Soil Stabilization

No road is stronger than its base. More and more it is the base course and sub grade of road construction that is occupying the attention of highway engineers. Often, highly designed thick pavements and rolled stone base courses built on unstable clay sub grades are suspect. Lime can be used to totally stabilize such clay sub bases.

Lime's reaction with soils is twofold. First, it agglomerates the fine clay (minus 40 mesh) particles into coarse, friable particles (silt sand sizes) through ion exchange of calcium replacing sodium, potassium and hydrogen ions. Next, it provides a cementing action in which the lime reacts chemically with available silica and alumina in the raw soil, forming complex calcium silicates and aluminates. These calcium silicate hydrates and calcium aluminate hydrates are the same cementing agents found in cement. Therefore, the soil cemented together for curing.

Lime reacts with all clay soils having a Plasticity Index (P.I.) of from 8 to 50 +. For soils have a lower P.I. than 8 such as low plastic sand and silt, lime and fly ash combinations may be employed to stabilize such soils with pozzolans mix. In soil Stabilization, lime alters the physical characteristics of clay bearing soils transforming them into stable material for road durability and strength. The following are the changes noted:

1. Plasticity Index decreases sharply.
2. The Plastic Limit increases and the Liquid Limit decreases.
3. The soil diner, clay and silt sizes, decreases because of agglomeration.
4. The lineal shrinkage and swell drop markedly.
5. Lime and water accelerate disintegration of clay clods during pulveration.
6. Unconfined compressive strength increases considerably.
7. Load bearing values (CBR) and triaxle strength increase substantially.
8. Lime facilitates drying of the soil by displacing water holding sodium.
9. Lime stabilized sub bases resist water penetration by forming barriers to moisture.

Ref.: Chemistry and Technology of Lime and Limestone, R. S. Boynton, Wiley & Sons, 2nd Ed.

Lime Stabilization Procedures in Place Mixing

In-place mixing may involve any of the following procedures:

1. Add a single increment of lime to soils easily pulverized and mixed. Mixing and compaction is done in one operation with no mellowing (curing) period required.
2. Add a single increment of lime and allow the mixture to mellow after compaction for about 1 to 7 days in order to break down the heavy plastic clay and facilitate mixing.
3. Add a single increment of lime as a pretreatment of soil prior to adding a 2nd stabilizer such as cement, fly ash, or asphalt.
4. Add a single increment of lime to modify the soil so that the soil will act as a working table for further construction.
5. Add two increments of lime in difficult to pulverize soils with a period of mellowing.
6. Add lime in a deep lift accomplished in two or more approaches.

Soil Preparation for Lime Application

The sub grade soil must be brought to final grade and alignment. Grade elevation may need adjustment due to fluff action of the lime-stabilized layer resulting from the fact that some soils tend to increase in volume with lime addition. Trimming can be accomplished by blading the material into the shoulder of the slopes. This fluff is due to significant flocculation of the soil and not swells through hydration of clays. This fluff is a beneficial change in that swell potential is increases and shear strength is increased. For lime slurry application, the sub grade or road bed should be scarified to a depth of at least four inches to allow deep penetration of the slurry and to allow the slurry to stay in place.

Determining Amount of Lime to be used for Permanent Stabilization (Not Modification)

The amount of lime to be used for permanent stabilization to the point of forming pozzolans (cementing) may be determined by using the Eades – Grim test for soil reactivity in the appendix of ASTM C977. This test is quick and simple. Further, soil labs may determine lime requirements using unconfined compressive strength charts or Plasticity Index Limits or a combination of both. Generally, unconfined compressive strengths of up to 2550 p.s.i. are desired and Plasticity Index after lime treatment of under 8 is sought.

Slurry Method with Hydrated Lime

Lime slurry is delivered to the job site in 5000 gallon tank trucks with lime laid down with distribution bars. If the lime is about 30% solids, then there is about 3 lbs. of dry lime (calcium hydroxide) per gallon. If the soil requires 10% by volume, 12 inches in depth, then the lime requirement is about 30 lbs. per square yard, or 10 gallons per square yard. Therefore, one 5000gallon truckload will treat approximately 500 square yards. Some lime slurries are delivered in 35 to 40% solids, depending on the processes used in manufacture. The limes should have high viscosity so that the slurry is not watery and will stay in place without draining off the area to be treated. Lime slurry should be placed in soil and result in about 2% above optimum moisture. If the soil is very wet, dry lime placement should be considered.

Advantages of Slurry Lime Application

1. Dust free application in highly populated and environmentally challenged areas.
2. Better distribution is achieved with slurry.
3. Finer particle size of lime contributes to faster, more complete soil reactions.
4. Lime slurry application and sprinkling functions are done with one operation.
5. During summer, slurry application pre-wets the soil and minimizes drying, requiring less mix water.

Disadvantages of Slurry Application

1. Application may be slower.
2. May not be practical with very wet soils.

Pulverization and Mixing

Adequate pulverization and mixing are absolutely essential to achieve satisfactory results with lime stabilization. Heavier, more plastic soils will require multiple pass mixing. Preliminary mixing can be achieved with disk harrows, but final mixing should be done with a rotary mixing. Rotary is preferred due to speed and uniformity. Two-stage mixing consists of mixing, moisture curing for 24 to 72 hours, and final mixing and re-mixing. The first pass is to distribute the lime throughout the soil. The lime treated soil should then be wetted to 2% higher than the optimum to help the breakdown of clay and sealed by lightly compacting with a rubber tire roller to allow curing. Curing should be done at temperatures above 50 deg. F. After mellowing for 24 to 48 hours, the soil is again pulverized to 100% minus 1 inch in diameter and 60% passing a 4 mesh sieve in order to achieve final compaction to proctor specifications. To assure maximum strength and durability, many agencies require at least 95% of AASHTO T-99 density for sub bases and 98% for bases. Sometimes compaction is left to the discretion of the engineers. The road base is then brought to grade using a motor grader and then a surface or base material applied.

Ref.: Handbook for Stabilization of pavement Sub grades and Base Courses with Lime, Dallas N. Little, Kendall/Hunt Publishing Company, Dubuque, Iowa

Lime Quality Control

Quality soil stabilization is achieved by (1) using quality lime reagents, (2) assuring the proper amount of lime is applies, (3) assuring thorough mixing of materials, (4) assuring that adequate pulverization and curing is achieved and finally (5) getting compaction to standards required.

Lime is usually delivered with chemical testing completed by the vendor. Sampling by the contractor is discretionary, but may be taken at the job site from sampling nozzles on the tanker truck. The lime should meet minimum requirements for chemical analysis as set by the contractor or agency purchasing the material. Chemical analysis for Available Lime is to be determined by ASTM C-25, Rapid Lime Index, Sugar Method. Percent solids content of the slurry is determined by weighing a set volume of slurry and determining bulk density and specific gravity of the lime solution. This specific gravity is then compared to a chart which shows percent solids per unit of specific gravity or bulk density at 77 deg. F. or 25 deg. C. The chart is derived by empirical data developed for a specific site and method of manufacture.

As an added control, ASTM D3155-73 has been developed for determining the lime content of uncured soil-lime mixtures. It must be noted, however, than lime left in soils for long periods is already chemically complexed with the soils and will not be found directly as calcium hydroxide. In that case, it might be necessary to analyze the soil for total calcium content as compared with background calcium found in untreated soil.

As a final control, the engineers can use the performance of the lime in creating a lowered Plasticity Index and increased confined compressive strength.