STATE OF OHIO
DEPARTMENT OF TRANSPORTATION

SUPPLEMENT 1120
MIXTURE DESIGN FOR CHEMICALLY STABILIZED SOILS

June 13, 2011

1120.01 Description. This work consists of sampling and testing soils mixed with cement, lime, or lime kiln dust to determine the optimum mix design. This supplement can be used in design to compare alternative mixes, and in construction to determine the optimum spreading percentage rate.

1120.02 Testing Laboratory. Use an accredited Geotechnical Testing Laboratory with a qualified staff experienced in testing and designing chemical stabilization and capable of performing the tests listed in the tables below. The staff must be under the supervision of a Professional Engineer with at least five years of geotechnical engineering experience. The Geotechnical Testing Laboratory must be currently accredited by either of the following:

AASHTO Materials Reference Laboratory (AMRL)
National Institute of Standards and Technology
100 Bureau Drive, Stop 8619
Building 202, Room 211
Gaithersburg, Maryland 20899-8619
(301)-975-5450 www.amrl.net

American Association of Laboratory Accreditation (A2LA)
5301 Buckeystown Pike, Suite 350
Frederick, Maryland 21704
(301)-644-3248 www.A2LA.org

The Geotechnical Testing Laboratory minimum accreditations required are a general laboratory inspection and the following AASHTO or ASTM designation tests:

TABLE 1120.02-1

Test Method	AASHTO Designation	ASTM Designation
Dry Preparation of Soil Samples	T 87	D 421
Particle Size Analysis of Soils	T 88	D 422
Determining the Liquid Limit of Soils	T 89	D 4318
Determining the Plastic Limit and Plasticity Index of Soils	T 90	D 4318
Moisture-Density Relations of Soils (Standard Proctor)	T 99	D 698
Specific Gravity of Soils	T 100	D 854
Unconfined Compressive Strength of Cohesive Soil	T 208	D 2166
Laboratory Determination of Moisture Content of Soils	T 265	D 2216

Ensure the Geotechnical Testing Laboratory is also proficient in the following tests:

TABLE 1120.02-2

Test Method	AASHTO Designation	ASTM Designation	Other Test Method
Family of Curves – One Point Method	T 272	–	–
Classification of Soils (as modified by the Department Specifications for Geotechnical Explorations)	M 145	–	–
Organic Content by Loss on Ignition	T 267	D 2974	–
Determining Sulfate Content in Soils – Colorimetric Method	–	–	TEX-145-E [1]
Moisture-Density Relations of Soil-Cement Mixtures	–	D 558	–
Wetting and Drying Compacted Soil-Cement Mixtures	–	D 559	–
Making and Curing Soil-Cement Compression and Flexure Test Specimens in the Laboratory	–	D 1632	–
Compressive Strength of Molded Soil-Cement Cylinders	–	D 1633	–
Laboratory Preparation of Soil-Lime Mixtures Using a Mechanical Mixer	–	D 3551	–
One Dimensional Expansion, Shrinkage, and Uplift Pressure of Soil-Lime Mixtures	–	D 3877	–
Unconfined Compressive Strength of Compacted Soil-Lime Mixtures	–	D 5102	–
Using pH to Estimate the Soil-Lime Proportion Requirement for Soil Stabilization	–	D 6276	–

[1] Texas Department of Transportation (Feb. 2005) ftp.dot.state.tx.us/pub/txdot-info/cst/TMS/100-E_series/pdfs/soi145.pdf

1120.03 Sampling and Testing of Untreated Soil. Collect one soil sample for every 5000 square yards (4000 m^2) of treated subgrade area or 2000 cubic yards (1500 m^3) of treated embankment, but not less than a total of four soil samples for a project. Each sample consists of 75 pounds (35 kg) of soil (about a five gallon bucket). Record the station, offset, and elevation of each sample location.

When this supplement is used during construction for stabilizing embankment (Item 205), collect samples from locations and elevations that represent the soils that will be chemically treated. When this supplement is used during construction for stabilizing subgrade (Item 206), collect samples of in-place soil at the proposed subgrade elevation. However, if the chemical stabilization will be performed on embankment fill, collect the soil samples from the source or sources of the embankment material that will be stabilized. Collect each sample from a different location. For in-place soil samples, collect the samples from locations distributed across the treated area. Obtain the Department's approval before collecting samples from outside the treated area.

When this supplement is used during the design phase, the geotechnical consultant shall submit a plan to modify the above sampling procedure to quantify the effects of chemical mixtures on the soil that will be stabilized.

Visually inspect each soil sample for the presence of gypsum ($CaSO_4 \cdot 2H_2O$). Gypsum crystals are soft (easily scratched by a knife; they will not scratch a copper penny), translucent (milky) to transparent, and do not have perfect cleavage (do not split into thin sheets). Photos of gypsum crystals are shown in Figures 1120-1 to 1120-4. If gypsum is present, immediately notify the Department.

Perform the following tests on each soil sample. Perform each test according to the test method shown and as modified by the Department Specifications for Geotechnical Exploration (Section 603.3). If more than one test method is shown for a test, use any of the given test methods to perform the test. If the sulfate content is greater than 3,000 parts per million (ppm), immediately notify the Department.

TABLE 1120.03-1 TESTS FOR UNTREATED SOIL

Test	AASHTO Designation	ASTM Designation	Other Test Method
Moisture content	T 265	D 2216	–
Particle-size analysis	T 88	D 422	–
Liquid limit	T 89	D 4318	–
Plastic limit and plasticity index	T 90	D 4318	–
Family of curves – one point method	T 272	–	–
Organic content by loss on ignition	T 267	D 2974	–
Sulfate content in soils – colorimetric method	–	–	TEX-145-E [1]

[1] Texas Department of Transportation (Feb. 2005) ftp.dot.state.tx.us/pub/txdot-info/cst/TMS/100-E_series/pdfs/soi145.pdf

Classify the soil sample according to the ODOT soil classification method described in the Department Specifications for Geotechnical Exploration (Section 603). Determine the optimum

moisture content and maximum dry density of the soil using the one-point Proctor test and the Ohio typical moisture-density curves according to Supplement 1015.

Submit the soil classification and test results for each sample to the Department for review before continuing with the mixture design test procedure. Also submit to the Department for review and acceptance a recommendation as to how the soil samples will be combined or grouped for the remaining mixture design test procedures. Obtain written acceptance from the Department before continuing with the mixture design test procedure. Allow seven days for the review. During construction, submit the information to the Project Engineer, who will forward the submittal to the District Geotechnical Engineer, the Office of Geotechnical Engineering, or the Office of Construction Administration. During design, submit the information to the District Geotechnical Engineer.

1120.04 Mixture Design Test Procedure. Use the following procedure to prepare four mixtures from each soil sample that will be tested. From each mixture, prepare three specimens for testing. This results in a total of 12 test specimens for each soil sample.

Each mixture consists of soil mixed with varying amounts of the stabilization chemical, except for the first mixture which consists of the untreated soil. The percentage of stabilization chemical in each mixture is shown in the table below. Calculate the quantity of stabilization chemical to add to the mixture by multiplying the given percentage by the dry weight of the soil.

TABLE 1120.04-1 PERCENTAGE OF CHEMICAL FOR TRIAL MIXES

	Cement	Lime	Lime Kiln Dust
Mix 1 (Untreated soil)	–	–	–
Mix 2	3%	MLP	4%
Mix 3	5%	MLP + 2%	6%
Mix 4	7%	MLP + 4%	8%

MLP – Minimum Lime Percentage (1120.04.A)

Carefully store the cement, lime, or lime kiln dust until used so that it does not react with moisture or excess carbon dioxide. When this supplement is used during construction, use cement, lime, or lime kiln dust from the same source that will supply the chemical for soil stabilization.

A. Minimum Lime Percentage. If using lime for chemical stabilization, determine the minimum percentage of lime required for soil stabilization using ASTM D 6276 (also known as the "Eades-Grim" test). Determine the lowest percentage of lime that produces a pH of 12.4. Report this value as the Minimum Lime Percentage. ASTM D 6276 addresses special cases where the highest measured laboratory pH is less than 12.4. Notify the Department if the measured pH is less than 12.3 or if the Minimum Lime Percentage is greater than 8 percent.

Not all laboratory pH-measuring devices are capable of accurate calibration to determine pH levels above 12.0. Ensure the pH meter can accurately measure pH up to 14 and can be calibrated with a pH 12 buffer solution.

B. Optimum Moisture Content and Maximum Dry Density. Determine the optimum moisture content and maximum dry density of treated soil mixtures using the one-point Proctor test and the Ohio typical moisture-density curves according to Supplement 1015 (the optimum moisture content and maximum dry density of the untreated soil were determined in 1120.03 above.) Prepare the mixtures according to ASTM D 3551 if using lime, and according to ASTM D 558 if using cement or lime kiln dust.

Thoroughly mix the soil, stabilization chemical, and water until the chemical appears to be consistently blended throughout the soil. Use a laboratory or commercial-grade mixer, such as a Hobart mixer. Do not mix by hand.

If using lime for stabilization, seal the mixture in an airtight, moisture-proof bag or container, and store it at room temperature for 20 to 24 hours. This is called the "mellowing" period. Remove the soil-lime mixture from the sealed container and lightly remix it for one to two minutes before performing the one-point Proctor test. Cement and lime kiln dust do not require a "mellowing" period.

C. Unconfined Compressive Strength Specimens. Prepare three specimens for unconfined compressive strength (UCS) testing from each mixture shown in Table 1120.04-1. If using lime for stabilization, use ASTM D 5102, Procedure B. If using cement or lime kiln dust, use ASTM D 1633, Method A. Compact the specimens at the moisture content shown in Table 1120.04-2.

TABLE 1120.04-2 MOISTURE CONTENT FOR PREPARING UCS SPECIMENS

	Cement	Lime	Lime Kiln Dust
Mix 1 (Untreated soil)	OMC (*u*)	OMC (*u*)	OMC (*u*)
Mix 2	OMC (*2*)	OMC (*2*) + 2%	OMC (*2*) + 1%
Mix 3	OMC (*3*)	OMC (*3*) + 2%	OMC (*3*) + 1%
Mix 4	OMC (*4*)	OMC (*4*) + 2%	OMC (*4*) + 1%

OMC (*u*) – Optimum moisture content of untreated soil (determined in 1120.03)
OMC (*n*) – Optimum moisture content of Mix *n* (determined in 1120.04.B)

D. Curing. Immediately wrap each specimen with plastic wrap and store each specimen in a separate airtight, moisture-proof bag. If using lime for stabilization, store the specimens at 104 ºF (40 ºC). If using cement or lime kiln dust for stabilization, store the specimens at 70 ºF (21 ºC). Allow the specimens from the treated soil mixtures (mixes 2, 3, and 4) to cure undisturbed for seven days. Do not cure the untreated soil specimens for more than 24 hours before performing the strength tests on them.

E. Moisture Conditioning. After curing, moisture condition the specimens from the treated soil mixtures by capillary soaking before performing the unconfined compressive strength tests. Do the following:

1. Remove the specimens from the airtight bag and remove the plastic wrap.
2. Use a caliper or pi-tape to measure the height and diameter of the specimens. Record at least three height and diameter measurements each. Calculate the average height and diameter.
3. Wrap the specimens with a damp, absorptive fabric.

4. In a shallow tray, place each wrapped specimen on a porous stone.
5. Add water to the tray until the water level is near the top of the stone and in contact with the absorptive fabric, but not in direct contact with the specimen.
6. Allow the specimens to capillary soak for 24 hours (± 1 hour).
7. Remove and unwrap the specimens and proceed with expansion testing.

Do not moisture condition the untreated soil specimens.

F. Expansion Testing. After moisture conditioning the specimens from the treated soil mixtures, but before performing the strength tests, measure the height and diameter again. Record and average at least three height and diameter measurements for each specimen. Calculate the volume change from before to after moisture conditioning. Report this change as a percentage. Notify the Department if the volume change exceeds 1.5 percent. Further expansion testing may be required using ASTM D 3877. If further expansion testing is required, the Department will pay for it as Extra Work. Do not perform the expansion testing on the untreated soil specimens.

G. Unconfined Compressive Strength Testing. Determine the unconfined compressive strength of each specimen according to the following:

1. For untreated soil, use AASHTO T 208 or ASTM D 2166.
2. For lime, use ASTM D 5102, Procedure B.
3. For cement or lime kiln dust, use ASTM D 1633, Method A.

Calculate the average unconfined compressive strength for each mixture.

1120.05 Recommended Spreading Percentage Rate. Estimate the recommended spreading percentage rate using the following procedure.

A. Generate a graph that shows the average unconfined compressive strength for each mixture versus the percent of stabilization chemical in the mixture (include the strength for the untreated soil at zero percent). Include the results from all tested soil samples.

B. Determine the minimum percentage of chemical that results in an average 8-day unconfined compressive strength that meets the minimum strengths shown in the following table. Interpolate the minimum percentage between points on the graph. If the average strength for the mixture with the greatest percentage of stabilization chemical does not meet the minimum strengths, contact the Department.

TABLE 1120.05-1 MINIMUM UNCONFINED COMPRESSIVE STRENGTH

	UCS after 8 days	Increase over UCS of Mix 1 (untreated soil)
Cement	100 psi (0.7 MPa)	+50 psi (+0.35 MPa)
Lime	100 psi (0.7 MPa)	+50 psi (+0.35 MPa)
Lime Kiln Dust	100 psi (0.7 Mpa)	+50 psi (+0.35 MPa)

C. Round the minimum percentage up to the nearest 0.5 percent.

D. Add 0.5 percent to the percentage.

The Department may adjust the recommended spreading percentage rate due to site specific conditions.

1120.06 Mixture Design Report. Submit a mixture design report to the Department for review that includes the following information:

A. For each soil sample, report the following:

1. Soil classification
2. Moisture content
3. Particle-size analysis
4. Liquid limit
5. Plastic limit and plasticity index
6. Sulfate content (ppm)

B. For each specimen, report the following:

1. Height and diameter measurements and averages from before and after moisture conditioning
2. Calculated percent volume change (swell)
3. Unconfined compressive strength

C. For each mixture, report the following:

1. Percent of chemical in the mixture
2. Optimum moisture content
3. Maximum dry density
4. Average volume change (swell)
5. Average unconfined compressive strength

D. The graph of average strength versus the percent of stabilization chemical in the mixture.

E. The recommended spreading percentage rate for the stabilization chemical.

During construction, submit the report to the Project Engineer for review. Allow seven days for the review. The Project Engineer will forward the submittal to the District Geotechnical Engineer, the Office of Geotechnical Engineering, or the Office of Construction Administration. The Department will determine the spreading percentage rate based on the mixture design report and site specific conditions.

During design, submit the report to the District Geotechnical Engineer.

1120.07 Field Verification of the Mix Design. During construction, sample the treated soil after mixing but before compaction. Take three samples from random locations for every 15,000 cubic yards (11,500 cubic meters) of treated soil for Item 205 and for every 40,000 square yards (33,500 square meters) for Item 206. Prepare three test specimens in the field from each sample according to 1120.04.C above, except compact the specimens at the in-place moisture content.

Immediately wrap each specimen with plastic wrap and store each specimen in a separate airtight, moisture-proof bag before transporting the specimens to the lab. Perform the procedures described in 1120.04.D through 1120.04.G.

Submit the measurements and test results for each set of field verification samples to the Project Engineer as they are completed. The Project Engineer will forward the submittal to the District Geotechnical Engineer, the Office of Geotechnical Engineering, or the Office of Construction Administration.

PHOTOS OF GYPSUM CRYSTALS

FIGURE 1120-1 Gypsum crystals

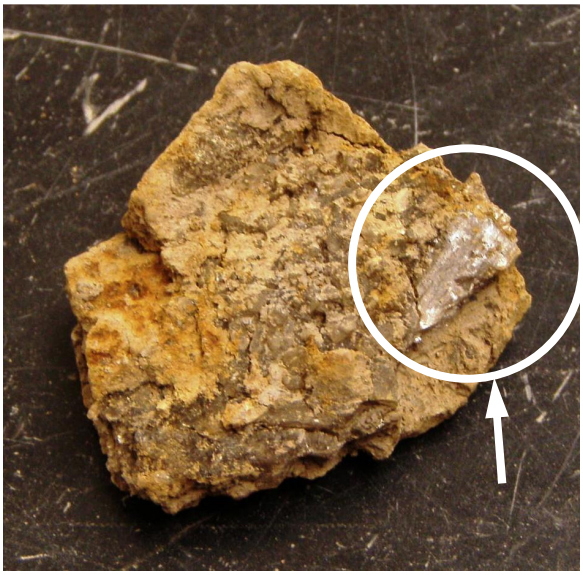

FIGURE 1120-2 Gypsum crystal in clay

FIGURE 1120-3
Specimen quality gypsum crystal

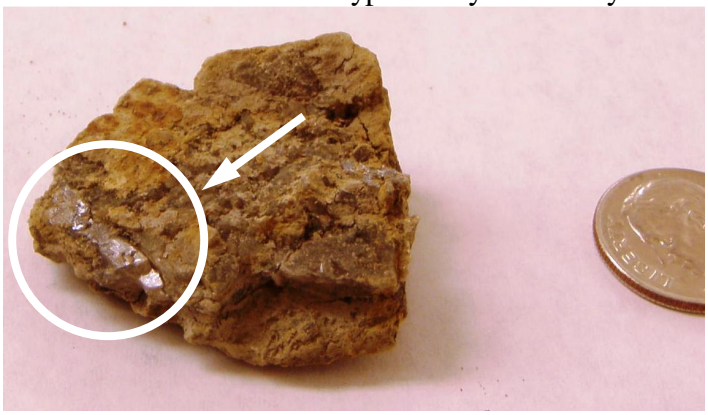

FIGURE 1120-4 Gypsum crystal in clay

FIGURE 1120-5 Gypsum crystals in clay

For more information about identifying minerals, see FHWA (1991) *Rock and Mineral Identification for Engineers*, Publication No. FHWA-HI-91-025, U.S. Department of Transportation.