Transportation Research Board
Technical Activities Division

Committee Research Problem Statements
Design and Construction Group (AF000)
Soil Mechanics Section (AFS00)
Cementitious Stabilization Committee (AFS80)

Preface

An important function of the Transportation Research Board (TRB) is to stimulate research that addresses problems facing the transportation community. In support of this function, TRB technical committees identify problems, and develop and disseminate research problem statements for use by practitioners, researchers, and others. The problem statements listed below were developed by the TRB committee noted above. These problem statements should not be considered comprehensive; they may only represent a portion of overall research problems identified by committee members.

Statements

Problem Number	Priority	Problem Statements	Date Posted
1		Environmental Impact of Coal Fly Ash in Road Constructions	06/03
2		Development of an In-Situ Test that will Measure Performance Properties of Sub-Grade Soils Stabilized with Cementitious Materials	06/03
3		Field Identification of Sulfate-Bearing Soils	06/03
4	1	Characterization of Cementitiously Stabilized Materials for the New Mechanistic-Empirical Pavement Design Guide (MEPDG)	06/05

I. Problem 1: Environmental Impact of Coal Fly Ash in Road Constructions

II. Research Problem Statement

Fly ash and bottom ash are by-products of coal-fired power plants, which represent part of the inorganic materials in coal. It is estimated that more than 150 million tons of fly ash is produced annually worldwide from the combustion of coal in power plants. Fly ash has been recognized as a successful resource material and can be added in construction materials for its pozzolanic nature, which will chemically react with calcium hydroxide in cement or carbonates in soil at ordinary temperatures to form compounds possessing cementitious properties when it is in contact with water. On the other hand, however, fly ash typically contains regulated elements such as **arsenic, barium, boron, cadmium, chromium, lead, mercury, selenium**, etc. The environmental impact of coal fly ash was primarily studied through leaching tests (References 1 – 7). The release of these elements to the environment will generate significant impact to the human, wildlife and ecosystem. Coal flyash caused groundwater contamination has been reported worldwide. For example, it was reported in Purulia district of West Bengal, India that a large number of people in the area are victims of lung infections and skin disease, caused by fly ash contamination of air and water. The effect of the ash is found on local animals and vegetation, too. The cattle feeding on contaminated vegetation are victims of skin diseases and dental disorders. The population of birds and water animals is also decreasing. (The Financial Express, 22 August 1999). HEC (2000, http://www.hecweb.org/ccw/CCW-Cases2aug00.htm) documented 63 cases related to coal fly ash caused contamination in the U.S. (References 8 – 15).

Although substantial studies have been conducted on the use of fly ash in road constructions, a comprehensive study on environmental impacts of fly ash when it is used in road works has not been available. A TRIS Online literature search at ***http://ntl.bts.gov/tris*** is carried out on research related to environmental impact of fly ash. Interestingly enough, there are 1033 publications related to the subject of "fly ash" from 1970 to 2003, where only 3 titles came up when the keyword "environment", "pollution", "groundwater" or "contamination" was added, all of them are:

> AN: 00758678 IN CEMENT, FLY ASH EMERGES AS A CURE TO LIMIT GREENHOUSE GASES
> **Journal:** ENR **Vol:** 241 **No:** 23
> **AUTHOR(S):** Rosenbaum, DB
> 12/21/1998
>
> AN: 00725536 USE OF COAL COMBUSTION RESIDUES AND WASTE FOUNDRY SANDS IN FLOWABLE FILL
> **AUTHOR(S):** Bhat, ST; Lovell, CW
> 05/00/1996
>
> AN: 00370678 IMPACT OF LIGHT DUTY DIESELS ON VISIBILITY IN CALIFORNIA
> **Journal:** Journal of the Air Pollution Control Association **Vol:** 32 **No:** 10
> **AUTHOR(S):** Trijonis, J
> 10/00/1982

Based on considerations that (1) standard methods of measuring trace element leaching from fly ash samples bear little relation to actual environmental conditions and add little to the understanding of the chemistry involved, (2) there has been no report on the environmental impact of fly ash when it is used as an additive to road works, and (3) fly ash has significant environmental impact if not managed properly, this research project is proposed.

III. Research Objective

The objectives of the research are

1. Collecting information on environmental impact of coal fly ash, which will enhance the state-of-the-art knowledge and facilitate utilization of coal fly ash. The focus of the research will be on collecting case studies related to the environmental impact of fly ash to subsurface, especially to aquifers.

2. Conducting short and long term dynamic column tests to study the release of contaminants from coal fly ash and soil with fly ash as an additive under simulated environmental conditions, which include, but are not limited to:
    a. Identify dominant contaminants from selected coal fly ash samples from six power generating stations
    b. Time dependent release of the contaminants in
        i. coal fly ash and
        ii. ash stabilized soil on road works
    c. pH dependency of the contaminants in
        i. coal fly ash and
        ii. ash stabilized soil on road works
3. Conducting numerical modeling on chemical equilibrium of coal fly ash as it relates to factors such as
    a. Fly ash composition
    b. Percentage of flyash in soil
    c. Chemical speciation of target elements (contaminants), including their solubility, complex formation and corresponding environmental impacts
    d. Prediction of long term impact of coal fly ash when they are used in road works.

IV. Estimate of Problem Funding and Research Period

Recommended Funding: The funds necessary to accomplish the objectives stated in III above are estimated to be approximately $300,000 over a period of two years. Research Period: The project is scheduled for two years (24 months):

Months from beginning of project	Tasks
0 – 3	Literature review, design and fabrication of dynamic testing columns, collection and characterization of fly ash samples
4 – 16	Long-term dynamic column tests, chemical analysis on regular basis, chemical equilibrium analysis of effluent from coal flyash and ash-soil mixture specimens. The testing conditions will be designed to simulate various scenarios such as acid rain, dilution by natural waters, and encountering acid mine drainage. Contaminants that are of major environmental concern will be identified and monitored during this stage.
12	1st progress meeting, review the up-to-date results and make necessary adjustments
17 – 20	Dismantle dynamic columns and perform physical, chemical, and mineralogical analysis on coal fly ash and ash-soil mixture after permeating with various influents. Perform data analysis and predict long term impact of the flyash to the environment in terms of target

	contaminants as related to natural precipitation and other conditions
21 – 23	Draft report: the three objectives proposed in IV above will be addressed in detail.
23	Meeting to finalize the draft report
24	Final report

V. Urgency, Payoff Potential, and Implementation

As discussed in III, the possibility of coal fly ash contamination in subsurface is a reality. When more effort is made to utilize coal fly ash as a cementitious material in road works, its potential environmental impact must be understood to facilitate the design and construction. The proposed research is inter-disciplinary in nature, which will bridge the gap among transportation, environmental management and energy resources professionals.

I. Problem 2: Development of an In-Situ Test that will Measure Performance Properties of Sub-Grade Soils Stabilized with Cementitious Materials

II. Research Problem Statement

Cementitious materials are commonly used to stabilize weak sub-grade soils in order to increase their stiffness, shear and tensile strengths. The increase in these engineering properties results in overall improvement in pavement performance of both rigid and flexible pavements. In the case of rigid pavements, stabilized sub-grades provide uniform support and a stable construction platform. In flexible pavements, sub-grade stabilization results in reduction of rutting, fatigue and longitudinal cracking.

The current state of practice is primarily based on laboratory testing to determine, the type of stabilizer and the amount required for a given situation. Particle size analysis and Atterberg limits tests are used to select the type of stabilizer. The unconfined compressive strength test is used to determine the amount of stabilizer required, to achieve a predetermined design strength based on a curing period of 7 days. The results of the unconfined compressive strength test can be used to estimate the compressive static modulus of elasticity, shear and tensile strengths of stabilized soils.

One major shortcoming of the current state of practice is that there is no easy and reliable field test that can be used on the constructed stabilized sub-grade after the 7 days curing period. Therefore design strengths cannot be verified prior to allowing heavy construction equipment to operate on the stabilized sub-grade. In an attempt to address this shortcoming, agencies have developed very detailed construction specifications. These specifications usually address methods of measuring rates of application, efficiency of pulverization, depth and uniformity of mixing, thickness of compacted layer, density, moisture control, quality of cementitious material and construction equipment required to execute the work. This approach has several shortcomings, some of which are summarized below:

- There is no assurance that the finished product will have the required design strength and/or stiffness at the end of 7 days curing period, even if the contractor strictly adhered to the specifications.

- There is no way of detecting when the design strengths have been achieved prior to the seven days curing period. This is very critical because there is tremendous pressure to speed up construction. Therefore if the contractor could be allowed to operate heavy equipment as soon as design strengths were obtained, this would shorten construction time and should result in lower bid prices.

- The current practice requires considerable oversight from the agencies. Most agencies are experiencing budget short falls and this is resulting in a reduction in the number of employees. Therefore, there is a need to reduce oversight and depend more on measuring the performance of the finished product, which should require less manpower because the amount of inspection is greatly reduced.

- The present practice places most of the liability on the agencies. This is because the agencies direct construction procedures and if the contractor adheres strictly to specifications he can not be held accountable for the finished product.

The development of an in-situ test that can directly or indirectly measure the unconfined compressive strength, compressive static modulus of elasticity or resilient modulus will go a long way in addressing these issues. Knowing any one of these engineering properties (although ideally a composite foundation modulus would be measured) will allow verification of design parameters and as a consequence expected pavement performance. In-situ testing will greatly simplify contract administration, because the only thing each agency inspectors will have to do is verify strength / stiffness and depth of stabilized sub-grade. This should reduce agency manpower requirements. It will also shift the liability of achieving the desired performance properties to the contractor. This should provide incentive to the contractors to be innovative and to use sound construction practices. Furthermore, this should facilitate faster construction because the strength / stiffness can be monitored daily and as soon as the design strength is achieved, the contractor can be allowed to operate heavy equipment on the stabilized sub-grade. This could result in considerable cost savings because contractors will not have to wait for 7 days if the strength / stiffness requirements have been met early and, equally importantly, will greatly reduce the likelihood of failure due to the design requirements having not been achieved at 7 days.. In many cases, therefore, the time required to deliver projects will be shortened and this should be reflected in lower bid prices. In all cases, there will be assurance that the as-constructed properties of the stabilized sub-grade are as specified.

III. Research Objective

The objective of this research is to identify or develop an in-situ test that will measure, directly or indirectly, performance based engineering properties of sub-grade soils stabilized with cementitious materials. The equipment must be capable of reliably measuring any one of the following properties: unconfined compressive strength, compressive static modulus of elasticity, and the resilient modulus. The equipment must also be easy to operate, easy to carry around in a station wagon or small pick-up and should not require more than a high school graduate to process and interpret the test results. Equipment requiring back calculation techniques will not be acceptable. The cost of the equipment should not exceed fifteen thousand dollars ($15,000).

1. Perform a national and international literature search to identify potential in-situ testing devices meeting the requirements set forth above.

2. Based on findings of Task 1, develop a screening procedure that will short-list equipment with the highest probability of success.

3. Develop a procedure for using the short-listed in-situ testing equipment to test stabilized soils with known engineering properties. This will help identify equipment with the highest degree of accuracy and repeatability.

4. Use the equipment selected in Task 3 on an actual project. Tests will be performed on stabilized soils that can be cored. Cores will be tested in the laboratory and test results will be compared to results obtained using in-situ tests. In addition, trafficking trials will be undertaken on site to determine true performance under rolling wheels.

5. Analyze all the data collected and recommend an in-situ test.

6. Prepare final report.

IV. Estimate of Problem Funding and Research Period

Total funds requested $ 400,000
Research period: 30 months.

V. Urgency, Payoff Potential, and Implementation

There is considerable pressure for State DOTs to speed up project delivery times. Often sub-grade stabilization requires longer project delivery times because of the time required for curing. This delay is becoming unacceptable and stabilization is being deleted from contracts even when the soils absolutely need it. There is a tremendous need for an in-situ test that can rapidly determine when to allow the contractors to proceed as quickly as possible, as well as being able to identify the rare cases in which the material is sub-standard. Also the State DOTs are experiencing budget shortfalls, and are reducing manpower. Therefore, they plan to use methods that efficiently utilize the available manpower and still ensure quality performance of the finished product. The potential payoff could be high, because if the contractors became innovative and were able to achieve the required design strengths in less than 72 hours, this would cut down on project contract times and result in savings that should show up in lower bid prices. The implementation should be very easy once the equipment has been identified. Training could be in the form of a workshop where each DOT can send a few people and then in turn these people will go back to their respective DOTs and train others.

I. Problem 3: Field Identification of Sulfate-Bearing Soils

II. Research Problem Statement

Sulfate-bearing soils present significant problems for subgrade soils stabilized with cementitious materials. Interaction between sulfates and lime can cause formation of expansive minerals resulting in subgrade heave and potential failure of the pavement structure. It is therefore desirable to identify the presence of sulfates prior to construction so that the sulfate-bearing material may be replaced or construction procedures modified. However, sulfates often are present in localized areas, which results in localized failure and also can result in the failure to identify the presence of sulfates by random sampling.

Several technologies have been developed for the field identification of sulfate-bearing soils and research has been presented on them at the TRB annual meeting. These methods include conductivity measurements using the EM-38 from Geonics and dielectric conductivity measurements of soil samples.

III. Research Objective

The objective of the proposed research is to identify existing technologies and evaluate their effectiveness for the field identification of sulfates on multiple test sections where sulfates are known to be present.

IV. Estimate of Problem Funding and Research Period

The estimated cost of this research for acquisition/rental of the equipment and research time is:

Funding: $90,000
Research Period: 1 year

V. Urgency, Payoff Potential, and Implementation

It is anticipated that the research will provide guidance on the relative effectiveness of the sulfate detection methods and recommendations for specifications for their use. These methods should make it possible to more easily identify occurrences of sulfate-bearing soils prior to construction, enabling the State to remove those soils or modify construction procedures to prevent pavement damage and traffic disruption. The cost/benefit ratio is very great given the methods would be relatively inexpensive to implement and could prevent significant pavement damage and the need for reconstruction.

I. Problem 4: Characterization of Cementitiously Stabilized Materials for the New Mechanistic-Empirical Pavement Design Guide (MEPDG)

II. Research Problem Statement

The NCHRP 1-37A Design Guide (DG) considers Cementitiously Stabilized Materials to include lean concrete, cement treated aggregate, open graded cement stabilized aggregate, soil cement, lime-cement-fly ash, lime-fly ash, fly ash and lime-stabilized soils. The parameters used to characterize these materials are elastic modulus (E) or resilient modulus (Mr) and flexural strength (MR). The Design Guide provides for three levels of inputs, Levels 1, 2, and 3. Level 1 inputs have the highest level of accuracy and Level 3 inputs have the lowest level of accuracy. Level 2's accuracy is somewhere in between the two extremes. At the present time there are no standard protocols for testing majority of these materials at Level 1 accuracy. The protocols included in the Design Guide are a combination of adaptations of various concrete testing methods and a limited number of procedures for Cementitiously Stabilized Materials. The Design Guide provides various relationships with Unconfined Compressive Strength for obtaining Level 2 inputs and Level 3 inputs are based on "typical" values available in literature.

Many State Highway Agencies utilize Cementitiously Stabilized Materials in pavement construction and are considering the potential utilization of the Design Guide. Furthermore, pavement thickness design is very sensitive to both E and Mr inputs. Therefore, there is an urgent need for developing standard testing protocols for obtaining moduli and flexural strength of Cementitiously Stabilized Materials. Also there is a compelling need for evaluating the accuracy of the Unconfined Compressive Strength correlations provided in the Design Guide for Level 2 inputs. Both laboratory and field testing protocols are needed. However, the scope of this study should be on laboratory procedures.

III. Research Objective

This research should include the evaluation of standard and new destructive testing procedures (compressive strength, flexural strength, indirect tensile strength, and other deemed worthy procedures) and consider the potential of utilizing such non-destructive-testing (NDT) techniques as pulse velocity, resonant frequency, impulse-echo, SASW (Spectral Analysis of Surface Waves), the Clegg Hammer, etc. Non destructive test procedures are particularly well adapted for characterizing the effect of curing (temperature/time) effects.

A comprehensive laboratory testing program conducted with a variety of Cementitiously Stabilized Materials is required. The research product would be a set of consistent and appropriate recommended procedures (in AASHTO format) for characterizing the moduli and flexural strength properties of Cementitiously Stabilized Materials for mechanistic-empirical pavement design inputs.

SUGGESTED ACTIVITIES

This study should start with a sensitivity analysis using the typical ranges of minimum and maximum elastic modulus or resilient modulus and flexural strength for each cementitious stabilized material. This will establish the parameter and material with the greatest impact on pavement thickness design and help in setting priorities for the laboratory testing program.

Review pertinent literature (emphasize the utility of the various test procedures identified) and summarize the Best Demonstrated Technology (BDAT). The following reference is a recent comprehensive report that considers cementitiously stabilized base properties. It can serve as a "starting point" for this effort.

Arellano, David, and M. R. Thompson. Stabilized Base Properties (Strength, Modulus, Fatigue) for Mechanistic-Based Airport Pavement Design. Final Report, COE Report No. 4, FAA Center of Excellence for Airport Pavement Research, University of Illinois at Urbana-Champaign, February, 1998.

Recommend (for NCHRP Panel review/comment) a comprehensive laboratory testing program utilizing the most promising procedures/techniques identified in the Best Demonstrated Technology effort.

Conduct the Panel approved laboratory program.

Prepare a Final Report summarizing the laboratory program and provide draft versions of AASHTO Test procedures for characterizing the modulus and strength properties of Cementitiously Stabilized Materials.

IV. Estimate of Problem Funding and Research Period

Recommended Funding:
The estimated cost for this study is $300,000.

Research Period:
The estimated duration of this study is 24 months.

V. Urgency, Payoff Potential, and Implementation

The NCHRP 1-37A Design Guide characterizes materials by the fundamental engineering properties of modulus and Poisson’s Ratio. These properties are used to predict states of stress, strain and displacement within the pavement structure when subjected to external wheel loads. These parameters are then used in transfer functions to predict major types of pavement distress. The successful implementation of this new Design Guide by State Agencies is therefore dependent upon the test methods employed to characterize the pavement materials. This research effort will support the implementation effort by the development of test procedures to characterize chemically stabilized soil for base and subbase pavement layers.