September
Slags

YEAR of the RECYCLED ROADWAY MATERIALS

This packet provides information about how and why to use slags in various road construction applications.

Case Study #1	Ground Granulated Blast Furnace (GGBF) Slag Used in Concrete in TxDOT's El Paso District
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Material Brief

Slags are nonmetallic by-products (or impurities) of metal manufacturing that consist primarily of various combinations of calcium, magnesium and aluminum silicates.

Blast furnace slag (from iron making) and steel furnace slag (from steel refining) are distinct types of slag produced in ferrous metallurgy. These slags are chemically inert and generally exempt from federal regulations. According to the U. S. Geological Survey (USGS), they are considered valuable coproducts and are among the most voluminous of usable recycled materials. In 1997, 21.4 million tons of iron and steel slag were consumed in the U.S.

When molten, slags float on the metal. Separating is not exact, so it is preferable to have some metal in the slag rather than slag in the metal. The molten slag is allowed to cool and solidify. Blast furnace slag and steel furnace slag are then crushed and screened to make the sizes needed for construction applications.

It is especially important that the metal be removed to avoid problems during the end use of slag and also to recover the higher value scrap for return to the iron- and steelmaking processes.

Iron slags account for approximately 65 percent of the national production tonnage. Within the road construction industry, slags are used in asphaltic and hydraulic concrete manufacturing, as aggregates, and as fill material.

Blast furnace slag is used predominately as base and concrete aggregate. It can also be granulated and used in the manufacture of cement. Steel aggregates can be used in base and hot mix. No iron slags are produced in Texas, but steel slag is derived from electric arc furnaces.

Ferrous Slag Types

Type of Slag	Processing Technique	Aggregate Description	Potential Use
Iron (Blast Furnace)	Air Cooled	Porous, low-density aggregate	--
	(two types)	Dense, hard aggregate	Suitable for road base
	Expanded	Lightweight aggregate	Concrete
	Granualted (GGBF)	Granular, glassy aggregate	Concrete (pozzolanic properties, after crushing)
Steel	--	Dense, hard aggregate	Suitable for road base and hot mix asphalt

Overview

Iron (Blast Furnace) Slag

Blast furnace slag is often used when maximum durability, higher strength, hardness of aggregate, fire resistance, better insulation and lighter weight are required. The shape and texture of blast furnace slag promote excellent bonding with cement mortar. Blast furnace slags can be used as aggregates although they are used increasingly as a cement admixture because this use has a higher value.

Blast furnace slag is nonreactive in a high alkali environment, such as concrete and soils. Blast furnace slag concrete can be reliably pumped when the slag is supplied to the ready-mix production in a saturated condition.

Use of the cementatious properties of ground granulated blast furnace (GGBF) slag was reported as early as 1774. GGBF slag has been used in concrete in Japan and Western Europe since the 1940s. Concrete containing slag is estimated to comprise approximately 20 percent of the hydraulic cement produced in Europe.

According to the USGS, there are only three companies in the nation that supply GGBF slag: Blue Circle Atlantic, Inc. of Maryland; Holnam, Inc. of Indiana and West Virginia; and Lafarge of Ohio. However, there are other GGBF slag concrete suppliers.

Steel Slag

Steel slag is generated by one of three processes: the electric arc furnace process (which is most common in Texas), the basic oxygen furnace process, and the open hearth process. Differences in the slag from these processes are due more to raw materials and desired final steel chemistry than to the process itself.

Steel slag is typically high in iron and calcium reacted with other impurities to form mineral compounds that are heavy, dense, hard, abrasion resistant, dark colored and highly angular in shape with rough surfaces.

It has a tendency to expand, which makes it unsuitable for use in portland cement concrete; however, it does not cause problems in hot mix asphalt.

In fact, studies at the Pennsylvania DOT indicate that steel slag from electric arc furnaces offers benefits when used in hot mix asphalts:

- high stability,
- high skid resistance,
- longer heat retention after mixing, and
- ease of compaction without "shoving" in front of a roller compactor.

The PenDOT steel slag hot mix specimens demonstrated a higher percent-retained tensile strength and stability with less stripping than limestone specimens.

According to a Transportation Research Board study, slag hot mix performed well in a number of high-volume, high-speed surface-course applications.

One other method to recycle steel slag was developed by Texas Industries (TXI). CemStar[SM] is a process where steel slag is used in the production of cement clinker. This process provides a good use of steel slag and allows cement production facilities a method that increases production from 5 to 15 percent while reducing CO_2 and NOx emissions. This beneficial recycling is employed in several plants inside of and outside Texas' borders.

Sources:

American Concrete Institute, "Ground Granulated Blast Furnace Slag as a Cementious Constituent in Concrete" ACI 233R-95.

Edward C. Levy, http://www.edwclevy.com.

Kalyoncu, Rusty S., U.S. Geological Survey, Mineral Commodity Summaries, January 1999.

Kalyoncu, Rusty S., U.S. Geological Survey, Mineral Commodity Summaries, January 1998.

Kalyoncu, Rusty S., U.S. Geological Survey, Mineral Commodity Summaries, January 1997.

Mayes, Greg, TXI, Dallas.

Noureldin, A.S., and McDanial, R.S., "Evaluation of Surface Mixtures of Steel Slag and Asphalt," Transportation Research Board, 1990.

Ramirez, T.L., "Steel Slag Aggregate in Bituminous Mixtures," Pennsylvania Department of Transportation, 1992.

Steel Slag Material Description, http://www.tfhrc.gov/hnr20/recycle/waste/ssa1/htm.

Case Study #1

Ground Granulated Blast Furnace (GGBF) Slag Used in Concrete in TxDOT's El Paso District

GGBF slag is produced when molten iron slag is solidified rapidly in water. This produces glassy, sand-size particles that, when ground, exhibit cementious properties.

GGBF slag is typically used between 25 and 50 percent by volume as a replacement for cement, although it can be used up to 70 percent. GGBF slags can be used in combination with portland cement and fly ash.

Project Overview

For more than six months, Jobe Concrete Products in El Paso has been substituting GGBF slag for cement at a rate of approximately 50 percent by volume in concrete. Jobe has been using GGBF on virtually all TxDOT concrete jobs, even bridges, except where those projects involved long haul distances.

As with most unfamiliar materials, there's been a learning curve. Although the GGBF slag concrete's strength is fine at 28 days, the concrete gains strength more slowly initially. This lengthens the time before forms can be wrecked and requires special handling of concrete cylinders. There have also been some unanticipated reactions between the GGBF slag and other admixtures. Additionally, project inspectors were a little taken aback when the concrete was a blue-green color initially, which is characteristic of GGBF slag concrete.

To avoid this learning curve, it would be tempting to continue using only the familiar cement and fly ash; however, GGBF slag does offer several benefits. GGBF slag concrete typically has greater workability and is easier to finish. Water demand for GGBF slag concrete is lower, which helps minimize shrinkage cracking potential. Another benefit of GGBF slag is greatly reduced permeability of the mature concrete. According to the literature, GGBF slag concrete is sulfate resistant, particularly when slag is a minimum of 50 percent of the total cementitious materials. (TxDOT has not yet verified this particular property.) The Environmental Protection Agency also encourages the use of GGBF slag in concrete. In fact, the law states that if more than $10,000 per year of federal funds are spent on concrete, then the agency or contractor is required to include GGBF slag or fly ash at the highest percentage practicable, taking into consideration competition, price, availability and performance

Specifications

TxDOT Special Specification 421–020 (English) allows for the use of GGBF slag and can be found at the end of this month's packet (421-016 Metric).

Results and Conclusions

Using GGBF offers many benefits:

- improves workability and finishing;
- lowers water requirement;
- reduces permeability;
- improves sulfate resistance; and
- acts as a retardant, which is beneficial in some circumstances.

TxDOT representatives in El Paso believe that GGBF slag does offer benefits in concrete; however, there is a learning curve. Jobe Concrete feels they could recycle more GGBF slag if it were available in the region.

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Ned Finney, Vice President, Jobe Concrete Products, El Paso	(915) 565-4681

Sources

Environmental Council of Concrete Organizations, "Reclaimed Industrial By-products Key to Concrete of the Future," Stokie, Illinois, 1998.

Ned Finney, Jobe Concrete, September 1999.

Tomás Saenz, TxDOT El Paso District Material Engineer, September 1999.

http://www.epa.gov/epaoswer/non-hw/procure/products/cement.htm.

http://www.epa.gov/docs/fedrgstr/EPA-WASTE/1995/May/Day-01/pr-213.html.

Case Study #2

Spent Blast Media (Boiler Slag) Used in Hot Mix Asphaltic Concrete in TxDOT's Beaumont District

Abstract

The Beaumont District demonstrates the three market factors that enable and encourage the recycling of nonhazardous recycled materials (NRMs):

- high rate of construction,
- remote aggregate resources, and
- large volume of available alternative feedstocks.

One source for these NRMs is sandblasting operations, frequently occurring in shipyards. This case study looks specifically at one TxDOT material supplier and its ongoing recycling effort which reclaims the value of previously discarded materials—in this case, spent blasting media.

The spent blasting media was originally boiler slag produced as a by-product of industrial operations. This material—made up of iron, aluminum and calcium silicates—is first recycled as a sand blasting material where it is prized for its sharp, angular particles. These same properties make it desirable for use in road construction applications and allow the second round of recycling, featured in this case study, to occur.

Project Overview

For several years, the APAC-Texas, Inc., Trotti and Thompson Division has been substituting spent blasting media for native sand at a rate of approximately 2,000 tons per month (25 percent of feed) to produce cement-stabilized base and hot- and cold-mix asphalt products.

APAC has contracted with a local solid waste collection firm to transport the blasting media from a local shipyard. APAC's contract with the waste company also ensures the material is properly tested and classified as nonhazardous prior to accepting the material for feedstock. This process has been ongoing for more than three years, and has been a team effort between APAC and regional TxDOT officials, including the TxDOT lab.

APAC found the material actually performs better than more rounded stream sands, and APAC prefers the angularity of the blasting media for its physical properties. APAC could recycle more of these products if they were available in the region.

APAC also recycles concrete into flexible base at a rate of about 30,000 tons per year, as well as 20,000 tons per year of reclaimed asphalt pavement (RAP).

Economic Analysis

Disposal of spent blasting material in local landfills has traditionally been the handling method. Local landfill rates for this material vary between $8 and $35 per ton, depending on the type of sand being disposed of. Additionally, some sands have been transported long distances for disposal. The numbers provided on page 7 indicate that recycling is an economically viable course of action.

Specifications

TxDOT Specification Item 340, "Hot Mix Asphaltic Concrete Pavement" requires that "the aggregate shall be composed of a coarse aggregate, a fine aggregate, and if required or allowed, a mineral filler and may include reclaimed asphalt pavement (RAP)." Additionally, under 340.2(c) "a maximum of 15 percent of the total virgin aggregate may be field sand or other

Economic Benefit of Slag Use

Disposal costs avoided assuming average $10/ton disposal	$240,000
Costs avoided compared to raw sand at $5/ton	$120,000
Total Economic Benefit	**$360,000**

uncrushed fine aggregate." Spent blasting media fulfills the specification requirement in this context.

Results and Conclusions

Recycled spent blasting media meets design and construction specifications as a substitute for raw field sands and mineral fillers in the production of hot mix asphaltic concrete, as well as other specification items. Potential uses for the material also include flexible base, cement stabilized base, engineered fill, and other concrete and asphaltic applications. Economic advantages to the department exist on the order of several million dollars annually for Texas markets.

Sources

Briggs, Mark, kei, Houston, Texas.

Rutledge, Rebecca, APAC, Inc., Beaumont, Texas.

http://www.reade.com/Products/Abrasives/black_beauty.html.

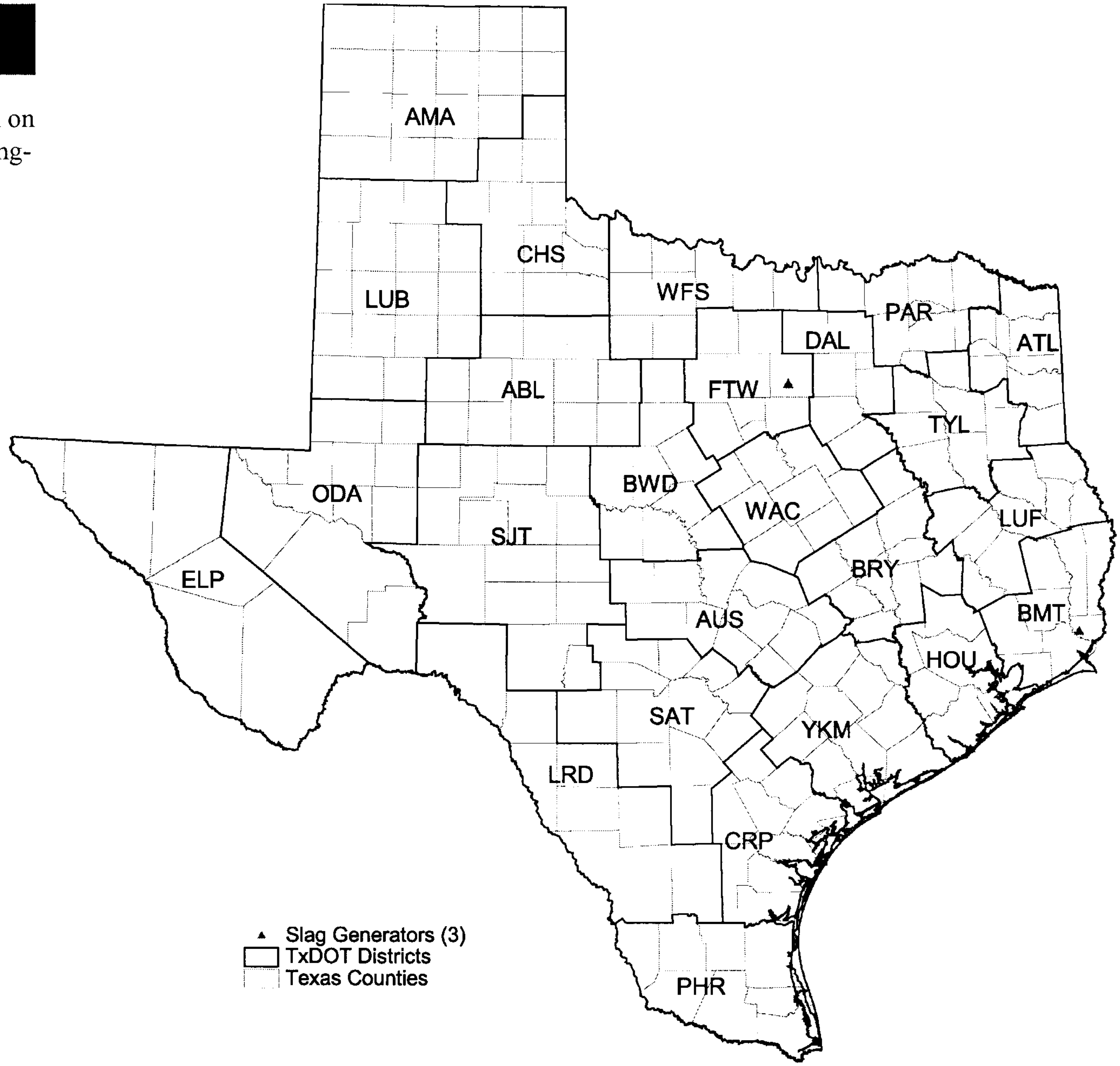
TxDOT Experience

This table provides information about TxDOT's experience using slags in paving materials.

District Name	Construction Application	Material	Results	Years of Experience	Spec	Location	Additional Comments
El Paso	Paving Materials-Asphaltic Concrete	Copper Slag		1993	340, 3063	El Paso	Discontinued because of environmental concerns. The discontinuation has nothing to do with the materials workability or strengths. The railroad has been using this slag as railroad ballast for decades with no restrictions.
El Paso	Paving Materials-Portland Cement Concrete (PCC)	Copper Slag		1993	360, 421	El Paso	Discontinued because of environmental concerns. The discontinuation has nothing to do with the materials workability or strengths. The railroad has been using this slag as railroad ballast for decades with no restrictions.
San Antonio	Paving Materials-Asphaltic Concrete	Ground Granulated Blast Furnace Slag	Good	1995	None	Bexar	Used as coarse aggregate in one of several test sections of microsurface placed by supplier.
Tyler	Paving Materials-Asphaltic Concrete	Ground Granulated Blast Furnace Slag	Good	1982	340	US 271, etc.	Usage ended when Lone Star Steel went out of business in the late 1970s
Atlanta	Paving Materials-Asphaltic Concrete	Steel Slag	Good	1987	Standard	District-wide	Good aggregate. No longer in production at Lone Star.
Tyler	Paving Materials-Portland Cement Concrete (PCC)	Steel Slag	Unknown		421	IH 20-Gregg Co.	Installation occurred in the 1960s.
Waco	Paving Materials-Asphaltic Concrete	Steel Slag	Excellent	1991	340	I-35 E-Hill Co.	Holding up well to date.

Material Availability

The map and table provide information on companies with the ability and/or willingness to generate slags.

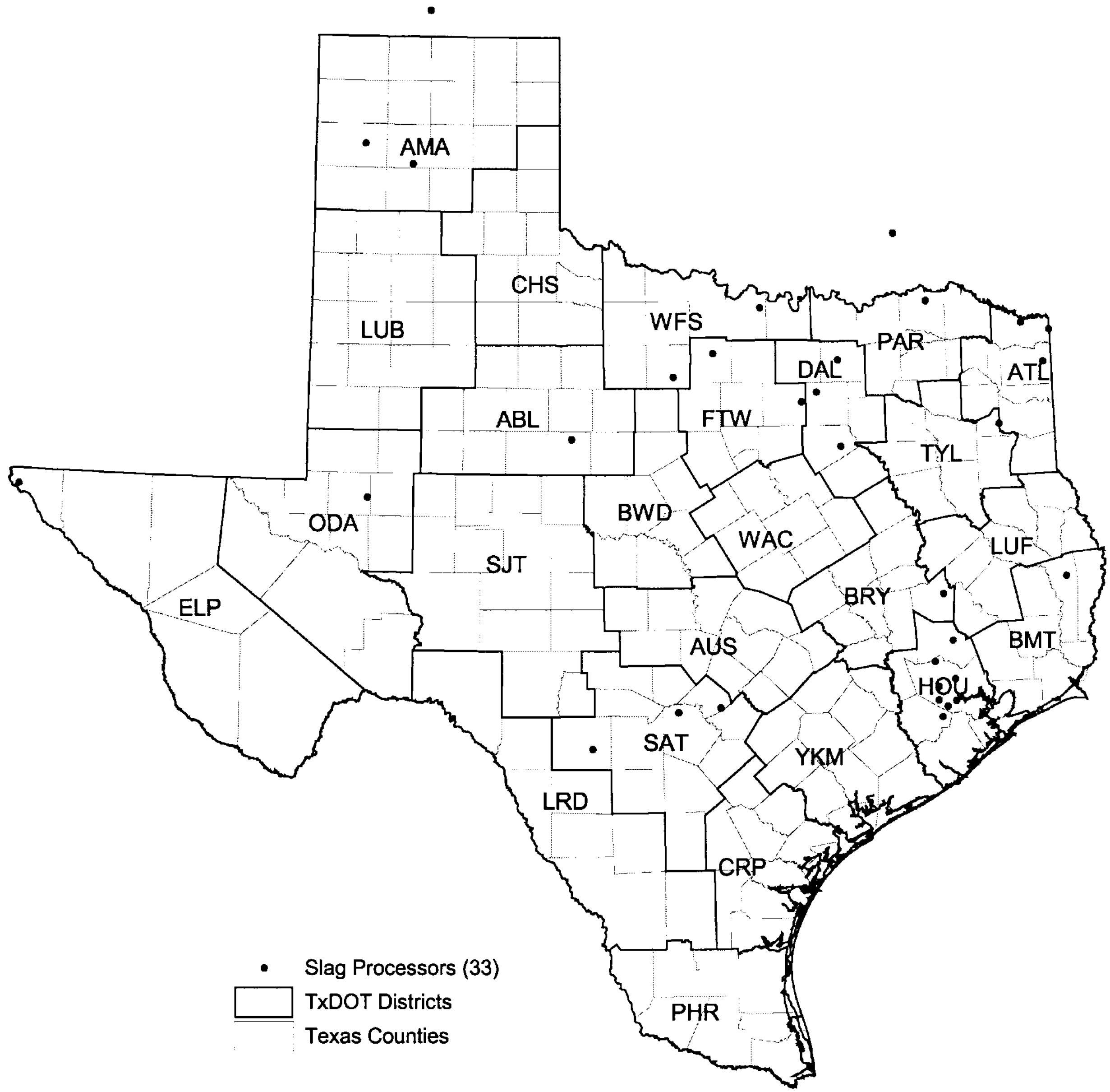


Companies with Ability and/or Willingness to Generate Slags

COMPANY	ADDRESS	CITY	STATE	ZIP
Gulf Chemical & Metallurgical Corporation	302 Midway Rd.	Freeport	TX	77541
Texas Steel Company	3901 Hemphill St.	Fort Worth	TX	76110
North Star Steel	Old Highway 90	Beaumont	TX	77704

Material Processors

This map and table provide information on companies that have expressed an ability and/or willingness to process slags.



Companies with Ability and/or Willingness to Process Slags

COMPANY	ADDRESS	CITY	STATE	ZIP	TXDOT_DIST	COUNTY
Redland Stone Products Co.	17910 IH-10 West	San Antonio	TX	78257	San Antonio	Bexar
Bowie Bridge LLC	CR 4004 & Hwy 8 South	New Boston	TX	75570	Atlanta	Bowie
H.V. Caver, Inc.	1303 W. Main	Atlanta	TX	75551	Atlanta	Cass
Lattimore Materials	1600 Redbud	McKinney	TX	75069	Dallas	Collin
John Stuart Sitework					San Antonio	Comal
Big City Crushed Concrete	11131 Goodnight Lane	Dallas	TX	75229	Dallas	Dallas
Jones Brothers	1401 S. Grandview	Odessa	TX	79760	Odessa	Ector
Jobe Concrete Products, Inc	#1 McKelligon Canyon Rd	El Paso	TX	79930	El Paso	El Paso
M. Hanna Construction Company		Ennis	TX		Dallas	Ennis
Russell & Sons Construction Co.	307 S. Eastman Road	Longview	TX	75602	Tyler	Gregg
Southern Crushed Concrete - Chrisman	14329 Chrisman Rd	Houston	TX	77039	Houston	Harris
Southern Crushed Concrete - Gasmer	5001 Gasmer	Houston	TX	77035	Houston	Harris
Southern Crushed Concrete - Griggs	5625 Griggs Rd	Houston	TX	77021	Houston	Harris
Southern Crushed Concrete - Tanner Road	10360 Tanner Rd	Houston	TX	77041	Houston	Harris
Southern Crushed Concrete - Wilcrest	3901 Wilcrest	Houston	TX	77072	Houston	Harris
Texas Industries (TXI)	24403 FM 2978	Tomball	TX	77375	Houston	Harris
Zack Burkett Co. - Richards Pit	3 mi S of Jacksboro, FM 4	Jacksboro	TX	76458	Fort Worth	Jack
Mathews Construction Company	641 E. Milam	Jasper	TX	75951	Beaumont	Jasper
Meridian Aggregates	Highway 271 North	Powderly	TX	75473	Paris	Lamar

Companies with Ability and/or Willingness to Process Slags, continued

COMPANY	ADDRESS	CITY	STATE	ZIP	TXDOT_DIST	COUNTY
J.R. Thompson, Inc. - Running N Quarry	3 mi of Saint Jo on SH 59	Saint Jo	TX	76265	Wichita Falls	Montague
Pavers Supply Co. - Conroe Plant	9498 FM 1485	Conroe	TX	77303	Houston	Montgomery
Garrett Construction	Garrett Road	Ingleside	TX	78362	Corpus Christi	Nueces
Vega Sand and Gravel Inc.	10 mi N. of Vega on US 385	Vega	TX	79092	Amarillo	Oldham
Amarillo Road Co. - Rock Crusher	Panhandle & West Texas	Amarillo	TX		Amarillo	Potter
L.A. Fuller & Sons Construction, Inc.	9401 Amarillo Blvd. East	Amarillo	TX	79107	Amarillo	Potter
Archer-Western Contractor	1170 W. Corp. Drive	Arlington	TX	76006	Fort Worth	Tarrant
J.H. Strain & Sons Inc. #1 Crusher		Tye	TX	79563	Abilene	Taylor
South Texas Aggregates	Main & Avenue B	Knippa	TX	78870	San Antonio	Uvalde
Recycled Stone Co. - Huntsville Plant	US190 East	Huntsville	TX	77340	Bryan	Walker
Zack Burkett Co. - Perry Pit	SH 16, 10 mi S of Graham	Graham	TX	76450	Wichita Falls	Young
Highway Contractors, Inc.	2900 US Hwy 54 East	Guymon	OK	73942		
Stringtown Materials, L.P.	100 East Mt. Blanc	Stringtown	OK	74569		
Jet Concrete Inc.		Texarkana	AR	75504		

1993 Specifications

SPECIAL PROVISION
TO
ITEM 421
PORTLAND CEMENT CONCRETE

For this project, Item 421, “Portland Cement Concrete”, of the Standard Specifications, is hereby amended with respect to the clauses cited below and no other clauses or requirements of this Item are waived or changed hereby.

Article 421.2. Materials, The first paragraph is voided and replaced by the following:

The concrete shall be composed of hydraulic cement (with or without) fly ash or ground granulated blast furnace slag (GGBF slag), fine and coarse aggregates and water.

Article 421.2. Materials, Subarticle (1) Cement, is voided and replaced by the following:

(1) Cement. The cement shall conform to Item 524, “Hydraulic Cement”.

Article 421.2. Materials, Subarticle (2) Fly Ash, is voided and replaced by the following:

(2) Fly Ash and GGBF Slag.

a. Fly ash shall conform to the requirements of Departmental Materials Specification DMS-8900. Copies of Departmental Materials Specifications are available from the Texas Department of Transportation, 125 East 11th Street, Austin, Texas 78701-2483.

b. GGBF slag shall conform to the requirements of ASTM C 989 Grade 100 or 120. GGBF slag may be accepted for use prior to testing provided it is from a prequalified source. A manufacturer shall become qualified by establishing a history of satisfactory quality control as evidenced by results of tests performed by the Construction Division and upon approval of production and storage facilities by the Director of Construction. Continued acceptance of GGBF slag from prequalified source will remain in effect as long as all test results on samples conform with specification requirements. Failure of GGBF slag to meet the requirements shall be just cause to remove a manufacturer from the prequalified status. In this event, all GGBF slag from that source will be subject to testing prior to use. This procedure will continue until the Director of Construction has determined that adequate quality control has been re-established. GGBF slag from nonprequalified sources will require sampling and testing prior to use.

Article 421.2. Materials, Subarticle (4) Coarse Aggregate. The first sentence of the first paragraph is voided and replaced by the following:

Coarse aggregate shall consist of durable particles of gravel, crushed blast furnace slag, recycled crushed portland cement concrete, crushed stone, or combinations thereof and shall be free from frozen material or injurious amounts of salt, alkali, vegetable matter, or other objectionable material either free or as an adherent coating. The use of recycled crushed portland cement concrete as a coarse aggregate shall be limited to Class B, Class D, Class E and Class P concrete.

Article 421.2. Materials, Subarticle (5) Fine Aggregate. The first and second paragraphs are voided and replaced by the following:

Fine Aggregate shall consist of clean, hard, durable particles of natural or manufactured sand or a combination thereof, with or without a mineral filler. Fine aggregate shall be free from frozen material or injurious amounts of salt, alkali, vegetable matter or other objectionable material and shall not contain more than 0.5 percent clay lumps by weight.

When fine aggregate is subjected to the color test for organic impurities in accordance with Test Method Tex-408-A, the test result shall not show a color darker than standard.

When white portland cement is specified, the fine aggregate shall be light colored.

Unless otherwise shown on the plans, the acid insoluble residue of fine aggregate used in concrete subjected to direct traffic shall not be less than 60 percent by weight when tested in accordance with Test Method Tex-612-J.

Unless otherwise shown on the plans, fine aggregates may be blended to meet the acid insoluble residue requirement. When blended, the following equation will be used:

Acid Insoluble (%) = {(A1)(P1)+(A2)(P2)}/100

where:

A1 = acid insoluble (%) of aggregate 1
A2 = acid insoluble (%) of aggregate 2
P1 = percent by weight of A1 of the fine aggregate blend
P2 = percent by weight of A2 of the fine aggregate blend

Article 421.2. Materials, Subarticle (5) Fine Aggregate is supplemented by the following:

The use of recycled fine aggregate shall be limited to a maximum of 20 percent of the fine-aggregate (sand) portion of the mixture and shall be limited to Class B, Class D, Class E and Class P concrete.

Article 421.3. Storage of Materials, Subarticle (1) Cement, Fly Ash and Mineral Filler. The first paragraph is voided and replaced by the following:

(1) Cement, Fly Ash, GGBF Slag and Mineral Filler. All cement, fly ash, GGBF slag and mineral filler shall be stored in well ventilated weatherproof buildings or approved bins, which will protect them from dampness or absorption of moisture. Each shipment of packaged cement shall be kept separated to provide easy access for identification and inspection.

Article 421.4. Measurement of Materials. The first sentence of the third paragraph is voided and replaced by the following:

Cement, fly ash or GGBF slag shall be weighed separately from other materials.

Article 421.8. Classification and Mix Design. The first paragraph is supplemented by the following:

If the Contractor can provide historical data obtained within the preceding 12-month period which demonstrates that an existing concrete mix design meets all requirements of the plans and specifications, the above requirements for concrete mix design verification may be waived by the Engineer.

Article 421.8. Classification and Mix Design. The eleventh paragraph is supplemented by the following:

Admixtures shall be used in accordance with manufacturers' recommendations.

Article 421.8. Classification and Mix Design. "Table 3, Slump Requirements", A. Structural Concrete is supplemented by the following:

High strength concrete (f'c>/=9000 psi) ——	Maximum slump may exceed eight (8) inches when approved by the Engineer

Article 421.8. Classification and Mix Design, is supplemented by the following:

Unless otherwise shown on the plans or in the specifications, the cement shall be either Type I, IP, IS, II, or III except as follows:

Type III cement shall not be used when the anticipated air temperature for the succeeding 12 hours will exceed 60 F.

Type III cement may be used, regardless of air temperature, in all precast concrete.

All cement used in a monolithic placement shall be of the same type.

Type I/II cement may be considered as either Type I or Type II cement except as otherwise noted.

Type IP or IS cement may be used in lieu of Type I or Type II cement.

The Contractor shall have the option of replacing a percentage of the required cement with either fly ash or ground granulated blast furnace slag, on a one to one basis by absolute volume, in accordance with the following:

The Contractor may substitute up to 50 percent of the cement with GGBF slag.

When aggregate sources have not been identified as potentially reactive, the Contractor may substitute up to 35 percent of the cement with fly ash.

When potentially reactive aggregates are used, the Contractor may substitute from a minimum of 20 percent to a maximum of 35 percent of the cement with fly ash.

Only GGBF slag or Type “A” fly ash may be used when Type II cement is specified.

No fly ash or GGBF slag will be permitted when a white portland cement is required. No additional fly ash or GGBF slag will be permitted when a Type IP or IS cement is used.

Article 421.9. Quality of Concrete. The third paragraph is supplemented by the following:

All compressive strength specimen molds for high strength concrete (f’c>/=9000 psi) shall be four (4) inch diameter by eight (8) inches in dimension, and shall have unbonded capping systems of durometer hardness adequate for testing concrete of the expected compressive strength.

Article 421.9. Quality of Concrete. The eleventh paragraph is voided and replaced by the following:

When control of concrete strength is by the 28 day compressive strength, job control may be by seven (7) day compressive tests which are shown to provide the required 28 day strength, based on results from trial batches. If the required seven (7) day strength is not obtained with the quantity of cement specified in Table 4, changes in the batch design will be made as specified in this article. For an occasional failure of the seven (7) day compressive test, the concrete may be tested at 28 days for final evaluation.

Article 421.9. Quality of Concrete. "Table 4, Classes of Concrete", is supplemented by the following:

NOTE: (e) For high strength concrete (f'c>/=9000 psi), the 56 day minimum compressive strength shall be as specified on the plans.

Article 421.9. Quality of Concrete, Table 4 Classes of Concrete A and C, are voided and replaced by the following:

TABLE 4
CLASS OF CONCRETE

Class of Conc.	Cement per C.Y. Min. sacks	Min. Comp Sgth. (fc) 28 Day psi	Min. Flex. Sgth. 7 day psi	Max. Water Cement Ratio Gal/sk	Coarse Aggr. Grade No.	General Usage (info. only)
A	5.0	3000	425 390 (c)	6.5	1-2- 3-4- 8 (a) (d)	Drilled Shafts; Inlets, Manholes, Appr. Slabs; Curb; Gutter; Curb & Gutter; Conc. Retards; Sidewalks; Driveways; Conc. Pavement; Back-up Walls; Anchors
C	6.0	3600	510 470 (c)	6.0	1-2-3- 4-5 (d)	Drilled Shafts; Bridge Substructure Bridge Railing; Cast-in-place Culverts,except Top Slab of Direct Traffic Culverts; Wingwalls; Headwalls; Approach Slab; Concrete Traffic Barrier (cast-in place)