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EVALUATION OF CHEMICAL STABILIZERS

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INTRODUCTION

This circular has been prepared by Committee A2J06 "Chemical Stabilization of Soil and Rock" in response to the Transportation Research Board call for manuals of practice that would make available to the profession a practicel approach to frequently occurring problems.

The objective of this circular is to provide a reasonable degree of uniformity and stardardization in the evaluation of chemical stabilizers used in soil stabilization. The circular is intended to provide the potential user of any chemical stabilizer with some guidelines to follow and important points to consider in evaluating whether or not the stabilizer is suitable for the intended use.

The Committee supports and recommends the use of the procedures outlined in this circular in order to achieve a more uniform approach to the evaluation of chemical stabilizers. However, the Committee recognizes the possibility that engineers who are thoroughly familiar with chemical stabilizers and/or those who are seeking specific performance criteria from the stabilized soil may prefer to use a modified testing technique that would be more applicable to the intended use of the product. In such cases, the procedures outlined in this circular should provide a norm for judging whether the results obtained using modified techniques are sufficiently different to warrant a departure from the circular's approach.

It is pointed out that many chemical stabilizers have been already evaluated in some manner by state highway or transportation departments. A "Special Product Evaluation List" of some of these chemicals has been published by FHWA (1). Another publication that includes similar information was produced by TRB Committee A2J06 and was published by TRB (2). Additionally, two comprehensive studies on the use of chemical stabilizers were conducted at the University of Arizona (3) and Iowa State University (4). It is recommended that potential users of any chemical stabilizer consult these publications prior to embarking on the evaluation of a product.

REQUIRED INFORMATION FROM MANUFACTURER OR SUPPLIER

It is recommended that as much of the following information as possible be obtained in written or printed form from the manufacturer or supplier of the chemical stabilizer. While some of this information may be supplied directly or indirectly, in an oral presentation and/or in a brochure describing the benefits of using the product, the prime reason for requiring such information is to avoid future conflicts arising from initial misunderstandings or misinformation regarding the items outlined below:

1. Legal status of chemical and supplier: Whether the chemical stabilizer is proprietary, patented and/or franchised; identification of its manufacturer; relationship between the chemical supplier and the manufacturer.
2. Purpose for using the stabilizer: Strength improvement, compaction aid, water proofer, water repellent, permeability reduction, etc.
3. Chemical classification of the stabilizer: Silicate, lignin, epoxy, ester, amine, formaldehyde, aliphatic compound, acetate, sulfonate, surfactant emulsifier, plasticizer, ether, alcohol, chloride (Na or Ca),... etc.
4. Information regarding the manufacturing process and quality control/assurance.
5. Mechanism(s) of stabilization: How agent stabilizes; whether verified or hypothesized; single or multiple phase stabilization.
6. Physical and chemical properties of stabilizer: Solid, powder, liquid, emulsion, unit weights, color, pH, viscosity, range of composition, chemical constituents,...etc.
7. Availability of material when (if) required: Capacity to produce and provide the chemical if needed in large quantities; potential for production; seasonal availability.
8. Precautions to be taken during handling and working with the chemical: Toxicity, toxic fumes, causticity, flammability, acidity, skin and eye irritations; need for goggles, gloves, ... etc.
9. Storage conditions: Type of containers, temperature, humidity, sensitivity to sunlight, continuous or intermittent agitation, aeration, ...etc.
10. Shelf life under given storage conditions.
11. Environmental Impact Statement on product: Effects on plants and vegetation and groundwater, leachability,...etc.
12. Method of application: Mixing, spraying, injection,...etc.; recommended application equipment.
13. Method of dilution, if required: Recommended dilution ratio; mixability with water, oils, or other solvents; is mixing required; method of centrifuge, dispersion, high shear rate,...etc.
14. Rate of application to the soil: Rate per unit volume, per unit area, ppm, percent by dry weight,...etc.
15. Cost of chemical: Per pound, gallon, bulk; FOB where; concentrate or dilution.
16. Compaction method(s) if required: How many passes, type of roller, lift thickness, ...etc.
17. Recommended curing conditions: Temperature, humidity, time for curing, dry-back,...etc.
18. Durability and permanence of treatment.
19. List of previous users, types of uses, and locations of projects.
20. Previous laboratory and/or field results.

LABORATORY TESTING PROGRAM

A. Chemical: The physical and chemical properties of the stabilizer shall be determined when not provided by supplier and/or to verify those given. Some of these properties are:

~~1. Chemical Constituents~~
2. pH Value
3. Specific Gravity or Weight Per Unit Volume
4. Viscosity
5. Color
6. Odor
7. Zeta Potential

Specify test method for each (use ASTM or AASHTO procedures, or other procedures as specified by an appropriate agency). See Table 1 for a partial listing.

B. Soil: The physical, mechanical and index properties of the soil to be stabilized shall be determined (as needed) in its untreated natural state, with particular emphasis on those properties that will be modified by the stabilizer:

- Color	- Tensile Strength
- Particle Size Distribution	
- Atterberg Limits	- Flexural Strength
- pH Value	- Shear Strength
- Classification	- Permeability
- Mineralogy	- Resilient Modulus
- Organic Content	- Wind Erosion
- Compaction Characteristics	- Rainwater Erosion
	- Traffic Erosion
- Swelling Potential	- Cation Exchange Capacity & Exchange Salts
- Compressive Strength	
- Durability Tests	- Zeta Potential
- Other	

Table 1 - Testing The Chemical

		ASTM	AASHTO
Chemical Constituents	Chemical Analysis of Limestone, Quick Lime, and Hydrated Lime	C25	
	Chemical Analysis of Glass Sand	C146	
	Chemical Analysis of Gypsum and Gypsum Products	C471	
	Chemical Analysis of Silica Refractories	C575	
	Sampling and Chemical Analysis of Fatty Alkyl Sulfates	D1570	
pH Value	pH of Aqueous Solutions with the Glass Electrode	E70	T200
	pH of Fatty Quatenary Ammonium Chlorides	D2081	
	Acid Number of Certain Alkali-Soluble Solutions	D3643	
	Acidity of Formaldehyde Solutions	D2379	
	Physical Testing of Quicklime, Hydrated Lime, and Limestone	C110	
Specific Gravity	Specific Gravity or API Gravity of Liquid Asphalts by Hydrometer Meth.	D3142	T227
	Specific Gravity of Semi-Solid Bituminous Materials	D70	
	Density or Specific Gravity of Pure Liquid Chemicals	D3505	
	Specific Gravity of Road Oils, Road Tars, Asphalt Cements, and Soft Tar Pitches		T228
Viscosity	Saybolt Viscosity	D88	T72
	Kinematic Viscosity of Transparent and Opaque Liquids (and the Calculation of Dynamic Viscosity)	D445	
	Viscosity of Resin Solutions	D1725	
	Viscosity of Epoxy Resins and Related Components	D2393	T201
Color	Specifying Color by the Munsell System	D1535	
	Visual Evaluation of Color Differences of Opaque Materials	D1729	
Odor	Determination of Odor and Taste Thresholds by a Forced-Choice Ascending Concentration Series Method of Limits	E679	
Toxicity	Evaluating Acute Toxicity of Water to Fresh-Water Fishes	D1345	

Table 2 - Testing The Soil

		ASTM	AASHTO
Color	Description of Soils (Visual-Manual Procedure)	D2488	
	Specifying Color by the Munsell System	D1535	
	Visual Evaluation of Color Differences of Opaque Materials	D1729	
Grain Size Distribution	Particle Size Analysis of Soils	D422	T88
Specific Gravity	Specific Gravity of Soils	D854	T100
Atterberg Limits	Liquid Limit of Soils	D423	T89
	Plastic Limit and Plasticity Index of Soils	D424	T90
Classification	Classification of Soils for Engineering Purposes	D2487	T86
	Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes	D3282	

(Continued - Table 2)

Table 2 - Testing The Soil

		ASTM	AASHTO
pH Value	pH of Peat Materials	D2976	
	pH of Soil for Use in Corrosion Testing	G51	
Organic Content	Moisture, Ash, and Organic Matter of Peat Materials	D2974	
	Organic Matter in Soils by Wet Combustion		T194
	Organic Impurities in Fine Aggregates for	C40	T21
Swell Potential	Concrete Expansive Soils		T258
	Wetting and Drying Tests of Compacted Soil-Cement Mixtures	D559	
Shrinkage Potential	Shrinkage Factors of Soils	D427	T92
	Wetting and Drying Tests of Compacted Soil-Cement Mixtures	D559	
Compaction Characteristics	Moisture-Density Relations of Soils and Soil Aggregate Mixtures Using 5.5 lb (2.49-kg) Rammer and 12-in. (305-mm) Drop	D698	T99
	Moisture-Density Relations of Soils and Soil Aggregate Mixtures Using 10 lb (4.54-kg) Rammer and 18-in. (457-mm) Drop	D1557	T180
Compressive Strength	Unconfined Compressive Strength of Cohesive Soils	D2166	T208
	Strength Parameters by Triaxial Compression		T234
Tensile Strength	Splitting Tensile Strength of Cylindrical Concrete Specimen	C496-71	T198
	Static Double Punch Test	Ref. 5	
Flexural Strength	Flexural Strength of Soil-Cement Using Simple Beam with Third-Point Loading	D1635	
Shear Strength	Direct Shear Test of Soils Under Consolidated Drained Conditions	D3080	T236
	Strength Parameters of Soils by Triaxial Compression		T234
Permeability	Permeability of Granular Soils (Constant Head)	D2434	T215
	Permeability of Cohesive Soils (Falling Head)		
Bearing Ratio	Bearing Ratio of Laboratory-Compacted Soils	D1883	T193
	Bearing Ratio for Laboratory Compacted Soil-Lime Mixtures	D3668	
	Iowa K-Test	Ref. 4	
Elastic Properties	Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression	C469	
Wind Erosion	See Ref. 3		
Rain Erosion	See Ref. 3		
Traffic Erosion	See Ref. 3		
Mineralogy	Identification of Crystalline Compounds in Water-Formed Deposits by X-Ray Diffraction	D934	
	General Techniques of Infrared Quantitative Analysis	E168	
	Thermal Analysis of Metals and Alloys	E14	

Specify test method for each (use ASTM or AASHTO procedures, or other procedures as specified by an appropriate agency). See Table 2 for a partial listing.

C. Evaluating Soil-Chemical Effectiveness: In all laboratory testing of chemically stabilized soils, it is recommended that serious efforts be made to test the material (as needed) under simulated in-situ conditions. Suggested simulations include:

1. Environmental Conditions:

   - Temperature Extremes, including Cyclical
   - Submersion
   - Cyclic Freezing/Thawing
   - Sunlight Exposure
   - Construction Sequencing
   - Degree of Saturation
   - Type of Water (Tap or Sea)
   - Cyclic Wetting/Drying
   - Leaching or Draining Effects
   - Preparation of Material
   - Etc.

2. Loading Conditions:

   - Rate of Loading
   - Strain Rates
   - Consolidation
   - Repetitive Loading
   - Curing Period Prior to Loading
   - Stress Levels
   - Creep Effects
   - Conditions of Drainage
   - Failure Condition (Criteria)
   - Construction Sequencing
   - Etc.

However, it is pointed out that some laboratory evaluations do not lend themselves to simulation of specialized field conditions. Under general circumstances, standardized test techniques (preferably recommended by ASTM or AASHTO) should be utilized to verify the properties of the treated soil to compare it with those obtained for untreated soil.

D. Changes of Physical Properties:

1. List of Conventional Tests (see Table 3):

   - Compressive Strength Test
   - Tensile Strength Test
   - Flexural Strength Test
   - Shear Strength Test
   - Permeability Test
   - Particle Size Distribution
   - Atterberg Limits
   - Compaction Characteristics
   - Swelling Potential
   - Resilient Modulus
   - Etc.

2. List of Previously Used and Developed Tests:

   - Wind Erosion Test
   - Rain Erosion Test
   - Traffic Erosion Test
   - Water Absorption Test
   - Water Repellency Test
   - Cyclic Double-Punch Test
   - Exchangeable Cations
   - Soluble Salt Testing
   - Iowa K-Test
   - Etc.

FIELD TESTING

In field evaluation tests, emphasis should be on following the expected (or recommended) methods of application, curing, compaction,etc., and subjecting the final product to the actual field conditions (environmental and loading) for a period of time.

Monitoring of the performance of the stabilized soils should be made periodically for a period of time (12-month minimum is recommended). However, field evaluation tests and monitoring of the performance of the product may be accelerated in cases where applicable to minimize the number of tests and to shorten the duration of the recommended 12-month minimum period. In addition, the potential user should be alert to recognize any incompatibility of the chemical stabilizer with other construction products. For example, the chemical additive may have a detrimental effect on culverts, buried utilities, vegetation, ...etc. Also the chemical may have beneficial effects such as accelerating the growth of shoulder grass, galvanic protection,...etc.

1. Field Application:

   - Site Preparation
   - Rate of Application
   - Densification
   - Degree of Pulverization
   - Observations of All Aspects of Above (e.g., penetration, compactibility, tracking, etc.)
   - Chemical Preparation
   - Method of Application
   - Method of Compaction and Number of Passes
   - Mixing Efficiency
   - Curing Requirements

2. Field Monitoring: Monitoring should be started immediately after curing and prior to subjecting the stabilized soil to loading or extreme environmental conditions. This shall be used as a basis of field performance.

3. Methods of Evaluation: The evaluation methods can be divided into direct evaluation in the field (by field testing) and/or recovering (or coring) of samples from the field for laboratory testing. In both cases, efforts shall be made to use standardized and accepted methods of evaluation (testing) as recommended by ASTM or AASHTO. Alternatively, methods that have been previously used for evaluation can be utilized to verify performance. Examples of field tests that may be needed are given below:

(i) Field Tests (see Table 4):

   - Penetration Resistance
   - Density
   - Surface Roughness
   - Dust Control
   - Soluble Salts Testing
   - Benkelman Beam
   - Subgrade Reaction
   - Permeability
   - Skid Resistance
   - Wind Erosion
   - Exchangeable Salts
   - Road Rater
   - Etc.

Table 3 - Laboratory Tests on Treated Soils

		ASTM	AASHTO
Specific Gravity	Specific Gravity of Compacted Bituminous Mixtures		T166
Swell Potential	Expansive Soils		T258
	Wetting and Drying Tests of Compacted Soil-Cement Mixtures	D559	
Shrinkage	Shrinkage Factors of Soils	D427	T92
	Wetting and Drying Tests of Compacted Soil-Cement Mixtures	D559	
Compaction Characteristics	Moisture-Density Relations of Soils and Soil Aggregate Mixtures Using 5.5 lb (2.49-kg) Rammer and 12-in. (305-mm) Drop	D698	T99
	Moisture-Density Relations of Soils and Soil Aggregate Mixtures Using 10 lb (4.54-kg) Rammer and 18-in. (457-mm) Drop	D1557	T180
Compressive Strength	Compressive Strength of Molded Soil-Cement Cylinders	D1633	
	Compressive Strength of Cylindrical Concrete Specimens	C39	T22
	Compressive Strength of Bituminous Mixtures		T167
	Immersion Compression Test	D1075	T165
Tensile Strength	Splitting Tensile Strength of Cylindrical Concrete Specimen	C496	T198
	Static Double Punch Test	Ref. 5	
Flexural Strength	Flexural Strength of Soil-Cement Using Simple Beam with Third-Point Loading	D1635	
	Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)	C78	T97
Shear Strength	Direct Shear Test of Soils Under Consolidated Drained Conditions	D3080	T236
	Strength Parameters of Soils by Triaxial Compression		T234
Permeability	Permeability of Bituminous Mixtures	D3637	
Bearing Ratio	Bearing Ratio of Laboratory-Compacted Soils	D1883	T193
	Iowa K-Test	Ref. 4	
	Bearing Ratio for Laboratory Compacted Soil-Lime Mixtures	D3668	
Elastic Properties	Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression	C469	
	Dynamic Modulus of Elasticity by Cyclic Double Punch Test	Ref. 6	
Cyclic Freezing/Thawing	Resistance of Concrete to Rapid Freezing and Thawing	C666	T161
	Freezing and Thawing Tests of Compacted Soil-Cement Mixtures	D560	T136
Cyclic Wetting/Drying	Wetting and Drying Tests of Compacted Soil-Cement Mixtures	D559	T135
Plastic Flow	Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus	D1559	T245
Deformation/ Cohesion	Resistance to Deformation and Cohesion of Bituminous Mixtures by Means of Hveem Apparatus	D1560	T246
Penetration	Penetration of Bituminous Materials	D5	T49

(Continued - Table 3)

Table 3 - Laboratory Tests on Treated Soils

		ASTM	AASHTO
Consolidation	One-Dimensional Consolidation Properties of Soils	D2435	T216
Resistance/ Expansion	Resistance R-Value and Expansion Pressure of Compacted Soils	D2844	T190
Water Absorption	Soil-Bituminous Mixtures	D915	
Mixing	Laboratory Preparation of Soil-Lime Mixtures Using a Mechanical Mixer	D3551	
Water Effect	Effect of Water on Cohesion of Compacted Bituminous Mixtures	D1075	T165
Wind Erosion	Ref. 3		
Traffic Erosion	Ref. 3		
Rainwater Erosion	Ref. 3		
Chemical Residue After Leaching	Ref. 3		

Table 4 - Field Tests

		ASTM	AASHTO
Density	Density of Soil in Place by the Sand-Cone Method	D1556	T191
	Density of Soil in Place by the Balloon Method	D2167	T205
	Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth)	D2922	T238
	Density of Soil in Place by the Drive-Cylinder Method	D2937	T204
Permeability	Permeability of Bituminous Mixtures	D3637	
	Bore Hole Tests (USBR E-18)	USBR-Earth Manual Ref. 7	
Penetration	Moisture-Penetration Resistance Relations of Fine-Grained Soils	D1558	
Load/ Deflection	Repetitive Static Plate Load Tests of Soils and Flexible Pavement Components, for Use in Evaluation and Design of Airport and Highway Pavements	D1195	T221
	Nonrepetitive Static Plate Load Tests of Soils and Flexible Pavement Components, for Use in Evaluation and Design of Airport and Highway Pavements	D1196	T222
Erosion/ Leaching Rate	Infiltration Rate of Soils in Field Using Double-Ring Infiltrometers	D3385	
Skid Resistance	Skid Resistance of Paved Surfaces Using a Full-Scale Tire		T242
Dust Analysis	Collection and Analysis of Dust Fall (Settleable Particulates)	D1739	
Wind Erosion	Ref. 3		

(ii) Laboratory Tests on Undisturbed Field Samples:

- Compression Test
- Shear Strength
- Permeability
- Rain Erosion
- Tensile Strength
- Density
- Leaching (Chemical Residue)
- Etc.

DATA PRESENTATION

Test results from either laboratory tests or field evaluation tests shall be presented in comparison with those performed on untreated soils under the same environmental and loading conditions. For the untreated soils (control sections), all mixing and mechanical manipulations of the in-place soil should be similar to those performed on the treated soils.

REFERENCES

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