Stabilization of Road Bases Containing Coal Combustion By-Product Sulfates and Sulfites using High Volume Fly Ash Cement

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INTRODUCTION

Of all coal combustion by-products produced by electric utilities, FGD material is the least utilized. Unoxidized FGD calcium sulfite material in particular has fewer potential end uses than oxidized FGD gypsum. One promising high-volume use is in road base material in federal, state and local roads and highways. Research has shown that appropriate strength, durability and constructability is achievable with FGD blends.[1] Agencies would benefit through availability of alternative, economical material sources, avoidance of virgin resource depletion, and utilization of recycled materials. The public would benefit due to the cost savings achieved by avoided disposal (lower electric bills) and through lower-cost road construction (fewer tax dollars).

The ability of high volume fly ash (HVFA) cements, especially those containing Class F ashes, to retard sulfate attack has been well established. The exploitation of this benefit to the stabilization of road bases and subgrades containing flue gas desulfurization (FGD) sulfates and sulfites and expansive clays has been the goal of a research program at Texas A&M University. [1] Typical Type I cements have been shown to be incompatible in road bases containing up to 93 percent by weight of FGD by-product calcium sulfate dihydrate. Even sulfate-resistant Type II cements did not significantly retard large scale expansion in these mixtures. The results of volumetric expansion tests (ASTM C845-90) on cements containing a wide range of tri-calcium aluminate revealed that C_3A contents below 5 percent were required to keep expansion within a reasonable level. For this reason a special Class C, oil sell cement (C_3A = 2.5 percent) produced by Texas Industries, Inc (TXI) in Midlothian, Texas has been used in previous proejcts to stabilize road base mixtures containing FGD by-products. Since 1991, a series of five such experimental field trials were constructed in which TXI's Class C cement was utilized as the stabilizer.[1] None of these test sections experienced any sulfate-related expansion.

In this paper a series of laboratory tests and an experimental field trial will be discussed in which HVFA cements, incorporating 58 percent Class F fly ash and a Type I cement, were used to stabilize road base mixtures containing FGD by-products.

OBJECTIVES

The objectives of this field demonstration project were to:

- Demonstrate the ability to stabilize FGD materials containing a high fraction of soluble sulfates and sulfites using a HVFA cement (58 percent Class F fly ash and 42% Type I cement).

- Demonstrate the reduction in the potential for sulfate attack provided by the HVFA cements.

- Demonstrate that an expansive, highly plastic clay subgrade can be stabilized with lime and Class F fly ash with a significant reduction in the amount of lime that would have typically been used.

DESIGN AND FIELD DATA

The experimental roadway was 150 feet long and 25 feet wide and was constructed on the Texas A&M University Riverside Campus in Bryan. The existing subgrade was composed of an inorganic, montmorillonite-type clay of medium plasticity. This clay had a plasticity index (PI) of 28 and ASTM classification A-7. After stabilization with 2 percent lime and 4 percent fly ash, the plasticity index was reduced to 15.

The existing base course was comprised of an eight inch layer of crushed iron ore gravel typically used throughout east Texas. During construction, all but an amount sufficient to provide a 4-inch thick buffer layer between the lime in the subgrade and the sulfate laden base course was removed. A cross section of the experimental roadway is shown below in Figure 1.

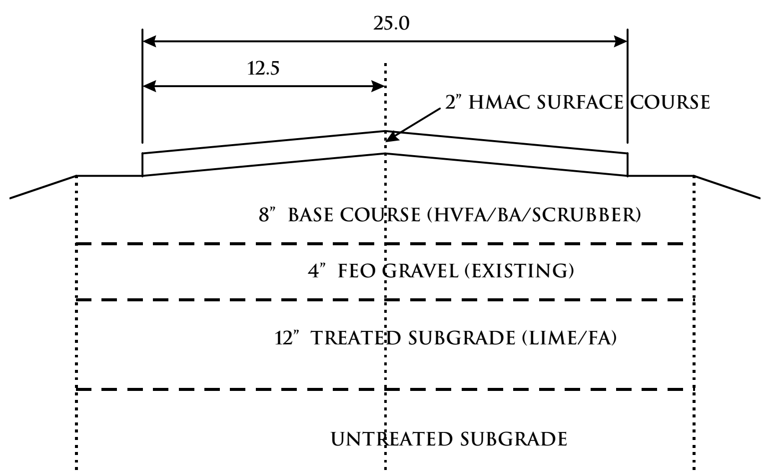

Figure 1. Cross Section of Experimental Roadway.

The design and field data for the subgrade and road base for the experimental test section are given below in Tables 1 and 2.

Table 1. Design and Field Data for Clay Subgrade.

Layer Thickness	12 inches
Stabilization Rate	5% Class F fly ash + 2% Class C Quick Lime of Grade DS
Design Dry Density/Field Dry Density	109 pcf (95% ASTM D1557) / 107 pcf
Optimum Moisture/ Actual Moisture	14.5% / 14.8%
Unconfined Compressive Strength	170 psi (7 days)

Table 2. Design and Field Data for Road Base
(50% Bottom Ash, 40% Scrubber Base and 10% HVFA Cement).

Layer Thickness	8 inches
Stabilization Rate	10% HVFA Cement (HVFA = 58% FA + 42% Type I Cement)
Design Dry Density / Field Dry Density	103 pcf / 114 pcf
Optimum Moisture / Actual Moisture	11% / 7.6%*
Unconfined Compressive Strength	646 psi (10 days)

* Researchers believe that cement hydration could be the reason for the low moisture content observed in the base since this measurement was made more than five hours after the base materials had been mixed.

CONSTRUCTION

Construction began on April 27, 1999 with scarifying the existing surface, iron ore gravel, and sufficient clay to a depth of 14 inches. All of the scarified material was removed and 2 percent quick lime and 5 percent fly ash were spread uniformly over the entire length of the roadway. The quick lime was activated by watering upon blending. The lime and fly ash were pulverized into the clay to a depth of 12 inches. Upon reaching homogeneity, the subgrade was grade, and compacted with a pneumatic compactor. Moisture was added to achieve optimum after which the subgrade was re-pulverized, graded and compacted.

On the following day the clay subgrade containing the lime and fly ash were remixed to a depth of 12 inches then compacted with a padded foot and pneumatic compactor. Four inches of iron ore gravel subbase was placed on top of the subgrade and compacted.

On the following day, bottom ash was evenly distributed over the iron ore subbase. Cement was then distributed over the bottom ash followed by scrubber base (FGD + fly ash). Finally additional fly ash was spread over the entire surface and all the materials were blended with a grader and pulver-mixer. The base was compacted first with a padded foot roller followed by a pneumatic roller. The base was primed with MC-30 on the following day and then allowed to cure for 3 days prior to placement of a 2-inch thick layer of dense graded hot mix asphalt concrete.

POST-CONSTRUCTION EVALUATION

A series of dynamic cone penetrometer (DCP) tests were performed on the experimental roadway and adjacent control section (which consists of 2 inches of hot mix over 8 inches of an iron ore gravel base atop an untreated clay subgrade). The DCP test consists of dropping an 18 pound hammer on a spike with graduated markings. The relationship between number of blows and depth of penetration (in mm) is plotted and the slope (n, in blows/mm) generated. The California Bearing Ratio is related to the DCP slope, and the Texas Triaxial Classification (TTC) ratings can be derived from the CBR values. The relationship between CBR, TTC and suggested roadway use is shown below in Table 3.

Table 3. Relationship between CBR, TTC and Suggested Roadway Use.

CBR	**TTC**	**QUALITY**
150 +	1	High Volume Traffic
85	2	Low Volume Traffic
38	3	Subgrade
14	4 and below	Poor

The results of the DCP tests for the control and experimental sections are shown in Figure 2 and 3, respectively. The results indicate that both that both the subgrade and base course exceed allowable Texas Triaxial Classifications for use on high volume traffic roadways. In addition, the experimental roadway, shows a significant improvement over the control section. Future evaluations will include inspections to identify possible expansion or heaving due to sulfate attack and Falling Weight Deflectometer tests to monitor in-situ stiffness and deflection of the subgrade and base.

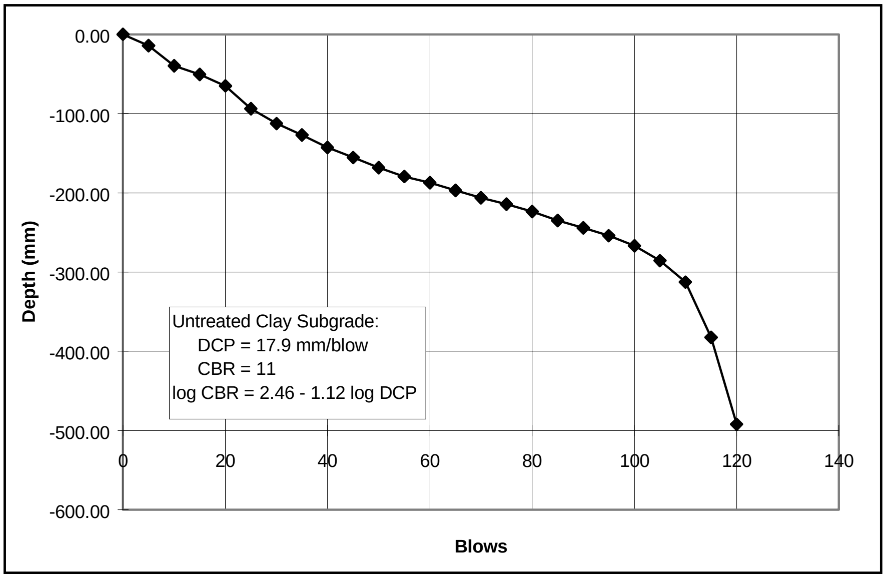

Figure 2. Dynamic Cone Penetrometer Test Data and CBR Values for Control - Untreated Clay Subgrade.

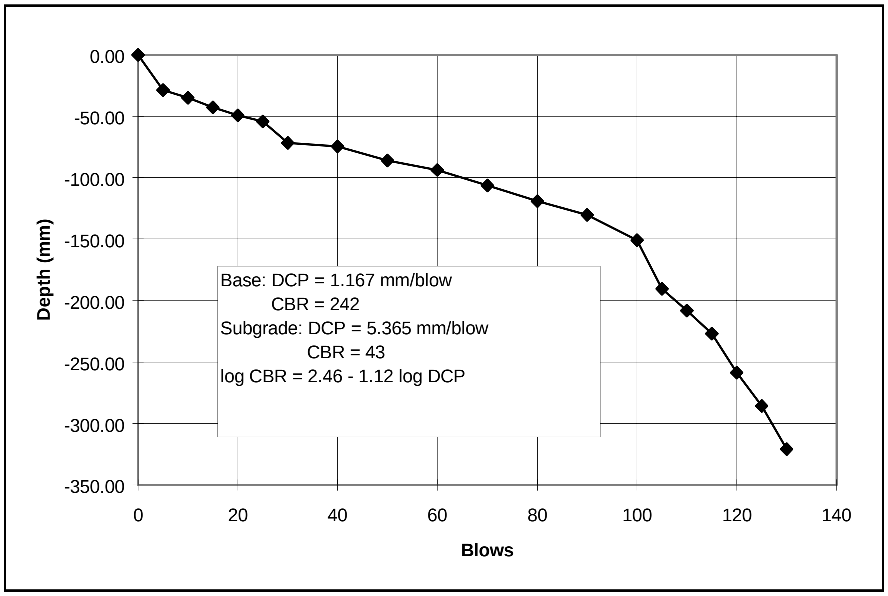

Figure 3. Dynamic Cone Penetrometer Test Data and CBR Values for Experimental Roadway Subgrade and Road Base.

CONCLUSIONS

A demonstration project was successfully completed and accomplishments can be summarized as follows:

- A highly-expansive, montmorillonite clay subgrade was stabilized with a blend of 2 percent lime and 5 percent Class F fly ash. Typically, 4 to 6 percent lime would have been required to produce the same result.
- A cement-stabilized base course material comprised of a blend of three coal combustion by-products including Class F fly ash, bottom ash, and flue gas desulfurization (FGD) calcium sulfate was successfully placed.
- A high volume fly ash (HVFA) cement was used to stabilize the base course. This cement was comprised of 58 percent Class F fly ash and 42 percent of a Type I portland cement. In addition to a 58 percent reduction in cement demand, the ability to utilize a Type I cement in a highly, sulfate-concentrated mixture without expansion could have further use with soils containing soluble sulfates.
- Post construction evaluation using the Dynamic Cone Penetrometer indicates both subgrade and base can be utilized under high volume traffic conditions.
- These coal combustion by-products are all readily available from 14 coal burning electric poser plants located throughout east Texas. Their use as alternatives to conventional aggregates could significantly reduce materials' cost in roadway construction.

REFERENCES

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