
AASHTO-AGC-ARTBA Joint Committee

Subcommittee On New Highway Materials

Task Force 28 Report

Guidelines and Guide Specifications for "Using Pozzolanic Stabilized Mixture (Base Course or Subbase) and Fly Ash for In-Place Subgrade Soil Modification"



INTRODUCTION

This document is disseminated upon the sponsorship of the Joint Committee of the American Association of State Highway and Transportation Officials, the Associated General Contractors of America and the American Road and Transportation Builders Association (the Joint AASHTO-AGC-ARTBA Committee) in the interest of information exchange, based on the combined technical expertise of the authors. As such, the opinions and conclusions implied or expressed herein do not necessarily reflect the official views or policies of the Joint Committee or its member organizations.

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American Association of State Highway
and Transportation Officials
444 N. Capitol St. N.W., Suite 225
Washington, D.C. 20001

Fax (202) 624-5806

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FOREWORD

These guidelines and guide specifications were developed by a Joint Committee of the American Association of State Highway and Transportation Officials (AASHTO), the Associated General Contractors (AGC), and the American Road and Transportation Builders Association (ARTBA). The Joint Committee, AASHTO-AGC-ARTBA, formed Task Force 28, to address the need for guidelines on the proper design and construction of pozzolanic stabilized base courses and subbases. The Task Force also developed guidelines for using fly ash (a pozzolanic material) for "in-place" subgrade soil modification. The Task Force members and their affiliation are as follows:

Mr. James Gehler, Chairman, Illinois Department of
Transportation

Mr. William F. Boles, Secretary, FHWA, Demonstration
Projects Division

Mr. David Anderson, Pennsylvania Transportation Institute

Mr. Donnie Braxton, DePauw Construction, Inc.

Mr. Robert Chapin, Chapin & Chapin, Inc.

Mr. Glen Ferguson, Terracon Consultants SE, Inc.

Mr. Theodore R. Ferragut, FHWA, Demonstration Projects
Division

Mr. Edward Galloway, Virginia Department of Highways and
Transportation

Mr. Colin Jensen, Irvin F. Jensen Company, Inc.

Mr. Walter L. Morris, Power Plant Aggregates

Mr. Joseph Pound, American Fly Ash Company

Mr. Joseph Sheffield, Mississippi State Highway Department

Professor Marshall Thompson, University of Illinois

Mr. Sam Tyson, American Coal Ash Association, Inc.

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**APPENDIX A - State of Illinois Department of Transportation -
Pozzolanic-Aggregate Mixture (PAM) Laboratory
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**APPENDIX B - Appendix B of NCHRP Synthesis Report No. 37,
"Lime-Fly Ash-Stabilized Bases and Subbases," - 1976**

AASHTO/AGC/ARTBA
GUIDELINES FOR USAGE OF
POZZOLANIC STABILIZED MIXTURE (PSM)
BASE COURSE OR SUBBASE

1. Introduction

The technology for stabilizing aggregate with lime or cement in conjunction with fly ash has been growing significantly for the last 30 years. Increasing energy and labor costs and depletion of high-quality natural resources are providing the impetus for the utilization of by-products such as fly ash, bottom ash, kiln dust, and wet-bottom boiler slag as construction materials. Available quantities of fly ash and kiln dust are increasing considerably in many areas of the country.

These guidelines are limited to stabilizing aggregate only with lime or cement in conjunction with fly ash. No attempt is made to present guidelines for use of by-product lime or cement. Guidelines for these materials could be better determined on a local basis.

Fly ash has been used for many years in conjunction with lime, cement, and aggregate for roller compacted materials for road construction. These materials must be compacted to a specified density to achieve a strong and durable product. Durability of the stabilized materials depends on constituents, method of placement, environment, and exposure conditions.

Despite the development of the technology, its acceptance has not been universal. In several areas of the country, substantial quantities of roller compacted materials are used annually in the construction of pavement bases and subbases, but in other areas with good resources of lime, cement, and fly ash, the materials are not used extensively. There are, no doubt, a number of reasons for this, including the fact that the technology for use of this material is not widely known in the construction industry and the engineering profession. One of the main objectives of this report is to summarize the current state-of-the-art of Pozzolanic Stabilization Mixture (PSM). A major portion of the information presented herein has been adapted from the NCHRP Synthesis No. 37, "LIME-FLY ASH-STABILIZED BASES AND SUBBASES," 1976.

2. Applications and Limitations

As with all paving materials and pavement systems, PSM are most effective when used under proper conditions and within specified limitations. Although these materials have wide applicability in pavement construction, there are conditions and limitations which the potential user should be aware.

2.1 Application - PSM may be used as either a base or subbase. A wearing surface is required for the PSM layer. In a flexible pavement system, this can vary from a seal coat for low-volume roads to asphaltic concrete for heavy-duty pavements. In a rigid pavement system, the wearing surface can be Portland cement concrete or continuously reinforced Portland cement concrete slab.

- 2.2 Activator - Activator in PSM is that substance which, upon addition of water to the mixture, initiates the cementing reaction. Most commercially available cement, hydrated lime, and quicklime are suitable activators for PSM. There are differences in the properties of these activators; therefore, each source should be validated before its use.

The Portland cement should meet the requirements of AASHTO M 85.

Hydrated lime and quicklime shall meet the requirements of ASTM C 977. The quicklime shall be properly slaked prior to its incorporation with other materials in the mix. The use of highly hydrated dolomitic lime is not recommended. Appropriate quality control testing should be conducted during the course of a project to ensure the quality and uniformity of the lime being incorporated into the PSM.

- 2.3 Fly Ash - Fly Ash is the finely divided residue that results from the combustion of ground or powdered coal and is transported from the combustion chamber by exhaust gases and collected in a precipitator. Chemical composition may vary both between plants and within a given plant with time. Significant chemical composition differences may affect the mix behavior. The CaO content of some of the "high lime" ashes are present in a combined state with aluminates and silicates, therefore, are not available to react with other constituents. The chemical difference in the fly ashes may have impact or control on the time for the mix transportation, placing, and compaction. In some cases, preconditioning may be required to offset early strength gain. Fly ash is siliceous material which, in the presence of water, will combine with lime or cement to produce a cementitious material with good structural properties.

Some fly ashes will set up when conditioned and may require crushing and screening before using. Fly ash stored in slurry ponds may segregate during discharge and settlement causing the final product to be more variable. Thus it is not usually appropriate for use.

Some of the fly ashes do possess cementitious properties in themselves; therefore, haul distance should be kept to minimum if the fly ashes are conditioned for transportation. They may set up similar to Portland cement in the trucks when the haul time is long.

Fly ash meeting the requirements of ASTM C 618, Class F or Class C, is suitable for use in these mixtures. Evaluation of strength development of fly ash in mixtures may be performed using procedures in ASTM C 593.

2.4 Aggregate - The quality of a PSM is highly dependent on the aggregates used (crushed stone, gravel, crushed bottom boiler slag, and granular sand). Other factors that affect the stability, durability, and strength of these mixtures include: gradation, plasticity index, liquid limit, soundness, compactive effort and curing. The aggregate should be free from deleterious organic or chemical substances that may interfere with desired chemical reaction and should consist of hard, durable particles, free from soft or disintegrated pieces. Specifications vary substantially regarding the physical and chemical properties of aggregates to be stabilized. ASTM C 593 does not consider aggregate or material properties at all, but rather specifies mixture quality as evaluated by cured strength and durability. Specifications included in the Guide Specifications for PSM do consider aggregate gradation and quality.

2.5 Mixture Proportions - PSM proportions can be established based on an analysis of the properties of the activator, fly ash, and material to be stabilized. Appropriate proportions are established during laboratory design procedures using the component materials to be incorporated into the field mixture.

Several different laboratory test procedures are used in developing the mixture proportions and for evaluating mixture quality. Typically used procedures are moisture-density, compressive strength, and durability tests.

2.5.1 Moisture-Density Test Procedures - Moisture-density shall be determined in accordance with AASHTO T 180, Method C (except that test requirement for five lifts is modified to require three lifts. It is important that, irrespective of the method used, the level of compaction used for specimen preparation and that required for construction should be high, and of comparable values. Compacted density has a very significant effect on the strength and durability of PSM. Quality criteria developed for one type of compaction should not be indiscriminately applied to PSM prepared in accordance with a different compaction procedure.

2.5.2 Compressive Strength - Compressive strength of cured PSM is used to evaluate mixture quality during production and to characterize engineering behavior for design. Important factors in this procedure are sample size, compaction procedure, and curing condition (time-temperature).

Strength development of adequately compacted PSM is strongly influenced by time and temperature during curing. Curing of design/acceptance specimens should closely approximate field conditions and take into consideration the range of temperatures expected in field cure. Curing conditions should be clearly stated when strength data are presented for evaluation.

A procedure for predicting field curing temperatures from air temperature or from strength-degree-day relationship should be developed. Field curing conditions are quite variable. This variability must be considered in developing cure time recommendation for field conditions. NCHRP - Synthesis of Highway Practice #37 offers a comprehensive discussion of this concept. A paper entitled, "Characterizing Temperature Effects for Pavement Analysis and Design", by Thompson, Dempsey, Hill, and Vogel, TRB Record No. 1121, also covers some of the latest thinking. Illinois Department of Transportation's laboratory evaluation/design procedure is attached (Appendix A).

- 2.5.3 Freeze-Thaw Durability - Durability is the most important property in the performance of PSM in areas subject to cyclic freeze-thaw and the use of de-icing salts. Several procedures are available for assessing the durability of these mixtures, namely: 1) The determination of residual compressive strength after cyclic freeze-thaw, 2) The determination of residual strength after vacuum saturation, or 3) The design of a mixture such that its cured strength is of a sufficiently high level to assure that even under cyclic freeze-thaw conditions, the minimum-tolerable-strength will be met or exceeded.

No standard criteria for durability can be given because the level of durability should relate to the insitu environmental conditions for the proposed pavements. Durability also varies with the amount of cure the mixture experiences before it is exposed to detrimental environmental conditions.

- 2.6 Construction - High relative compacted density is critical for the development of high-strength and highly durable materials. Because high density is achieved primarily through compactive effort, it is important that adequate subgrade conditions exist for achieving densification with the application of compaction effort. Attempts to achieve a high relative compaction in materials supported on soft subgrades results in shoving rather than densification of the materials. There are special problems of compaction near the edge of any pavement layer because, without lateral support, the material is likely to shove rather than to densify under the compactor. Two types of construction-related distress have been observed on PSM pavements. One type occurs when the material becomes saturated before setting and shoves under traffic. This is corrected by reshaping and compacting the unstable layer and permitting it to dry. A more harmful type of distress is caused when construction traffic causes cracks in partially set PSM.

If high groundwater is present at the site, installation of subsurface drainage facilities can provide substantial improvement in performance. Similiar to any other cementitious mix, the salt brine is also detrimental to PSM therefore good surface drainage should be provided.

- 2.7 Joints - When the PSM is used in a flexible pavement system, joints should be cut to control shrinkage cracks. This will control the appearance of wandering reflection cracks in the asphaltic surface. These wandering cracks allow water, often containing de-icing salts to enter the base. The salt water, combined with freeze-thaw cycles, may lead to localized deterioration and a decrease in rideability. To combat this problem, Illinois Department of Transportation requires contraction joints at 30-foot centers. Design detail as used in Illinois is given in the Guide Specification.
- 2.8 Construction Season - Construction season varies with the climatic conditions of any particular site and the manner in which the paved section will be used during the first winter. Early-season construction may be limited by the dates during which heavy construction equipment can effectively operate on the site after the normal last freezing date. The late-season cutoff date may be determined by such factors as the rate of strength development of the PSM and the anticipated daily temperature between the last construction date and the beginning of heavy frost penetration.

Procedures have been determined for the systematic determination of the late-season cutoff date based on historical data from a first-order weather station in the area. A copy of Appendix B of NCHRP Synthesis #37 is attached. The same cutoff date procedure may be adopted for CFA mixes. In general, the use of CFA can extend the cutoff date by 10-15 days. It should be kept in mind that each type of activator could have a different cut-off date.

3. Summary

PSM materials can be most effective when used under proper conditions and within specified limitations. Some of the main items to be considered are:

- 3.1 PSM materials can be used for a wide range of pavement systems from low volume to heavy volume.
- 3.2 A good long-term performance depends on good mixture selection and sound construction techniques.
- 3.3 Durability depends on the PSM constituents and is a very important consideration in the freeze-thaw areas.
- 3.4 In the freeze-thaw areas, procedures are required for establishing cut-off dates for late-season construction with these mixtures. These procedures should include evaluation of strength development characteristics of the mix in respect to degree-days (40° F. base) and anticipated fall curing temperatures.
- 3.5 High relative density is critical for high strength and durability.
- 3.6 Joints should be cut to control the wandering reflective cracking, and they should be appropriately sealed to prevent intrusion of water.

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AASHTO/AGC/ARTBA
GUIDE SPECIFICATION
FOR
POZZOLANIC STABILIZED MIXTURE (PSM)
BASE COURSE OR SUBBASE

1. DESCRIPTION: This work shall consist of furnishing, placing, compacting, and finishing a mixture composed of lime/cement, fly ash, aggregate, and water in accordance with these specifications and in conformity with the lines, grades, thicknesses, and typical cross sections shown on the plans or established by the Agency. PSM may be placed under the asphaltic wearing surface layer (base) or under the PCC slab (subbase). Unless otherwise provided, the Contractor may use either the central plant mixing method or the in-place mixing method as described herein.

2. MATERIALS:

2.1 Water - Water shall be potable or meet the requirements of AASHTO T 26.

2.2 Aggregate - The aggregate shall be sound and durable and may consist of gravel, crushed gravel, crushed stone, crushed air cooled blast furnace slag, wet bottom boiler slag, crushed Portland cement concrete, or a blend thereof. All coarse aggregate shall meet the specified quality requirement herein specified before being proportioned in the mixture or combined to adjust gradation.

2.2.1 Quality Requirement - The quality requirement shall be as follows:

Soundness

Soundness requirement shall be established by the using Agency.

Abrasion

Resistance to abrasion of small size coarse aggregate by use of the Los Angeles machine, AASHTO T 96, shall not exceed 45 percent.

2.2.2 Gradation - For gradation, the aggregate shall meet the requirement of AASHTO M 147. Grading B, C, and D are preferred.

Alternate gradations may be considered provided mixture design data is furnished to the Agency for analysis. Specialized durability testing may be required for unique aggregate gradations or proposed combinations of materials for which the Agency does not have historical performance data.

In addition to the natural aggregates, wet bottom boiler slag may be used. The gradation requirement shall be established by the using Agency.

- 2.3 Lime - Quicklime and hydrated lime shall meet the requirement of ASTM C 977. The quicklime shall be properly slaked prior to its incorporation with other materials in the mix.
- 2.4 Portland Cement - The Portland cement shall meet the requirements of AASHTO M 85.
- 2.5 Fly Ash - The fly ash^{1/} shall comply with the requirements of ASTM C 618 except the allowable loss on ignition shall be 10 percent (maximum). The tests prescribed in ASTM C 593 shall be performed at the option of the Agency. Gradation of mixing the fly ash shall be, when dry sieved, as follows:

<u>Sieve</u>	<u>Minimum Percent Passing</u>
1/2 inch	100%
3/8 inch	95%
No. 10	75%

The moisture content of dampened fly ash shall not exceed 35 percent.

- 2.6 Retarding and Water Reducing Admixture - Admixtures for increasing workability, decreasing water content, or retarding the set of the mix may be used if permitted by the Agency. No adjustments will be made in the required cement and fly ash components for this addition. The water reducing admixture shall comply with the requirements of AASHTO M 194, Type A, when AASHTO T 161, Procedure B, is used. The retarding admixture shall comply with the requirements of AASHTO M 194, Type D, when AASHTO T 161, Procedure B is used.
- 2.7 Bituminous Cure Material - The bituminous curing material shall comply with the requirements of AASHTO M 140, M 208, M 81, or M 82.
- 2.8 Hot-Poured Joint Sealer - Hot-poured joint sealer shall comply with the requirements of ASTM D 3405.

3. EQUIPMENT:

All methods employed in performing the work and all equipment, tools, and machinery used for handling and executing any part of the work shall be subject to the approval of the Agency before the work is started. If equipment is found unsatisfactory, it shall be changed or improved. All equipment, tools, machinery, and plants must be maintained in satisfactory working condition.

- ^{1/} Some of the fly ashes may possess cementitious properties (in addition to pozzolanic properties) which occur very rapidly in a manner similar to Portland cement; therefore, the haul distance should be kept to minimum if the fly ash is dampened for transportation to jobsite to reduce dusting during its application.

4. GENERAL CONDITIONS:

The PSM base or subbase course shall be constructed between and (April 15 and October 15 suggested) unless extended by the Agency^{1/}. Extensions beyond (October 15 suggested) must be requested in writing accompanied by proposed mix formulation or modifications^{1/}. Samples of ingredient materials and request for verification shall be submitted to the Agency by (September 15 suggested). Approval will be based on the consideration of cured strength development characteristics as determined by the Agency's test procedure and the predicted curing degree days^{2/}.

The Contractor shall assure the Agency that sufficient quantities of inspected ingredient materials are available to complete the work. The amount of base or subbase course constructed should be limited to that which can be surfaced during the current construction season.

5. PROPORTIONING:

The actual proportions of lime, fly ash, and aggregate will be determined utilizing the Agency's design method.

5.1 Samples - At his own expense, the Contractor shall provide, from the stockpiled material he proposes to use, a minimum of 25 pounds of lime/cement, 50 pounds of fly ash, and 100 pounds of aggregate. Samples shall be furnished at least (45-60 suggested) days prior to the construction of the base or subbase course. The submitted samples will be tested for individual acceptance, for making design mixes, and for determining a tentative placement cut-off date.

5.2 Mix Design - Proportions shall be determined using Agency's Laboratory-based mixture design procedure and using the component materials to be incorporated into the field mixture. The minimum average compressive strength of psi (600 suggested) when samples are cured at° F. ($72+2$ suggested) for days (14 suggested) in a sealed container. Until the standard deviation is determined based on plant production tests (10 suggested) are determined, the lime or cement content shall be increased by 0.5 percent above the mix design. Once established, a tolerance of +2 standard deviations shall be applied to field mix production. The

^{1/} These dates can be changed by individual Agencies to meet local conditions and practices. Dates shown in parentheses represent the Midwest's winter conditions and are used by Illinois Department of Transportation.

^{2/} There are three main lab test procedures: 1) moisture-density test procedure, 2) compressive strength, and 3) durability test. In Illinois, compressive strength test procedure is used, and the procedure is presented in attached (Appendix A). Cut-off dates are based on degree days (time-temperature-strength reaction), and the procedure is attached (Appendix B).

minimum lime and cement content shall be 3.0 and 2.5 percent, respectively. The Lime/Cement Fly Ash Aggregate (LFA/CFA) mixture will be proportioned, on a dry weight basis of total mixture within the following approximate limits:

APPROXIMATE PERCENT BY WEIGHT
OF OVEN DRY AGGREGATE
FOR LFA MIXTURE

<u>Ingredient</u>	<u>Gravel, Crushed Stone, Crushed Slag or Aggregate Blend</u>	<u>Wet Bottom Boiler Slag</u>
Lime	3-6	3-6
Fly Ash	9-20	18-40
Aggregate	74-88	54-79

APPROXIMATE PERCENT BY WEIGHT
OF OVEN DRY AGGREGATE
FOR CFA MIXTURE

<u>Ingredient</u>	<u>Gravel, Crushed Stone, Crushed Slag or Aggregate Blend</u>	<u>Wet Bottom Boiler Slag</u>
Cement	2.5-5	2.5-6
Fly Ash	9-20	18-40
Aggregate	75-88.5	54-79.5

The right is reserved by the Agency to make changes in proportions during the progress of the work as may be considered necessary.

6. CONSTRUCTION METHODS:

6.1 Mixing and Placing

6.1.1 Central Plant Mix

6.1.1.1 Mixing - The constituents of the mix shall be accurately proportioned, thoroughly mixed in a mechanical mixer at a central mixing plant (batch or continuous mixing), and placed on a suitably prepared subgrade. The measuring devices for proportioning, by weight, shall be of such accuracy that the proportions of the mix will be maintained within the tolerances set forth in Article 5.2 of this specification. The equipment used must be provided with the means, for calibration and check tests of the measuring devices. The mixer shall be capable of producing a uniform mixture. Mixing operations shall be continued until all

ingredients are distributed evenly throughout the mixture and a uniform mixture, free of segregation, satisfactory to the Agency, is obtained. The moisture content at the time of mixing shall be such that the moisture content at the time of compaction will be within (80 to 110 suggested) percent of the optimum moisture determined^{1/}. The proportions of the mixture based on total dry weight will be maintained within the following tolerances^{2/}:

Lime/Cement +0.5 percent by weight.
Fly Ash +1.5 percent by weight.
Aggregate +2.0 percent by weight.

If a water reducing/retarder admixture is used, the automatic dispensing system shall be capable of continuously introducing the desired quantity of admixture within the range of +0.03 gallons per minute.

- 6.1.1.2 Placing - The mixture shall be placed on a suitably prepared subgrade meeting the requirements set by the Agency. No mixture shall be placed on frozen or muddy subgrade. The Contractor shall have at all times, at least (800 suggested) feet of subgrade prepared in advance of base or subbase placement.

The mix shall be placed and compacted the day it is mixed. Compaction shall begin as soon as possible after the mix has been placed.

Each layer of mixture shall be deposited on the subgrade by an approved mechanical spreader with automatic grade control, ready for compaction without further shaping to the tolerances specified.

In areas where irregular width, inaccessibility, or unavoidable obstacles make the use of mechanical spreading equipment impractical, such equipment will not be required, and the Contractor may use other methods approved by the Agency.

If full width placement is impractical, placing the adjacent pass(es) with the specified mechanical spreader to achieve the desired pavement width must be completed the same day as placement of the first pass.

If the base or subbase paving operations are discontinued for more than 24 hours or when the mixture has taken a set prior to the achievement of acceptable compaction, a longitudinal and/or transverse saw joint shall be cut and the material in the affected area shall be removed and disposed of as directed by the Agency.

^{1/} The moisture content can be changed by individual Agency to meet local conditions and practices.

^{2/} Tolerances may be established by the Agency when the proportions of the mixture are based on the volume.