LIME
Technical Brief
The Versatile Chemical

Mixture Design and Testing Procedures for Lime Stabilized Soil

Steps for Mixture Design and Testing for Lime Stabilized Soil

Evaluate soil to gain a general understanding of its suitability for lime stabilization.

Determine minimum amount of lime required for stabilization.

Evaluate lime-stabilized soil strength for long term durability within its exposure environment, with special attention to cyclic freezing and thawing and periods of extended soaking.

If soils to be stabilized are expansive, evaluate using capillary soaking and expansion measurements.

The use of lime to dry, modify, and stabilize soil is a well established construction technique, documented in studies dating back to the 1950s and 1960s [see Ref. 1]. A variety of mixture proportioning procedures have evolved, as various agencies have developed criteria and procedures to fit their specific design needs and objectives, often reflecting local conditions and experience [1].*

The procedures outlined in this publication are intended for soil that is to be stabilized with lime, not merely dried or modified. These procedures are intended to help ensure the long term strength and durability of a lime stabilized soil and are not typically required when soil drying and modification is the desired goal. Other laboratory tests, such as measuring decrease in soil moisture content or reduction in plasticity index (PI), are more appropriate when soil drying/modification is the intended result.

In 1999, the National Lime Association commissioned Dr. Dallas Little to evaluate various procedures and develop a definitive lime stabilization mixture design and testing procedure (MDTP) that specifying agencies, design engineers, and laboratory personnel could use with confidence for soil conditions and environmental exposures throughout the United States. The resulting series of reports summarize the literature on lime stabilization [2, 3]; describe mix proportioning and testing procedures for lime stabilized soil [4]; and present a field validation of the protocol [5].

Lime-Treated Soil – Drying, Modification, and Stabilization

Lime has a number of effects when added into soil [6, 7], which can be generally categorized as soil drying, soil modification, and soil stabilization:

- Soil drying is a rapid decrease in soil moisture content due to the chemical reaction between water and quicklime and the addition of dry material into a moist soil. [8]
- Modification effects include: reduction in soil plasticity, increase in optimum moisture content, decrease in maximum dry density, improved compactability, reduction of the soil's capacity to swell and shrink, and improved strength and stability after compaction. These effects generally take place within a short time period after the lime is introduced – typically 1 to 48 hours – and are more pronounced in soils with sizable clay content, but may or may not be permanent.
- Lime stabilization occurs in soils containing a suitable amount of clay and the proper mineralogy to produce long-term strength; and permanent reduction in shrinking, swelling, and soil plasticity

** Construction techniques are not addressed in this publication--see Ref. 6.*

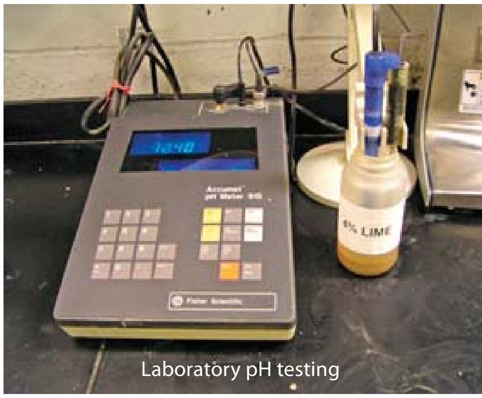
with adequate durability to resist the detrimental effects of cyclic freezing and thawing and prolonged soaking. Lime stabilization occurs over a longer time period of "curing." The effects of lime stabilization are typically measured after 28 days or longer, but can be accelerated by increasing the soil temperature during the curing period. A soil that is lime stabilized also experiences the effects of soil drying and modification.

Lime Stabilization Mix Design and Testing Procedures

The procedures outlined in this document are to evaluate if a soil can be stabilized with lime and, if so, determine the minimum amount of lime required for long-term strength, durability and the other desired properties of the stabilized soil. This is achieved by:

- Initially evaluating the soil to gain a general understanding of its suitability for lime stabilization.
- Determining the minimum amount of lime required for stabilization.
- Evaluating the lime-stabilized soil strength for long term durability within its exposure environment, with special attention to cyclic freezing and thawing and periods of extended soaking.
- If the soils to be stabilized are expansive, evaluate using capillary soaking and expansion measurements.

Steps for Mixture Design and Testing for Lime Stabilized Soil



Laboratory pH testing

Step 1 – Initial Soil Evaluation

Purpose: Evaluate key soil characteristics as an initial step to determine if it is suitable for lime stabilization.

Procedure: Use ASTM C136 [10] procedures to determine the amount of soil passing the 75 micron (75-μm) screen and ASTM D 4318 (wet method) [11] to determine the soil plasticity index (PI).

Criteria: Generally, soil with at least 25% passing a 75 micron screen and having a PI of 10 or greater are candidates for lime stabilization. Some soils with lower PI can be successfully stabilized with lime, provided the pH and strength criteria described in this document can be satisfied.

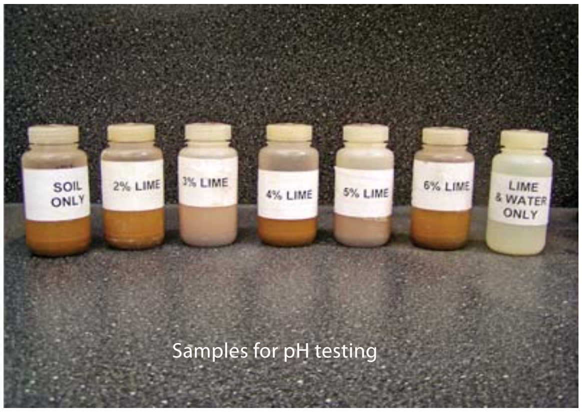
Additional Considerations: Soil with organics content above 1-2% by weight as determined by ASTM D 2974 [12] may be incapable of achieving the desired unconfined compressive strength for lime stabilized soil (Step 6) [13]. Soils containing soluble sulfates greater than 0.3% can be successfully stabilized with lime, but may require special precautions (see NLA's "Technical Memorandum – Guidelines for Stabilization of Soils Containing Sulfates" Ref. 14 for more information).

Step 2 – Determine the Approximate Lime Demand

Purpose: Determine the minimum amount of lime required for stabilization.

Procedure: Use ASTM D 6276 [15] procedures. This is also known as the "Eades-Grim" test.

Criteria: The lowest percentage of lime in soil that produces a laboratory pH of 12.4 [flat section of the pH vs. lime percentage curve produced by the test] is the minimum lime percentage for stabilizing the soil.



Samples for pH testing

Additional Considerations: ASTM D 6276 has additional provisions for cases in which the measured laboratory pH is 12.3 or less. Note that lime can react with moisture and carbon dioxide. Careful storage is required to maintain lime's integrity and produce reliable results.

Step 3 – Determine Optimum Moisture Content and Maximum Dry Density of the Lime-Treated Soil

Purpose: Determine optimum moisture content (OMC) and maximum dry density (MDD) of the soil after lime has been added. This is necessary because adding lime will change the soil's OMC and MDD.


Lab mixing of soil & lime

Procedure: Make a mixture of soil, lime, and water at the minimum percentage of lime as determined from Step 2 (Eades-Grim test), using a water content of OMC + 2-3%. Seal the mixture in an airtight, moisture proof bag stored at room temperature for 1-24 hours. Determine the OMC and MDD of the mixture using ASTM D 698 procedures (standard compaction effort) [16].

Criteria: Determine the OMC and MDD for Step 4.

Additional Considerations: When using quicklime, the mixture should be stored for 20-24 hours to ensure hydration.

Step 4 – Fabricate Unconfined Compressive Strength (UCS) Specimens

Purpose: Fabricate test specimens for UCS testing (Step 6).

Procedure: Using ASTM D 5102 [17] procedure B, fabricate a minimum of two test specimens of lime, soil and water using the amount (percentage) of lime determined from Step 2 at the OMC (± 1%) as determined from Step 3. The soil-lime-water mixture should be stored in an airtight, waterproof bag for 1-24 hours prior to fabricating the test specimens.

Desired Result: A minimum of two specimens for UCS testing.


Making Proctor specimen

Additional Considerations: When using quicklime, the mixture should be stored for 20-24 hours to ensure hydration. Additional specimens may be fabricated if additional testing is desired. In some cases it may be advisable to make test specimens at higher lime content(s) than that determined from ASTM D 6276 testing (Step 2). These additional specimens can be used to determine the UCS of lime-soil-water mixtures at higher lime contents. For instance, if ASTM D 6276 testing (Step 2) indicates that 4% lime is needed, additional UCS testing could be done at 5% and 6% lime to ensure that the UCS criteria (Step 6) is also achieved.

Step 5 – Cure and Condition the Unconfined Compressive Strength (UCS) Specimens

Purpose: Approximate, in an accelerated manner, field curing and moisture conditions.


Soaking specimens

Procedure: Immediately following the fabrication of the test specimens, wrap the specimens in plastic wrap and seal in an airtight, moisture proof bag. Cure the specimens for 7 days at 40°C. Subject the specimens to a 24 hour capillary soak prior to testing.

The capillary soaking process should be done by removing the specimens from the airtight bag, then removing the plastic wrapping. The specimens are wrapped with wet absorptive fabric and placed on a porous stone. The water level should reach the top of the stone and be in contact with the fabric wrap throughout the capillary soak process, but the soil specimen should not come directly into contact with the water.

Desired Result: A minimum of two cured and moisture conditioned specimens for UCS testing.

Step 6 – Determine the Unconfined Compressive Strength (UCS) of the Cured and Moisture Conditioned Specimens


Unconfined compressive strength test (ASTM D5102)

Purpose: To determine the UCS of the lime-stabilized soil to ensure adequate field performance in a cyclic freezing and thawing and an extended soaking environment.

Procedure: Use ASTM D 5102 procedure B to determine the UCS of the cured and moisture conditioned specimens. The UCS is the average of the test results for a least two specimens.

Criteria: The minimum desired UCS depends on the intended use of the soil, the amount of cover material over the stabilized soil, exposure to soaking conditions, and the expected number of freezing and thawing cycles during the first winter of exposure. Suggested minimum UCS are shown in the following table.

Soil-Lime Mixture Unconfined Compressive Strength Recommendations [18]				
Anticipated Use	UCS Recommendations for Various Anticipated Service Conditions			
	Extended Soaking for 8 Days (psi)	Cyclic Freeze-Thaw[a]		
		3 Cycles (psi)	7 Cycles (psi)	10 Cycles (psi)
Subbase				
Rigid Pavement/ Floor Slabs/ Foundations	50	50	90	120
Flexible Pavement (> 10 in.)[b]	60	60	100	130
Flexible Pavement (8 in -10 in.)[b]	70	70	100	140
Flexible Pavement (5 in. – 8 in.)[b]	90	90	130	160
Base				
	130	130	170	200

Notes:

a – Number of freeze-thaw cycles expected in soil-lime layer during the 1st winter of exposure.

b – Total pavement thickness overlying the subbase.

Step 7 – Determine the Change in Expansion Characteristics [only for expansive soils]

Purpose: To evaluate the expansiveness of lime stabilized soils.

Procedure: Note the vertical and circumferential dimensions of the samples fabricated in Step 5 prior to performing the capillary soak. After soaking, perform new measurements using a caliper for the vertical dimension and a pi-tape for the circumference. Calculate the volume change between the initial (dry) condition and the soaked condition.

Criteria: Three-dimensional expansion of between 1 and 2% is commonly regarded as acceptable.

Additional Considerations: If the expansion exceeds the design parameter, fabricate additional samples increasing the lime content by 1 and 2% and repeat the test. If additional expansion, shrinkage, and uplift pressure data is desired, perform ASTM D3877 [19]. This step is applicable only to expansive soils.

Other Considerations

The procedures outlined in this document can be used to determine whether a soil can be stabilized with lime and, if so, to quantify the minimum amount of lime required to produce long-term strength, durability, and the other desired properties of a lime-stabilized soil. Typical construction specifications require 0.5 - 1.0 percent more lime than suggested by laboratory procedures, to account for differences between lab and field techniques (for example, field gradation vs. controlled lab pulverization) and field variability.

Other characteristics and properties of the soil, both untreated and lime-treated, may be important for engineering design, construction, and quality control. These characteristics and properties may include, for example: moisture content, moisture reduction, gradation, soil classification, Atterberg limits, organic content, soluble sulfate content, strength characteristics and indices such as CBR, modulus of resilience (Mr), modulus of subgrade reaction (k), R-value, shear strength, and bearing strength. The effect of lime to improve many of these soil properties and characteristics is often substantial, but beyond the scope of this document. They should however, be evaluated as required on a project by project basis.

References

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10. ASTM C136 "Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates." (www.astm.org)

11. ASTM D4318 "Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils." (www.astm.org)

12. ASTM D2974 "Standard Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils." (www.astm.org)

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14. "Technical Memorandum–Guidelines for Stabilization of Soils Containing Sulfates," 2000. (http://www.lime.org/sulfate.pdf)

15. ASTM D6276 "Standard Test Method for Using pH to Estimate the Soil-Lime Proportion Requirement for Soil Stabilization." (www.astm.org)

16. ASTM D698 "Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort" Note that some jurisdictions require modified compaction, D1557. (www.astm.org)

17. ASTM D5102 "Standard Test Method for Unconfined Compressive Strength of Compacted Soil-Lime Mixtures" (www.astm.org)

18. Excerpted from Reference 2, Table 3, page 36 (after Thompson, 1970).

19. ASTM D3877 "Standard Test Methods for One-Dimensional Expansion, Shrinkage, and Uplift Pressure of Soil-Lime Mixtures" (www.astm.org).

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