

LIME TREATED SOILS SAVE TIME & MONEY

This booklet provides information to the construction professional who needs an effective and economical means for dealing with unstable soils. Lime can be used to dry, temporarily modify, or permanently stabilize soils. Lime is a unique product capable of providing a variety of benefits.

Benefits of Lime Treatment

Drying with Lime

- Minimizes weather-related construction delays
- Extends construction season
- Acts quickly—allowing return to work in hours

Lime Modification

- Speeds construction with stable working platform that resists subsequent rain
- Maximizes use of low cost, on-site materials
- Reduces plasticity
- Improves compactability
- Permits reworking

Lime Stabilization

- Chemically transforms clay soils
- Permanently increases strength
- Eliminates soil expansion
- Creates excellent freeze-thaw resistance
- Resists cracking
- Reduces thickness of overlying pavement layers, saving money
- Permits reworking
- Maximizes use of low cost, on-site materials

This booklet briefly summarizes each type of lime treatment, why it is used, and how it performs. More details are available from [lime companies](#) and from [other publications](#).

Lime Dries Wet Soils

Because quicklime chemically combines with water, it can be used very effectively to dry any type of wet soil. Heat from this reaction further dries wet soils. The reaction with water occurs even if the soils do not contain significant clay fractions. When clays are present, lime's chemical reactions with clays increase the moisture-holding capacity of the soil, which reduces free liquids and causes further drying.

The net effect is that drying occurs quickly, within a matter of hours, enabling more rapid site access and soil compaction than by

HIGHLIGHTS:

- Lime *drying* of wet soils minimizes weather-related construction delays.
- Lime *modification* chemically transforms clay soils into friable, workable, compactable material.
- Lime *stabilization* creates long-term chemical changes in unstable clay soils to create strong, but flexible, permanent structural layers in pavement systems and other foundations.

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Before and after lime treatment to dry soils

waiting for the soil to dry through natural evaporation. “Dry-up” of wet soil at construction sites is one of the widest uses of lime for soil treatment. Generally, between 1 and 4 percent lime by mass of dry soil will improve a wet site sufficiently to allow construction activities to proceed.

Lime Modifies Clay Soils

On many construction sites there is a need for short-term soil *modification* to temporarily strengthen the working area. The benefits of modified soils include:

1. Making clay soils friable and easier to handle.
2. Providing a working platform for subsequent construction.
3. Reducing plasticity to meet specifications.
4. Conditioning the soil for further treatment.
5. Spot treatment of spongy subsoil areas.

After initial mixing, the calcium ions (Ca^{++}) from the lime migrate to the surface of the clay particles and displace water and other ions. The soil becomes friable and granular, making it easier to work and compact. At this stage the Plasticity Index of the soil decreases dramatically, as does its tendency to swell and shrink. The process, which is called “flocculation and agglomeration,” generally occurs in a matter of hours.

Small amounts of lime, such as 1 to 4 percent by mass of dry soil, can upgrade many unstable fine-grained soils. With heavy clay soils, additional lime may be necessary for these purposes. Modification improvements are generally temporary and will not produce permanent strength in clay soils.



Clay soil, before and after lime modification



Lime flocculating clay

Lime Permanently Stabilizes Clay Soils

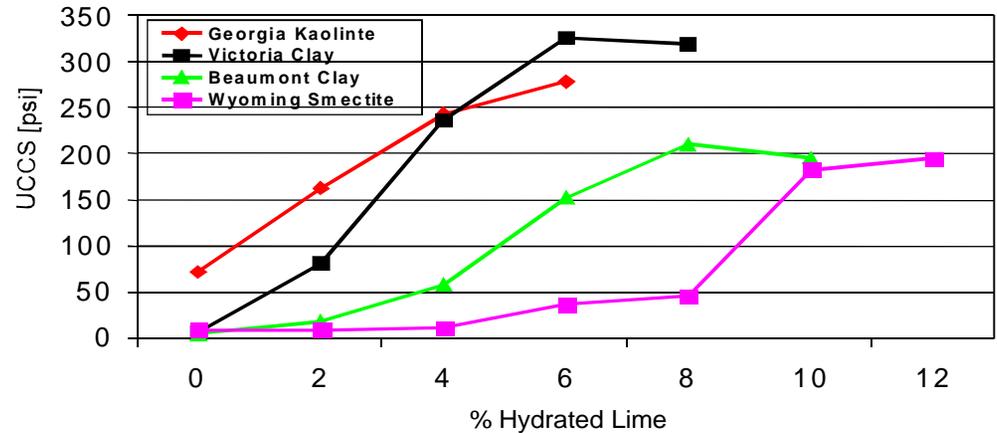
In contrast to lime modification, lime *stabilization* creates long-lasting changes in soil characteristics that provide structural benefits. Lime is used in stabilizing and strengthening subgrades (or subbases) and bases below pavements. Non-pavement applications for lime treatment include building foundations and embankment stabilization.



Test demonstrating stability created by lime stabilization

Lime stabilization chemically changes most clay soils:

1. Markedly reduces shrinkage and swell characteristics of clay soils.
2. Increases unconfined compressive strength by as much as 40 times.
3. Substantially increases load-bearing values as measured by such tests as CBR, R-value, Resilient Modulus, and the Texas Triaxial tests.
4. Develops beam strength in the stabilized layer and greatly increases the tensile or flexural strength.
5. Creates a water-resistant barrier. Impedes migration of surface water from above and capillary moisture from below; thus helping to maintain foundation strength.
6. In addition to lowering the plasticity in most cases and initially strengthening the improved soil, the strengthening effect increases over time.



Lime stabilization increases unconfined compressive strength (UCCS)

When adequate quantities of lime and water are added, the pH of the soil quickly increases to above 10.5, which enables the clay particles to break down. Silica and alumina are released and react with calcium from the lime to form calcium-silicate-hydrates (CSH) and calcium-aluminate-hydrates (CAH). These compounds form the matrix that contributes to the strength of lime-stabilized soil layers. As this matrix forms, the soil is transformed from its highly expansive, undesirable natural state to a more granular, relatively impermeable material that can be compacted into a layer with significant load bearing capacity. In a properly designed system, days of mellowing and curing produce years of performance. The controlled pozzolanic reaction creates a new material that is permanent, durable, resistant to cracking, and significantly impermeable. The structural layer that forms is both strong and flexible.

Lime addition of three to six percent by mass of the dry soil is the customary range for lime stabilization in road foundations. Precise amounts should be determined through mix design and testing protocols—see [NLA's model protocol](#).

Performance

Lime's success in stabilizing troublesome soils over many years has been well documented.

- ❑ Lime stabilization was successfully used for the construction and expansion of the Denver International Airport in 1991-1993 and more recently in 2003. Lime has been used over the past 30 years for the construction and expansions of the Dallas-Fort Worth International Airport. Nine inches of lime-treated subgrade underlies runways and taxiways and 18 inches of lime-treated subgrade provides support under terminal aprons. For the recent Houston International Airport expansion, the pavement system included a 24-inch lime stabilized subbase and a lime/cement/fly ash base.
- ❑ Lime-stabilized layers can create cost-effective design alternatives. A recent interstate highway project in Pennsylvania, for example, began with a \$29.3 million traditional design approach. The pavement engineers evaluated—and ultimately used—an alternate design incorporating lime stabilization, consistent with mechanistic-empirical designs, that cost only \$21.6 million—more than a 25 percent savings.
- ❑ The construction of a 14 acre General Motors assembly plant in Arlington, Texas substituted lime stabilization for 39 inches of aggregate fill, saving hundreds of thousands of dollars and enabling the contractor to achieve aggressive milestones on the fast track project.
- ❑ A Kentucky study of twenty subgrade sections of between 8 and 15

years of age found that subgrades mixed with hydrated lime, Portland cement, a combination of hydrated lime and Portland cement, or lime kiln dust (LKD) had substantially greater bearing strength than untreated subgrades. The study concludes “chemical admixture stabilization is a good, durable and economical technique for improving subgrade strengths.” Texas and Mississippi are other states that have long histories of lime stabilization of pavement subgrades.

Quicklime and hydrated lime are products manufactured to specification from select, chemical-grade limestone. In the U.S., lime is the fifth largest commodity chemical—more than 21 million short tons were manufactured in 2003 and more than 1.8 million tons were used for soil treatment. Lime manufacturing facilities are located throughout the U.S. and Canada. More information is available from the National Lime Association at www.lime.org.

Construction Procedures

The goal of lime treatment for drying is to mix lime with the wet soil to create chemical reactions between the soil, water, and lime to remove standing water and transform unstable wet soils into workable materials. After spreading the lime, disc harrows alone may be adequate for mixing in extremely wet situations, but rotary mixers are still preferred for heavier soils.

The construction steps in lime modification and lime stabilization are similar. In general, lime stabilization requires more thorough processing and job control than lime modification. Basic steps in both activities treat the soil to a prescribed depth.

Subgrade and subbase stabilization measures include scarifying, partial pulverization, lime spreading, watering (which might not be necessary when lime slurry has been used), mixing, and compaction to a specified density. Construction practices are discussed in more detail in [NLA's Lime-Treated Soil Construction Manual](#).

Conclusions

Lime treatment of soils is a proven method to save time and money on construction projects. Lime drying of wet soils minimizes weather-related construction delays and permits a return to work within hours. Lime modification chemically transforms clay soils into friable, workable, compactable material. Lime stabilization creates long-term chemical changes in unstable clay soils to create strong, but flexible, permanent structural layers in pavement systems and other foundations. Further reference and design documents are available on the National Lime Association website, www.lime.org.

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