Fly Ash Stabilization of Subgrade

RESEARCH PROJECT TITLE
Central Iowa Expo Pavement Test Sections: Phase I – Foundation Construction (InTrans Project 12-433)

SPONSORS
Iowa Department of Transportation
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RESEARCH TEAM
David J. White, PhD, PE
Director, Center for Earthworks Engineering Research
Associate Professor
515-294-1463, djwhite@iastate.edu

Pavana K. R. Vennapusa, PhD, PE
Assistant Director, Center for Earthworks Engineering Research
Research Assistant Professor
515-294-2395, pavanv@iastate.edu

Peter Becker
Research Assistant

Christianna White, PhD
Technical Editor

RESEARCH PARTNERS
Iowa Department of Transportation
Central Iowa Expo
Boone County, Iowa Engineer
Foth Engineering Alliance
JB Holland Construction, Inc.
Center for Earthworks Engineering Research

IOWA DOT CONTACT
Mark Dunn, PE
Operations Research Engineer
Office of Research & Analytics
Iowa Department of Transportation
515-239-1447, mark.dunn@dot.iowa.gov

MORE INFORMATION
http://www.ceer.iastate.edu

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CENTER FOR CEER EARTHWORKS ENGINEERING RESEARCH
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The Iowa Department of Transportation (DOT) worked with its research partners to design comparative pavement foundation test sections at the Central Iowa Expo Site in Boone, Iowa. The project was constructed from May through July 2012. Sixteen 700 ft long test sections were constructed on 4.8 miles of roadway with the following goals:

- Construct a test area that will allow long-term performance monitoring
- Develop local experience with new stiffness measurement technologies to assist with near-term implementation
- Increase the range of stabilization technologies to be considered for future pavement foundation design to optimize the pavement system

This tech brief provides an overview of in situ test results and key findings from three test sections constructed using a subgrade fly ash (FA) stabilization method with varying FA content.

Background

Because Iowa subgrade soils rate generally from fair to poor with the majority of soils classifying as AASHTO A-4 to A-7-6, these soils can exhibit low bearing strength, high volumetric instability, and freeze/thaw durability problems. Stabilization offers opportunities to improve these soil conditions.

ASTM class C self-cementing FA has been used on a limited scale in Iowa to treat or stabilize unstable/wet subgrade. Primarily, stabilization serves the purpose of creating a construction platform in wet soils for either embankment fill construction, soft subgrades, or temporary roadway foundations.

Some of the reported benefits of using self-cementing FA for soil stabilization include environmental incentives in terms of using a waste product, cost savings relative to other chemical stabilizers, and availability at several power plants across Iowa (White et al. 2005). The American Coal Ash Association (ACAA) (2008) indicates that the characteristics of FA can vary significanty between different plants due to variations in the coal used and various operating conditions in the plant. Laboratory mix design procedures for FA stabilization are discussed in ACAA (2008) and Terrel et al. (1999).

Because FA stabilization is not used currently to improve the strength/stiffness of pavement foundations, this study set out to investigate its application for pavement thickness design optimization. This investigation required studying the in situ engineering properties over an extended duration with special focus on freeze/thaw performance.

Description of Test Sections and In Situ Testing

The test sections consisted originally of a thin chipseal coat and an 8 in. recycled asphalt subbase at the surface. The subbase material was excavated down to the subgrade level (Figure 1). The existing subgrade material is classified as CL or

Figure 1. Preparation of subgrade prior to placement of FA on 11th St. South section

A-6(5). The top 12 in. of subgrade for 12th St. South, 12th St. North, and 11th St. North were stabilized using several sources of self-cementing FA at addition rates of 10%, 15%, and 20% FA, respectively, on a dry weight of soil basis.

FA from multiple sources was used to meet the demands of the project. The 10% FA section used on 12th St. South was obtained from the Muscatine and Port Neal power plants (each covered about 50% of the test section). The 15% FA section on 12th St. North was obtained from the Ames power plant, and the 20% FA section used on 11th St. North was obtained from the Port Neal power plant.

Data from six contractor bidder unit prices indicated a median price of $4.87/sq yd for 10% FA, $5.91/sq yd for $15% FA, and $7.21/sq yd for 20% FA. This cost only includes the stabilization cost and not the cost of placing the modified subbase layer on the surface.

The subgrade was scarified using a motor grader (Figure 1). The FA was distributed onto the scarified subgrade and a soil reclaimer was used to mix the subgrade soil and to moisture-condition the mixture by injecting water into the mixing drum (Figures 2 through 4).

Figure 2. Spreading Ames FA on the 12th St. North section

Figure 3. Mixing and moisture-conditioning Port Neal FA with subgrade on the 11th St. South section using a soil reclaimer

Figure 4. Compaction of subgrade mixed with Port Neal FA on 12th St. North using a padfoot roller

A padfoot roller was used to compact the stabilized soil mixture immediately behind the reclaimer. After compaction, the sections were trimmed with a motor grader. After curing for 1 to 2 days, a nominal 6 in. crushed limestone modified subbase layer was placed over the FA-stabilized subgrade sections and compacted using a vibratory smooth drum roller (Figure 5).

The field-estimated FA content in each test section was determined by dividing the delivered weight of dry fly ash over roadway area, assuming uniform reclamation depth of 12 in. Laboratory testing to determine set times was conducted on the FA from all three sources using a FA/water content ratio of 32.5 percent. Table 1 lists some of the key compositional values from x-ray fluorescence analysis and the ASTM C 618 classification.

In situ testing involved testing the foundation layers prior to construction (May 2012) and 1, 3, 5, 7, 28, 56, and 104 to 106 days after stabilization (July-October 2012), and 285 to 288 days after stabilization (April 2013), immediately after the spring thaw.

In situ testing methods used included light weight deflectometer (LWD), dynamic cone penetrometer (DCP), falling weight deflectometer (FWD), and roller-integrated compaction monitoring (RICM). Only results from DCP and FWD tests are presented here. All test results are presented in the Phase I final report.

The temperature profiles in the pavement foundation layers are being monitored on a nearby site on US Highway 30 near Ames, Iowa. The maximum and minimum temperatures recorded up to a depth of about 64 in. below surface and the number of freeze-

Figure 5. Compaction of a crushed limestone subbase layer using a vibratory smooth drum roller

Table 1. Key compositional values from x-ray fluorescence analysis and ASTM C 618 classification

Chemical composition and other properties	Port Neal	Ames	Riverside
$SiO_2 + Al_2O_3 + Fe_2O_3$	61.22	56.16	64.25
CaO	25.3	26.4	22.9
SO_3	2.25	2.53	2.14
Moisture content, %	0.2	0.1	0.2
Loss on ignition, %	1.0	1.5	0.4
ASTM C 618 Class	C	C	C
Final set time (minutes)	6	19	170

thaw (F/T) cycles observed at various depths are shown in Figure 6a. Figure 6b shows a 2010-2011 winter F/T cycle profile for a roadway in Plainfield, Iowa from Johnson (2012) which indicates that the number of F/T cycles can be on the order of 40 to 50 at the top of the subbase/subgrade foundation layers.

Various laboratory tests to characterize the compressive strength and F/T durability of the FA-stabilized mixtures at various mix proportions is also underway and will be reported separately.

Laboratory and In Situ Test Results

Based on the records of truck weights and coverage area, the calculated FA content was about 10% in the 12th St. South sections, about 16% in the 12th St. North section, and about 22% in the 11th St. South section.

Set times of the three FA materials are shown in Figure 7. Results indicated that the Muscatine FA material had longer set times (107 min initial and 170 min final) than Ames FA (4 min initial and 19 min final) and Port Neal FA (3 min initial and 6 min final). The set time gives an indication of the rate at which the cementation reaction products form in the FA that cements soil particles together and provides a basis for setting the compaction schedule. On this project, a maximum 1 hour compaction delay was specified.

DCP-CBR and cumulative blow profiles with depths from the four test sections before stabilization and after several days of curing up to three months after construction, and during the thawing period in April 2013, are shown in Figures 8 through 11.

A summary of the changes in average CBRs of the subbase, FA-stabilized subgrade, and the subgrade layers are shown in Figure 12. Similarly, bar charts of FWD modulus values of the four test sections are shown in Figure 13.

CBR of the subbase layers achieved peak values at about three months after construction, while the CBR of FA-stabilized subgrade layers achieved peak values at about two or three months after construction. FWD modulus of subbase layers achieved peak values at about three months after construction.

Testing during the thawing period showed the lowest CBR and FWD modulus values. These results show a significant weakening

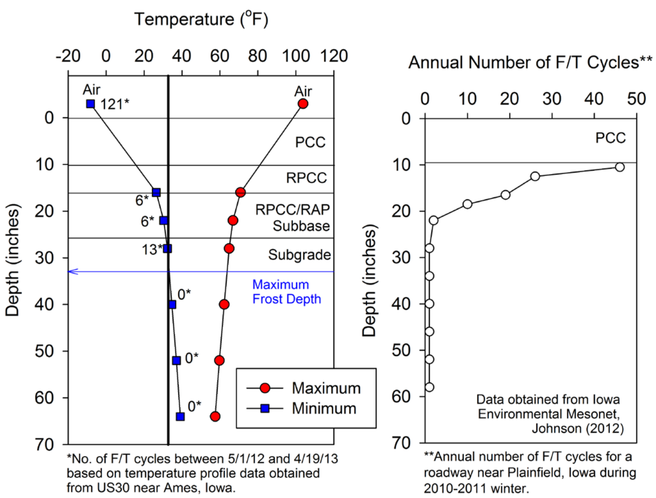

Figure 6. (a) Maximum and minimum temperatures and number of F/T cycles recorded at various depths in pavement foundation layers from US Highway 30 near Ames, Iowa; (b) Annual number of F/T cycles recorded on a roadway near Plainfield, Iowa during 2010-2011 winter

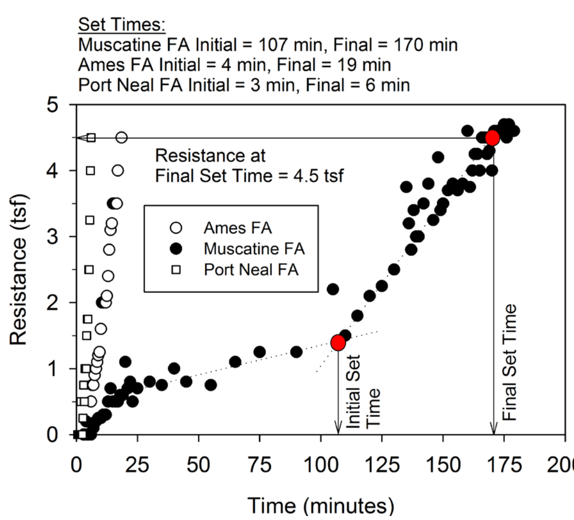

Figure 7. Set times of FA materials used in this project

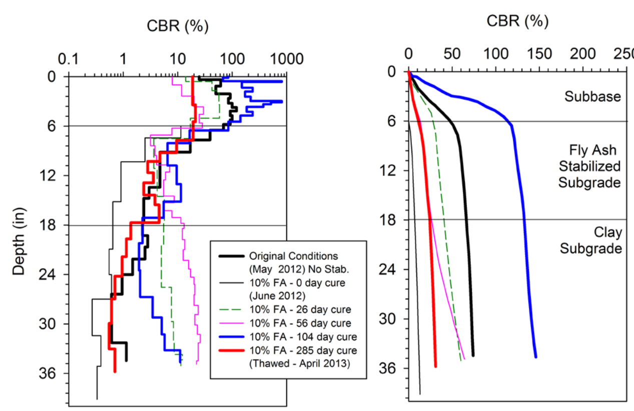

Figure 8. DCP-CBR and cumulative DCP blows with depth profiles from tests conducted on 12th St. South before stabilization and at five different times after stabilization with nominal 10% Muscatine FA

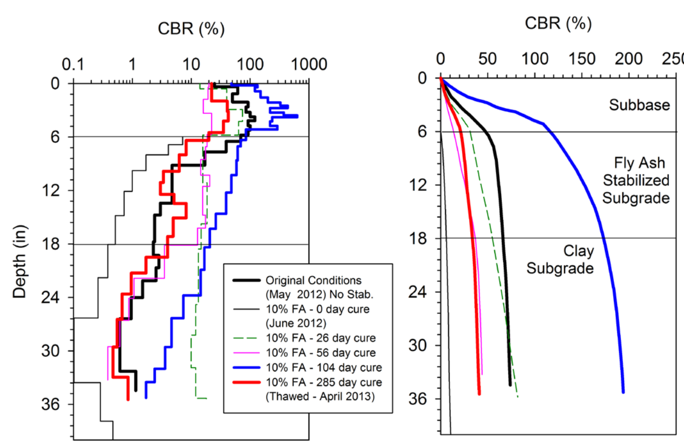

Figure 9. DCP-CBR and cumulative DCP blows with depth profiles from tests conducted on 12th St. South before stabilization and at five different times after stabilization with nominal 10% Port Neal FA

during the spring thaw and warrant additional investigation and monitoring. Previously, White (2006) documented that FA bases can have poor F/T durability, but can regain strength due to long-term pozzolanic reactions.

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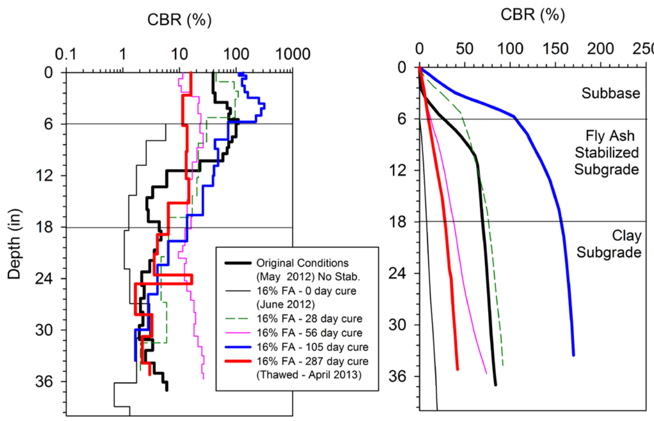

Figure 10. DCP-CBR and cumulative DCP blows with depth profiles from tests conducted on 12th St. North before stabilization and at five different times after stabilization with nominal 16% Ames FA

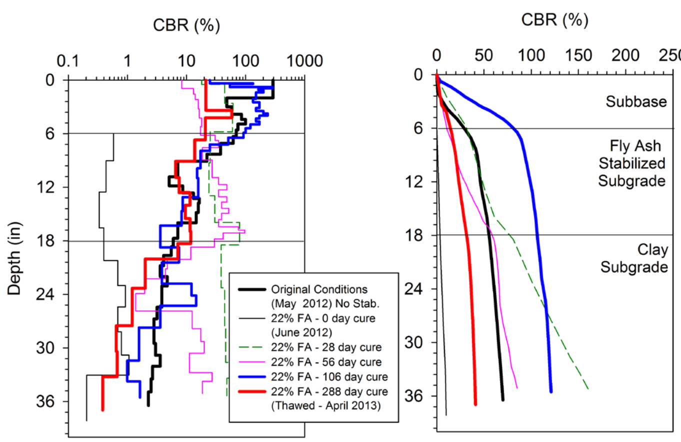

Figure 11. DCP-CBR and cumulative DCP blows with depth profiles from tests conducted on 11th St. South before stabilization and at five different times after stabilization with nominal 20% Ames FA

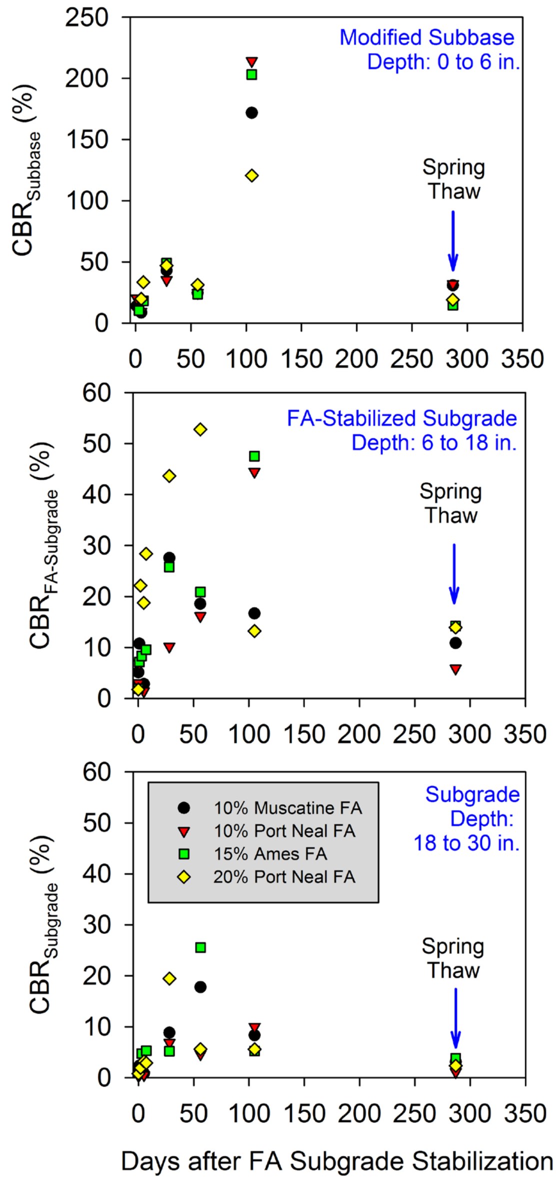

Figure 12. Average (based on three to five measurements) CBR of subbase, FA-stabilized subgrade, and subgrade layers at several days after stabilization from the four FA test sections

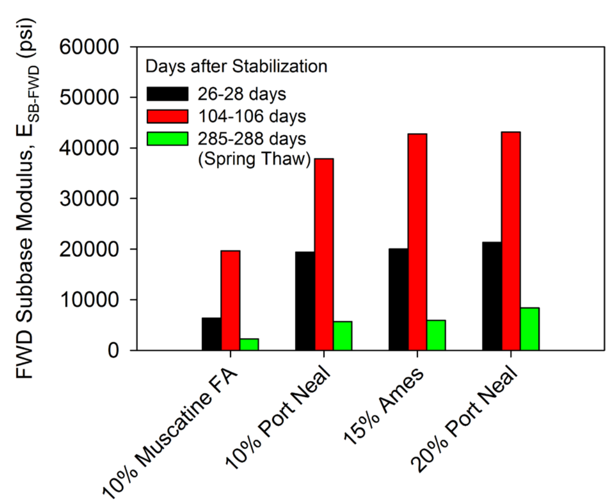

Figure 13. Average FWD subbase modulus of all four FA test sections after curing