

OHD L-50

SOIL STABILIZATION MIX DESIGN PROCEDURE

The soil stabilization mix design procedure consists of two methods. The first method consists of an abbreviated laboratory test procedure with determination of the recommended percentage of stabilization additive from the Soil Stabilization Table. The second method is the complete laboratory test procedure with determination of the recommended percentage of stabilization additive from the test results. The second method is considered the preferred method and is also used if a checkmark appears in the Soil Stabilization Table or if requested due to specific concerns on a project. The laboratory test procedure follows the general requirements of the ASTM D6276, and Annexes A1 and A2 of ASTM D4609, except as noted herein and as described below. The stabilization additive and water used in the mix design procedure shall be from the source proposed for use on the project. Laboratories performing soil stabilization mix designs shall be qualified by the Materials Division. The final report and recommendations shall be reviewed, signed, and sealed by a registered Professional Engineer in the State of Oklahoma. The Professional Engineer of record shall be a geotechnical engineer.

A) Initial Soil Testing and Screening:

Soil classification testing

Test the sample for gradation according to AASHTO T-88, liquid limit according to AASHTO T-89, and plastic limit and plasticity index according to AASHTO T-90. Determine the soil group classification according to AASHTO M-145.

Screening for soluble sulfates

Certain minerals, such as gypsum or anhydrite, slowly dissolve in water and release sulfate ions. These ions react with clay minerals and calcium-based soil stabilization additives to produce potentially damaging expansive crystal growth (sulfate-induced heave). All soils that are to be stabilized as well as the proposed source of water to be used for the stabilization of the soil must be tested for soluble sulfate concentration regardless of the geographic location of the sample.

Test the sample for soluble sulfates according to OHD L-49. If the soluble sulfate content is greater than 500ppm, additional samples for soluble sulfate testing should be taken throughout the length of the project represented by the sample. If the soluble sulfate content is greater than 1000ppm for any of the additional samples, a mellowing process during construction will likely be necessary if stabilization is used. (NOTE: ODOT does not currently have a standard process for mellowing. Please consult the Materials Division Geotechnical Engineer prior to commencing any mellowing procedure.) If the soluble sulfate content is greater than 8000ppm for any of the additional samples, stabilization with calcium-based additives is not recommended.

Test the undiluted mixing water for soluble sulfates according to OHD L-49. The combined soluble sulfate concentration of the untreated soil at optimum moisture content is calculated as:

$$C_T = \frac{C_S + \frac{m_{opt}}{100} C_W}{1 + \frac{m_{opt}}{100}}$$

where C_T combined soluble sulfate concentration

C_S	soluble sulfate concentration in untreated soil
C_W	soluble sulfate concentration in mixing water
m_{opt}	optimum moisture content

Screening for dispersive clays

Certain clay soils because of their chemical makeup are prone to severe erosion, or dispersion. If dispersive soils are encountered or used in construction, soils may be stabilized as normal, but all other exposed grading surfaces constructed with this soil will require special treatment to prevent erosion problems. Surface protection by clay plating or thickened layers of topsoil may be used; alternatively, exposed surfaces of dispersive soils may be modified as detailed in OHD L-51.

Dispersive soils most frequently occur in Districts 2, 5, and 7. Test samples from these districts for soil dispersion using the Crumb Test, ASTM D6572. If a Grade 3 or 4 is indicated by this test procedure, further testing for soil dispersion is required. Test the soil using the Pinhole test procedure, ASTM D4647, or the Double Hydrometer test, ASTM D4221. If either test indicates a dispersive soil, notify the Resident Engineer.

After Districts 2, 5, and 7, the presence of dispersive soils in descending order is District 1, 3, 4, 8, and 6. For samples from these districts, if evidence of dispersive soils is reported or observed, conduct soil dispersion testing as described above.

B) For Fly Ash, Cement Kiln Dust, or Portland Cement Stabilization:

Verify the stabilization additive is from an approved source. If the abbreviated mix design procedure is used, determine the recommended percentage of stabilization additive from the table. If a checkmark appears in the table for the soil group classification and additive or if requested due to concern over a specific soil, use the full mix design procedure. The full mix design procedure is the preferred method.

Water used in the mix design shall be from the source planned for use in construction. If the source of construction water is unknown or unavailable at the time of performing the mix design, this shall be prominently noted in the mix design report. In this case, the water used in the mix design may be distilled, deionized, or tap water, as approved by the professional engineer of record and noted in the report. It should be noted that some sources of tap water contain soluble sulfates; test the water used in the mix design for soluble sulfates.

The mix design procedure shall follow the general requirements of the Annexes A1 and A2 of ASTM D4609 except as noted herein. The curing period is five days for moisture absorption specimens and seven days for the remaining specimens.

Three or more percentages of stabilization additive are to be tested in addition to the untreated soil. The suggested percentages for Portland Cement and cement kiln dust from pre-calciner plants are 2, 4, and 6. The suggested percentages for cement kiln dust from other type plants are 7, 9, and 11. The suggested percentages for fly ash are 6, 9, 12, and 15 percent. Other percentages may be used. As of the latest revision of this standard, there are no true pre-calciner plants in the State of Oklahoma.

Determine the recommended percentage of stabilization additive based on the unconfined compressive strength of the specimens. Using the cured samples, select an additive percentage that gives a minimum increase of 50 psi, but no more than 150 psi, above the unconfined compressive strength of the untreated soil. Using the immersed samples, select an additive percent that gives a minimum increase of 50 psi above the unconfined compressive strength of the untreated sample. Use the higher of the two values.

C) For Lime Stabilization:

Verify the stabilization additive is from an approved source. If the abbreviated mix design procedure is used, determine the recommended percentage of stabilization additive from the table.

The full mix design procedure is the preferred method. In the case of lime stabilization, the full mix design procedure shall follow the requirements of ASTM D6276 ("pH method").

D) Target Density and Optimum Moisture:

Determine moisture-density relationships for the untreated soil and treated soil at each additive percentage, as well as the final recommended percentage of additive, using AASHTO T-99. The moisture-density relationships should be performed on the gradation of material the Unconfined Compressive Strength (UCS) specimens will be molded with. No oversize correction should be applied to the optimum moisture and maximum density values used for compacting UCS specimens. It is our understanding that specimens up to 4 inches in diameter are common. Therefore, as per ASTM D2166 section 7.1, the maximum particle size is 1/6 the diameter (0.66in.) and oversize correction should not be necessary.

However, the Proctor performed for the final recommended percentage of additive is intended for field QC/QA purposes. This Proctor should include the oversize-correction when applicable. If the final recommended percentage of additive happens to be one of the percentages of additive tested for UCS, the oversize correction if applicable should be reported.

E) Specimens for Unconfined Compressive Strength Testing:

Use the appropriate maximum dry density and optimum moisture for each set of specimens at each treatment rate. UCS specimens shall be compacted to 95% of maximum dry density +/- 1 pcf. The UCS specimens shall be within +/- 2% of optimum moisture. These requirements are to replicate field conditions. If the minimum allowable maximum dry density and acceptable range of moisture content is different for a given project, then UCS specimen densities and target moistures shall conform to the project specific requirements accordingly.

Specimen dimensions and maximum particle size shall conform to ASTM D2166. Kneading compaction and static compaction are both acceptable means of sample preparation. Specimens shall be prepared with a minimum of five (5) layers to ensure uniformity; scarify between layers.

F) For Lime Pretreatment:

Use procedure OHD L-51 to determine the percent lime required to modify the material. Mix the soil with the chosen percentage of lime and cure for 72 hours. Determine the group classification of the lime pretreated soil to determine if the pretreatment has changed the material properties of the soil so that it now meets an A-1 through A-6 Group Classification. If yes, follow the mix design procedure in section B to determine the recommended stabilization additive percent. If not, choose a higher lime percentage and repeat.

G) The Mix Design Report shall include the following information, when applicable:

- AASHTO group classification of raw soil.
- Soluble sulfate content of soil.
- Dispersive soil test results, if applicable
- AASHTO group classification of lime pretreated soil (if applicable).
- Unconfined compressive strengths of cured specimens and graph of strength vs. percent additive (if applicable).

- Unconfined compressive strengths, moisture absorption, and graph of strength vs. percent additive of immersed specimens (if applicable).
- Recommended percent stabilization additive and source.
- Source of water used in mix design testing, and soluble sulfate content
- Density and optimum moisture content for raw soil and each percentage of additive (if applicable).
- Density and optimum moisture content for soil containing the recommended percentage of stabilization additive.

H) Soil Stabilization Table

When using the abbreviated laboratory test procedure, the recommended amount of the stabilization additive shall be determined by the AASHTO Group Classification as detailed in the following table.

SOIL STABILIZATION TABLE												
ADDITIVE (Expressed as a percentage added on oven-dry basis)	SOIL GROUP CLASSIFICATION - AASHTO M-145											
	A-1		A-2				A-3	A-4	A-5	A-6	A-7	
	A-1-a	A-1-b	A-2-4	A-2-5	A-2-6	A-2-7					A-7-5	A-7-6
PORTLAND CEMENT	4	4	4	4	4	4	5	✓	✓	✓		
FLY ASH					12	12	13	14	14	14		
CEMENT KILN DUST (Pre-Calcliner Plants)	5	5	5	5	5	5	6	✓	✓			
CEMENT KILN DUST (Other Type Plants)	10	10	10	11	11	11	12	12	12			
HYDRATED LIME*										4	5**	5**

A blank in the table indicates the additive is not recommended for that soil group. Recommended amounts include a safety factor for loss due to wind, grading, and/or mixing. Pre-Calcliner plants are identified on the Materials Division approved list for cement kiln dust.

✓ = Mix Design Required

* = Reduce quantity by 20% when quick lime is used, i.e. 4% x 0.8 = 3.2%, 5% x 0.8 = 4.0%, 6% x 0.8 = 4.8%

** = Use 6% when the liquid limit is greater than 50.

Revision Date	Revision Description
10/20/06	Soil Stabilization Table revised to split Cement Kiln Dust into two types and provide recommended percentages for each type. Changed recommended percentages for most entries in the table
	In Section B, changed suggested percentages to use for laboratory mix design. Deleted higher strength requirement for Portland cement. Deleted rock adjustment. Target density and optimum moisture moved to Section D.
	In Section C, deleted rock adjustment. Target density and optimum moisture moved to Section D.
	Added new Section D and renumbered remaining sections.
	In Section E, added option to choose a higher lime percentage and repeat.
07/28/09	Revised description at beginning of procedure.
	Soil Stabilization Table moved from beginning to new Section G. Revised recommended percentages for cement kiln dust and fly ash.
06/18/2019	Requirement of a geotechnical engineer is specified in the first paragraph. Specifying the full mix design procedure as the preferred method is specified and reiterated throughout. Various formatting updates.
05/27/2021	<p>Section A: Renamed and divided into three subsections. Expanded and clarified sections on sulfate and dispersive soil testing. Added sulfate testing for construction water. Added equation to calculate combined soluble sulfates. Mentioned mellowing as possible option for high sulfates. Added Double Hydrometer as a screening test for dispersive soils. Removed redundant caution for treating soils from District 6 with lime.</p> <p>Section B: Added paragraph on construction water. Removed note on gradation for Proctor and Harvard Miniature specimens. Added sentence noting absence of pre-calciner plants in Oklahoma.</p> <p>Section D: Revised language dealing with oversize correction, and allowing UCS specimens up to 4-inch diameter.</p> <p>Section E: New section E providing more detail on UCS specimens.</p> <p>Section F: Substituted a reference to OHD L-51 in lieu of reducing percentage require for stabilization.</p> <p>Section G: Added required reporting for dispersive clay results, UCS tests, mixing water testing, and Proctor results for each percent additive.</p> <p>Editorial and formatting changes throughout.</p>