November
Coal Combustion Products

This packet provides information about how and why to use coal combustion products in roadway construction and maintenance projects.

Research Summary #1	Guidelines for Using Hydrated Fly Ash as a Flexible Base
Research Summary #2	Evaluation of the Use of Coal Combustion Products in Highway and Airfield Pavement Construction
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TxDOT Experience	Summary of TxDOT experience using coal combustion products in various applications
Material Availability	Map and table listing companies that market coal combustion products
Specifications	• Special Provision to Item 421-024, Portland Cement Concrete • Special Specification, Item 2028, Lime-Fly Ash (LFA) or Fly Ash (FA) Treatment for Materials in Place • Special Specification, Item 4156, Flowable Backfill • Draft Specification, Hydrated Fly Ash as a Base Course Material • Plan Notes for Bottom Ash in Asphalt Stabilized Base (ASB) and Hot-Mix Asphalt

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Material Brief

Coal combustion products, sometimes referred to as coal combustion *by*-products, are the residual of coal after it is burned to produce electricity.

Burning coal produces more than half the electricity generated in the U.S. Coal combustion products are the third largest mineral resource produced in the country, behind crushed stone, and sand and gravel. Of the 97.8 million metric tons of coal combustion products produced in 1998, approximately 15.6 million tons were used in construction applications, with another 700 thousand metric tons used for snow and ice control.

Texas generates more than 50 percent of its electricity using coal as a fuel. In 1996, Texas produced 12.8 million tons of coal combustion products and used 2.4 million tons, less than 20 percent.

Coal combustion products include fly ash, bottom ash and flue gas desulfurization (FGD) material.

Fly ash is defined as the fine gas-borne particles of noncombustible material. Hydrated fly ash is produced when water is added and the material is allowed to harden. The resulting product is crushed into large aggregate particles.

Bottom ash consists of the heavier noncombustible sand-like particles and fused clinkers that fall to the bottom of the utility boiler.

Flue Gas Desulfurization (FGD) material is produced when power plants that burn high-sulfur coal install equipment to reduce the amount of sulfur oxide emissions released into the air. It is composed principally of calcium sulfate and sulfite (gypsum-like material). The amount of FGD material is likely to increase significantly in the future as additional power plants comply with the Clean Air Act Amendments of 1990 to reduce the acid rain problem in North America.

In the U.S., fly ash currently contributes the largest percentage of coal combustion product volume at 58 percent, followed by FGD at 23 percent, and bottom ash at 16 percent.

Quantities of Coal Combustion Products Produced and Used in the United States in 1998

	Quantity (million metric tons)	Usage Percentage
Fly Ash	54.7 (58%)	34%
FGD Material	22.7 (23%)	10%
Bottom Ash	15.2 (16%)	31%

In 1993, after more than 20 years of study, the Environmental Protection Agency (EPA) affirmed that coal combustion products are nonhazardous. In fact, using fly ash as a cement replacement improves air quality. For every ton of fly ash used in concrete a ton of carbon dioxide (CO_2) emissions is avoided.

According to *Environmental Building News*, "increasing the fraction of mineral admixtures in all concrete from 15 percent of the cementing materials to 50 percent would eliminate up to 600 million tonnes (metric) of CO_2 emissions—equivalent to removing one quarter of all cars in the world."

Section 223.046 of the Transportation Code, Texas Senate Bill 1340, effective January 1, 1992, states that "Design standards, guidelines and specifications of the [Texas] department [of Transportation], a county or a municipality shall require that contract specifications for road construction project allow for the use of fly ash and bottom ash resulting from combustion of coal or other fossil fuels and used paving, bridge construction, and other appropriate road construction, unless that use is technically inappropriate according to sound engineering principles or increase the cost of that construction."

Overview

Fly Ash

Fly ash is normally gray, brown or tan in color and consists of particles in the size range of fine sand to silt. These particles are predominantly glassy spheres with some crystalline matter, carbon and lime. Coal fly ash, like Portland cement and volcanic ash, is composed of mineral matter mainly in the form of oxide compounds derived from limestone, iron ore, silica sand and clay.

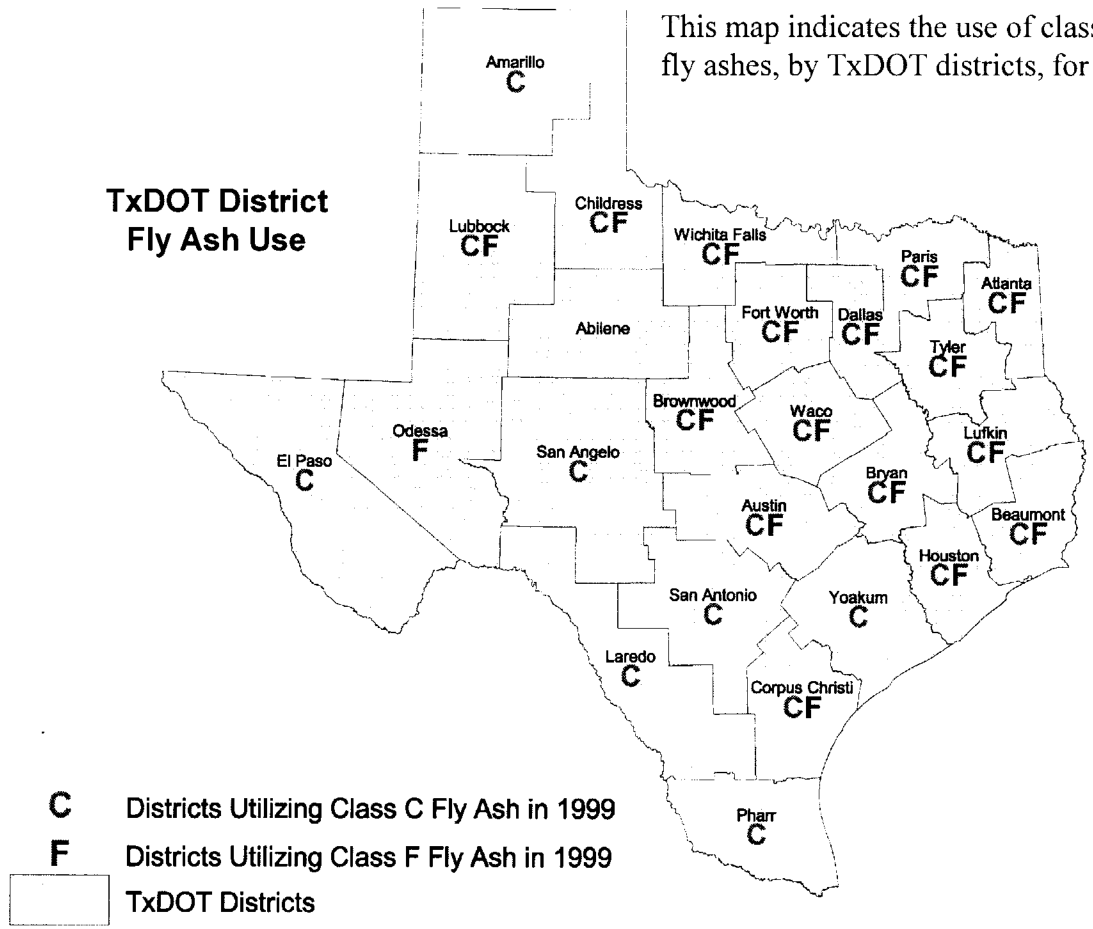
Class C and F fly ash

There is sometimes confusion about the difference between coal fly ash and ash residue from combustion of other materials. Only coal fly ash meets the standards established by American Society for Testing and Materials (ASTM) for use in concrete. ASTM Standard C 618 defines two classes of fly ash: class C and class F.

The class of fly ash depends on the type of coal from which it was derived. Class F fly ash, sometimes referred to as "low lime" ash, usually results from the burning of anthracite or bituminous coals. The lime content of class F fly ash is typically less than 10 percent. Class F fly ash does not harden until it is combined with portland cement or lime.

TxDOT is increasing its use of class F ash in hydraulic concrete to help mitigate alkali silica reactivity (ASR), which can cause severe cracking, spalling, deterioration and failure of the concrete. A new special provision to the concrete specification allows several options for the design of portland cement concrete for all mixes with six sacks of cement or more, including one that requires the use of 20 to 35 percent class F fly ash.

This map indicates the use of class C and F fly ashes, by TxDOT districts, for FY99.



Class C fly ash, usually resulting from the combustion of lignite or subbituminous coal, is often called "high lime" ash because it contains a significantly higher percentage of calcium compounds than class F fly ash (typically 20 percent or more). Class C fly ash is generally somewhat self-reactive or "cementitious" in the presence of water, in addition to being pozzolanic.

Comparison of Class F and C Fly Ashes

	Class F Fly Ash	Class C Fly Ash
Coal Type	anthracite/ bituminous	lignite/ subbituminous
Lime Content	less than 10%	20-30%
Reactant	portland cement or lime	water

Fly Ash Uses

There are a number of highway uses for fly ash including use in concrete, flowable fill, soil stabilization, and as an asphalt mineral filler.

Fly ash in concrete can:

- improve workability,
- reduce permeability,
- improve resistance to sulfates and seawater,
- enhance protection for reinforcing steel,
- increase pumpability,
- reduce segregation,
- reduce the heat of hydration, which reduces shrinkage and thermal cracking,
- lower water-to-cement ratios,
- reduce costs, and
- yield higher ultimate strengths, although initial strength gain is slower.

High performance concrete—mixes containing more than 25 percent fly ash by weight of cementitious materials—offers many benefits. It is stronger, less permeable and more durable, nearly doubling the expected life of traditional concrete.

On January 28, 1983, EPA issued a guideline for purchasing cement containing fly ash. It requires all federal, state and local government agencies and contractors that use federal funds to purchase cement and concrete to implement a preference program favoring the purchase of cement and concrete containing coal fly ash.

Fly ash can be used alone or in conjunction with lime, quicklime and Portland cement as a soil stabilizer in bases and subbases. A characteristic of fly ash modified base layers is their continued strength development because of long-term pozzolanic reactions. They also have the ability to heal or re-cement across cracks by a process referred to as "autogenous healing."

Stabilizing areas of construction sites with self-cementing fly ash can be a much faster and more economical method of dealing with soft, compressible soils, wet soils or high-plasticity clays with a tendency to shrink and swell than removing and replacing these low-quality onsite soils.

According to ASTM D5239, "Standard Practice for Characterizing Fly Ash for Use in Soil Stabilization," the use of self-cementing fly ash can result in an improvement in soil properties, including: increased stiffness, strength and freeze-thaw durability; reduced permeability, plasticity and swelling; and increased control of soil compressibility and moisture.

Flowable fill is ideal for backfill and structural fill applications. Flowable fill, or controlled low-strength material, is wet, flowable slurry that is used as an economical fill or backfill material. Flowable fill flows like a liquid, sets like a solid, is self-leveling and requires no compaction or vibration to achieve maximum density. It can take the place of concrete, compacted soils, or sand commonly used to fill around pipes and in utility trenches or other void areas.

Because it does not require compaction or vibration, flowable fill can be a cost-effective fill material. According to the American Concrete Institute, advantages of flowable fill include reduced labor and equipment requirements because it is self-leveling; versatility in terms of flowability, strength, and setting times; higher load-carrying capacity than compacted soil or granular fill; reduced excavation costs; and improved worker safety because flowable fill can be placed without workers entering the trench.

In 1999, EPA designated flowable fill containing fly ash as a recovered-content material which entities receiving federal funds must procure. This designation does not not preclude a procuring agency from purchasing other types of fill materials, such as conventional concrete or compacted soil. It simply requires that a procuring agency, when purchasing or contracting for the use of flowable fill, purchase this item containing recovered materials when it meets applicable specifications and performance requirements.

Bottom Ash Uses

Bottom ash is most commonly used in road base and structural fill. Bottom ash can also be used for de-icing, as flowable fill and as a mineral filler and aggregate in asphalt concrete.

FGD Material Uses

FGD material can be used in road base and concrete. The biggest current use is in wallboard.

Sources

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Research Summary #1

Guidelines for Using Hydrated Fly Ash as a Flexible Base

Problem

The cost of transporting granular materials for flexible bases can be a major factor in pavement construction costs. Sources of adequate construction aggregates are scarce in some areas of Texas, and pavement construction requires transporting significant amounts of aggregate to the construction site. High transportation costs create the need for alternative sources of material that are available locally.

Hydrated fly ash—a stiff material produced by allowing powdered fly ash from coal power plants to cure with moisture—may be used to make aggregate for flexible bases. Hydrated (cured) fly ash is so stiff that it can attain compressive strengths as high as 15,000 kPa. With its natural reactivity, fly ash will set in stockpiles, even in the absence of organized curing.

Fly ash is currently used as a cement replacement in Portland cement concrete, yet large quantities of fly ash are still available for use in Texas.

Objectives

The Texas Tech University Department of Civil Engineering conducted study 0-1365, "Guidelines for Using Hydrated Fly Ash as a Flexible Base," for TxDOT, the Federal Highway Administration (FHWA), and the Texas Natural Resource Conservation Commission (TNRCC). The purpose of this study was to refine the existing specifications for using hydrated fly ash as a flexible base.

Findings

Crushed hydrated fly ash forms an aggregate material. When properly processed, mixtures continue to gain strength after placement and can function satisfactorily as road bases for an extended period.

Available information on hydrated fly ash appears to indicate significant potential as a flexible-base material, easily meeting the TxDOT strength criterion for flexible-base materials.

Several TxDOT districts, including Amarillo, Childress and Atlanta, have experimented with hydrated fly ash as a flexible-base material. Special specifications have been developed so that fly ash can be used experimentally in districts where conventional flexible-base materials are in short supply.

Several problems have been identified in the Atlanta District, however. One problem is that the seal coat strips away from the hydrated fly ash flexible base, particularly in test sections where vehicles accelerate and decelerate. TxDOT sources in Atlanta have indicated that there appears to be a lack of bonding between the hydrated fly ash base and seal coat. Another problem has been the formation of a white crystalline material near areas of pavement where the surface layer is exposed to the environment.

Specifications need further development in several areas including:

- water demand,
- curing conditions,
- mechanism of bonding between the hydrated fly ash flexible base and asphalt surfaces such as seal coats and asphalt concrete, and
- the formation mechanism of crystalline products in locations where the hydrated fly ash base is exposed to moisture.

Implementation

Analyses yielded laboratory characterization of fly ash available in the Amarillo district, draft specifications and guidance on the use of hydrated fly ash material as flexible base and a cost-benefit analysis.

Based on the data and limited experience with fly ash in flexible-base construction, the following observations can be made:

1. Fly ash is extremely strong when compared to TxDOT specification triaxial classes. It meets TxDOT's unconfined compressive strength criterion for Class I base material very easily.
2. Observations indicate fly ash gets crushed during compaction and, as a result, the construction layer may not meet the master grading criteria in the TxDOT specifications. However, this appears to have had little impact on achieving maximum dry density.
3. Field observation found that fly ash undergoes further hydration after placement, forming a stiff, nearly homogeneous layer. Therefore, strict adherence to the gradation specification may not be needed.
4. Laboratory compaction tests using hydrated fly ash with two different gradations (gap-graded and well-graded) revealed that both gradations achieved nearly the same maximum dry density values, but at different moisture contents.
5. Powdered fly ash hydrated at lower moisture content provides much higher strengths, resulting in better resistance of the aggregate to degradation. Also, the fly ash should be thoroughly mixed with water during the hydration process.
6. Aggregates produced using higher hydrating moisture content have a lower unit weight and less strength.
7. Care must be taken when fly ash is cured to ensure that it attains the required level of strength before it is milled. Otherwise, the fly ash may not meet specifications for degradation and durability.
8. Care must be taken when fly ash is cured and during road construction to ensure that it is not allowed to dry excessively. If this happens, the fly ash will form undesirable compounds that may decrease the material's durability.
9. Hydrated fly ash has a high water demand. Therefore, sufficient allowance should be made for subsequent wetting during curing and construction.
10. Shrinkage cracks may appear if the fly ash has not reached an advanced stage of hydration in the curing ponds.

Available information on hydrated fly ash appears to indicate that, in regard to strength, it has great potential for use as a flexible-base material. Hydrated fly ash has the potential to perform as well as any other flexible-base material in use today. More research is needed to enhance understanding of the material, particularly with regard to its durability.

The contents of this summary are reported in detail in Texas Tech University's College of Engineering Research Report 0-1365-1F, "Guidelines for Using Hydrated Fly Ash as a Flexible Base," Phillip T. Nash, Priyantha Jayawickrama, Sanjaya Senadherra, John Borrelli, and A.S.M. Ashek Rana, Preliminary report dated August 1995. This summary does not necessarily reflect the official views of the FHWA, TNRCC or TxDOT.

To obtain a copy of this report, please contact the TxDOT Construction Division—Research Librarian at (512) 465-7644.

Research Summary #2

Evaluation of the Use of Coal Combustion Products in Highway and Airfield Pavement Construction

Problem Statement

The large quantities of coal ash produced in Texas rank it with municipal solid waste (MSW) as one of the largest by-product or waste streams at the state level. Coal combustion product (CCP) production is almost three-quarters the size of the Texas MSW stream (about 16 million Mg annually).

Objective

The objective of this study was to exploit the CCPs as low-cost alternate aggregates and stabilizers in roadway and airfield construction. A literature review and laboratory investigation investigated the use of CCPs in three highway construction applications:

- Fly ash for subgrade stabilization,
- Flue gas desulfurized (FGD) gypsum and gypsite for base and subbase construction materials, and
- Bottom ash (with sulfur modification) in asphaltic mixtures.

Findings

Use of Fly Ash for Soil Stabilization

To evaluate the effectiveness of fly ash as a stabilizer, researchers chose two very different subgrade soils commonly encountered in the Bryan District: A-3, which is a poorly graded sand, and A-7-6, which can be described as a highly plastic clay. Class C and Class F fly ashes were chosen from nearby power plants. Overall findings are as follows:

- Class C fly ash is a more effective stabilizer than Class F fly ash.
- Class F fly ash-lime blends are more effective stabilizers than Class F fly ash alone.
- Moisture requirements of lime and lime-fly ash mixes are greater than that of fly ash mixes alone.
- For the poorly graded fine sand (A-3), Class C fly ash or lime-fly ash mixes are more effective stabilizers than lime alone.
- For very highly plastic clays, PI of 60 or more, excavation and disposal may be a more cost-effective alternative than stabilization.

Conclusions related to stabilization of the poorly graded fine sand (A-3) are as follows:

- Class C fly ash or lime-fly ash blends are more effective stabilizers than lime alone.
- The maximum dry density for the A-3 soil increases with the addition of fly ash.
- The optimum moisture content for the A-3 soil decreases with the addition of lime and/or fly ash.
- The unconfined compressive strength of the A-3 soil increases with increasing Class C fly ash content.
- The unconfined compressive strength of the A-3 soil is greater with quick lime-Class F fly ash mixes than with either quick lime or Class F fly ash only.
- For the A-3 soil, a delay between mixing the stabilizer and molding has a greater influence on the unconfined compressive strength than on the maximum dry density.

Conclusions related to stabilization of the highly plastic clay (A-7-6) are as follows:

- Lime is the most effective stabilizer.
- Class F fly ash-lime blend is an effective alternative stabilizer.

- The addition of lime and/or fly ash to the A-7-6 soil makes the soil more workable but reduces the maximum dry density achieved.
- The optimum moisture content increases with the addition of lime and/or fly ash to the A-7-6 soil.
- An increase in Class C fly ash content reduces the PI and increases the strength of the A-7-6 soil. However, with increasing Class C fly ash content, the amount of swell reduction decreases.

FGD in Base and Subbase

A comprehensive literature review revealed that FGD by-product calcium sulfate (gypsum) and sulfites (gypsite) can be combined with either cement or fly ash and used as road bases or subbases. This research, along with work previously done at the Texas Transportation Institute (TTI), shows that these procedures developed for FGD materials also apply to other forms of gypsums.

Gypsum and gypsites require high-sulfate-resistant cements for stabilization that exceed the protection provided by Type II cements. This protection is achieved with tri-calcium aluminate levels of less than 4 percent.

Post-construction evaluations of the structural integrity and environmental impact of a series of TTI-constructed test sections classify stabilized FGD road bases as excellent, with negligible effect on groundwater, surface runoff and leachates.

Mix designs of FGD scrubber bases from two power generating stations indicate that, depending on the amount and type of fly ash relative to FGD material in the stockpile, sufficient stabilization could be accomplished with as low as two percent or as high as seven percent cement.

Due to the chemically active nature of some fly ashes, the age of the stockpile should be considered in the mix design. The best window of opportunity exists between a stockpile age of one to three days. Beyond this time, additional stabilizer may need to be provided.

FGD by-products would appear to offer a cost-effective alternative to natural aggregates currently in use. The fact that sources for these materials coincide with regions where conventional aggregate supplies are nonexistent or depleting represents an additional advantage.

Sulfur-modified Bottom Ash (SMBA) Asphalt Mixtures

The results of this phase of the program indicate that SMBA mixtures perform very well as both base and surface course materials. Except for ash produced from Wyoming coal, SMBA mixtures exhibit good durability. All SMBA mixtures reflect good fracture resistance and excellent resistance to rutting. The low unit weights of SMBA mixtures allow 20 to 35 percent more roadway to be built per ton of mix at approximately the same value demands of asphalt, thus offering significant cost savings.

Several test mixtures were designed to meet the requirement for TxDOT Type D mixtures while minimizing the need for conventional aggregates. The need to meet Type D specifications on gradation and air voids required at least 50 percent crushed stone in the mixtures. One mixture with a 25/75 blend of boiler slag/ bottom ash as the sole aggregate fraction performed very well in characterizations testing even though its gradation and air void content were not in accordance with Type D specifications. This suggests that SMBA mixtures should not be restricted to specifications developed for mixtures containing conventional aggregates.

There is a need to minimize field compaction of SMBA mixtures which are vulnerable to compaction during construction an subsequently under heavy traffic loads.

> The contents of this summary are reported in detail in Texas Transportation Institute Research Report 2969-1F, *Evaluation of the Use of Coal Combustion By-Products in Highway and Airfield Pavement Construction*, Donald Saylak, Cindy K. Estakhri, Rajan Viswanathan, Dustin Tauferner, and Harsha Chimakurthy, report dated November 1996.
>
> To obtain a copy of this report, please contact the TxDOT Construction Division—Research Librarian at (512) 465-7644

Case Study

Use of Coal Bottom Ash as Fine Aggregate in Asphalt Concrete

Project Overview

In 1980, TxDOT's Paris District, in cooperation with FHWA, constructed three test sections of asphaltic concrete pavement using bottom ash as one of the components. The purpose was to evaluate the characteristics of bottom ash as a potential construction material.

These sections were located on Farm-to-Market Road 1870, Interstate Highway 30 (I-30) and State Highway 11 in Hopkins County near Sulphur Springs. The test sections were chosen because of different traffic volumes and were from 300 to 800 feet in length. The aggregate used in the hot-mix asphalt consisted of 55 percent crushed gravel and 45 percent bottom ash. The mix was classified as a TxDOT Type D mix. The asphalt content ranged from 10 percent to 12 percent.

In addition, a test project was constructed as a TxDOT research project in 1985. It was a 14-mile section along I-30 in Hopkins County and included both east and westbound lanes. The pavement consisted of two inches of Type C level-up overlaid by one inch of Type D surface. Both courses contained approximately 20 percent bottom ash by weight of total mixture. The conventional aggregate in the mix included crushed sandstone, sandstone screenings and a local field sand. The asphalt content was seven percent.

The evaluations of these sections and I-30 experimental project led to the development and extensive use of bottom ash mixes in Paris District.

Encouraged by the experience gathered from various successful projects, TxDOT Paris District constructed two 1,000-foot sections using bottom ash, as shown in Figure 1. One section had bottom ash in the surface and base (Section 1), while the other had bottom ash in the surface only (Section 2). These two test sections are part of a 17-kilometer rehabilitation project on I-30 near Mt. Vernon in Franklin County that starts at milepost 142.528 and ends at milepost 153.222. The pavement section consisted of a four-inch thick Type B hot-mix asphalt concrete (HMAC) base layer and a two-inch thick Type C HMAC as the surface course. Approximately 187 tons of bottom ash were used in these two sections.

The market prices (F.O.B.) of bottom ash and field sand in the area are $1 and $.50 per ton respectively. The demand for bottom ash is low whereas the demand for field sand is moderate (Jones, 1998).

The construction work started in March 1996. The average daily traffic on this highway is 17,000. The bottom ash came from the Monticello plant and was supplied by Boral Materials Technologies, Inc. of San Antonio. The average temperature and rainfall were 85°F and 3.0 inches respectively, during the construction.

Specifications

The method used for bottom ash mixes in the project was based on “Plan Notes,” which can be found at the end of this packet.

Test Data

Bottom ash used in this project was of gray color and had fine texture. The moisture content of the ash was 20 percent at source. The unit weight was 62.0 lbs./ft^3.

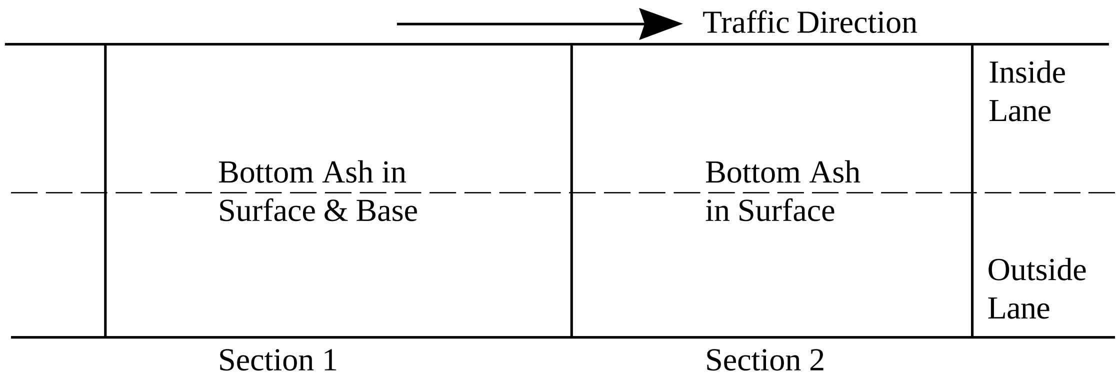


Figure 1. Bottom Ash Test Section Layout along Westbound I-30, Mt. Vernon

In ASB, 87 percent of conventional aggregate (67 percent coarse aggregate and 20 percent fine aggregate) was blended with 13 percent bottom ash. The crushed aggregate had a maximum size of 5/8 inch and a course surface texture.

In the hot-mix asphalt concrete (HMAC) surface mix, 91 percent of conventional aggregate (58 percent coarse aggregate and 33 percent fine aggregate) was blended with 9 percent bottom ash. The crushed aggregate had a maximum size of 3/8 inch and a medium surface texture. The bulk specific gravity was 2.5.

The gradation (cumulative passing) of bottom ash used in the stabilized base and surface course, combined gradation (cumulative passing) of aggregates used in asphalt stabilized base and surface and TxDOT specification requirements are shown in Table 1 on the next page.

The optimum asphalt content for this Type B HMAC base and Type C Surface Course were 6.6 percent and 6.3, respectively. The grade of the asphalt was AC-20. Permatac one percent has been used as the anti-stripping agent. The properties of mix at optimum asphalt content are presented in Table 2 on the next page.

Table 1. Aggregate Gradation

Sieve Size	Bottom Ash Gradation in Type B HMAC Base	Bottom Ash Gradation in Type C HMAC Surface	Type B Asphalt Stablized Base		Type C HMAC Surface Course	
			Combined Mix Gradation	TxDOT Spec.	Combined Mix Gradation	TxDOT Spec.
1"	100.0	100.0	100.0	100-100	100.0	100-100
7/8"	100.0	100.0	100.0	95-100	100.0	100-100
5/8"	100.0	100.0	87.2	75-95	99.6	95-100
3/8"	99.0	98.5	74.6	60-80	77.2	70-85
#4	92.1	92.7	53.0	40-60	54.6	43-63
#10	79.7	80.5	30.0	27-40	34.0	30-40
#40	53.4	58.1	17.8	10-25	19.4	10-25
#80	34.1	36.2	11.8	3-13	12.5	3-13
#200	12.9	11.6	4.6	2-8	5.2	1-6

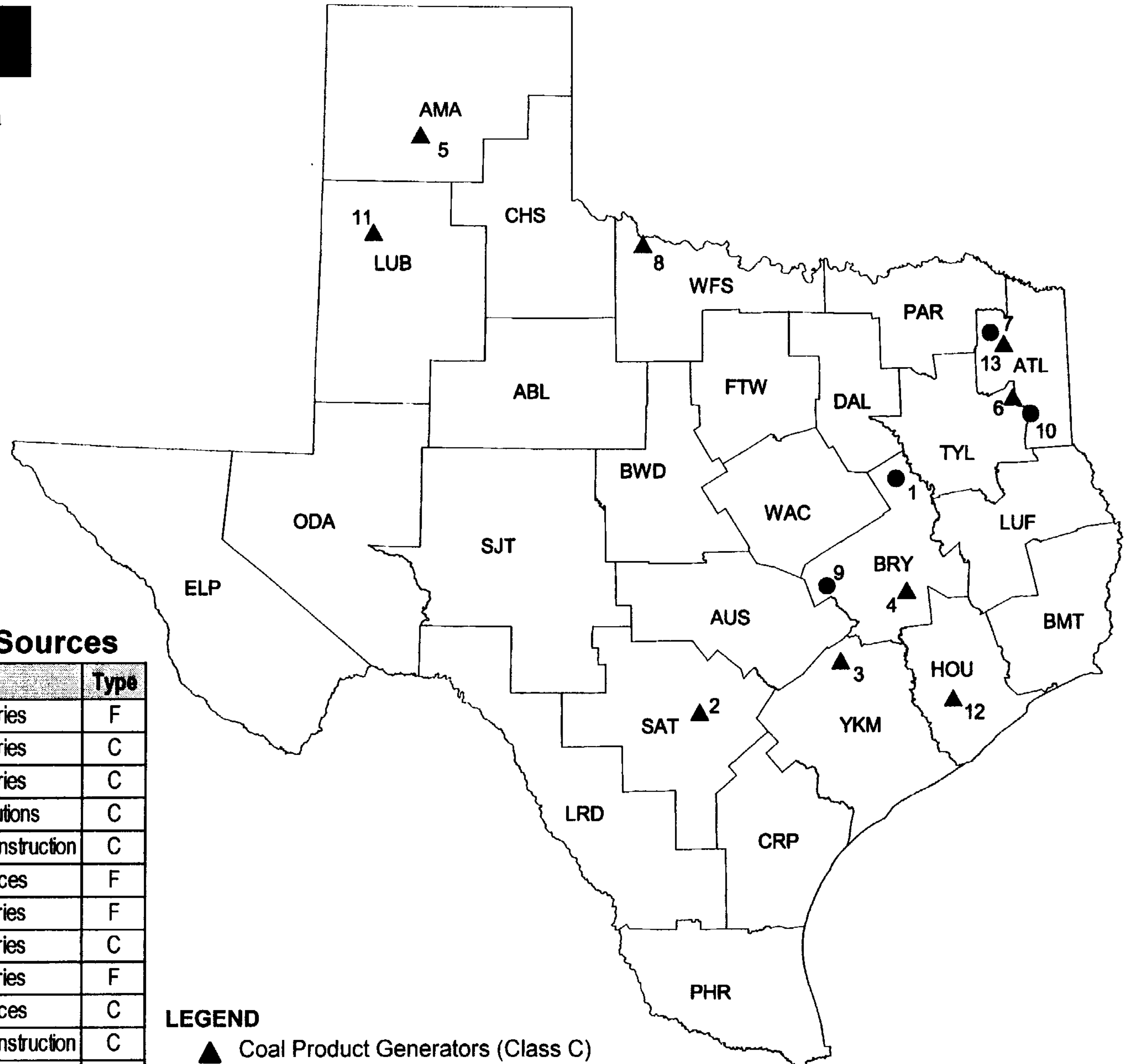
Table 2. Mix Properties of Type B Asphalt Stabilized Base & Type C Surface Course

Mix Properties	Type B Asphalt Stabilized Base		Type C Surface Course	
	Measured Value	TxDOT Spec. Requirements	Measured Value	TxDOT Spec. Requirements
Asphalt Content (%)	6.6		6.3	
Effective Specific Gravity	2.5		2.5	
VMA (%)	18.0	13 (Min.)	18.0	14 (Min.)
Air Void (%)	4.0		4.0	
Hveem Stability (%)	51.0	35* (Min.)	48.4	35*

* or as shown on plans

Material Availability

This map and table provide information about companies that market coal combustion products.



LEGEND

- ▲ Coal Product Generators (Class C)
- ● Coal Product Generators (Class F)
- TxDOT Districts

TxDOT Approved Fly Ash Sources

Label	Plant	Location	Supplier	Type
1	Big Brown	Fairfield	Boral Industries	F
2	Deely	San Antonio	Boral Industries	C
3	Fayette	La Grange	Boral Industries	C
4	Gibbons Creek	Carlos	Mineral Solutions	C
5	Harrington	Amarillo	DePauw Construction	C
6	Martin Lake	Tatum	ISG Resources	F
7	Monitcello	Mt. Pleasant	Boral Industries	F
8	Oklaunion	Oklaunion	Boral Industries	C
9	Sandow	Rockdale	Boral Industries	F
10	Texas Eastman	Longview	ISG Resources	C
11	Tolk Station	Earth	DePauw Construction	C
12	W.A. Parish	Thompsons	ISG Resources	C
13	Welsh	Cason	Hanson	C

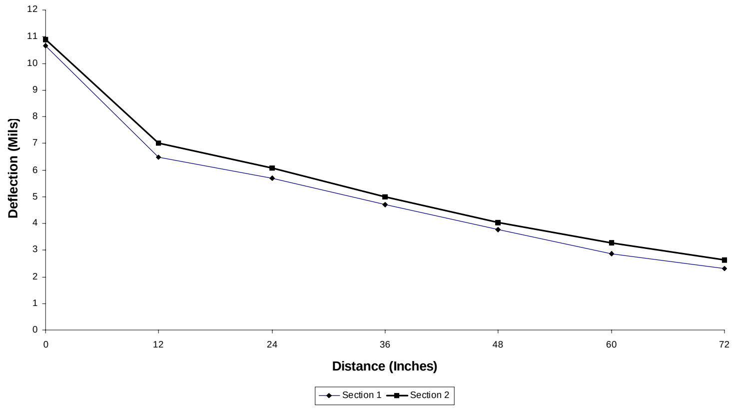


Figure 4. Comparison of FWD Test Results (15,500 lbs) for Section 1 and Section 2 in Outside Lane, 1999

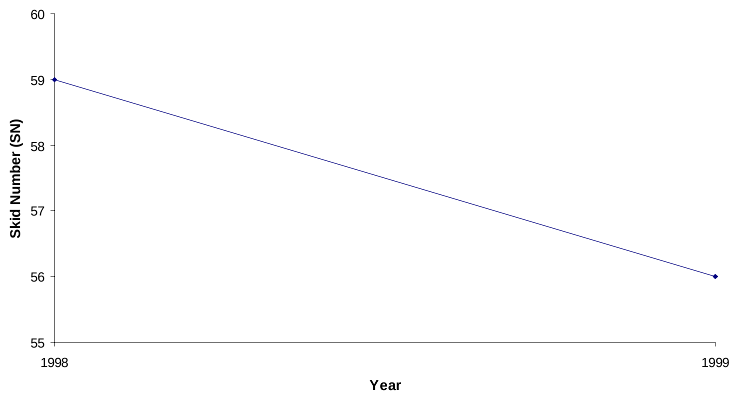


Figure 5. Skid Number in Outside Lane

Results

Texas Tech University researchers, with help from TxDOT, conducted some field tests in these bottom ash sections in August 1998 and June 1999. The tests included a visual survey, skid resistance tests, falling weight deflectometer (FWD) tests and rutbar/profiler tests. Figures 2-5 show FWD and skid test results.

Visual distress surveys did not reveal any major distresses (rutting and cracking) in either of these two sections. FWD tests indicated no significant difference in structural integrity between the two lanes in the same section and between sections in the same lane. However, the deflection values in 1998 are slightly higher than those values in 1999, possibly due to the different climatic and pavement conditions under which tests were performed. After 1,750,000-traffic application, the skid number shows the value of 56 (Figure 5), which is well above the skid number required by TxDOT. At this rate, after 6 years, the skid number will be 34.

Table 3. International Roughness Index (IRI) and Ride Score Information

Test Section Location	IRI		Ride Score
	Left	Right	
Section 1 (outside lane)	0.79	0.69	4.8
Section 1 (inside lane)	1.02	0.69	4.7
Section 2 (outside lane)	0.70	0.61	4.8
Section 2 (inside lane)	0.76	0.67	4.8

Table 3 presents roughness measurements taken using the TxDOT rutbar/profiler. Results indicate a smooth pavement surface for ride scores between 4.0 and 5.0 as per TxDOT PMIS classification (TxDOT, 1994).

The experience gathered from the construction and performance of these test sections led to the following conclusions about using bottom ash in mix.

- Bottom ash mixes require more asphalt cement than conventional mixes.
- Bottom ash mixes produce lower compacted density than natural aggregate mixes.
- Bottom ash mixes promote good microtextured skid properties.
- Bottom ash mixes resist rutting, cracking and stripping.
- Bottom ash mix is higher in cost because of additional asphalt used.
- Bottom ash mixes produce high quality and economical pavements compared to local field sand mixes.
- Bottom ash mixes meet standard specifications and design methods.
- Bottom ash may be substituted for field sands, stone screenings or both .

Contact Persons

Name	Organization	Contact Numbers
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TxDOT Experience

This table provides information about TxDOT's experience using coal bottom ash and coal fly ash in various roadway applications.

District Name	Construction Application	Material	Results	Years Experience	Specification	Location
Abilene	Paving Materials-Base/Subbase	Coal Fly Ash	Unknown	1993	265	Borden, Kent & Howard Co.
Amarillo	Embankments & Backfill	Coal Bottom Ash	Excellent	1993	1147	US 60 & 15th Street
Amarillo	Embankments & Backfill	Coal Fly Ash	Good	1987		Randall
Amarillo	Paving Materials- Asphaltic Concrete	Coal Fly Ash	Good		N/A	Potter - IH40
Amarillo	Paving Materials- Portland Cement Concrete (PCC)	Coal Fly Ash	Excellent	1987		Randall - IH 27
Amarillo	Paving Materials-Base/Subbase	Coal Fly Ash	Good	1996	2017, 247, 251	Oldham, Potter - FM 809, IH 40
Amarillo	Paving Materials-Base/Subbase	Coal Fly Ash	Excellent	1977	2017, 247, 251	Sherman - US 54
Atlanta	Embankments & Backfill	Coal Fly Ash	Good - Poor	1985	Standard	District wide
Atlanta	Paving Materials- Asphaltic Concrete	Coal Bottom Ash	Unknown	1996	Maint. Req.	Harrison (US 80 east of Wasrom)
Atlanta	Paving Materials- Portland Cement Concrete (PCC)	Coal Fly Ash	Poor	1982	Standard	District wide
Atlanta	Paving Materials-Base/Subbase	Coal Fly Ash	Poor	1985	Standard	District wide
Austin	Paving Materials- Portland Cement Concrete (PCC)	Coal Fly Ash		1982	No	District wide
Beaumont	Paving Materials- Portland Cement Concrete (PCC)	Coal Fly Ash	Good	1990	360	Hardin, Jefferson
Beaumont	Paving Materials- Portland Cement Concrete (PCC)	Coal Fly Ash	Good	1988	360, 420, 421	Liberty, Chambers

District Name	Construction Application	Material	Results	Years Experience	Specification	Location
Brownwood	Paving Materials-Portland Cement Concrete (PCC)	Coal Fly Ash	Good	1991	HCM 430	SH 36 - Comanche
Bryan	Paving Materials-Portland Cement Concrete (PCC)	Coal Fly Ash	Excellent	1987	Item 421	Various
Bryan	Paving Materials-Base/Subbase	Coal Bottom Ash	Good	1996	Special OTU on FM 1512	Leon
Childress	Embankments & Backfill	Coal Fly Ash	Good	1989	265	Wheeler (SH 222), Donley (US 287)
Childress	Paving Materials-Portland Cement Concrete (PCC)	Coal Fly Ash	Good	1989	266	US 287 in Childress, Hall, & Donley Co.
El Paso	Paving Materials-Asphaltic Concrete	Coal Bottom Ash		1996	340	El Paso
El Paso	Paving Materials-Portland Cement Concrete (PCC)	Coal Fly Ash		1992	360, 421	El Paso
Fort Worth	Paving Materials-Portland Cement Concrete (PCC)	Coal Fly Ash	Good	1987	421	Fort Worth District
Houston	Paving Materials-Portland Cement Concrete (PCC)	Coal Fly Ash	Good	1987	Item 360, Item 421	District wide
Lubbock	Embankments & Backfill	Coal Fly Ash	Excellent	1987	Item 2074, 2012, 2003	Castro, Lamb, Cochran, & Bailey Co.
Lubbock	Embankments & Backfill	Coal Fly Ash	Excellent	1993	Item 2012	District wide
Lubbock	Paving Materials-Asphaltic Concrete	Coal Fly Ash	Unknown	1995	Item 2025	Garza, Lynn
Lubbock	Paving Materials-Base/Subbase	Coal Fly Ash	Excellent	1995	Item 2012	Floyd, Hale Co.

District Name	Construction Application	Material	Results	Years Experience	Specification	Location
Lubbock	Paving Materials-Base/Subbase	Coal Fly Ash	Poor	1996	Item 2020	Hale, Castro Co.
Lubbock	Paving Materials-Base/Subbase	Coal Fly Ash	Good	1996	Item 2018	FM 37-Lamb Co.
Lubbock	Paving Materials-Base/Subbase	Coal Fly Ash	Good	1996	Item 2014	Cochran Co.- (FM 301, 1894, 1779, 595)
Lubbock	Paving Materials-Base/Subbase	Coal Fly Ash	Unknown	1995	Item 2025	Garza
Lubbock	Paving Materials-Base/Subbase	Coal Fly Ash	Good	1995	Item 2005-000	Yoakum Co.
Lubbock	Paving Materials-Base/Subbase	Coal Fly Ash	Good			
Lufkin	Paving Materials - Portland Cement Concrete (PCC)	Coal Fly Ash	Poor	1995		District wide
Paris	Paving Materials- Asphaltic Concrete	Coal Bottom Ash	Excellent	1987	Item 340 & QC/QA	District wide
San Antonio	Paving Materials-Base/Subbase	Coal Bottom Ash	Excellent	1996	None	Wilson
Tyler	Paving Materials - Portland Cement Concrete (PCC)	Coal Fly Ash	Good	1987	421	Everywhere
Tyler	Paving Materials-Base/Subbase	Coal Fly Ash	Good		Special Specs.	FM 344, FM 3226, US 287
Wichita Falls	Paving Materials - Portland Cement Concrete (PCC)	Coal Fly Ash		1987	TxDOT Standard Spec.	Entire District
Wichita Falls	Paving Materials-Base/Subbase	Coal Fly Ash		1996		Clay, Archer
Yoakum	Paving Materials - Portland Cement Concrete (PCC)	Coal Fly Ash	Good	1989	Item 421 D-9-8900	District wide

- Special Provision to Item 421, Portland Cement Concrete
- Special Specification, Item 2028, Lime-Fly Ash (LFA) or Fly Ash (FA) Treatment for Materials in Place
- Special Specification, Item 4156, Flowable Backfill
- Draft Specification, Hydrated Fly Ash as a Base Course Material
- Plan Notes for Bottom Ash in Asphalt Stabilized Base (ASB) and Hot Mix Asphalt

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), silica fume 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, GGBF Slag and Silica Fume.

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

b. GGBF slag shall conform to the requirements of ASTM C 989, “Standard Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars,” 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 Materials Section of the Construction Division and upon approval of production and storage facilities by the Director of the Materials Section. Continued acceptance of GGBF slag from a 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 the Materials Section has determined that adequate quality control has been re-established. GGBF slag from nonqualified sources will require sampling and testing prior to use.

c. Silica fume shall conform to the requirements of ASTM C 1240, "Standard Specification for Silica Fume for Use as a Mineral Admixture in Hydraulic-Cement Concrete, Mortar, and Grout," and shall contain no more than 1.50 percent available alkalies as Na2O equivalent.

Article 421.2. Materials, Subarticle (3) Mixing Water is voided and replaced by the following:

(3) Mixing Water. The mixing and curing water shall be free from oils, acids, organic matter or other deleterious substances. Water from municipal supplies approved by the State Health Department will not require testing.

Total water content, that is a blend of wash water and other water sources, that is certified by the concrete producer as complying with the requirements of both "Acceptance Criteria for Questionable Water Supplies" and "Chemical Limits for Mix Water" as specified herein, may
be used as mix water. When wash water is used, the total mix water shall be tested by the concrete producer at a weekly interval for four

(4) weeks, and thereafter at a monthly interval provided no single test exceeds the applicable limits specified herein. If the specified limits are exceeded, the water shall not be used as mix water until such time the concrete producer can control the mix water within the limits specified to the satisfaction of the Engineer. Upon request, test results shall also be provided to the Engineer.

Acceptance Criteria for Questionable Water Supplies

	Limits	Test Method
Compressive strength, min %, control at 7 days	90	C 109*
Time of set, deviation from control, h:min	from 1:00 early to 1:30 later	C 191*

*Comparison shall be based on fixed proportions and the same volume of test water compared to control mix using city water or distilled water.

Chemical Limits for Mix Water

	Limits	Test Method*
Chemical requirements maximum concentration in mixing water, ppm		
Chloride as C1,:		D 512
Prestressed concrete	500	
Bridge Decks, Superstructure and substructure	500	
All other concrete	1000	
Sulfate as SO4	1000	D 516
Alkalies as (Na2O+0.658 K2O)	600	
Total solids	50,000	AASHTO T26

The wash water shall be metered when added to the mix and a uniform amount shall be added in consecutive batches. When used, wash water shall have no adverse effect on the air-entraining agent or on any other chemical admixture used and it shall have no adverse effect on strength or time of set of the concrete.

Wash water shall not be used when potentially reactive aggregates are used in the mix.

Water used in white portland cement concrete shall be free from iron and other impurities which may cause staining or discoloration.

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 seperately 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 with the following:

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

Type III cement may be used in all precast concrete or when shown on the plans, specified in the Item, or as directed by the Engineer.

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 Type IP cement shall be uniform blend of Portland cement and Class F fly ash produced by intergrinding Portland cement clinker and Class F fly ash, in which the fly ash constituent is between 20 and 35 percent by absolute volume of the Type IP cement.

Only GGBF slag and/or Class F fly ash may be substituted for a portion of the cement when Type II cement is specified.

When Class C fly ash is used, it shall replace a minimum of 20 to 35 percent of the cement by absolute volume.

A maximum of 10 percent silica fume, by absolute volume, may be used in the mix.

No fly ash or GGBF slag will be permitted when a white Portland cement is required, unless otherwise approved by the Engineer and proven by the Contractor to have no adverse effect on the desired color of the concrete.

In addition to the above the Contractor shall use one of the following options when designing the concrete mix for concrete Classes C, E, F, H, S, DC, CO, SS, and K:

Option 1. When using cement only, the total alkali contribution from the cement in the concrete shall not exceed 4.00 pounds per cubic yard of concrete when calculated as follows:

lb. alkali per cu.yd. = (lb. cement per cu.yd.) x (% Na_2O equivalent in cement)/100

The cement alkali content to be used in the above calculation shall be the actual cement alkali content as reported on the cement mill certificate.

Option 2. 20 to 35 percent of the cement shall be replaced, by absolute volume, with Class F fly ash meeting the requirements of Departmental Material Specification DMS - 8900, "Fly Ash."

Option 3. 35 to 50 percent of the cement shall be replaced, by absolute volume, with GGBF slag.

Option 4. 35 to 50 percent of the cement, by absolute volume, may be replaced with a combination of Class F fly ash, GGBF slag, or silica fume. However, no more than 35 percent may be fly ash nor more than 10 percent may be silica fume.

Option 5. Type IP or IS cement shall be used. Up to 10 percent of a Type IP or IS, by absolute volume, may be replaced with Class F fly ash, GGBF slag, or silica fume.

Option 6. The Contractor shall also have the option of deviating from the above listed options by (a) using Class C fly ash in lieu of Class F fly ash, except when Type II cement is specified, (b) substituting a lesser percentage of fly ash and/or GGBF slag for the cement or (c) using a cement-only mix with a total alkali contribution greater than 4.00 pounds per cubic yard as calculated in Option 1. However, the Contractor shall demonstrate that such mix, using job materials in the proportions intended on the job, does not exhibit an expansion greater than 0.10 percent at 14 days when tested in accordance with ASTM C 1260, "Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)."

The test shall be performed by using 440 grams of the proposed blended cementitious material, in the proportion to be used on the job, and 990 grams of the combined aggregates, in the proportions to be used on the job. Mix the blended cement combination with the job aggregates and test in accordance with ASTM C 1260. Any changes in source of materials, including aggregates, cement, fly ash, GGBF slag, silica fume, or changes in cement Type will require another test.

In lieu of ASTM C 1260, the Contractor may evaluate the cementitious materials for Options 6(a) and 6(b), in the proportions to be used on the project, by performing ASTM C 441, "Standard Test Method for Effectiveness of Mineral Admixtures or Ground Blast-Furnace Slag in Preventing Excessive Expansion of Concrete Due to the Alkali-Silica Reaction." The cementitious material shall exhibit an expansion of no more than 0.020 percent at 14 days or 0.10 percent at 56 days, when tested in accordance with ASTM C 441, using the crushed Pyrex glass specified in the procedure. Any changes in source of cementitious materials, including cement, fly ash, GGBF slag, silica fume, or changes in cement Type or changes in mitigating admixtures will require another test.

ASR mitigating admixtures, such as lithium nitrate, may be used in the mix, provided it is included in the effectiveness test, in the proportions proposed for use on the job.

These tests shall be the responsibility of the Contractor and shall be performed by a qualified independent laboratory. The report shall be sealed by a Registered Professional Engineer and furnished to the project Engineer for review. The test shall be performed at the Contractor's expense.

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 sixth paragraph is voided and replaced by the following:

Slump tests will be performed in accordance with Test Method Tex-415-A.

Entrained air tests will be performed in accordance with Test Method Tex-414-A or Tex-416-A.

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:

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)

SPECIAL SPECIFICATION

ITEM 2028

LIME-FLY ASH (LFA) OR FLY ASH (FA) TREATMENT FOR MATERIALS IN PLACE

1. Description. This Item shall govern for treating the subgrade, existing subbase or existing base by pulverizing, adding lime and/or fly ash, mixing and compacting the mixed material to the required density. This Item applies to natural ground, embankment, or existing pavement structure and shall be constructed as specified herein and in conformity with the typical sections, lines and grades as shown on the plans or as established by the Engineer.

2. Materials.

   (1) Lime. Lime shall meet the requirements of Item 264, “Lime and Lime Slurry”, for the type of lime specified. All lime shall be applied in slurry form under “Slurry Placing” unless “Dry Placing” is allowed for Type A Hydrated Lime or Type C Quicklime by means of a specific note on the plans or by the approval of the Engineer, when subgrade conditions warrant dry placement.

   The Contractor shall select, from the types shown on the plans, prior to construction, the type to be used and shall notify the Engineer in writing before changing from one type to another.

   All lime slurries used in “Slurry Placing” shall be furnished at or above the minimum “Dry Solids Content” as prescribed by the Engineer.

   The percent of lime to be added will be as shown on the plans.
   This percent may be varied by the Engineer if conditions warrant.

   (2) Fly Ash. Fly ash shall meet the requirements of Departmental Material Specification DMS-8900.

   (3) Water. Water shall meet the material requirements of Item 204, “Sprinkling”.

   (4) Asphalt. Asphalt shall conform to the requirements of Item 300, “Asphalts, Oils and Emulsions”.

   (5) Mix Design. If the minimum design strength or percent of lime-fly ash or fly ash to be used for the treated subgrade, existing subbase or existing base is specified, it will be determined by preliminary tests performed in accordance with Test Method Tex-127-E.

3. Equipment.

(1) General. The machinery, tools and equipment necessary for proper prosecution of the work shall be on the project and approved by the Engineer prior to the beginning of construction operations for this Item. All machinery, tools and equipment used shall be maintained in a satisfactory working condition.

(2) Material Storage. Hydrated lime in dry form, quicklime and fly ash shall be suitably stored and handled in closed, weatherproof containers until immediately before distribution on the road.

If storage bins are used, they shall be completely enclosed. Materials in bags shall be stored in weatherproof buildings with adequate protection from ground dampness. If Type C Quicklime is permitted, it shall be shipped only in bulk; bagged material will not be acceptable.

(3) Material Weight Verification. When lime and/or fly ash is furnished in trucks, each truck shall have the weight of lime and fly ash certified on public scales or the Contractor shall place a set of standard platform truck scales or hopper scales at a location approved by the Engineer.

Scales shall conform to the requirements of Item 520, “Weighing and Measuring Equipment”.

When dry hydrated lime and/or fly ash is furnished in bags, each bag shall bear the manufacturer’s certified weight. Bags varying more than five (5) percent from that weight may be rejected and the average weight of bags in any shipment, as shown by weighing 10 bags taken at random, shall not be less than the manufacturer’s certified weight.

(4) Slurry Equipment. Type C Quicklime of Grade “DS” or “S” when used to manufacture slurry for slurry placing shall be slurried on the project in one or more agitated slurry tanks. The slurrying of Type C Quicklime must be handled in such a way as to not generate any dust hazardous to job personnel or to the public or be potentially damaging to any adjacent property.

The distributor truck used for slurry placing need not necessarily be equipped with an agitator; however, the slurry at the time of distribution must meet the consistency requirements specified. The Contractor shall, if necessary, use appropriate equipment to achieve compliance with the consistency requirements so the slurry can be handled and uniformly applied without difficulty.

4. Construction Methods.

(1) General. It is the primary requirement of this specification to secure a completed course of treated material containing a uniform lime-fly ash or fly ash mixture free from loose or segregated areas, of uniform density and moisture content, well bound for its full depth and with a smooth surface suitable for placing subsequent courses. It shall be the responsibility of the Contractor to regulate the sequence of his work, to process a sufficient quantity of material to provide full depth as shown on plans, to use the proper amounts of lime and/or fly ash, maintain the work and rework the courses as necessary to meet the above requirements.

CAUTION: Use of quicklime can be dangerous. Users should be informed of the recommended precautions in handling, storage and use of quicklime.

(2) Preparation of Roadbed. Before other operations are begun, the roadbed shall be graded and shaped as required to construct the lime-fly ash or fly ash treatment for materials in place in conformance with the lines, grades, thickness and typical cross section shown on the plans. Unsuitable soil or material shall be removed and replaced with acceptable material.

Before pulverizing or scarifying an existing material, when shown on the plans and when directed by the Engineer, the Contractor shall proof roll the roadbed in accordance with Item 216, "Rolling (Proof)". Soft spots shall be corrected as directed by the Engineer.

If the Contractor elects to use a cutting and pulverizing machine that will remove the subgrade material accurately to the secondary grade and pulverize the material at the same time, he will not be required to expose the secondary grade nor windrow the material. However, the Contractor shall be required to roll the subgrade, as directed by the Engineer, before using the pulverizing machine and correct any soft areas that this rolling may reveal. This method will be permitted only where a machine is provided which will insure that the material is cut uniformly to the proper depth and which has cutters that will plane the secondary grade to a smooth surface over the entire width of the cut. The machine shall be of such design that a visible indication is given at all times that the machine is cutting to the proper depth.

(3) Application. Lime shall be spread only on that area where the first mixing operation can be completed during the same working day.

The sequence for application of lime and fly ash shall be as specified below in Section 4.(4)(b).

The application and mixing of lime or fly ash with the material shall be accomplished by the methods hereinafter described as “Dry Placing” or “Slurry Placing”.

When a Type A Hydrated Lime or Type C Quicklime is used, the “Slurry Placing” method shall be used unless “Dry Placing” is allowed by means of a specific note on the plans or by the approval of the Engineer, when subgrade conditions warrant dry placement. Should Type C Quicklime be used for “Dry placing”, it must be Grade “DS”. Type C Quicklime for slurry placement may be either Grade “DS” or Grade “S”. Grade “S” is for use in slurry placement only.

(a) Dry Placing. The lime or fly ash shall be spread by an approved spreader or by bag distribution at the rates shown on the plans or as directed by the Engineer.

The lime or fly ash shall be distributed at a uniform rate and in such a manner as to reduce the scattering of lime or fly ash by wind to a minimum. Lime or fly ash shall not be applied when wind conditions, in the opinion of the Engineer, are such that blowing lime or fly ash becomes objectional to adjacent property owners or dangerous to traffic.

A motor grader shall not be used to spread Type A Hydrated Lime or fly ash, but may be used to spread Type C Quicklime of Grade “DS” only.

The material shall be sprinkled as directed by the Engineer, until the proper moisture content has been secured. However, initial mixing after the addition of lime or fly ash will be accomplished dry or with a minimum of water to prevent lime and/or fly ash balls.

(b) Slurry Placing. Where Type A Hydrated Lime is specified and slurry placement is to be used, the Type A hydrate shall be mixed with water to form a slurry of the solids content designated by the Engineer.

Where Type B Commercial Lime Slurry is to be used, it shall be delivered to the project in slurry form at or above the minimum dry solids content designated by the Engineer. The distribution of lime at the rates shown on the plans or as directed by the Engineer shall be attained by successive passes over a measured section of roadway until the proper moisture and lime content have been secured.

When Type C Quicklime is slurried, the slurry shall contain at least the minimum dry solids content designated by the Engineer. The residue from the slurrying procedure shall be spread reasonably uniformly over the length of the roadway currently being processed unless otherwise directed by the

Engineer. This residue is primarily inert material with little stabilizing value, but may contain a small amount of quicklime particles that slake slowly. A concentration of these particles could cause the compacted stabilized material to swell during slaking.

These lime slurries (Type A, B or C), must be of a uniform consistency that can be handled and uniformly applied without difficulty.

Just prior to discharge from the distributor, the lime and water shall be sufficiently agitated or mixed as to place the lime in suspension and to obtain a uniform mixture.

If the distributor truck is not equipped with an agitator, the Contractor will be required to have a stand-by pump available on the project for agitating the lime and water in case of undue delays in dispersing the slurry.

Lime should be added first. Fly ash shall be placed in the dry form only.

(4) Mixing. The mixing procedure shall be the same for "Dry Placing" or "Slurry Placing" as hereinafter described.

(a) First Mixing. The material and lime shall be thoroughly mixed by approved road mixers or other approved equipment, and the mixing continued until, in the opinion of the Engineer, a homogeneous, friable mixture of material and lime is obtained, free from all clods or lumps. Materials containing plastic clays or other material which will not readily mix with lime shall be mixed as thoroughly as possible at the time of the lime application, brought to the proper moisture content and left to cure one (1) to four (4) days as directed by the Engineer. During the curing period the material shall be kept moist as directed by the Engineer.

(b) Final Mixing. After the required curing time, the material shall be uniformly mixed by approved methods. If the material-lime mixture contains clods, they shall be reduced in size by raking, blading, disking, harrowing, scarifying or the use of other approved pulverization methods so that when all nonslaking aggregates retained on the No. 4 sieve (for subgrade materials) and on the 3/4 inch sieve (for subbase or base materials) are removed, the remainder of the material shall meet the following requirements when tested by Test Method Tex-101-E, Part III:

Subgrade Materials:
Minimum passing 1-3/4" sieve 100 Percent
Minimum passing No. 4 sieve 60 Percent

Subbase or Base Materials:
Minimum passing 1-3/4" sieve 100 percent
Minimum passing 3/4" sieve 85 percent

Fly ash application is started immediately after the lime modified material has passed the above grading requirement. The time between lime application and fly ash application shall not exceed four (4) calendar days. Fly ash shall be applied only to such a limed area that all the operations can be continuous and completed in daylight within six (6) hours after fly ash has been added.

If the material to be stabilized with lime-fly ash meets the above gradation in its natural state, the Engineer may elect to apply the fly ash first followed with the lime application. In any event, it is the intent of this specification to mix and compact the materials within six (6) hours after the fly ash has been added.

During the interval of time between application and mixing, hydrated lime or fly ash that has been exposed to the open air for a period of six (6) hours or more or to excessive loss due to washing or blowing will not be accepted for payment.

(c) Mixing Procedure for Fly Ash Only. If fly ash only is to be used without lime, the following procedures shall apply.

(i) Pulverization. The raw material shall be thoroughly pulverized by approved road mixers or other approved equipment so that when all nonslaking aggregates retained on the No. 4 sieve (for subgrade materials) and on the 3/4 inch sieve (for subbase or base materials) are removed, the remainder of the material shall meet the following requirements when tested by Test Method Tex-101-E, Part III:

Subgrade Materials:
Minimum passing 1-3/4" sieve 100 percent
Minimum passing No. 4 sieve 60 percent

Subbase or Base Materials:
Minimum passing 1-3/4" sieve 100 percent
Minimum passing 3/4" sieve 85 percent

(ii) Application. The fly ash shall be distributed at a uniform rate and in such manner as to reduce the scattering of fly ash by wind to a minimum. Fly ash shall not be applied when wind conditions, in the opinion of the Engineer, are such that blowing fly ash becomes objectionable to adjacent property owners or dangerous to traffic. A motor grader shall not be used to spread fly ash.

(iii) Mixing. The material and fly ash shall be thoroughly mixed by approved road mixers or other approved equipment, and the mixing continued until, in the opinion of the Engineer, a homogeneous, friable mixture of material is obtained.

Fly ash shall be applied only to such an area that all the operations can be continuous and completed in daylight within six (6) hours after fly ash has been added.

During the interval of time between application and mixing, fly ash that has been exposed to the open air for a period of six (6) hours or more or to excessive loss due to washing or blowing will not be accepted for payment.

Mixing after the addition of fly ash will be accomplished dry or with a minimum of water to prevent fly ash balls.

(d) Mixing Procedure Only for Type C Quicklime, Grade "DS". When Type C Quicklime, Grade "DS", is used, the material and lime shall be mixed as thoroughly as possible at the time of the lime application. Sufficient moisture is to be added during the mixing to hydrate the quicklime plus that moisture needed for compaction. After mixing, and prior to compaction, the mixture of the material, quicklime and water is to be left to cure for two (2) to seven (7) days, as directed by the Engineer. During the curing period, the material shall be kept moist as directed by the Engineer. After the two (2) to seven (7) day curing period, final mixing shall be done as stated above, or as directed by the Engineer.

(5) Compaction. Compaction of the mixture shall begin immediately after adding and uniformly mixing of the last stabilizing agent. Compaction shall be completed within six (6) hours after fly ash has been added. When Type C Quicklime, Grade "DS", is used, after the above gradation requirement has been met, compaction shall begin after the two-to-seven-day curing period, as directed by the Engineer. The material shall be aerated or sprinkled as necessary to provide the optimum moisture. Compaction shall begin at the bottom and shall continue until the entire depth of mixture is uniformly compacted by the method of compaction hereinafter specified as the "Ordinary Compaction" method or the "Density Control" method as indicated on the plans.

When the "Ordinary Compaction" method is indicated on the plans the following provisions shall apply:

The material shall be sprinkled and rolled as directed by the Engineer. All irregularities, depressions or weak spots which develop shall be corrected immediately by scarifying the areas affected, adding or removing material as required and reshaping and recompacting by sprinkling and rolling. The surface of the course shall be maintained in a smooth condition, free from undulations and ruts, until other material is placed thereon or the work is accepted.

When the "Density Control" method of compaction is indicated on the plans the following provisions shall apply:

Description	Density, Percent
For lime-fly ash or fly ash treated subgrade, existing subbase or existing base that will receive subsequent subbase or base courses	Not less than 95 except when otherwise shown on the plans
For lime-fly ash or fly ash treated existing subbase or existing base that will receive surface courses	Not less than 96 except when otherwise shown on the plans

The laboratory testing will be as outlined in Test Method Tex-127-E or other approved methods. Roadway density testing will be as outlined in Test Method Tex-115-E or other approved methods. In addition to the requirements specified for density, the full depth of the material shown on the plans shall be compacted to the extent necessary to remain firm and stable under construction equipment. After each section is completed, tests as necessary will be made by the Engineer. If the material fails to meet the density requirements, the Engineer may require it to be reworked as necessary to meet these requirements or require the Contractor to change his construction methods to obtain required density on the next section.

Throughout this entire operation the shape of the course shall be maintained by blading, and the surface upon completion shall be smooth and in conformity with the typical section shown on the plans and to the established lines and grades. Should the material due to any reason or cause, lose the required stability, density and finish before the next course is placed or the work is accepted, it shall be reworked at the sole expense of the Contractor in accordance with Subarticle 4.(6).

Density Tolerances: The limits establishing reasonably close conformity with the percent density specified are defined by the following:

The Engineer may accept work providing not more than 25% of the density tests performed each day are outside the specified density by no more than three (3) pounds per cubic foot and where no two consecutive tests on continuous work are outside the specified limit.

(6) Reworking a Section. When a section is reworked within 72 hours after placement, the Contractor shall rework the section to provide the required compaction. When a section is reworked more than 72 hours after placement, the Contractor shall add 25 percent of the specified rate of lime-fly ash or fly ash. Reworking shall include loosening, road mixing as approved by the Engineer, compacting and finishing. Then a section is reworked, a new optimum density will be determined from the reworked material in accordance with Test Method Tex-121-E, Part II using lime-fly ash or fly ash.

(7) Finishing, Curing and Preparation for Surfacing. After the final layer or course of the lime-fly ash or fly ash treated subgrade, subbase or base has been compacted, it shall be brought to the required lines and grades in accordance with the typical sections.

The resulting base surface shall be thoroughly rolled with a pneumatic-tire roller and "clipped", "skinned" or "tight bladed" by a power grader to a depth of approximately 1/4 inch, removing all loosened stabilized material from the section. The surface shall then be thoroughly compacted with the pneumatic-tire roller, adding small increments of moisture as needed during rolling. If plus No. 4 aggregate is present in the mixture, one complete coverage of the section with the flat wheel roller shall be made immediately after the "clipping" operation. When directed by the Engineer, surface finishing methods may be varied from this procedure provided a dense, uniform surface, free of surface compaction planes, is produced. The moisture content of the surface material must be maintained at its specified optimum during all finishing operations. Surface compaction and finishing shall proceed in such a manner as to produce, in not more than two (2) hours, a smooth, closely knit surface, free of cracks, ridges or loose material conforming to the crown, grade and line shown on the plans.

After the lime-fly ash or fly ash treated course has been finished as specified herein, the surface shall be protected against rapid drying by either of the following curing methods for a period of not less than three (3) days or until the surface or subsequent courses are placed:

(a) Maintain in a thorough and continuously moist condition by sprinkling.

(b) Apply a 2-inch layer of earth on the completed course and maintain in a moist condition.

(c) Apply an asphalt membrane to the treated course, immediately after same is completed. The quantity and type of asphalt approved for use by the Engineer shall be sufficient to completely cover and seal the total surface of the base between crown lines and fill all voids. If the Contractor elects to use this method, it shall be the responsibility of the Contractor to protect the asphalt membrane from being picked up by traffic by either sanding or dusting the surface of same. The asphalt membrane may remain in place when the proposed surface or other base courses are placed.

Completed sections of lime-fly ash or fly ash treated material in place may be opened immediately to local traffic and to construction equipment and to all traffic after the curing period, provided the lime-fly ash or fly ash treated course has hardened sufficiently to prevent marring or distorting the surface by equipment or traffic.

5. Measurement. Lime-fly ash or fly ash treatment of the subgrade existing subbase and existing base will be measured by the square yard to neat lines and grades as shown on the typical sections.

When Type A Hydrated Lime is used under “Dry Placing”, the quantity of lime will be measured by the ton of 2000 pounds, dry weight. When Type A Hydrated Lime is used under “Slurry Placing”, the quantity of lime will be measured by the ton of 2000 pounds, dry weight of the powdered bulk hydrated lime being used to prepare the hydrated lime slurry at the job site.

When Type B Commercial Lime Slurry is used, the quantity of lime will be calculated from the minimum percent “Dry Solids Content” of the slurry previously agreed upon for the project by the Contractor and the Engineer. This figure will be multiplied by the weight of the slurry in tons delivered, which must be at or above the required minimum “Dry Solids Content”.

When Type C Quicklime is used under “Dry Placing”, the quantity of lime will be measured by the ton of 2000 pounds, dry weight of the quicklime actually delivered on the road.

When Type C Quicklime is used under “Slurry Placing”, the quantity will be measured by the ton of 2000 pounds, dry weight of the quicklime being used to prepare the hydrated lime slurry at the job site. For payment purposes, slurry placed quicklime will be converted to the equivalent weight of Type A Hydrated Lime. The measured tonnage of Type C Quicklime will be multiplied by the conversion factor 1.28 to give the quantity of equivalent hydrated lime, which will be the basis of payment.

Fly ash will be measured by the ton of 2000 pounds, dry weight of the fly ash actually delivered on the road.

6. Payment. The work performed and materials furnished in accordance with this Item and measured as provided under "Measurement" will be paid for as follows:

Lime will be paid for at the unit price bid for "Lime" of the type specified, which price shall be full compensation for furnishing all lime.

Fly ash will be paid for at the unit price bid for "Fly Ash", which price shall be full compensation for furnishing all fly ash.

"LFA Treated Subgrade (Ordinary Compaction)" and "LFA Treated Existing Base (Ordinary Compaction)" and "LFA Treated Existing Base (Ordinary Compaction)" or "LFA Treated Subgrade (Density Control)", "LFA Treated Existing Subbase (Density Control)" and "LFA Treated Existing Base (Density Control)", of the depths specified, will be paid for at the unit price bid per square yard. "FA Treated Subgrade (Ordinary Compaction)", "FA Treated Existing Subbase (Ordinary Compaction)" and "FA Treated Existing Base (Ordinary Compaction)" or "FA Treated Subgrade (Density Control)", "FA Treated Existing Subbase (Density Control)" and "FA Treated Existing Base (Density Control)", of the depths specified, will be paid for at the unit price bid per square yard. The unit price bid shall be full compensation for all correction of secondary subgrade; for loosening, mixing, pulverizing, spreading, drying, application of lime and/or application of fly ash, water content of the slurry, shaping and maintaining; for all curing including all curing water and/or other curing materials; for all manipulations required; for all hauling and freight involved; for all tools, equipment, labor, and for all incidentals necessary to complete the work except as specified below:

When "Ordinary Compaction" is indicated on the plans, all sprinkling and rolling, except proof rolling, performed as required will not be paid for directly, but will be considered subsidiary to this Item, unless otherwise shown on the plans.

When "Density Control" is indicated on the plans, all sprinkling and rolling, except proof rolling, will not be paid for directly, but will be considered subsidiary to this Item.

When proof rolling is shown on the plans and directed by the Engineer, it will be paid for in accordance with Item 216, "Rolling (Proof)".

SPECIAL SPECIFICATION

ITEM 4156

FLOWABLE BACKFILL

1. DESCRIPTION. This Item shall govern for flowable backfill composed of portland cement, fly ash (optional), fine aggregate, water, and admixtures when required by the Engineer. Flowable backfill may be used, when shown on the plans or approved by the Engineer, as trench, hole, or other cavity backfill, structural, insulating, and isolation fill, pavement bases, conduit bedding, erosion control, void filling, and other uses.

2. MATERIALS.

   (1) Cement. The cement shall be either Type I or II portland cement conforming to Item 524, "Hydraulic Cement."

   (2) Fly Ash. Fly Ash, when used, shall conform to the requirements of Item 421, "Portland Cement Concrete."

   (3) Admixtures. Admixtures shall be added to the mix in accordance with the manufacturer's recommendations and shall be tested by the Contractor to insure they accomplish the desired effects in the mix.

   (4) Fine Agregate. The fine aggregate shall be fine enough to stay in suspension in the mortar to the extent required for proper flow. The fine aggregate shall conform to the following gradation and plasticity index (PI) requirements.

Sieve Size	Percent Passing
19 mm	100
75 um	0-30

   PI shall not exceed six (6) when tested in accordance with Test Method Tex-106-A.

   The fine aggregate gradation shall be tested in accordance with Test Method Tex-401-A.

   (5) Mixing Water. Mixing water shall conform to the requirements of Item 421, "Portland Cement Concrete."

3. MIX DESIGN. Unless otherwise shown on the plans, the Contractor shall furnish an acceptable mix meeting the following requirements:

   (1) Strength. The 28 day compressive strength range, when tested in accordance with Test Method Tex-418-A, shall be 550 kPa to 1030 kPa, to

insure efficient future excavation. Variations of the specified strength will be allowed as approved by the Engineer.

(2) Consistence. The mix shall be designated to be placed without consolidation and shall fill all intended voids. The consistency shall be tested by filling an open-ended 76 mm diameter by 156 mm high cylinder to the top with flowable fill. The cylinder shall be immediately pulled straight up and the correct consistency of the mix shall produce a minimum of 203 mm diameter circular spread with no segregation.

The Contractor shall have the option of using specialty type admixtures to enhance the flowability, reduce shrinkage, and reduce segregation by maintaining solids in suspension. When shrinkage is a concern, the Engineer may require the flowable backfill to contain a shrinkage compensator or other chemical admixtures to enhance the properties of the mix. All admixtures shall be proportioned in accordance with the manufacturer's recommendations.

The flowable fill shall be mixed by central-mixed concrete plant, ready-mix concrete truck, pugmill, or other method approved by the Engineer.

4. QUALITY FLOWABLE FILL. Unless otherwise shown on the plans, the Contractor shall furnish and properly maintain all test molds. The test molds shall meet the requirements of Test Method Tex-418-A and, in the opinion of the Engineer, must be satisfactory for use at the time of use. In addition, the Contractor shall be responsible for furnishing personnel to remove the test specimens from the molds and transport them to the proper curing location at the schedule designated by the Engineer and in accordance with the governing specification. For all concrete items the Contractor shall have a wheelbarrow, or other container acceptable to the Engineer, available to use in the sampling of the concrete. The Contractor is responsible for disposing of used, broken test specimens. A strength test is defined as the average of the breaking strength of two (2) cylinders. Each specimen will be tested in accordance with Test Method Tex-418-A.

   Curing of the specimen shall be in accordance with the following. Storage conditions during the first 24 hours have an important influence on the strength developed in concrete. During the first 24 hours, all test specimens shall be stored under conditions that prevent loss of moisture and where the temperature range is 16 to 27 C. Immediately after forming the cylinders, cover them with cover plates or caps, then with several thicknesses of wet burlap or wet cotton mats. Keep the covering thoroughly saturated until the cylinders are removed from the molds. For shipment to the laboratory for strength testing, wrap the cylinders carefully in wet paper, secure in wet burlap or seal in a plastic bag.

5. CONSTRUCTION METHODS. The Contractor shall submit a construction method and a plan for approval of the Engineer. The Contractor must provide a means of filling the entire void area and be able to demonstrate that this has been accomplished. This must be done without the use of a vibrator. Care shall be taken to prevent the movement of

the insert structure from it's designated location. If voids are found in the fill or if any of the requirements are not met as shown on the plans, it will be the Contractor's responsibility to remove and replace or correct the problem without additional cost to the State.

6. MEASUREMENT. This Item will be measured by the cubic meter of material in place. Cubic meters will be computed on the basis of the measured area to the lines and grades shown on the plans or as directed by the Engineer. Measurement will not include additional volume caused by slips, slides or cave-ins resulting from the action of the elements or the Contractor's opera tions.

7. PAYMENT. The work performed and materials furnished in accordance with this Item and measured as provided under "Measurement" will be paid for at the unit price bid for "Flowable Backfill". This price shall be full compensation for furnishing, hauling, and placing all materials and for all tools, labor, equipment, and incidentals necessary to complete the work.

DRAFT

Draft Specification

HYDRATED FLY ASH AS A BASE COURSE MATERIAL

2010.1. Description.

This item shall govern for the delivery, stockpiling and/or the construction including the placement, compaction, finishing and shaping of foundation or base courses as herein specified and in conformity with the typical sections and to the lines and grades shown on the plans or established by the Engineer.

2010.2. Materials.

(1) **Crushed, Hydrated Fly Ash.** Crushed, hydrated fly ash is an aggregate material prepared by mining, crushing and sizing of hydrated fly ash. The crushed, hydrated fly ash shall be free of injurious or hazardous products and free of organic material or other foreign matter. The contractor is responsible for furnishing the Engineer with documentation certifying that the crushed, cured fly ash complies with class 3 industrial waste requirements in accordance with 30 TAC 335.507. The source shall be approved by the Engineer prior to use.

(2) **Fly Ash.** Fly Ash shall meet the requirements of "Departmental Materials Specification D-9-8900, Fly Ash".

(3) **Water.** Water shall meet the material requirements of Item 204, "Sprinkling".

(4) **Asphalt.** Asphalt shall conform to the requirements of Item 300, "Asphalts, Oils and Emulsions".

(5) **Physical Requirements.**

(a) **General.** Crushed hydrated fly ash shall meet the physical requirements for the specified grade as set forth in Table 1.

Additives, such as, but not limited to, lime, cement, or fly ash, shall not be used to alter the soil constants or strengths shown in Table 1, unless otherwise shown on the plans.

Unless otherwise shown on the plans, the base material shall have a minimum bar linear shrinkage of 2 percent as determined by Test Method Tex-107-E, Part II.

Unless otherwise shown on the plans, the optimum moisture content for compaction for the crushed hydrated fly ash as determined by Test Method Tex-113-E, shall be no more than 25 percent.

Unless otherwise shown on the plans, the dry density of crushed hydrated fly ash as determined by Test Method Tex-113-E, shall not be less than 85 pounds per cubic foot.

TABLE C-1
PHYSICAL REQUIREMENTS FOR CRUSHED, HYDRATED FLY ASH

Physical Property	Parameter	Value
Strength	Triaxial Class	1.0
	Compressive Strength at 0 psi Lateral Pressure	45 psi
	Compressive Strength at 15 psi Lateral Pressure	175 psi
Master Grading	Cumulative Percent Retained on Sieve 1-3/4”	0
	Cumulative Percent Retained on Sieve 7/8”	10-35
	Cumulative Percent Retained on Sieve 3/8”	30-60
	Cumulative Percent Retained on Sieve No. 4	45-70
	Cumulative Percent Retained on Sieve No. 40	70-85
Atterberg Limits	Maximum Liquid Limit	40
	Maximum Plasticity Index	10
Wet Ball Mill Value	Maximum Value	40
	Maximum Increase in Passing No. 40	20

(6) **Pilot Grading.** When pilot grading is required on the plans, the flexible base shall not vary from the designated pilot grading of each sieve by more than five (5) percentage points. However, the flexible base grading shall be within the master grading limits as shown in Table 1. The pilot grading may be varied by the Engineer as necessary to insure that the base material produced will meet the physical requirements shown in Table 1.

2010.3. Construction Methods.

(1) **General.** It is the primary requirement of this specification to secure a completed base course of fly ash base uniformly compacted to the specified density with no loose or poorly compacted areas, and with uniform moisture content, well bound throughout its full depth and with a surface finish suitable for placing a surface course. It shall be the responsibility of the contractor to regulate the sequence of work, maintain the work, and rework the courses as necessary to meet the requirements of this specification.

(2) **Preparation of Subgrade.** The roadbed shall be excavated and shaped in conformity with the typical sections shown on the plans to the lines and grades established by the Engineer. All suitable or otherwise objectionable material or roots shall be removed from the subgrade and replaced with approved material. All holes, ruts and depressions shall be filled with approved material and, if required, the subgrade shall be thoroughly wetted with water and reshaped and rolled to the extent directed in order to place the subgrade in an acceptable condition to receive the base material. The surface of the subgrade shall be finished to lines and grades as established and shall be in conformity with the typical sections shown on the plans. A subgrade planer may be used. Any deviation in excess of one-half

inch in cross section or one-half inch in a length of 16 feet measured longitudinally shall be corrected by loosening, adding or removing material, reshaping and recompacting by sprinkling and rolling. Sufficient subgrade shall be prepared in advance to insure satisfactory progression of the work. Material excavated in preparation of the subgrade shall be utilized in the construction of adjacent shoulders and slopes or otherwise disposed of as directed by the Engineer. Work required for preparation of subgrade will be measured and paid for under item 110, "excavation" and item 132, "embankment" or in accordance with the provisions of other applicable bid items.

The prepared subgrade surface shall be adequately wetted to the satisfaction of the Engineer immediately prior to the placement of the base course material. This is to ensure that no excessive moisture loss occurs from the base material to the subgrade.

(3) Placing. The fly ash base shall be placed in uniform layers on the prepared moist subgrade to produce the depth specified on the plans. The materials shall be consoli dated with rollers capable of compacting from the bottom up. The depth of layers shall be as approved by the Engineer. To insure homogeneous distribution of the fly ash base material in each layer, the material shall be placed using an approved spreader. The spreading operations shall be done in such a manner as to eliminate nests or pockets of material of non-uniform gradation resulting from segregation in the hauling or dumping operations and in such a manner as to eliminate planes of weakness.

The fly ash base shall not be placed when the air temperature is below 40 °F and is falling, but may be placed when the air temperature is above 35 °F, and is rising, with the temperature being taken in the shade and away from artificial heat and with further provision that fly ash base shall be mixed or placed only when weather conditions in the opinion of the Engineer are suitable for such work.

(4) Construction Joints. If a road section is not completed at the end of a construction day, a straight transverse construction joint shall be formed by cutting back into the completed work to form a vertical face.

(5) Compaction. Unless otherwise shown on the plans, the fly ash base shall be sprinkled as required and compacted to a density of not less than 97 percent of compaction ratio density, Test Method Tex-113-E and shall be checked in the field by Test Method Tex-115-E. The moisture content of the mixture during compaction operations shall be maintained within a range from optimum percentage to two (2) percentage points above or 5.0 percentage points below the optimum percentage or within the range directed by the Engineer. If the obtained density does not satisfy requirements, the contractor shall make adjustments in roller weight, lift thickness or material moisture level or replace the material in question. The material shall not be compacted until the necessary shape and thickness has been achieved by grading. When additional lifts are necessary, the existing layer shall be lightly sprinkled prior to placing the additional courses. Additional lift(s) shall be mixed with previous lifts to ensure the base is homogeneous.

(6) Finishing. After the final course of the fly ash base, except the top mulch, is compacted, the surface shall be finished to grade and section by blading and shall be sealed with approved pneumatic tire rollers. When directed by the Engineer, surface finishing methods may be varied from this procedure provided a dense uniform surface is produced and further provided that the construction of compaction planes is avoided.

Unless otherwise shown on plans,

(a) not more than two (2) hours shall elapse between the start of mixing and the time of starting the compaction of the fly ash base on the prepared subgrade.
(b) any mixture of aggregate, fly ash and water that has not been compacted shall not be left undisturbed for more than 90 minutes.
(c) all finishing operations shall be completed within a period of eight (8) hours after fly ash is added to the aggregate and water.

(7) Curing. Immediately after the fly ash base has been brought to line and grade, an asphaltic membrane shall be placed on the fly ash base to prevent evaporation of water and provide curing. The asphalt used for curing shall be of the type and grade shown on the plans or as approved by the Engineer and shall be applied at the rate of approximately 0.1 gallon per square yard unless the plans require otherwise.

If there is a time delay prior to application of the asphalt membrane which is sufficient to cause surface drying, the Engineer may require the surface to be moistened.

If some drying has taken place at the surface prior to the placement of the curing membrane, the contractor shall scrape off any compounds that may have been formed on the surface due to drying to the satisfaction of the Engineer.

(8) Traffic. The fly ash base shall be opened to traffic as specified on the plans or as directed by the Engineer.

2010.4. Maintenance

The contractor will be required within the limits of his contract to maintain the fly ash base in good condition until all work has been completed and accepted. Maintenance shall include immediate repair of any defects that may occur. This work shall be done by the contractor at his entire expense and shall be repeated as often as may be necessary to keep the area continuously intact. Repairs to fly ash base shall be effected by replacing the fly ash base for its full depth rather than by adding a thin layer of fly ash base to the layer of base in need of repair.

2010.5. Thickness Measurement

The fly ash base will be measured for depth in units of 4000 square yards, or fraction thereof. The measurements will be at location(s) determined by the Engineer and performed in accordance with the Test Method Tex-140-E. In any unit where fly ash base is deficient by more than 1/2 inch in thickness, the deficiency shall be corrected by scarifying, adding material as required, reshaping, re-compacting and refinishing at the contractor's expense.

2010.6. Measurement

This item will be measured by the square yard of surface area in the completed and accepted position.

2010.7. Payment

The work performed and materials furnished in accordance with this item and measured as provided under "measurement" will be paid for at the unit price bid for "fly ash base (density control)" of the depth specified.

This price shall be full compensation for securing and furnishing all materials; including all royalty, freight and storage involved; for all processing, crushing and loading; for all hauling, delivering, stockpiling, placing, spreading, blading, mixing, stripping, dragging, finishing, curing and maintaining; for all fine grading; for wetting and compacting and all manipulation, labor, tools and incidentals necessary to complete the work.

Plan Notes for Bottom Ash in Asphalt Stabilized Base and Hot Mix

Plan Notes used in Paris District in addition to QC/QA of Hot Mix Asphalt are furnished below:

The asphalt binder used for this Item shall be PG 64-22.

All sampling for aggregate quality testing shall be performed on stockpiles at the HMAC plant.

Five-cycle magnesium sulfate soundness loss (Test Method TEX-411-A) shall be no greater than 20 percent.

The blended polish value for the virgin coarse aggregate used in the surface course of the main lanes shall not be less than 30.

There is no polish value requirement for aggregates used in base courses.

The use of field sand as a fine aggegate in all HMAC designs on this project is prohibited. A minimum of 10 percent and a maximum 15 percent bottom ash, by weight of combined aggregates, will be required as a replacement.

Bottom ash shall conform to the following gradation requirements:

Seive	Percent Passing
3/8	100
# 4	90–100
# 10	70–100
# 200	0–20

The contractor is advised that the physical characteristics of bottom ash typically dictate that additional asphalt be required in bottom ash mixes. Any additional asphalt that fills coarse aggregate mixes shall be considered subsidiary to this bid Item.