all calculations. Generally, in determining foundation pressures use the buoyancy due to extreme low water, and for stability against lateral forces use the buoyancy effect of extreme high water.

39. TIMBER STRUCTURES. The following unit stresses are permitted for first quality White Oak, Southern Yellow Pine, Douglas Fir, Longleaf Pine, Shortleaf Pine, Cuban Pine, or a timber having as great strength and durability; and are for use with computed stresses which contain no allowance for live load impact.

Axial tension and bending in extreme fiber	1,600
Horizontal Shear in Beams	110.
Compression Parallel to the Grain: Short columns, Cs	1,150
Compression perpendicular to the grain	275
Shear parallel to the grain	180
Ultimate modulus of elasticity	1,600,000

Axial Compression in Timber Columns

$$P = (4/3\ Cs)\ \left(1 - \frac{L}{40\ D}\right)$$

The value of "p" shall not exceed the value of "Cs"

p = unit compressive stress in column
Cs = unit stress for compression parallel to grain in short columns
L = unsupported length of column
D = least diameter of column

Bearing on Inclined Surfaces

$$P = Cp\ (Cs - Cp)\ \frac{\theta}{8100}$$

p = unit bearing stress on inclined surface
C_p = unit stress for compression perpendicular to grain
C_s = unit stress for compression parallel to grain in short columns
θ = angle in degrees between bearing surface and direction of fibers (axis of piece)

Horizontal Shear in Beams:

Horizontal shear in beams shall be computed from the maximum shear occuring at a distance from the support equal to three times the depth of the beam.

DISTRIBUTION OF LOADS

40. THROUGH EARTH FILLS. When the depth of fill is 3'-0" or more, concentrated loads shall be considered as uniformly distributed over a square, the sides of which are equal to 1 3/4 times the depth of fill. When such areas from several concentrations overlap, the total load shall be considered as uniformly distributed over the area defined by the outside limits of the individual areas, but the total width of distribution shall not exceed the total width of the supporting slab. For single spans, the effect of live load may be neglected when the depth of fill is more than 4 feet and exceeds the span length for multiple spans. It may be neglected when the depth of fill exceeds the distance between faces of end supports or abutments.

41. IN CONCRETE SLABS. In calculating bending stresses due to wheel loads on concrete slabs, no distribution in the direction of the span of the slab shall be assumed. In the direction perpendicular to the span of the slab, the wheel load shall be considered as distributed uniformly over a width of slab which is known as the "effective width".

In the following equations let
S = span of slab in feet
W = width of wheel or tire in feet
X = distance in feet from the center of the near support to the center of wheel
E = effective width in feet for one wheel

Case I. Main Reinforcement Parallel to Direction of Traffic.

$E = .7\ S + W$

For this case the value of "E" shall not exceed 7 feet.

When two wheels are so located on a transverse element of the slab that their effective widths overlap, the effective width for each wheel shall be 1/2 (E + a), where "a" is the distance between centers of wheels.

Case II. Main Reinforcement Perpendicular to Direction of Traffic.

$E = 0.7\ (2X + W)$

For this case the bending moment on a strip of slab one foot in width shall be determined by placing the wheel loads in the position to produce maximum bending; determining the effective width for each wheel; and assuming the load delivered by each wheel to the one foot strip to be the wheel load divided by its respective effective width.

This design assumption does not provide for the effect of loads near unsupported edges. Therefore, at the ends of the bridge and at intermediate points where the continuity of the slab is broken, the edges of the slab shall be supported by diaphragm or other suitable means.

Slabs designed for bending moment in accordance with the foregoing rules and for the wheel loads contemplated by these specifications may be considered adequate for shear without special reinforcement.

42. <u>IN FLAT SLABS SUPPORTED ON FOUR SIDES</u>. In the case of flat slabs supported along four edges and reinforced in both directions, the proportion of the load carried by the short span of the slab shall be assumed as given by the following equations:

Load Uniformly Distributed

$$p = \frac{b^4}{a^4 + b^4}$$

Load Concentrated at Center

$$p = \frac{b^3}{a^3 + b^3}$$

where p = proportion of load carried by short span
a = length of short span of slab
b = length of long span of slab

When the length of the slab exceeds $1\frac{1}{2}$ times its width, the entire load shall be assumed to be carried by the transverse reinforcement.

In placing the reinforcement in such slabs, consideration shall

be given to the fact that the bending moment is greater near the center of the slab than near the edges. Also, in the design of the supporting beams, consideration shall be given to the fact that the loads delivered to the supporting beams are not uniformly distributed along the beams.

43. DISTRIBUTION OF TRUCK WHEEL LOADS TO STRINGERS AND FLOORBEAMS. In calculating end shears and end reactions of stringers and floorbeams, no lateral or longitudinal distribution of wheel loads shall be assumed.

44. BENDING MOMENTS IN STRINGERS. In determining bending moments in stringers, each wheel load shall be assumed as concentrated at a point. When the floor system is designed for one truck, each interior stringer shall be proportioned to support that part of one rear wheel load, or those parts of one front wheel load and one rear wheel load, represented by a fraction whose numerator is the stringer spacing in feet and whose denominator is:

4'-0" for plank floors.
5'-0" for strip floors 4 inches or more in thickness and for wood blocks on a 4" plank sub-floor.
6'-0" for reinforced concrete floors.

45. When the floor system is designed for two trucks, each interior stringer shall be proportioned to support that part of one rear wheel load, or those parts of one front wheel lead and one rear wheel load, represented by a fraction whose numerator is the stringer spacing in feet and whose denominator is:

3'-6" for plank floors.
4'-0" for strip floors 4 inches or more in thickness and for wood blocks on 4" plank sub-floor.
4'-6" for reinforced concrete floors.

46. The live load supported by the outside stringers shall be the reaction of the truck wheels in the most unfavorable position, assuming the flooring to act as a simple beam.

47. The above distribution rules govern only when the stringer spacing is not greater than 5'-0" for plank floors, 5'-6" for strip floors 4" or more in thickness and for wood blocks on 4" plank sub-floor, and 10'-0" for reinforced concrete floors. When the stringer spacing is greater than this distance, the stringer loads shall be determined by the reactions of the truck wheels placed in the most unfavorable position, assuming the flooring between stringers to act as simple beams.

48. The combined load capacity of the stringers in a panel shall be not less than the total live and dead load in the panel.

49. BENDING MOMENTS IN FLOORBEAMS. In determining bending moments in floorbeams, each wheel load shall be assumed as concentrated at a point.

When stringers are omitted and the floor is supported directly on the floorbeams, the latter shall be proportioned to carry that fraction of one axle load, when the floor system is designed for one truck, or of two axle loads, when the floor system is designed for two trucks, whose numerator is the floorbeam spacing in feet and whose denominator is:

4'-0" for plank floors
5'-0" for strip floors 4 inches or more in thickness and for wood blocks on 4" plant sub-floor.
6'-0" for reinforced concrete floors

When the spacing of floorbeams exceeds those specified above for the different types of floor the floorbeam loads shall be determined by the reactions of the truck wheels, assuming the flooring between floorbeams to act as a simple beam.

50. When the spacing of floorbeams exceeds the denominator given but is less than the axle spacing (14'-0") each beam shall be proportioned to carry the full axle load or loads.

When the floorbeam spacing exceeds the spacing of axles the load supported on each floorbeam shall be the maximum reaction due to the axle loads, assuming the flooring between floorbeams to act as a simple beam.

51. TRANSMISSION OF DEAD LOAD OF FILLS TO CULVERTS AND SHORT SPAN SLABS. All culverts and short span slab structures carrying a superimposed earth fill shall be proportioned to carry the entire weight of all the filling material directly above the structure.

SUBSTRUCTURES AND RETAINING WALLS

52. PILING. Use of Piling. In general, piling shall be used when footings can not, at a reasonable expense, be founded on rock or other solid foundation material. In streams where erosion is possible, piling preferably shall be used (if possible to drive) as a protection against scour, even though the safe bearing resistance of the natural soil is sufficient to support the structure without piling.

Design Loads. Preferably, structures shall be proportioned to limit the maximum design load on timber piling to 15 tons per pile. In no case shall they be designed to support more than 22 tons per pile. The maximum design load on concrete piling may be assumed as from 25 to 35 tons per pile, depending on conditions.

Piling shall be designed to carry the entire superimposed load, no allowance being made for the supporting value of the material between the piling.

Spacing. Footing areas shall be so proportioned that pile spacing shall be not less than 2'-6" center to center for timber piling. For concrete piling the spacing center to center shall be 3'-0" for piling having load intensity to and including 30 tons; 3'-6" for piling having load

intensity 31 to 35 tons, incl.; and 4'-0" for piling having load intensity 36 to 40 tons, incl. The distance from the side of any pile to the nearest edge of the footing shall be not less than 9 inches.

Batter Piling. When it is necessary to use piling under arch abutments, batter piling shall be used.

Piling for hard driving preferably shall be shod with a metal shoe of approved pattern.

53. FOOTINGS. Depth. The depths of footings shall be determined with respect to the character of the foundation materials and the possibility of undermining. Except where solid rock is encountered or in other special cases, the footings of all structures, other than culverts, which are exposed to the erosive action of stream currents preferably shall be founded at a depth of not less than four feet below the permanent bed of the stream. Stream piers and arch abutments preferably shall be founded at a depth of not less than six feet below stream bed. The above preferred minimum depths shall be increased as conditions may require.

Footings not exposed to the action of stream currents shall be founded on a firm foundation and at a depth below frost.

Footings for culverts shall be carried to an elevation sufficient to secure a firm foundation, or a heavy reinforced floor shall be used to distribute the pressure over the entire horizontal area of the structure. In any location liable to erosion, apron or cut-off walls shall be used at both ends of the culvert, and, where necessary, the entire floor area between the wingwalls shall be paved. Baffle walls or struts across the unpaved bottom of a culvert barrel shall not be used where the stream bed is subject to erosion. When conditions require, culvert footings shall be reinforced longitudinally.

Anchorage. Footings on solid rock, unless they are restrained by an overburden of resistant materials, shall be effectively anchored by means of anchor bolts, dowels, keys or other suitable means.

Distribution of Pressure. All footings shall be designed to keep the maximum soil pressures within safe bearing values. In order to prevent unequal settlement, footings shall be designed to keep the pressure as nearly uniform as practicable. In footings having unequal pressures and requiring piling, the spacing of the piling shall be such as to secure as nearly equal loads on each piling as may be practicable.

Internal Stresses in Spread Footings. Spread footings shall be considered as under the action of downward forces, due to the superimposed loads, resisted by an upward pressure exerted by the foundation material and distributed over the area of the footings as determined by the eccentricity of the resultant of the downward forces.

When pilings are used under footings, the upward reaction of the foundation shall be considered as a series of concentrated loads applied at the pile centers, each pile being assumed to carry its computed proportion of the total footing load.

Footings shall be designed for bending stresses, for diagonal tension stresses, and for punching shear around the periphery of the column or pier shaft. The critical section for bending shall be taken at the face of the column, wall or pier shaft. Bending need not be considered unless the projection of the footing is more than two-thirds the depth.

When a single spread footing supports a column, pier or wall, this footing shall be assumed to act as a contilever. When two or more piers or columns are placed upon a common footing, the footing slab shall be designed for the actual conditions of continuity and restraint.

Reinforcement. Footing slabs shall be reinforced for bending stresses and, where necessary, for diagonal tension. All bars shall be effectively anchored to develop in bond the computed stress in the bar.

The reinforcement for square footings shall consist of two or more bands of bars. The reinforcement necessary to resist the bending moment in each direction in the footing shall be determined as for a reinforced concrete beam; the effective depth of the footing shall be the depth from the top to the plans of the reinforcement. The required reinforcement shall be spaced uniformly across the footing, unless the footing width is greater than the size of the column or pedestal plus twice the effective depth of the footing, in which case the width over which the reinforcement is spread may equal the width of the column or pedestal plus twice the effective depth of the footings plus one-half the remaining width of the footing. In order that no considerable area of the footing shall remain unreinforced, additional bars shall be placed outside of the width specified, but such bars shall not be considered as effective in resisting the calculated bending moment. For the extra bars a spacing double that used for the reinforcement within the effective belt may be used. When reinforcement is used in more than one direction the allowable unit bond stresses shall be reduced as follows:

For two-way reinforcement 25%
For each additional direction 10%

Transfer of Stress from Vertical Reinforcement. The stresses in the vertical reinforcement of columns or walls shall be transferred to the footings by extending the reinforcement into them a sufficient distance to develop the strength of the bars in bond, or by means of dowels anchored in the footings and overlapping or fastened to the vertical bars in such manner as to develop their strength. If the dimensions of the footings are not sufficient to permit the use of straight bars, the bars may be hooked or otherwise mechanically anchored in the footings.

54. ABUTMENTS. Abutments shall be designed to withstand earth pressure, the weight of abutment and superstructure, live load over any portion of the superstructure or approach fill and wind forces. The design shall be investigated for any combination of these forces which may produce the most severe condition of loading.

Abutments shall be designed to be safe against overturning about the toe of the footing, against sliding on the footing base and against crushing of foundation material or overloading of piling at the point of maximum pressure.

In computing stresses in abutments, the weight of filling material directly over an inclined or stepped rear face, or over a reinforced concrete spread footing extending back from the face wall, may be considered as part of the effective weight of the abutment. In

the case of a spread footing, the rear projection shall be designed as a centilever supported at the abutment stem and loaded with the full weight of the superimposed material.

The cross section of stone masonry or plain concrete abutments shall be proportioned to avoid the introduction of tensile stress in the material.

Reinforcement for Temperature. Except in gravity abutments, not less than one-eighth (0.125) square inch of horizontal reinforcement per foot of height shall be provided near exposed surfaces not otherwise reinforced, to resist the formation of temperature and shrinkage cracks.

Wingwalls. Wingwalls shall be of sufficient length to retain the roadway embankment to the required extent and to furnish protection against erosion.

Reinforcing rods or other suitable rolled sections preferably shall be spaced across the junction between all wingwalls and abutments to thoroughly tie them together. Such bars shall extend into the masonry on each side of the joint far enough to develop the strength of the bar as specified for bar reinforcement. If bars are not used, an expansion joint shall be provided at this point in which the wings shall be mortised into the body of the abutment.

Drainage. The filling material behind abutments shall be effectively drained by weep holes with French drains, placed at suitable intervals.

55. RETAINING WALLS. Retaining walls shall be designed to withstand earth pressure, including any live load surcharge, and the weight of the wall, in accordance with the general principles specified above for abutments.

Stone masonry and plain concrete walls shall be of the gravity type. Reinforced concrete walls may be of either the cantilever, counterforted, buttressed, or cellular types.

Base or Footing Slabs. The rear projection or heel of base slabs shall be designed to support the entire weight of the superimposed material. The base slabs of cantilever walls shall be designed as cantilevers supported by the wall.

The base slabs of counterforted and buttressed walls shall be designed as fixed or continuous beams of spans equal to the distance between counterforts or buttresses.

Vertical Walls. The vertical stems of cantilever walls shall be designed as centilevers supported at the base.

The vertical or face walls of counterforted and buttressed walls

shall be designed as fixed or continuous beams. The face walls shall be securely anchored to the supporting counterforts or buttresses by means of adequate reinforcement.

Counterforts and Buttresses. Counterforts shall be designed as T-beams. Buttresses shall be designed as rectangular beams. In connection with the main tension reinforcement of counterforts there shall be a system of horizontal and vertical bars or stirrups to effectively anchor the face wall and base slab. The stirrups shall be anchored as near the outside faces of the face walls, and as near the bottom of the base slab, as practicable.

Reinforcement for Temperature. Except in gravity walls, not less than one-eighth (0.125) square inch of horizontal reinforcement per foot of height shall be provided near exposed surfaces not otherwise reinforced, to resist the formation of temperature and shrinkage cracks.

Expansion Joints. Expansion joints shall be provided at intervals not exceeding 30 feet for gravity walls and 50 feet for reinforcement walls.

Drainage. The filling material behind all retaining walls shall be effectively drained by weep holes with French drains, placed at suitable intervals. In counterforted walls there shall be at least one drain for each pocket formed by the counterforts.

56. PIERS. Piers shall be designed to withstand the dead and live loads superimposed thereon, wind pressures acting on the pier and superstructure, the forces due to stream current, floating ice and drift.

Where necessary, peirs shall be protected against abrasion by facing them with granite, vitrified brick, timber or other suitable material within the limits of damage by floating ice or debris.

In streams carrying ice or drift, the pier nose shall be designed as an ice breaker. When a steel angle or other metal nosing is used it shall be effectively secured to the masonry by means of suitable anchor bolts having countersunk heads.

Piers may be either mass or double shaft type and may be plain or reinforced. Dimensions of piers shall be proportioned by the forces to be resisted, but for double shaft types of piers, the dimensions of the shafts at the point midway between the base and the cap shall be not less than would be required by the specifications governing plain concrete columns, in the case of plain piers, and by the rules governing reinforced columns, in the case of reinforced piers. The two shafts shall be reinforced by concrete webs not less than 15 inches thick where the total height of the web is less than 20 feet. Where the height is greater than this, the web shall be at least 18 inches thick. These webs shall in all cases extend

from above high water line to the low water line, and as much lower as the Engineer deems advisable.

Pivot piers for swing spans may be either mass or cellular construction. The circumferential and cell walls of cellular piers shall be not less than two feet in thickness, and shall have double systems of reinforcement consisting of not less than 5/8-inch round bars spaced not over 15 inches center to center horizontally and vertically. The footing shall cover the entire base of the pier and be proportioned to distribute the load over the entire area. The top shall be covered with a cap. Suitable passages for the equalization of water pressure shall be provided through the cell walls and the outside wall.

CONCRETE DESIGN

57. GENERAL ASSUMPTIONS. The design of reinforced concrete members under these specifications shall be based on the following assumptions:

(a) Calculations are made with reference to unit working stresses and safe loads, as elsewhere specified herein, rather than with reference to ultimate strength and ultimate loads.

(b) A plane section before bending remains plane after bending.

(c) The modulus of elasticity of concrete in compression is constant within the limits of working stresses; the distribution of compressive stress in flexure is therefore rectilinear.

(d) The value of the modulus of elasticity of concrete shall be assumed as one-fifteenth (1/15) that of steel in computations of strength, and shall be assumed as one-eighth (1/8) that of steel in computing the deflection of reinforced concrete beams which are free to move longitudinally at the supports.

(e) Concrete shall be assumed as offering no tensile resistance.

(f) The bond between concrete and metal reinforcement is assumed to remain unbroken throughout the range of working stresses. Under compression the two materials are therefore stressed in proportion to their moduli of elasticity.

(g) Initial stress in the reinforcement due to contraction or expansion of the concrete is neglected, except in the design of reinforced concrete columns.

58. EFFECTIVE SPAN LENGTHS. The effective span length of freely supported beams and slabs shall be the distance between centers of the supports, but shall not exceed the clear span plus the depth of beam or slab. The span length of continuous or restrained beams built monolithically with supports shall be the clear distance between faces of supports. Where brackets having a width not less than the width of the beam, and making an angle of 45° or more with the axis of a restrained beam, are built monolithic with the beam and support, the span shall be measured from the section where the com-

bined depth of the beam and bracket is at least one-half more than the depth of the beam. Maximum negative moments are to be considered as existing at the ends of the span, as above defined. No portion of a bracket shall be considered as adding to the effective depth of the beam.

59. MOMENTS IN BEAMS FREELY SUPPORTED. The following moments at critical sections of freely supported beams and slabs of equal spans carrying uniformly distributed loads shall apply:-

(a) Maximum Positive Moment for One Span

$$M = \frac{Wl^2}{8}$$

(b) Slabs and Beams Continuous for Two Spans Only.

1. Positive Moment at Center

$$M = \frac{Wl^2}{10}$$

2. Maximum Negative Moment

$$M = \frac{Wl^2}{8}$$

(c) Slabs and Beams Continuous for More than Two Spans

1. Center of Interior Spans and Supports not Adjacent to End Spans

$$M = \frac{Wl^2}{12}$$

2. Center and Interior Supports of End Spans

$$M = \frac{Wl^2}{10}$$

MOMENTS IN FIXED BEAMS

(a) Supports of Intermediate Spans

$$M = \frac{Wl^2}{12}$$

(b) Center of Intermediate Spans

$$M = \frac{Wl^2}{16}$$

60. MOMENTS IN FLOOR SLABS. Concrete floor slabs built continuously over supporting beams or joists shall be designed for 80%

of the maximum live load bending moment of a simply supported slab of the same span.

61. EXPANSION JOINTS. Provision for end expansion shall be made in all concrete slab or girder bridges having a clear span length in excess of 40 feet. When multiple span construction is used, of spans 40 feet or less in length, expansion joints shall be provided at intervals of not more than 80 feet. When no expansion joints are used, the superstructure being cast integrally with the abutments, the reinforcement in the slab or girders shall be increased to provide for the thermal forces induced by a temperature drop of 40 degrees Fahrenheit.

In concrete floors on metal structures, expansion joints shall be provided at both fixed and expansion ends of the span.

62. T-BEAMS. Effective Flange Width. In beams and slab construction, effective and adequate bond and shear resistance shall be provided at the junction of the beam and slab. The slab may then be considered an integral part of the beam but its assumed effective width as a T-beam flange shall not exceed the following:

(a) One-fourth of the span length of the beam
(b) The distance center to center of beams
(c) Six times the width of the beam
(d) Eight times the least thickness of the slab plus the width of the girder stem

T-beams with flange on one side only, the effective width of slab shall be limited to 6 times the thickness of the slab.

Shear. The flange of the slab shall not be considered as effective in computing the shear and diagonal tension resistance of T-beams.

Isolated Beams. Isolated beams in which the T-form is used only for the purpose of providing additional compression area, shall have a flange thickness of not less than one-half the width of the web, and a total flange width of not more than 4 times the web thickness.

Diaphragms. For T-beam spans over 40 feet in length diaphragms or spreaders shall be placed between the beams at the middle or third points.

63. REINFORCEMENT. Spacing. The clear distance between reinforcing bars preferably shall be not less than 3 inches and in no case less than $2\frac{1}{2}$ inches and in slabs, not more than $1\frac{1}{2}$ times the thickness of the slab.

The minimum covering, measured from the surface of the concrete to the face of any reinforcing bar, shall be not less than 2 inches

except in the slabs where the minimum covering shall be 1 inch. In the footings of abutments and retaining walls and in piers the minimum covering shall be 3 inches. In work exposed to the action of sea water the minimum covering shall be 4 inches except in precast concrete piles where a minimum of 3 inches may be used.

Splicing. Tensile reinforcement shall not be splied at points of maximum stress. When reinforcement is spliced, the spliced bars shall lap sufficiently to develp the full strength in bond.

Anchorage. Anchorage of longitudinal reinforcement may be provided by extending the bars a sufficient distance beyond the theoretical point of termination to develop their full strength in bond. Anchorages may also be provided by bending the end of the bar through 180 degrees to a diameter not less than 6 times the diameter of the bar, the total length of the hook being not less than 16 diameters of the bar.

Reinforcement for negative moments shall be thoroughly anchored at or across the support, or shall extend into the span a sufficient distance to develop by bond the tensile stresses.

Maximum Sizes. The maximum size of bar reinforcement shall be $1\frac{1}{4}$ inches square or equivalent, unless the particular conditions warrant the adoption of special reinforcement design. When structural shapes are used for reinforcement, no section having a surface area per foot of length of more than 150 square inches shall be used as a reinforcing member unless mechanical bond is provided by means of lugs, bars or other details which will effectively bond the member to the surrounding concrete mass.

64. DESIGN OF WEB REINFORCEMENT. When the allowable unit shearing stress for concrete is exceeded, web reinforcement shall be provided by one of the following methods:

(a) Longitudinal bars bent up in series or in a single plane.
(b) Vertical stirrups.
(c) Combination of bent-up bars and vertical stirrups.

When any of the above methods of reinforcement are used, the concrete may be assumed to carry external vertical shear not to exceed 40 pounds per square inch, the remainder of the shear being carried by the web reinforcement.

The webs of T-beams shall be reinforced with vertical stirrups in all cases.

Bent-up Bars. Bent-up bars used as web reinforcement may be bent at any angle between 20 and 45 degrees with the longitudinal reinforcement. The radius of bend shall not be less than 4 diameters of the bar.

The spacing of bent-up bars shall be measured perpendicular to their direction and in a plane parallel to the longitudinal axis of the beam. This spacing shall not exceed 3/4 of the effective depth of the beam. The first bar from the support shall cross the neutral axis of the beam at a distance from the face of the support measured along the axis of the beam, not greater than 1/4 of the effective depth.

Vertical Stirrups. The spacing of vertical stirrups shall not exceed 3/4 of the effective depth of the beam. The first stirrup shall be placed at a distance from the face of the support not greater than 1/4 of the effective depth of the beam. Stirrups shall surround three sides of the tensile reinforcement.

Anchorage. Web reinforcement shall be securely anchored in the compression portion of the beam, which may be considered as developing bond for a vertical distance equal to 4/10 the effective depth of the beam. Stirrups and bent-up bars shall be securely anchored to the tensile reinforcement.

65. COLUMNS. The ratio of the unsupported length of a column to its least diameter or dimension shall not exceed 4 for unreinforced and 15 for reinforced sections. The least diameter or dimension in no case shall be less than 15 inches. For reinforced concrete viaduct construction or for "pedestal" or "buried" abutments, the least dimension shall be not less than 24 inches.

The reinforcement of columns shall consist of at least 4 longitudinal bars tied together with lateral ties or hoops enclosing the longitudinal reinforcement. The longitudinal reinforcement shall be of bars not less than 1 inch in diameter and shall have a total cross-sectional area of not less than 0.7% of the total cross-sectional area of the column. Reinforcement in excess of 2.0% of the cross-sectional area of the column shall not be considered in computing compressive stresses. The lateral ties or hoops shall be not less than 1/4 inch in diameter and spaced not farther apart than 12 inches.

Bending. When columns are subjected to bending stresses due to eccentric loads, monolithic construction or lateral forces, they shall be so proportioned that the combined direct and bending stresses shall not exceed the allowable unit compressive stresses herein specified.

Columns placed in earth fills, as in the case of "pedestal" or "buried" abutments, shall be designed to withstand the earth pressure from the rear, disregarding the effect of the fill in front.

Column Struts. Longitudinal or lateral struts used to brace columns shall be proportioned to support a uniform load equal to at least twice the dead load of the strut.

66. CONCRETE ARCHES. Shape of Arch Ring. Arch rings shall be selected as to shape in such manner that the axis of the ring shall conform, as nearly as practicable, to the equilibrium polygon for full dead load or, if desired, to the equilibrium polygon for full dead plus one-half live load over the full span.

Spandrel Walls. When the spandrel wall of filled spandrel arches exceed 5 feet in height above the intrados they shall be designed as vertical slabs supported by transverse diaphragn walls or deep counterforts. Vertical cantilever walls over 5 feet in height, or counterforts having a back slope of less than 45 degrees with the vertical, shall not be used, on account of the excessive and indeterminate stresses set up in the arch ring by torsion.

Expansion Joints. Vertical expansion joints shall be placed in the spandrel walls of arches to provide for movement due to temperature change and arch deflection. These joints shall be placed at the ends of spans and at intermediate points, generally not more than 50 feet apart.

Reinforcement. Arch ribs in reinforced concrete construction shall be reinforced with a complete double line of longitudinal reinforcement consisting of an intradosal system and an extradosal system connected by a series of stirrups or tie-rods.

For barrel arches, a system of transverse reinforcement, thoroughly anchored to the longitudinal reinforcement, shall be used in both intrados and extrados. The transverse reinforcement shall be proportioned to resist the bending stresses due to any overturning action of the spandrel wall.

For rib arches, hoops or tie bars shall be used in connection with the longitudinal rib reinforcement, as in the case of reinforced concrete columns.

Waterproofing. Preferably, the top of the arch ring and the interior faces of the spandrel walls of all filled spandrel arches shall be waterproofed with a membrane waterproofing constructed in accordance with these specifications.

Drainage of Spandrel Fill. The fills of filled spandrel arches shall be effectively drained by a system of tile drains of French drains laid along the intersections of the spandrel walls and arch ring and discharging through suitable outlets in the piers and abutments. The location and details of the drainage outlets shall be such as to eliminate, as far as possible, the discoloration by drainage water of the exposed masonry faces.

67. VIADUCT BENTS AND TOWERS. When concrete columns are used in viaduct construction, bents and towers shall be effectively braced by means of longitudinal and transverse struts. For heights greater than 40 feet, both longitudinal and transverse

cross or diagonal bracing preferably shall be used and the footings for the columns forming a single bent shall be thoroughly tied together.

STRUCTURAL STEEL DESIGN

68. SPACING OF TRUSSES AND GIRDERS. Main trusses and girders shall be spaced a sufficient distance apart, center to center, to be secure against overturning by the assumed lateral and other forces.

69. DIMENSIONS FOR STRESS CALCULATION. Effective Span. For the calculation of stresses, span lengths shall be assumed as follows:

Beams and girders, distance between centers of bearings.
Trusses, distance between centers of end pins or of bearings.
Floorbeams, distance between centers of trusses or girders.
Stringers, distance between centers of floorbeams.

Effective Depth. For the calculation of stresses, effective depths shall be assumed as follows:

Riveted trusses, distance between centers of gravity of the chords.
Pin-connected trusses, distance between centers of chord pins.
Plate girders, distance between centers of gravity of the flanges but not to exceed the distance back to back of flange angles.

70. REVERSAL OF STRESS. Members subject to reversal of stress during the passage of live load shall be proportioned as follows: Determine the tensile and the compressive stresses and increase each by 50% of the smaller; then proportion the member so that it will be capable of resisting each increased stress. The connections shall be proportioned for the sum of the actual stresses.

No pin-connected member shall be subjected to reversal of stress.

When the live load and dead load stresses are of opposite sign, only 70% of the dead load stress shall be considered as effective in counteracting the live load stress.

71. COMBINED STRESSES. Axial and Bending. Members subject to both axial and bending stresses shall be proportioned so that the combined fiber stresses will not exceed the allowable axial stress. Members continuous over panel points shall be proportioned for the live and dead load bending moments computed for a simple beam having a span equal to one panel length.

Stresses due to Lateral and Longitudinal Forces and Temperature. In proportioning the various parts of the structure, provision shall be made for the following stress combinations:

Group A	Dead Load Live Load Impact Centrifugal Force
Group B	Lateral Force Longitudinal Force Temperature

Members subject to the stresses of Group A in combination with the stresses of Group B, either direct or flexural or both, shall be designated for any of the following combinations, at Unit Stresses 25% greater than those specified, but the resulting sections shall be not less than would be required if the stresses of Group A were considered alone.

1. The combined stresses of Group B in combination with dead load only.

2. The combined stresses of Group A in combination with 50% of the combined stresses of Group B.

3. The combined stresses of Group A in combination with temperature only.

72. SECONDARY STRESSES. Members and their details shall be proportioned to reduce secondary stresses to a minimum. In simple trusses without subdivided panels the secondary stresses due to deformation in any member whose width measured in the plane of flexure is less than one-tenth of its length need not be considered. When this ratio is exceeded, or where subdivided panels are used, the secondary stresses shall be computed.

In members designed for secondary stresses in combination with other stresses the specified allowable unit stresses may be increased 30% but the sections shall be not less than required for primary stresses.

73. ALLOWANCE FOR OVERLOAD. For the calculation of stress reversal or counter stresses, the specified live loads, either uniform or concentrated, shall be increased 100% and for this loading conditions the specific unit stresses shall be increased not more than 50%. The resulting sections shall be not less than would have been required had the allowance for overload not been considered.

74. COMPRESSION FLANGES OF BEAMS AND GIRDERS. The gross area of the compression flanges of beams and plate girders shall be not less than the gross area of the tension flanges.

The laterally unsupported length of the compression flanges of beams and girders shall not exceed 40 times the flange width. When the unsupported length of flange exceeds 12 times the flange width, the compressive stress in pounds per square inch shall not exceed

$$19000 - 250\frac{L}{b} \text{ (Maximum value, 16000 lbs.)}$$

where L = length, in inches, of unsupported flanges, between lateral connections or knee braces.

b = flange width in inches

75. PROPORTIONING ROLLED BEAMS. Rolled beams shall be proportioned by the moments of inertia of their sections. Proper allowance shall be made for any reduction in strength due to rivet holes in the tension flange or for any reduction in allowable stress due to the length of unsupported compression flange.

76. LIMITING LENGTHS OF MEMBERS. Compression Members. The ratio of unsupported length to the least radius of gyration shall not exceed 120 for main compression and stiffening members nor 140 for laterals and sway bracing. In proportioning the top chords of low trusses the unsupported length shall be assumed as the length between the rigid verticals.

Tension Members. For main riveted tension members the ratio of length of the horizontal projection of the unsupported length to least radius of gyration shall not exceed 200.

77. EFFECTIVE BEARING AREA. The effective bearing area of a pin, bolt, or rivet shall be its nominal diameter multiplied by the thickness of the metal on which it bears.

78. EFFECTIVE DIAMETER OF RIVETS. In proportioning rivets, the nominal diameter of the rivet shall be used.

79. SIZE OF RIVETS. Rivets shall be of the size specified but generally shall be 3/4 inch or 7/8 inch in diameter. 5/8 inch rivets shall not be used in members carrying calculated stress except in $2\frac{1}{2}$ inch legs of angles and in flanges of 6 inch and 7 inch beams and channels.

All rivets not countersunk or flattened to have button heads.

The diameter of rivets in angles carrying calculated stress shall not exceed one-fourth of the width of the leg in which they are driven. In angles whose size is not so determined 5/8 inch rivets may be used in 2 inch legs, 3/4 inch rivets in $2\frac{1}{2}$ inch legs and 7/8 inch rivets in 3 inch legs.

In no case, except in handrails, shall structural shapes be used which do not admit the use of 5/8 inch diameter rivets.

80. PITCH OF RIVETS. The minimum allowable distance between centers of rivets shall be three times the diameter of the rivet but preferably shall be not less than the following:

For 7/8 inch diameter rivets ..... 3 inches
For 3/4 inch diameter rivets ..... $2\frac{1}{2}$ inches
For 5/8 inch diameter rivets ..... $2\frac{1}{4}$ inches

The maximum allowable pitch in the line of stress shall not exceed 6 inches of 16 times the thickness of the thinnest outside plate or angle connected, except in angles having two gage lines with rivets staggered where the pitch in each line may be twice the above with a maximum of 10 inches.

In webs of members composed of two or more plates in contact, the rivets shall be spaced not more than ten inches between centers in gage and pitch, provided such rivets serve no other purpose than to hold the plates in close contact. Tension members composed of two angles in contact shall be stitch riveted using a pitch not greater than 12 inches.

81. PITCH IN ENDS OF COMPRESSION MEMBERS. In the ends of built compression members the pitch of rivets connecting the component parts of the member shall not exceed four times the diameter of the rivet for a length equal to $1\frac{1}{2}$ times the maximum width of member. Beyond this point the rivet pitch shall be gradually increased for a length equal to $1\frac{1}{2}$ times the maximum width of the member until the maximum spacing is reached. In angles having two lines of staggered rivets in one leg, the pitch on each line may be twice that specified above but not greater than that allowed for the body of the member.

82. EDGE DISTANCE OF RIVETS. The minimum distance from the center of any rivet to a sheared edge shall be:

For 7/8 inch diameter rivets ..... $1\frac{1}{2}$ inches
For 3/4 inch diameter rivets ..... $1\frac{1}{4}$ inches
For 5/8 inch diameter rivets ..... 1-1/8 inches

The minimum distance from rolled or planed edges, except flanges of beams and channels, shall be:

For 7/8 inch diameter rivets ..... $1\frac{1}{4}$ inches
For 3/4 inch diameter rivets ..... 1-1/8 inches
For 5/8 inch diameter rivets ..... 1 inch

The maximum distance from any edge shall be eight times the thickness of the thinnest outside plate, but shall not exceed 5 inches.

83. LONG RIVETS. Long rivets subjected to calculated stress and having a grip in excess of $4\frac{1}{2}$ diameters shall be increased in number at least one per cent for each additional 1/16 inch of grip. If the grip exceeds 6 times the diameter of the rivet, specially designed rivets shall be used.

84. RIVETS IN TENSION. Rivets in direct tension shall, in general, not be used. However, where so used their value shall be one-half that permitted for rivets in shear. Countersunk rivets shall not be used in tension.

85. DEPTHS RATIOS. Trusses preferably shall have a depth not less than 1/10 the span, the plate girders a depth not less than 1/12 the span, and rolled beams a depth of not less than 1/20 the span. If lesser depths than these are used, the sections shall be increased so that the maximum deflection will not be greater than if these limiting ratios had not been exceeded.

86. PARTS ACCESSIBLE. The accessibility of all parts of a structure for inspection, cleaning and painting shall be insured by the proper proportioning of members and the design of their details.

87. OPEN SECTIONS AND POCKETS. Closed sections shall in general be avoided.

Pockets or depressions which will retain water shall be avoided as far as possible and those which are unavoidable shall be provided with effective drain holes or shall be effectively filled with waterproof material.

Details shall be arranged so that the retention of dirt, leaves or other foreign matter will be reduced to a minimum. Wherever angles are used, either singly or in pairs, they preferably shall be placed with the vertical legs extending downward.

88. SYMMETRICAL SECTIONS. Main members shall be proportioned so that their neutral axes shall be as nearly as practicable in the center of the section.

In general, the gravity axes of main truss and other important members, meeting to form a joint, shall intersect in a common point so as to avoid eccentricity of stress. In cases of unavoidable eccentricity the members affected thereby shall be proportioned and the connection details designed to resist the stresses produced.

89. EFFECTIVE AREA OF ANGLES IN TENSION. The effective area of single angles in tension shall be assumed as the net area of the connected leg plus 50% of the area of the unconnected leg.

The effective area of a double angle tension member shall be assumed as 80% of the net area of the member unless the end details and connections are such that the individual angles are held against

bending in both directions, in which case the full net area may be used. When the angles connect to separate gusset plates, as in the case of a double-webbed truss, the gusset plates shall be stiffened by diaphragms in the line of the connected angles or by tie plates extending to the ends of the angles if they are to be considered as offering such resistance to bending that the full net area can be used. When the angles are connected back to back on opposite sides of a single gusset plate the support may be assumed to be sufficient to allow the use of the full net section.

Lug angles shall not be considered as effective in transmitting stress.

90. STRENGTH OF CONNECTIONS. Unless otherwise provided and where practicable all connections shall be proportioned to develop not less than the full strength of the members connected.

No connection, except for lacing bars and handrails, shall contain less than three rivets.

91. SPLICES. Continuous compression members in riveted structures, such as chords and trestle posts, shall have milled ends and full contact bearing at the splices.

All splices, whether in tension or compression, shall be proportioned to develop the full strength of the members spliced and no allowance shall be made for milled ends of compression members.

Splices shall be located as close to panel points as possible and, in general, shall be on that side of the panel point which is subjected to the smaller stress.

The arrangement of the plates, angles or other splice elements shall be such as to make proper provision for the stresses in the component parts of the members spliced.

Where the splice material for tension members consist of plates they shall be "Universal Milled" or sheared 1/4 inch large and ground to required width.

92. INDIRECT SPLICES. In all splice plates not in direct contact with the parts they connect, the number of rivets on each side of the point shall be in excess of the number which would otherwise be required for a contact splice to the extent of two extra transverse lines for each intervening plate.

93. FILLERS. Where indirect splices involve rivets carrying stress and passing through fillers, the fillers shall be extended beyond the splicing material and the extension secured by additional rivets sufficient in number to develop the section of the filler.

When the filler is less than 1/4 inch thick the splicing mate-

rial shall also be extended.

94. GUSSET PLATES. Gusset or connecting plates shall be used for connecting all main members, except in pin-connected structures. In proportioning and detailing these plates the rivets connecting each member shall be located, as nearly as practicable, symmetrically with the axis of the member. However, the full development of the elements of the member shall be given due consideration. The gusset plates shall be of ample thickness to resist shear, direct stress and flexure acting on the weakest or critical section of maximum stress.

Re-entrant cuts shall be avoided as far as possible.

95. MINIMUM THICKNESS. The minimum thickness of structural steel shall be 5/16 inch except for fillers and railings. However, gusset plates shall not be less than 3/8 inch in thickness.

Metal subjected to marked corrosive influence shall be increased in thickness.

Cast steel shall not be less than one inch and cast iron not less than $1\frac{1}{4}$ inch thick, except for filler blocks.

96. COMPRESSION MEMBERS. In built compression members the metal shall be concentrated as much as possible in the webs and flanges, so that the center of gravity of the section may be as near the center line of the member as practicable.

97. PLATES IN COMPRESSION. Cover plates of built compression members and cover plates on the compression flanges of plate girders shall have a minimum thickness of 1/40, and the web plates of compression members a minimum thickness of 1/30, of the transverse distance between the lines of rivets connecting them to the flanges. However, failing to meet this requirement, the width of plate between the connecting lines of rivets in excess of 40 times the thickness for cover plates and 30 times the thickness for web plates, shall not be considered as effective in resisting stress.

98. OUTSTANDING FLANGES. Outstanding compression flanges of girders and main compression members shall have a minimum thickness of 1/12 of the width of outstanding flange. For lateral bracing and other secondary members this minimum thickness may be 1/14 of the width of the outstanding flange.

99. TIE PLATES. The open sides of compression members shall be provided with lacing bars and shall have tie plates as near each end as practicable and at intermediate points where the lacing is interrupted. Compression members composed of two angles and a cover plate shall have, on their open side, ties composed of short lengths of channel section with the flanges riveted to the vertical legs of the angles.

Tension members composed of shapes shall have their separate segments connected by tie plates or by tie plates and lacing bars.

The thickness of the tie plates shall be not less than 1/50 of the distance between the connecting lines of rivets. Tie plates shall be connected by not less than 3 rivets on each side, and in members having lacing bars the last rivet in the tie plate shall preferably also pass through the end of the adjacent bar.

For main compression members, the end of tie plates shall have a length not less than $1\frac{1}{2}$ times the perpendicular distance between the lines of rivets connecting them to the member, and the intermediate tie plates a length not less than that distance. For main tension members the end tie plates shall have the length above specified for end tie plates on main compression members and the length of the intermediate tie plates shall be not less than 3/4 the length specified for intermediate tie plates on compression members. In tension members whose elements are connected by tie plates only, the distance center to center of plates shall not exceed 3 feet.

For lateral struts and other secondary members, the length of end and intermediate tie plates shall be not less than 3/4 the perpendicular distance between the lines of rivets connecting them to the member.

100. <u>LACING BARS</u>. The lacing of compression members shall be proportioned to resist a transverse shear not less than that calculated by the formula:

$$S = 300\ A$$

Where S = Transverse shear in pounds
and A = Gross area of member in square inches.

This shear shall be considered as divided equally among all stiffening parts in parallel planes, whether made up of continuous plates or of lattice. The stress in the individual lacing bar shall be taken as the component of the shear, in the direction of the bar, in case single lacing is used and half that amount if double lacing is used. The size of the bar shall be determined by the column formula in which "L" shall be taken as the distance between the connections to the main sections.

The minimum width of lacing bars shall be:

For 7/8 inch diameter rivets ..... $2\frac{1}{2}$ inches
For 3/4 inch diameter rivets ..... $2\frac{1}{4}$ inches
For 5/8 inch diameter rivets ..... 2 inches

Lacing bars having two rivets in each end shall be used for flanges 5 inches or more in width.

The minimum thickness of bars shall be 1/40 of the distance between end rivets in the case of single lacing and 1/60 of this distance for double lacing.

Double lacing, riveted at the intersections, shall be used when the perpendicular distance between rivet lines exceeds 15 inches.

The inclination of single lacing shall generally be about sixty degrees and for double lacing it shall be about forty-five degrees to the axis of the member. Furthermore, the maximum spacing of lacing bars shall be such that the ratio of length to radius of gyration (L/r) for the portion of single flange between consecutive connections will be smaller than this ratio for the member as a whole.

Shapes of equivalent strength may be used instead of flats.

101. NET SECTION AT PINS. Pin-connected riveted tension members shall have a net section, both through the pin hole and back of the pin hole, at least 25% in excess of the net section of the body of the member.

102. NET SECTION OF RIVETED TENSION MEMBERS. In calculating the required area of riveted tension members, net sections shall be used in all cases and, in deducting rivet holes, they shall be taken as 1/8 inch larger than the nominal diameter of the rivet.

The net section shall be the least area which can be obtained by deducting from the gross sectional area, the area of holes cut by any straight or zigzag section across the member, counting the full area of the first hole and a fractional part of each succeeding hole, the fractional part being determined by the formula:

$$X = 1 - \frac{S^2}{4gh}$$

Where X = fraction of rivet hole to be deducted
S = stagger or longitudinal spacing of rivet with respect to rivet on last gage line
g = distance between gage lines, or transverse spacing
h = diameter of rivet holes, or nominal diameter of rivet plus 1/8 inch.

103. LOCATION OF PINS. Pins shall be located, with respect to the neutral axis of the members, so as to reduce to a minimum secondary stresses due to bending.

104. PIN PLATES. Pin plates shall be of a sufficient thickness to provide the required bearing area upon the pin; they shall be as wide as the dimensions of the member will allow; and their length, measured from pin center to end, shall be at least equal to their width. Pin plates shall contain sufficient rivets to distribute their due proportion of the pin pressure to the full cross section of the members; only the rivets located within two lines drawn from the pin center toward the body of the member and inclined at 45 degrees to the axis of the member shall be considered effective for this purpose. In the case of members composed of web plates and flange angles (with or without a cover plate) there shall be at least one outside pin plate covering the vertical legs of the flange angles.

At the ends of compression members at least one pair of pin plates shall extend not less than 6 inches beyond the near edge of the tie plate.

All pin-connected compression members shall be provided with hinge plates having a minimum thickness of 3/8 inch.

105. FORKED ENDS. Forked ends on compression members will be permitted only when unavoidable. When used, a sufficient number of pin plates shall be provided to give each jaw the full strength of the compression member.

At least one pair of these plates shall extend to the far edge of the tie plates, and the others not less than 6 inches beyond the near edge of the tie plates.

106. PINS AND PIN NUTS. Pins shall be proportioned for the maximum shears and bending moments produced by the stresses in the members connected. If there are eye-bars among the parts connected, the diameter of the pin shall be not less than 2/3 of the width of the widest bar attached.

Pins shall be of sufficient length to secure a full bearing of all parts connected upon the turned body of the pin. They shall be secured in position by hexagonal chamfered recessed nuts.

107. BOLTS. Unless specifically authorized, bolted connections will not be permitted. Bolts when used, shall be unfinished or turned as specified.

Bolts in tension shall have double nuts.

108. UPSET ENDS. Bars and rods with screw ends shall upset to provide a cross sectional area at the root of the thread which shall exceed the net section of the body of the member by at least 15 per cent.

109. SLEEVE NUTS. Sleeve nuts shall not be used.

110. EXPANSION. Provision for expansion and contraction, to the extent of 1/8 inch for each 10 feet of span, shall be made for all bridges. Expansion ends shall be firmly secured against lifting or lateral movement.

111. EXPANSION BEARINGS. Spans of less than 70 feet may be arranged to slide upon metal plates with smooth surfaces. Spans of 70 feet and over shall be provided with rollers or rockers, or with the special sliding bearings described below. Neither rollers nor rockers shall be used for expansion bearings at the top of trestle posts.

112. FIXED BEARINGS. Fixed bearings shall be firmly anchored.

113. HINGED OR PIN BEARINGS. Spans of 70 feet and over shall have hinged pin bearings at both ends. The pedestals or shoes shall be so designed that all loads will act through the end pins which will be located directly over the geometrical center of the bearing.

114. ROLLERS. Expansion rollers shall be not less than 4 inches in diameter for span lengths of 100 feet or less and this minimum shall be increased not less than 1 inch for each additional 100 feet of span, and proportionally for intermediate lengths. They shall be connected together by substantial side bars and shall be effectually guided so as to prevent lateral movement, skewing or creeping. The rollers and bearing plates shall be protected from dirt and water as far as possible and the construction shall be such that water will not be retained and that the roller nests may be inspected and cleaned with the minimum difficulty.

115. ROCKERS. Pin bearing expansion rockers shall be of cast steel or cast iron.

116. SPECIAL SLIDING EXPANSION BEARINGS. Sliding plates for the expansion bearings of spans of 70 feet and over shall be of bronze.

These plates shall be chamfered at the ends and shall be held securely in position, usually being inset into the metal of the pedestals and sole plates. Provision shall be made against any accumulation of dirt which will obstruct their free movement.

117. PEDESTALS AND SHOES. Pedestals and shoes shall be designed to secure rigidity and stability and to distribute the reaction uniformly over the entire bearing area. Preferably, they shall be made of cast steel or structural steel. The bottom bearing widths shall not exceed the top bearing widths by more than twice the depth of pedestal and, when involving pin bearings, this depth shall be measured from the center of pin.

Where built pedestals and shoes are used, the web-plates and the angles connecting them to the base plates shall be not less than 1/2 in. thick. If the size of the pedestal permits, the webs shall be rigidly connected transversely.

118. INCLINED BEARINGS. For spans on an inclined grade without pin or hinged bearings, the sole plates shall be beveled so that the substructure bridge seats will be level.

119. ANCHOR BOLTS. Trusses, girders and I-beam spans shall be securely anchored to their substructure. Anchor bolts shall be roughened by being screw-threaded or swedged to secure a satisfactory grip upon the material used to embed them in the holes.

The following are the minimum requirements for each bearing:

For I-beam spans the outer beams shall be anchored at each end with two bolts 1 inch in diameter, set 10 inches in the masonry.

For girder and truss spans

50 feet in length or less, 2 bolts, 1 inch diameter, set 10 inches in masonry.
51 to 100 feet in length, 2 bolts, 1½ inch diameter, set 1'-0" in masonry.
101 to 150 feet in length, 2 bolts, 1½ inch diameter, set 1'-3" in masonry.
151 feet and over, 4 bolts, 1½ inch diameter, set 1'-6" in masonry.

Anchor bolts subject to tension, as in the column bases of trestle bents and towers, shall be designed to engage a mass of masonry which will secure a resistance equal to 1½ times the calculated uplift.

FLOOR SYSTEM

120. FLOORBEAMS. Floorbeams preferably shall be at right angles to the trusses or main girders and shall be rigidly connected thereto. In

general, floorbeam connections shall be located above the bottom chord and, in riveted work, the bottom chord lateral system shall engage both the bottom chord and the floor beam. Floorbeam connections to pin-connected trusses preferably shall be above the bottom chord pins but, if located below, the vertical posts shall be extended below the pins to secure rigid connections to the floor beams.

121. END FLOORBEAMS. Except in skew bridges end floorbeams shall be provided in all truss and girder spans. End floorbeams preferably shall be designed to permit the use of jacks for the future lifting of the superstructure, under which condition the specified unit stresses shall not be exceeded by more than 50 per cent.

End floorbeams shall be arranged to permit future painting of the sides of the beams adjacent to the abutment backwalls.

122. STRINGERS. Steel stringers preferably shall be riveted between the floorbeams, with end connections to the floor beam webs. Stringers shall extend 1/2 inch into concrete floors.

123. END STRUTS. When end floorbeams are not used the end panel stringers shall be secured in correct locations by end struts securely connected to the stringers and to the main trusses or girders. The end panel lateral bracing shall be rigidly attached to the main trusses or girders and shall also be attached to the end struts. Adequate provision shall be made for the expansion movement of stringers.

124. END CONNECTIONS FOR FLOORBEAMS AND STRINGERS. The end connection angles of floorbeams and stringers shall be not less than 3/8 inch in thickness. When milled ends are required, the thickness of connection angles shall be 1/16 inch greater than for connection angles not required to be milled. Except in cases of special end floorbeam details, end connections for floorbeams and stringers shall be made with two angles at each end. Bracket or shelf angles which may be used to furnish support during erection shall not be considered in determining the number of rivets required to transmit end shears.

End connection angles shall develop the full depth of the webs by having a length as great as the flanges will permit.

In the preparation of end connection details, special care shall be exercised to provide ample clearance for the driving of field connection rivets.

The use of any type of floorbeam hanger which does not prevent all rotation or longitudinal motion of the floorbeam, will not be permitted.

Expansion Joints. To provide for expansion and contraction movement, suitable floor expansion joints shall be provided at the expansion ends of all spans and at other points where they may be required.

Apron plates, when used, shall be designed to properly bridge the joint and to prevent, as far as possible, the deposit of roadway debris upon the bridge seats.

BRACING.

125. DESIGN OF BRACING. Lateral, longitudinal and transverse bracing shall be composed of angles or other shapes offering resistance to deformation when subjected to compressive stress, and shall have riveted connections.

In general, bracing shall consist of a double system of diagonal tension members with transverse compression members. The diagonals in each system shall be proportioned to carry the total lateral stress in tension, the transverse struts (or floorbeams) acting as compression members for both systems.

All intersections of lateral and sway bracing shall be riveted to add rigidity and prevent deformations.

126. LATERAL BRACING. Bottom lateral bracing shall be provided in all bridges except I-beam spans, from which it may be omitted. Bottom laterals preferably shall be supported by rigid hangers at the intersections.

Top lateral bracing shall be provided in deck spans and in through spans having sufficient headroom.

Lateral bracing for compression chords shall preferably consist of either two or four angle latticed sections; and so designed as to effectively engage both flanges of the chords.

Lateral bracing shall have concentric connections, chords at end joints, and preferably throughout. The connections between the lateral bracing and the chords shall be designed to avoid, as far as possible, any bending stress in the truss members.

127. PORTAL AND SWAY BRACING. Through truss spans shall have portal bracing, preferably of the two plane or box type, rigidly connected to the end post and top chord flanges, and constructed as deep as the minimum clearance will allow. When a single plane portal is used it preferably shall be located in the central transverse plane of the end posts with diaframs between the webs of the posts to provide for a proper distribution of the portal stresses. The portal bracing shall be designed to take the full end reaction of the top chord lateral system and the end posts shall be designed to transfer this reaction to the truss bearings.

Deck truss spans shall have adequate sway bracing at the ends and at all intermediate panel points. This bracing shall occupy the full depth of the trusses below the floor system. The bracing shall be proportioned to transfer the end reaction of the top lateral system to the substructure.

Through truss spans shall have sway bracing at each intermediate panel point if the height of the trusses is such as to permit a depth of 5 feet or more for the bracing. When the height of the trusses will not permit of such depth the top lateral struts shall be provided with knee braces. Top lateral struts shall be at least as deep as the top chord. Sway bracing shall be of ample strength to transfer one-half of the wind presure to the leeward truss.

128. CROSS FRAMES. Deck plate girder spans shall be provided with cross frames at each end proportioned to resist all lateral forces, and shall have intermediate cross frames at intervals not exceeding 15 feet. These frames shall be connected to the outstanding legs of the stiffener angles and to the girder flanges.

129. LOW TRUSS SPANS. The vertical truss members and the floorbeam connections of low truss spans shall be proportioned to resist a lateral force, applied at the top chord panel points of the truss, determined by the following equation:

$$R = 150\ (A/P)$$

where R = lateral force in pounds
A = area of cross section of chord in square inches
P = panel length in feet

This rigidity may be secured in part by extending one or both of the floorbeam connection angles upward along the inside of the post. Outrigger brackets attached to the vertical posts on the outside of the trusses shall not be used.

130. THROUGH GIRDER SPANS. Through plate girder spans shall be stiffened against lateral deformations by means of gusset plates, or knee braces with solid webs, attached to the stiffener angles and floorbeams. If the unsupported length of the inclined edge of the gusset plate exceeds 60 times its thickness, the gusset plate shall have stiffener angles riveted along its edge.

These braces generally shall extend to the clearance line and preferably shall be spaced not farther apart than 15 feet.

PLATE GIRDERS.

131. PROPORTIONING. Plate girders shall be proportioned either by assuming the flanges to be concentrated at their centers of gravity or by the moment of inertia of the net section. In the former case 1/8 of the gross area of the web is available as net flange area but the effective depth shall not be assumed to be greater than the distance back to back of flange angles. For girders having unusual cross section the moment of inertia method shall be used.

132. FLANGE SECTIONS. The gross section of the compression flange shall not be less than the gross section of the tension flange. The compression flange preferably shall be stayed against lateral deflection at intervals not exceeding 12 times its width.

The flange angles shall form as large a portion of the gross area of the flange as practicable.

When flange plates are used, at least one plate on the top flange shall extend the full length of the girder. Any additional flange plates shall be of such length as to allow two rows of rivets to be placed at each end of the plate beyond its theoretical end, and there shall be a sufficient number of rivets at the ends of each plate to develop its full stress value before the theoretical end of the next outside plate is reached.

Flange cover plates shall be equal in thickness, or shall diminish in thickness from the flange angles outward. No plate shall have a thickness greater than that of the flange angles.

133. WEB PLATES. Web plates shall be proportioned for both the vertical and horizontal shearing stresses. Splices in web plates shall be avoided as far as possible, but, when used, they shall be designed to develop the full value of the web plate for both bending and shearing stresses.

134. FLANGE RIVETS. The number of rivets connecting the flange angles to the web plates shall be sufficient to develop the increment of flange stress transmitted to the flange angles combined with any load that is applied directly to the flange. For electric railways, one wheel load, when applied directly to the flange, shall be assumed to be distributed uniformly over a length of 3 feet.

135. FLANGE SPLICES. Splices in flange members shall not be used except by special permission of the Engineer. Two members shall not be spliced at the same cross section and, if practicable, splices shall be located at points where there is an excess of section. The net section of the splice shall exceed by 10 per cent the net section of the member spliced. Flange angle splices shall consist of two angles, one on each side. Splice angles shall be fitted to secure close contact with the material spliced.

136. WEB SPLICES. Web plates shall be symmetrically spliced by plates on each side. The splice shall be equal in strength to the web in both shear and moment. There shall be at least two rows of rivets on each side of the joint.

137. END STIFFENERS. Plate girders shall have stiffener angles over end bearings, the outstanding legs of which shall be as wide as the flange angles will allow and shall fit tightly against them. These end stiffeners shall be proportioned for bearing on the outstanding legs of the flange angles, no allowance being made for the legs fitted to the fillets of the flange angles. End stiffeners shall be arranged to transmit the total end reaction and to distribute it over the bearings. They shall not be crimped and the connection to the web shall contain a sufficient number of rivets to transmit the entire reaction.

138. INTERMEDIATE STIFFENERS. Intermediate stiffener angles shall be riveted in pairs to the web of the girder. The outstanding leg of each angle shall have a width of not more than 16 times its thickness and not less than 2 inches plus 1/30 of the depth of the girder.

Intermediate stiffeners shall be spaced at intervals not exceeding:

(a) 6 feet
(b) The depth of the web
(c) The distance given by the formula

$$d = \frac{t}{40} (12000 - S)$$

where d = distance between rivet lines of stiffeners, in inches
t = thickness of web, in inches
s = web shear, in pounds per square inch, at the point considered.

When the depth of the web between the flange angles or side plates is less than 60 times the web thickness, intermediate stiffeners may be omitted.

Intermediate stiffener angles shall be placed at points of concentrated loading and shall be designed to transmit the reactions to the girder web. Such stiffeners shall not be crimped.

Other intermediate stiffeners may be crimped.

139. ENDS OF THROUGH GIRDERS. The upper corners of through plate girders, where exposed, shall be neatly rounded to a radius consistent with the size of the flange angles and the vertical height of the girder above the roadway. The first flange plate or a plate of the same width will be bent around the curve and continued to the bottom of the girder. In a bridge consisting of two or more spans only the corners on the extreme ends need be rounded, unless the spans have girders varying heights, which case the higher girders shall have their top flanges neatly curved down at the ends to meet the top corners of the girders in the adjacent spans.

140. END BEARINGS. End bearings of girders on masonry shall be raised above the bridge seat by metal pedestals or plates a height of at least 2 inches.

141. SOLE AND MASONRY PLATES. Sole and masonry plates shall each be not less than 3/4 inch thick.

142. CAMBER. In general, camber will not be required in plate girders except for long spans or special conditions. When used, it shall be sufficient in amount to meet the requirements of the Engineer.

TRUSSES

143. MAIN FEATURES. Preference will be given to trusses with single intersecting web members or other forms of trusses possessing the least ambiguity in computed stresses and the greatest elements of serviceability Adjustable members in any part of the structure preferably shall be avoided. Members shall be symmetrical about the central planes of trusses and all parts shall be so designed that they can be inspected, cleaned and painted.

Through riveted and pin-connected spans will generally have inclined end posts. Low truss spans shall be of the riveted type. In low truss spans, laterally unsupported hip joints or "flying hips" shall be avoided.

144. TOP CHORDS AND END POSTS. Top chords and end posts of low and through truss spans shall be made usually of two side segments with one cover plate and with tie plates and lacing on the open side. In chords of light section, tie plates and lacing may be used in place of a cover plate.

Top chords of deck trusses subjected to direct loading shall be designed for the cross bending occasioned by the dead, live and impact loads of the floor system in addition to the direct chord stresses, and all top chord splices shall be proportioned for those stresses and any

shearing stresses they may receive.

Where the shape of the truss permits, compression chords shall be built continuous, with splices located as near the panel points as possible and preferably on the side subjected to the smaller stress.

The top chord sections of low truss spans shall be so proportioned that the redius of gyration about the vertical axis of the member shall be at least $1\frac{1}{2}$ times the radius of gyration about the horizontal axis.

145. BOTTOM CHORDS. The bottom chords of riveted trusses generally shall be spliced near panel points and on the side farthest away from the center of the span.

Bottom chords composed of angles preferably shall be constructed with the vertical legs of the angles extending downward.

146. WORKING LINES AND GRAVITY AXIS. For compression members, formed of side segments and a cover plate, the working line shall coincide as nearly as practicable with the gravity axis of the section. For symmetrical sections the working line shall coincide with the gravity axis. For two-angle bottom chord or diagonal members the working line may be taken as the gage line nearest the back of the angle.

147. CAMBER. Trusses shall in general be given a camber by increasing the length of the top chords an amount in each panel length equal to three-sixteenths inch for each ten feet of their horizontal projection.

148. RIGID MEMBERS IN PIN-CONNECTED TRUSSES. Pin-connected trusses shall have stiff riveted members in the first two main panels of the bottom chords at each end of the span, and all web members performing the function of suspenders shall be of stiff riveted construction.

149. COUNTERS AND ADJUSTABLE MEMBERS. Rigid counters are preferred. Adjustable counters, when used, shall have open turn-buckles and in the design of these members an allowance of 10,000 pounds shall be made for initial stress. Only one set of diagonals in any panel shall be adjustable. Sleeve nuts and loop bars shall not be used.

150. EYE-BARS. Eye-bar heads shall have a cross sectional area through the center of the pin hole exceeding that of the body of the bar by at least 40 per cent. The net section adjacent to the head shall be not less than that of the main body of the bar. The thickness of the bar shall be not less than 1/8 of the width and not greater than 2 inches. The form of the head shall be submitted to the Engineer for approval before the bars are made. The diameter of the pin shall be not less than 2/3 of the width of the widest bar connected.

151. PACKING EYE-BARS. The eye-bars of a set shall be packed symmetrically about the central plane of the truss and as nearly parallel as practicable, but in no case shall the inclination of any bar to the plane of the truss exceed 1/16 inch per foot. Bars shall be packed as closely as practicable and held against lateral movement, but they shall be arranged so that adjacent bars in the same panel will be separated by at least 3/4 inch.

All intersecting diagonal bars not far enough apart to clear each other at all times shall be well clamped together at intersections.

Steel filling rings shall be provided, when required, to prevent lateral movements of eye-bars or other members connected upon pins.

152. DIAFRAMS. Diaframs shall be provided in the trusses at the end connections of all floorbeams. In general, such diaframs shall extend down to the bottom flange of the floorbeam and for at least two rivet spaces above the top flange.

The gusset plates engaging the pedestal pin at the end of a truss shall be rigidly connected by a diafram which shall, in general, take direct bearing on the pin. Similarly, the pedestal webs shall, where practicable, be connected by a diafram which shall, in general, take bearing on the pin.

A diafram shall be provided between gusset plates engaging main members whenever the end tie plate is located at a distance of 4 feet or more from the point of intersection of the members. In general, the web of this diafram shall be located in the plane of the latticed flange.

153. SOLE AND MASONRY PLATES. Sole and masonry plates supporting trusses and columns shall each have a thickness of not less than 3/4 inch. The bottom chords of trusses shall be raised above the bridge seat at least 2 inches by the use of metal plates or pedestals.

VIADUCTS.

154. TYPE. Viaducts shall consist usually of alternate tower spans and free spans of plate girders or riveted trusses supported on trestle towers. However, in viaducts having a column height less than 35 feet, trestle bents may alternate with the towers.

In viaducts requiring freedom of waterway and in structures having a less total column height than 20 feet, the number of intermediate trestle bents may be increased over that specified above but, in general, shall not exceed four in number. Ample rigidity shall be secured in the attachment of the superimposed spans to the column caps of the bents.

155. BENTS AND TOWERS. Each trestle bent shall be composed preferably of two main supporting columns. Towers shall be composed of two bents rigidly braced and strutted both longitudinally and transversely.

156. SINGLE BENTS. For viaduct spans supported on single bents, the bents, if less than 20 feet in height, shall be pin-connected to their base sections or shall be designed to resist bending.

157. BATTER. Columns preferably shall have a transverse batter of not less than 1 horizontal to 12 vertical.

158. DEPTH OF GIRDERS. The depths of plate girders in viaducts preferably shall be uniform.

159. GIRDER CONNECTIONS. Girders of tower spans shall be fastened at each end to the tops of the columns or to the cross girders. Girders between towers shall have one end riveted, and shall be provided with an effective expansion joint at the other end. No bracing or sway frame shall be common to abuttin spans.

160. BRACING. Towers shall be thoroughly braced, both transversely and longitudinally, with a double system of stiff tension diagonals having riveted connections. Longitudinal and transverse struts shall be placed at caps and bases and at all intermediate panel points. All bracing connections shall be made by gusset plates.

Column splices generally shall be located close to and above the panel points of the bracing.

Horizontal diagonal bracing shall be provided at the tops and bases of towers and at least at all intermediate panel points of the lateral bracing where the tower columns are spliced.

Provision shall be made in column bearings for expansion of the tower bracing. The struts at the base of towers shall be strong enough to slide the movable shoes with the structure unloaded. The co-efficient of friction shall be taken at 0.3.

161. SOLE AND MASONRY PLATES. Sole and masonry plates shall each be not less than 3/4 inch thick.

162. ANCHORAGE. Viaduct bents preferably shall have a sufficient spread at the base to prevent tension in any windward leg. When this is impracticable, the column anchorages shall be designed to safely resist not less than $1\frac{1}{2}$ times the calculated uplift.

163. APPROVAL OF PLANS. The construction plans shall consist of shop detail, erection and other working plans showing details, dimensions, sizes of material and other information and data necessary for the complete fabrication and erection of the metal work. Approval of the construction plans shall be secured before fabrication of steelwork is commenced.

The Contractor shall furnish the Engineer with such blueprint copies of the plans as may be required for approval and construction purposes and upon completion of the work the original plans, if required, shall be supplied to the Engineer. No deviation from the approved plans will be permitted without the written order of the Engineer.

DESIGN OF TIMBER STRUCTURES

164. BOLTS. Bolts of diameters not exceeding 1 inch preferably shall be spaced not closer than 6 inches center to center, not less than 6 inches from the center of the bolt to the end of any timber, and not less than $2\frac{1}{2}$ inches from the center of the bolt to the side of any timber. These distances preferably shall be increased for bolts larger than 1 inch in diameter. Inclined bolts through timber preferably shall be provided with beveled cast washers to eliminate the cutting of inclined daps in the timber.

165. WASHERS. A washer shall be used under all bolt heads and nuts which would otherwise come in contact with wood. Washers may be cast or plate and shall be designed to prevent excessive crushing of the wood when the bolts are tightened. For bolts in important locations, such as joints and splices, and for rods, the washers shall be designed to develop the bolt or rod in tension at the unit bearing stresses specified for compression perpendicular to the grain of timber.

A standard circular washer shall be used under the heels of all lag screws.

166. HARDWARE FOR SEA-COAST STRUCTURES. The hardware used in structure on the sea-coast preferably shall be galvanized.

167. COLUMNS AND POSTS. No column shall have an unsupported length greater than 30 times its least dimension.

The strength of built-up columns composed of two or more sticks bolted together, either with or without packing blocks, shall be considered as equal to the combined strength of the single sticks, each considered as an independent column.

168. PILE AND FRAMED BENTS. Pile Bents. Pile bents generally shall not exceed 40 feet in height. Pile bents over 10 feet high shall be sway braced transversely with diagonal braces on each side of the bent, and shall be adequately braced longitudinally. In general, pile bents shall contain not less than 4 piling each and the outside piling preferably shall be battered. The piling shall be designed for safe bearing and for column action.

Framed Bents. Framed bents may be supported on piling, concrete pedestals or mud sills. All bents shall be sway braced transversely and adequate provision shall be made for longitudinal bracing. In general, framed bents shall contain not less than 4 posts each and the outside posts of the bent shall be battered. The posts shall be designed as columns.

Sills and Mud Sills. Mud sills, and all sills which are to be located in close proximity to the ground surface, preferably shall be given a preservative treatment. When possible the design shall be such as to insure that sills will be located clear of all earth so that there may be a free circulation of air around them. Sills shall be fastened to mud sills or piling with drift bolts of not less than 3/4 inch diameter and extending into the mud sills or piling at least 6 inches. Sills shall be fastened to pedestals with dowels of not less than 3/4 inch diameter, set in the pedestals and extending into the sills at least 6 inches.

Posts shall be fastened to sills by dowels of not less than 3/4 inch diameter extending at least 6 inches into posts and sills, or by drift bolts of not less than 3/4 inch diameter driven diagonally through the base of the posts and extending at least 9 inches into the sill. Posts shall be fastened to pedestals with dowels of not less than 3/4 inch diameter and extending into the posts at least 6 inches.

Caps. Timber caps shall be not less in size than 10 by 10 inches. They shall be fastened with drift bolts of not less than 3/4 inch diameter extending at least 9 inches into the piles and posts.

Bracing. Single story bracing shall not exceed 20 feet in height. The minimum size of transverse sway braces shall be 3 by 8 inches. All bracing shall be bolted through the piles, posts or caps at ends; at intermediate intersections it may be bolted or spiked. In all cases, spikes shall be provided in addition to bolts. The bolts used shall be of not less than 5/8 inch diameter.

Pile Bent Abutments. Pile bent abutments shall be adequately braced or anchored to resist earth pressure. Bulkhead plank shall be not less than 3 inches thick and preferably shall be treated. It shall be fastened to the piles with spikes, the length of which shall be at least 3 inches greater than the thickness of the plank.

169. TRUSSES. Joints and Splices. Joints shall be detailed to shed water to the maximum degree practicable. Joints and splices shall be designed to develop the computed stresses in the members connected and preferably to develop the full strength of those members. Posts or struts bearing against the sides of timber members preferably shall be provided with metal end bearings. Joints involving end bearing on inclined surfaces shall be avoided, preference being given to square-cut ends of timbers bearing against blocks.

In end-shoe plates and tension-splice plates the bearing faces of lugs or tables shall have a smooth even surface. If rolled plates or bars are used for tables, they shall be milled or cold sawed on the bearing edges. The bolts holding the lugs or tables in the notches in the timber shall be placed as near to the lugs or tables as possible. No metal lug or table shall have a gearing face less than 5/8 inch thick. In details of end-shoes employing lugs or tables set in the lower chord, the spacing of such lugs or tables shall be arranged so that no lug or table occurs directly under the end of the end post. The end joint between lower chord and end post shall provide definite lines of action and shall be a simple joint depending for its strength upon the type of detail. When inclined bolts are used to connect the main members of an end-joint, such bolts shall be at an angle of not more than 60 degrees with the center line of lower chord. Holes in timbers for inclined bolts in details employing end-shoe plates shall be 1/4 inch larger than the nominal diameter of the bolt.

No daps in chords for butt blocks shall be less than 3/4 inch deep.

Tension splices shall be of such a type that the effects of cross shrinkage of the timber will be a minimum. Neither steel table fish plates nor shear pin splices shall be used on timbers over 8 inches thick, since the cross shrinkage of the timber will allow the plates or pads to separate. The shear-pin joint shall be used only with fully seasoned timber and gas-pipe shall not be used for shear-pins.

Floorbeams. Floorbeams shall be sized at bearing points. In floorbeams composd of two or more timbers, the timbers shall be separated by at least 2 inches for air circulation. Floorbeams shall be connected to the main truss members by means of rods or structural shapes.

Hangers. Hangers generally shall be rods having upset ends with a suitably designed washer or bearing plate at each end. Upset ends conform to the requirements specified for Structural Steel Design.

Eyebars and Counters. The requirements specified for Structural Steel Design, for counters, eyebars and eyebar packing shall apply to such members when used in timber trusses.

Bracing. Timber trusses shall be provided with a rigid system of laterals in the plane of the loaded chord. When the details will permit, this lateral bracing shall be securely fastened to all longitudinal stringers. Lateral bracing, preferably rigid, in the plane of the unloaded chord, and rigid portal and sway bracing shall be provided in all trusses having sufficient head room. Outrigger brackets connected to extensions of the floorbeams shall be used for bracing through trusses having head room insufficient for a top lateral system.

Camber. Camber, in addition to that required to provide for dead load and shrinkage, shall be provided in timber trusses in sufficient amount to give the structure a good appearance.

170. FLOORS AND RAILING. Stringers. Stringers shall be of sufficient length to take bearing over the full width of caps or floorbeams, except outside stringers which may have butt joints. Preferably they shall be of two panel lengths placed with staggered joints. The lapped ends of untreated stringers shall be separated at least 1/2 inch for air circulation. Stringers shall be secured to caps or floorbeams.

Bridging. Stringers shall be braced by cross bridging in each panel. The bridging shall be not less in size than 2" x 4".

Nailing Strips. When timber floors are supported by steel joists the joists shall be provided with nailing strips which shall be bolted either to the top flanges or the webs.

When nailing strips are bolted to the flanges they shall be used on all joists. They shall be not less than 4 inches deep and shall be wider than the supporting flange. They shall be secured with 5/8 inch bolts through the flanges, spaced not more than 4 feet apart and not more than 18 inches from the ends of the strips.

Nailing strips bolted to the webs shall be not farther apart than 5 feet and shall be not less than 4 inches thick to provide a spiking face of sufficient width. They shall be held clear of the flanges by blocks between the web and strip, and bolted through the web with 5/8 inch bolts spaced not more than 4 feet apart and not more than 18 inches from the ends of the strips.

Flooring. Roadway floor plank shall have a nominal thickness of not less than 3 inches. Sidewalk floor plank shall have a nominal thickness of not less than 2 inches.

The minimum size of material used for laminated or strip floors shall be 2" x 4".

Retaining pieces. Retaining pieces, where required, shall be not less than 6 inches in width. In general, they shall be secured in place by 5/8 inch bolts at 3 foot intervals and spiked at 1 foot intervals.

Wheel Guards. Wheel guards having a cross section of not less than 6" x 8" shall be provided on each side of the roadway. The guard timbers shall be in lengths of not less than 12 feet. They shall be secured with 5/8 inch bolts at the ends and at intermediate points not more than 4 feet apart.

In strip floors or cambered floors, not provided with retaining pieces, the wheel guards shall be placed directly on the flooring with scupper holes at suitable intervals. In other floors the wheel guards shall be supported by scupper blocks not less than 4 inches thick and 1 foot long, held in place by spikes and a bolt through the wheel guard and flooring, and spaced not more than 5 feet apart.

Cambered Floors. In strip floors or floors crowned for drainage the ends of the flooring shall be securely held down by the retaining pieces or wheel guards. In this case the bolts through the retaining pieces or wheel guards shall pass through the flooring and through the outside stringer or spiking piece.

Drainage. Adequate provision shall be made for the proper drainage of timber floors.

Railings. Wood railings shall consist of not less than two horizontal lines of rails. Rails shall have a cross section not less than 2' x 6".

Rail posts shall have a cross section not less than 4" x 6" and shall be spaced not more than 8 feet apart.

Preferably, rails shall be surfaced four sides (S4S) and painted white.

171. FIRE STOPS. To check the spread of fire lengthwise of the structure, timber floors, or trestles of any considerable length preferably shall be provided with fire stops.

In timber floors these fire stops should be provided at intervals not over 75 feet apart. They may consist of diaframs of wood or fire resistant material at least as thick as the flooring, located over caps or floorbeams and completely filling the openings between the joints.

In timber trestle bridges, in addition to the fire stops in the floor, fire curtains should be provided at intervals of 100 feet or more. These curtains may consist of plank or asbestos-covered metal spiked to the bents or concrete. They should extend downward from the bottom of the joists at least five feet and horizontally at least to the ends of the caps. A fire stop between the joists should be located over each curtain.

10-35-1311
Sheet 55

Table of Moments, Shears and Floorbeam Loads for H-15

Loading - One Lane.

Moment in Thousands of Foot Pounds - Shears and Reactions

in Thousands of Pounds.

	Shear		Moment		F.B. Loads	
Span	L.L.	Impact	L.L.	Impact	L.L.	Impact
5	24.0	9.2	30.0	11.5	24.0	8.9
6	24.0	9.1	36.0	13.7	24.0	8.8
7	24.0	9.1	42.0	15.9	24.0	8.6
8	24.0	9.0	48.0	18.1	24.0	8.5
9	24.0	8.9	54.0	20.2	24.0	8.4
10	24.0	8.9	60.0	22.2	24.0	8.3
11	24.0	8.9	66.0	24.2	24.0	8.2
12	24.0	8.8	72.0	26.2	24.0	8.0
13	24.0	8.7	78.0	28.3	24.0	8.0
14	24.0	8.6	84.0	30.2	24.0	7.9
15	24.4	8.7	90.0	32.2	24.4	7.9
16	24.7	8.8	96.0	34.0	24.7	7.9
17	25.0	8.9	102.0	35.9	25.0	7.9
18	25.3	8.9	108.0	37.7	25.3	7.9
19	25.6	8.9	114.0	39.6	25.6	7.9
20	25.8	8.9	120.0	41.3	25.8	7.8
21	26.0	8.9	126.0	43.1	26.0	7.8
22	26.2	8.9	132.0	44.9	26.2	7.7
23	26.3	8.9	138.0	46.6	26.3	7.7
24	26.5	8.9	144.0	48.2	26.5	7.7
25	26.6	8.9	150.0	50.0	26.6	7.6
26	26.8	8.9	156.0	51.6	26.8	7.6
27	26.9	8.9	162.7	53.5	26.9	7.5
28	27.0	8.9	170.1	55.6	27.0	7.4
29	27.1	8.8	177.5	57.6	27.1	7.4
30	27.2	8.8	185.0	59.7	27.2	7.3
31	27.3	8.8	192.4	61.6	27.4	7.3
32	27.4	8.7	199.9	63.6	27.7	7.3
33	27.4	8.7	207.3	65.5	27.9	7.3
34	27.5	8.6	214.7	67.5	28.0	7.3
35	27.6	8.6	222.3	69.5	28.3	7.3

Span	Shear L.L.	Shear Impact	Moment L.L.	Moment Impact	F.B. Loads L.L.	F.B. Loads Impact
36	27.7	8.6	229.7	71.3	28.4	7.2
37	27.8	8.6	237.1	73.2	28.6	7.2
38	27.8	8.6	244.8	75.0	28.7	7.1
39	27.8	8.5	252.0	76.9	28.9	7.1
40	27.9	8.5	259.5	78.6	29.0	7.0
41	28.0	8.4	266.9	80.4	29.2	7.1
42	28.0	8.4	274.4	82.1	29.3	7.0
43	28.0	8.3	281.9	83.9	29.4	7.0
44	28.1	8.3	289.4	85.6	29.6	6.9
45	28.5	8.4	296.8	87.3	30.5	7.1
46	29.0	8.5	304.3	89.0	31.3	7.2
47	29.4	8.6	311.8	90.6	32.1	7.4
48	29.8	8.7	319.2	92.3	32.9	7.4
49	30.2	8.7	326.7	93.9	33.7	7.6
50	30.5	8.7	334.2	95.5	34.4	7.7
51	30.8	8.8	341.6	97.1	35.2	7.7
52	31.1	8.8	349.1	98.6	35.9	7.8
53	31.5	8.9	356.6	100.2	36.5	7.9
54	31.8	8.9	364.1	101.7	37.1	8.0
55	32.1	8.9	371.6	103.2	37.7	8.0
56	32.3	8.9	379.1	104.7	38.3	8.1
57	32.6	9.0	386.6	106.2	38.9	8.1
58	32.9	9.0	394.1	107.6	39.5	8.2
59	33.2	9.0	401.5	109.1	40.1	8.3
60	33.5	9.1	409.0	110.6	40.6	8.3

10-35-1311
Sheet 57