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PORTLAND CEMENT CONCRETE
PAVEMENT TECHNOLOGY

IOWA STATE UNIVERSITY

Fly Ash Soil Stabilization for Non-Uniform Subgrade Soils

tech transfer summary

RESEARCH PROJECT TITLE
Fly Ash Soil Stabilization for Non-Uniform Subgrade Soils, Volume I: Engineering Properties and Construction Guidelines (IHRB Project TR-461, FHWA Project 4)

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The Center for Portland Cement Concrete Pavement Technology (PCC Center) is housed at the Center for Transportation Research and Education (CTRE) at Iowa State University. The mission of the PCC Center is to advance the state of the art of portland cement concrete pavement technology.

Objectives

- Evaluate the effects of self-cementing fly ash addition on the engineering properties of several Iowa soils.
- Develop construction guidelines and specifications for using self-cementing fly ashes to stabilize soils, using hydrated or conditioned fly ashes to stabilize soils, and using hydrated or conditioned fly ash as select fill under pavement structures.

Problem Statement

When fly ash production exceeds demand in the construction industry, the material is typically hydrated or conditioned with water and stored on site. The hydrated and conditioned materials can later be reclaimed and used as soil stabilizers or as select fill under pavement structures.

Soil treated with self-cementing fly ash is increasingly being used in Iowa to stabilize fine-grained pavement subgrades, but without a complete understanding of the short- and long-term behavior.

Research Description

To develop a broader understanding of the engineering properties of fly ash, mixtures of five different soil types (ranging from ML to CH) and several different fly ash sources (including hydrated and conditioned fly ashes from six power plants in Iowa) were evaluated. The evaluation included strength, the influence of curing temperature on strength gain, and the effects of compaction delay time on density and strength gain. Strength and durability testing was conducted using the Iowa State University 2 x 2 apparatus, standard Proctor, and California bearing ratio (CBR) test methods.

The morphology of soil-fly ash mixtures and soil clay mineralogy were studied using x-ray diffraction and scanning electron microscopy techniques. To simulate harsh Iowa field conditions, several specimens were subjected to freeze/thaw and wet/dry curing environments prior to testing. Some specimens were cured for up to 2.5 years.

Key Findings

- Iowa self-cementing fly ashes are effective at stabilizing fine-grained Iowa soils for earthwork and paving operations.
- Fly ash increases compacted dry density and reduces the optimum moisture content.
- Strength gain in soil-fly ash mixtures depends on cure time and temperature, compaction energy, and compaction delay.
- Rapid strength gain of soil-fly ash mixtures occurs during the first 7 to 28 days of curing, and a less pronounced increase continues with time due to long-term pozzolanic reactions.

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Key Findings continued

- Unsoaked soil-fly ash exhibits higher strengths for higher compaction energies at low moisture contents. Samples compacted dry of optimum moisture content tend to slake when saturated. This overly dry condition should be avoided in the field. Increasing compaction effort at high moisture contents shows little benefit for increasing compressive strength. In most instances, compaction delay has a negative influence on strength gain of soil-fly ash mixtures. Soaking of laboratory samples before strength testing is recommended to evaluate samples in a saturated condition.
- Sulfur contents can form expansive minerals in soil-fly ash mixtures, which severely reduces the long-term strength and durability. Tests should be performed to determine the sulfur contents of the fly ash, soil, and mix water.
- Fly ash increases the CBR of natural fine-grained soils, and in the case of 20% fly ash addition, the CBR can be increased up to values simulating compacted gravel (~75%).
- Fly ash effectively dries wet soils and provides an initial rapid strength gain, which is useful during construction in wet, unstable ground conditions. Fly ash also decreases swell potential of expansive soils by replacing some of the volume previously held by expansive clay minerals and by cementing the soil particles together.
- Soil-fly ash mixtures cured below freezing temperatures and then soaked in water are highly susceptible to slaking and strength loss. Compressive strength increases as fly ash content and curing temperature increase.
- Soil stabilized with fly ash exhibits increased freeze-thaw durability.
- Moisture-strength relationships of HFA and CFA do not show a clear trend, but most materials exhibit a strength decrease with increased moisture content. HFA shows a continued strength gain over long cure times (365 days). Compaction delay does not have a pronounced negative effect on HFA and CFA strengths. HFA shows a strength increase with increasing cure temperature.
- Soil strength can be increased with the addition of hydrated fly ash and conditioned fly ash, but at higher rates and not as effective as self-cementing fly ash.
- CaO , Al_2O_3 , SO_3 , and Na_2O influence set time characteristics of self-cementing fly ash.

Major Conclusion

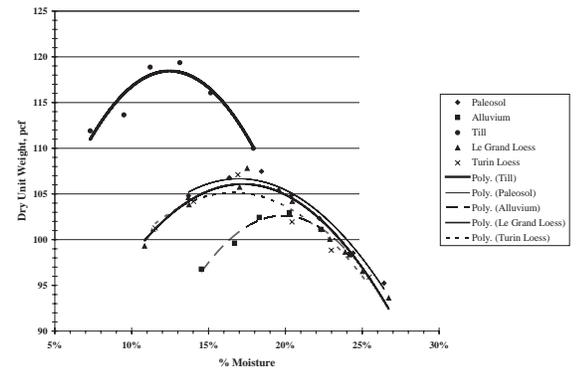
Soil compaction characteristics, compressive strength, wet/dry durability, freeze/thaw durability, hydration characteristics, rate of strength gain, and plasticity characteristics are all affected by the addition of fly ash.

Implementation Benefits

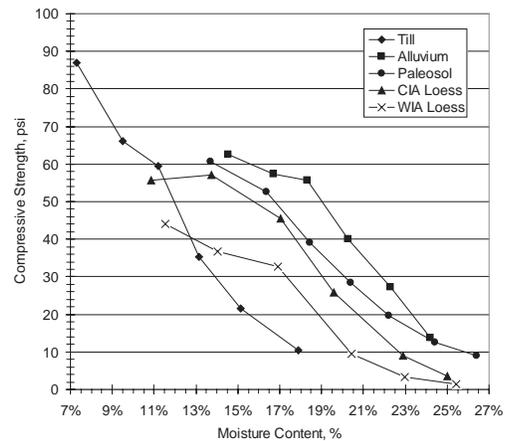
The primary benefits of using self-cementing fly ash for soil stabilization are (1) environmental incentives, because material used does not have to be wasted; (2) cost savings, because fly ash is typically cheaper than cement and lime; and (3) availability, because fly ash sources are distributed geographically across the state.

Implementation Readiness

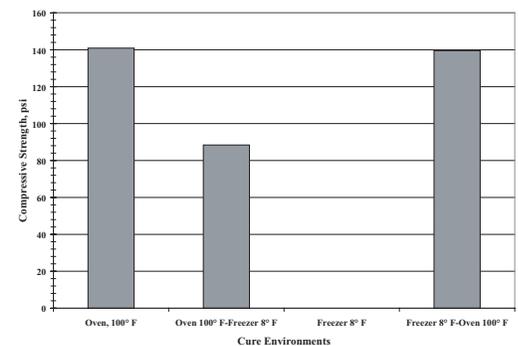
Based on the results of this study, three proposed specifications were developed for using self-cementing fly ash, HFA, and CFA. These specifications describe laboratory evaluation, field placement, moisture conditioning, compaction, quality control testing procedures, and basis of payment.



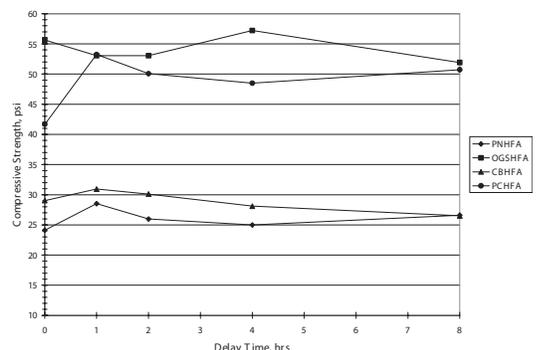
Moisture-density relationships of soils



Moisture-strength relationships of soils



Influence of cure environment on strength gain of self-cementing fly ash-soil mixtures



Influence of compaction delay on strength gain of HFA and CFA