Mixture Design Procedures for Lime Stabilized Soil

ODOT GCW – 5/13/09
CL&S Lime Plants and Terminals

PLANTS
1.....Blind River, Ontario
2.....Dundas, Ontario
3.....Beachville, Ontario
4.....River Rouge, MI
5.....Manitowoc, WI
6.....South Chicago, IL
7.....Gary, IN
8.....Millersville, OH
9.....Maple Grove, OH
10...Grand River, OH
11...Annville, PA
12...Winchester, VA
13...Strasburg, VA
14...Black River, KY
15...Maysville, KY
16...Longview, AL
17...Macon, GA

TERMINALS
A.....Baton Rouge, LA Terminal
B.....Tampa Terminal, Tampa, FL
C.....Fort Lauderdale Terminal, FL
D.....Sanford Terminal, FL
E.....Jacksonville Terminal, FL
F.....Brunswick Terminal, GA
G.....Raleigh Terminal, NC
H.....Richmond Terminal, VA
I.....Hagerstown Terminal, MD
J.....Detroit Terminal, MI

- Dolomitic Lime
- High Calcium Lime
- Hydrator
- Terminals
CaCO$_3$ + MgCO$_3$ $\rightarrow$ CaO + MgO + CO$_2$

CaO + MgO --- “Quicklime”
Lime Products for Treating Soil at the Construction Site

Quicklime:
- Total Oxides ≈ 90% CaO/MgO
- Meets ASTM C977

EnviroLime (Lime Kiln Dust)
Total Oxides ≈ 18% - 30%
Alumina & Silica Oxide ≈ 7% - 15%
Lime Treatment Options

Drying up wet soil:
  – Plasticity and swell reduction

Modification:
  – Plasticity and swell reduction
  – Improved stability and compaction
  – Solid working platform

Stabilization:
  – Permanent strength increase
  – Long-term strength gains
  – Less moisture absorption
  – Freeze-thaw durability
Pozzolanic Reactions Using Lime (Clay Soil)

On-going reaction with available silica and alumina in the soil forms complex cementitious materials (the POZZOLANIC effect.)
Lime-Soil Pozzolanic Action
STATE OF OHIO
DEPARTMENT OF TRANSPORTATION
SUPPLEMENT 1120
Mixture Design for Chemically Stabilized Soils
July 20, 2007
Mixture Design and Testing Procedures for Lime Stabilized Soil

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].

Procedures developed by Dr. Dallas Little, Texas A&M University
Requirements for Lime Stabilization

1. Right Combination of Materials
   - Clay contains silica and alumina → Lime
   - Silt and sand → LKD

2. Adequate Lime to Keep Pozzolanic Action Going

3. Adequate Strength to Resist Freeze-Thaw

4. Adequate Compaction and Moisture
Lime Based Mix Designs for Different Soil Types

| Soil Type | Travels and gravel sand or no fines | Gravel and gravel little or no fines | Gravel-sand-silt mixtures | Sands and gravelly sands, no fines | Sand-silt mixtures | Sand-clay mixtures | Clayey gravels, gravel-sand-clay mixtures | Well-graded sands and gravelly sands, little or no fines | Poorly graded sands and gravelly sands, little or no fines | Silty sands, sand-silt mixtures | Clayey, sands, sand-clay mixtures | Inorganic silts, very fine sands, rock flour, silty or clayey fine sands | Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays | Organic silts and organic silty clays of low plasticity | Inorganic clays of high plasticity, fat clays | Peat, muck, and other highly organic soils |
|-----------|-----------------------------------|--------------------------------------|---------------------------|----------------------------------|----------------|----------------|------------------------------------------|-----------------------------------------------|-----------------------------------------------|-------------------------|--------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|
| AASHTO Group Classification | A-1-a | A-1-a | A-1-b | A-1-b | A-1-b or A-3 | A-2-4 or A-2-5 | A-2-6 or A-2-7 | A-4 | A-6 | A-4 | A-5 | A-7-6 | A-7-5 | A-8 |
| Recommended Additives | LIME (Stabilization & Modification) | LIME PLUS TYPE "F" Coal Fly Ash (Stabilization) |

Lime stabilization should be considered when:
- Soil PI > 10   and
- % passing #200 > 25%
Requirements for Lime Stabilization

Right Combination of Materials

- Clay contains silica and alumina → Lime
- Silt and sand → LKD

Adequate Lime to Keep Pozzolanic Action Going

Adequate Strength to Resist Freeze-Thaw

Adequate Compaction and Moisture
Strength Changes with Time and Temp

"Autogenous Healing"
Laboratory Evaluations for Lime Stabilization

1. pH Determination for Minimum Lime Content:
   - ASTM D 6276 (Eads – Grim Test)
   - Min amount of lime to raise soil pH level to 12.4

2. Optimum Moisture Content
   - ASTM D 698 (Standard Proctor Density)
   - Generally increases with lime or LFA

3. Unconfined Compressive Strength
   - ASTM D 5102
   - Minimum of 100 psi
   - Freeze-thaw durability
• In place moisture content
• Particle size analysis
• Liquid limits, plastic limit, PI
• Soil classification
• *Optimum moisture content*
Laboratory Evaluations for Lime Stabilization

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Mix Design for Lime Stabilization

pH Determination for Minimum Lime Content:

- ASTM D 6276 (Eads – Grim Test)
- Min amount of lime to raise soil pH level to 12.4
ASTM D 6276 - Significance & Use

What the test does:

The soil-lime pH test is performed as a test to indicate the soil-lime proportion needed to maintain the elevated pH necessary for sustaining the reactions necessary to stabilize soils (i.e., the min. % of lime required to raise the soil’s pH to 12.4).

What the test does not do:

The test provides no reliable information relative to the potential reactivity of a particular soil, nor will it provide information on the magnitude of increased strength realized upon treatment of this soil with the indicated percentage of lime.
Caution (pH meter):

Not all pH meters are created equal!!! – 1120.03 Sec A

To ensure the best test results, look for the following specifications when selecting a pH meter to use for this test:

Specifications:
- Memory function stores up to 50 sets of customizable pH, mV, or relative mV with the temperature at the time of the reading
- For more accurate results, pH calibration can be done using one, two or three-point, auto-buffer recognition or by choosing USA or NIST* buffer sets
- pH mode: 0.00 to 14.00pH; with a resolution of 0.01pH with accuracy of ±0.01pH
- Temperature: 0.0° to 100.0°C with a resolution of 0.1°C and an accuracy of ±0.3°C
ASTM D 6276 (Eads – Grim Test)

pH = 12.4
Laboratory Evaluations for Lime Stabilization

1. pH Determination for Minimum Lime Content:
   - ASTM D 6276 (Eads – Grim Test)
   – Min amount of lime to raise soil pH level to 12.4

2. Optimum Moisture Content
   – ASTM D 698 (Standard Proctor Density)
   – Generally increases with lime or LKD

3. Unconfined Compressive Strength
   – ASTM D 5102
   – Minimum of 100 psi
   – Freeze-thaw durability
Lime Changes Optimum Moisture Content

OMC = 17%
OMC = 21%
Laboratory Evaluations for Lime Stabilization

1. pH Determination for Minimum Lime Content:
   - ASTM D 6276 (Eads – Grim Test)
   – Min amount of Lime to raise soil pH level to 12.4

2. Optimum Moisture Content
   – ASTM D 698 (Standard Proctor Density)
   – Generally increases with lime or LKD

3. Unconfined Compressive Strength
   – ASTM D 5102
   – Minimum of 100 psi
   – Freeze-thaw durability
Mix soil, lime and water at OMC for UCCS specimens
Compacted at OMC for UCCS specimens
Expansion Testing (ODOT 1120.06)

• Measure the height and circumference of the UCS specimens after curing (dry) and then measure again after 24 hour Capillary Soak Test.

• Report in percentage if the change of initial (dry) and soaked exceeds 1.5%

• This is NOT a NLA required test and typically shows NO real value to the mix design procedure.
Cure the UCCS Specimens for 7 days @ 40 °C
Strength Required for Durability (ODOT)

Unconfined Compressive Strength after 7 day cure at 40 C and 24 hour Capillary Soak:
- 50 psi greater than UCS with no Lime
- Minimum 100 psi
Laboratory Evaluations for Lime Stabilization

1. pH Determination for Minimum Lime Content:
   - ASTM D 6276 (Eads – Grim Test)
   - Min amount of Lime to raise soil pH level to 12.4

2. Optimum Moisture Content
   - ASTM D 698 (Standard Proctor Density)
   - Generally increases with lime or LFA

3. Unconfined Compressive Strength
   - ASTM D 5102
   - Minimum of 100 psi before freezing
   - Freeze-thaw durability
Differences When Testing LKD

• No 24 hour mellowing period – Why?
• Increased strength requirements – 150 psi vs. 100 psi – Why?
• Curing procedures remain the same.
Typical laboratory mistakes

• Compaction of OMC/MDD and UCS specimens prior to a 24 hour mellow period. Inadequate hydration of Lime can lead to poor OMC/MDD results and poor UCS.
• pH meter not equipped to reach a reading higher than 12.4.
• pH buffer solutions not up to 12.45 and may be expired.
• Mixing Lime, soil, and water by hand and not using a mixer. Inadequate dispersion of Lime throughout the mix.
• Old Lime. Lime is a perishable and needs to be “fresh” for mix design. 60 days typical.
Outside Comments

- “Eads-Grim pH test is designated for Quicklime and Hydrated Lime. Sometimes it is very difficult to achieve a pH of 12.4 when using LKD.” – Why?
- “When bidding the testing, it seems to be difficult to get a grasp on how many actual test need to be performed because we don’t know how many soil types are on a given project. Bidding this item as a unit price would be much easier and competitive (Price per soil type).”
- “Time seems to be a very limiting factor to the specification.”
- “We have never seen any results from the swell test.”
Requirements for Lime Stabilization

1. Right Combination of Materials
   • For Lime, PI > 10 and % passing #200 > 25%

2. Adequate Lime to Keep Pozzolanic Action Going
   • pH = 12.4 (per ASTM D 6276)

3. Adequate Compaction and Moisture
   • With Lime, the OMC increases, MDD decreases

4. Adequate Strength to Resist Freeze-Thaw
   • UCS > 100 psi (after 7 days @ 40°C curing, 24-hr cap. soak)
Lime Treatment Options

Drying up wet soil:
  – Plasticity and swell reduction

Modification:
  – Plasticity and swell reduction
  – Improved stability and compaction
  – Solid working platform

Stabilization:
  – Permanent strength increase
  – Long-term strength gains
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Any Questions?