LIME-STABILIZED SOIL FOR USE AS A COMPOST PAD

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Designing a successful compost facility requires consideration of several site and environmental constraints. The site must be far enough from area housing so that risks of dust and odor complaints are minimized. It must be close enough to necessary raw materials and a source of water so that its operation is economically feasible. Finally, the site must possess suitable characteristics(e. g. , slope, drainage, distance) to avoid pollution of local streams, groundwater and wetlands. The On Farm Composting Handbook (1992) states that a compost site should transport leachate and runoff from the site surface so that muddy conditions and odorous pools of standing liquid do not develop. One possibility is to place the compost site on a well-drained soil where distance to groundwater is greater than 5 ft. However, due to the long-term nature of a compost facility and the volumes of material processed yearly, an impervious surface that directs leachate to a treatment area would be more environmentally suitable than a well-drained soil.

Although an impervious pad is considered a luxury, there may be certain situations where regulations demand an impervious pad for which several options are now available. Besides concrete or asphalt, soil stabilization methods are available that produce a hardened, nearly impervious layer capable of supporting all the equipment normally located at a compost facility.

Although not a new concept, soil stabilization has been practiced more frequently in road construction due to excessive costs of aggregate. Depending upon the type of soil, stabilization can be accomplished with lime, lime-fly ash, Portland cement, asphalt or combinations of all. Experience at the Beltsville Agricultural Research Center showed that soil stabilization with quicklime produced a hardened surface that supported wheeled composting equipment 12 months a year (Fig. 1). An average of 10,000 yds^3 of organic by-products were composted annually for the last 3-and- half years at the Beltsville Agricultural Research Center Research Composting facility. The following is a description of the site preparation.

Figure 1. Beltsville Agricultural Research Center. Windrows cover the compost pad and an orchard grass buffer area is seen in the foreground.

SOIL STABILIZATION

Soil stabilization with lime achieves the dual goals of producing an impervious layer so water does not penetrate and a tough all-weather surface that allows vehicular traffic under all conditions. Lime-stabilized soil has a hydraulic conductivity similar to clays, i.e. 10^{-7} cm/sec., preventing leaching of soluble nutrients from composting mixtures through the soil profile. The lime stabilized soils which go through a 'curing' phase do not swell or shrink with changes in water availability and have a strong load-bearing capacity. Although most soils can be lime-stabilized, some soils are more easily stabilized than others.

Stabilization of Clay Soils

In soil stabilization with lime, clay soils (clay content greater than 10%) are chemically changed into a natural cement structure of calcium silicates/aluminates. When lime products are added to raise the pH of the soil above 11.5, clays become a gel. This silicate/aluminate gel reacts with calcium in the presence of water to form a calcium- silicate/aluminate glue (natural cement). This is a pozzolonic or cementing reaction (Fig. 2). The pH decreases from around 11 over several days as the mixture adsorbs atmospheric carbon dioxide and particles bind together into crystals forming a natural cement.

Figure 2. Transition of pad from the ripped soil with lime amendment (right), tilled soil to mix in lime and water (center) and rolled soil to form smooth pad surface (left)

Raising the pH of soils to above 11.5 requires a highly reactive lime product such as quicklime (Calcium Oxide -CaO) or hydrated lime [Calcium Hydroxide- $Ca(OH)_2$]. Ordinary agricultural limestone(Calcium Carbonate- $CaCO_3$) is not sufficiently reactive to raise the pH to 11.5, and thus is not a suitable substitute. Other industrial lime-containing products such as fly ash and carbide sludge may be suitable if the available Calcium Oxide Index (CAO) level is sufficiently high and availability, transportation and manipulation costs are economical. Even when these materials are free, their transportation costs and the additional soil manipulation required to achieve stabilization often makes them uneconomical.

Stabilization of Sandy - Silty soils

Soils containing less than 10% clay will need a source of silicates and aluminates to build the 'bridges' between soil particles for the natural cement to form. A source for these "pozzolons " is fly ash, a by-product of the coal burning power industry. Some fly ash has more reactive material than others and the source would have to be checked for suitable cementing characteristics. Sufficient fly ash to bring the pozzolon (clay) content above 10 % is needed.

CURING OF LIME-STABILIZED SOILS

Curing during soil stabilization is relatively slow in comparison to the quick setting time of Portland cement. The compacted mass must be kept damp so that the cementing processes and products are formed. Lime soil stabilization takes approximately one week under mild weather conditions after which the site can be used by vehicles. Stabilization and strength gain continue slowly with time called ‘curing’. Because the process is slow, the natural cement formed is not as brittle as Portland cement-treated soils. It does, however, provide sufficient strength to meet load requirements. Ideally, one would work lime/soil mixtures at temperatures above 40 degrees F (2 degrees C) to assure that the natural cementing chemical reactions proceed. The site can be reworked within a few days or weeks using the same techniques if unforeseen problems like freezing weather occur during the construction process. Freezing weather affected the curing of the Beltsville pad, which was left uncovered. After two weeks when it was noted that curing was unsuccessful, the pad was tilled again, wetted, packed and rolled. The pad was covered with hay for insulation and allowed to cure for two weeks after which the first windrows were made (Fig. 3).

Figure 3. Photo of rototilling and roller equipment working in tandem to form lime stabilized pad. Steam is formed when quick lime and water come into contact.

POTENTIAL PROBLEM AREAS

A. Soil organic matter does affect the amount of lime needed to stabilize the soil, but in most cases it is not a factor. In most soils in the US, organic matter normally does not exceed 5 % and where organic matter is high, clay content will generally be low. Ideally, soils with less than 1 % organic matter stabilize the easiest. Similarly with more than 10 % clay, soils stabilize without fly ash amendments.

B. Soils with excess sulfate can also pose a problem, creating heaving of the compacted soil as it cures. However, if the soil/lime mixture is manipulated and compacted at about 5% above optimum moisture, the sulfates in the soil react during mixing, and form non-expansive, stable compounds, with no potential for heaving. If heaving occurs, the site can be re-mixed and compacted without further damage. Attention to these potential problems will insure a satisfactory project.

C. Soils with significant sodium or potassium carbonate content will react with the lime, forming sodium and potassium hydroxides in solution. The level of these salts may compromise the formation of natural cements. As a general rule, when encountering these soils, lime is added until the pH rise stabilizes. Then the soil-lime mixture is cured and formed into cylinders for un-confined compression testing. An increase in strength of 50 pounds per square inch (psi) over the untreated soil sample indicates that the soil is reactive with lime and stabilization is possible.

DETERMINING THE AMOUNT OF LIME NEEDED

Simple tests are available to determine the amount of quick lime or hydrated lime needed to form the stabilized soil natural cement. ASTM (American Society of Testing and Materials) Method C-977, addendum, outlines the Eades-Grimm pH test method, giving a simple method for determining the amount of lime needed to achieve stabilization of a particular soil. Briefly, it tests the amount of lime required to raise the pH of the soil mixture to pH 12.4 after a one-hour contact.

An extra test that may be of interest is the load bearing capacity - unconfined compressive strength - of the final mixture. This test determines the maximum weight of equipment that the site will bear. Specific engineering test equipment is required for this test which can be performed by geo-technical consulting companies. Alternatively, a small test pad can be constructed, cured and driven over with the equipment expected to be used. This is called a “pumping" test and is used by contractors to determine if the soil strength is satisfactory. This test assures that cementing products are formed.

SAFETY

Caution must be exercised when working with quicklime (CaO) because it generates very high temperatures when it comes in contact with water, and can cause burns on the skin and the eyes. The reaction with water is an exothermic (heat producing) chemical reaction process - forming Calcium hydroxide (hydrated lime) which is generally complete within about 30 minutes.

Alternatively, calcium hydroxide can be purchased to mix with the soil, but calcium hydroxide is less reactive than quicklime, requiring about 25% more material. However, it is safer to handle from the heat-generating aspect, but it is a dry powder and dusty and requires masks during the application. Though hydrated lime is safer to use, it is very dusty if used as a dry powder. The dry powder hydrated lime can be made into a slurry using water prior to application. A 30% solids slurry is made by mixing one ton of hydrated lime mixed with 500 gallons of water. The slurry needs to be kept in suspension while applying it to the soil. When using quicklime or hydrated lime, goggles, gloves, and a simple dust mask should be utilized for personal safety. A sufficient supply of clean water should be available for washing the skin and eyes, if necessary.

ECONOMICS

Soil stabilization is generally more economical than the cost of concrete built to bear the same weight. The minimal equipment needed to stabilize soils for a compost pad include a front-end loader to apply the lime amendments, a roto-tiller to mix the ingredients, a means of applying water to begin the reaction, and a roller to pack the surface. The cost of lime stabilizing the 77,000 sq. ft site for composting at Beltsville was approximately $0.50 per sq ft. This cost was based on a commercial company using road equipment to stabilize the pad. An estimate for a reinforced concrete pad six inches thick was approximately $1.80 sq. ft. Economies of scale reduce the cost of both methods. In 1994, The Kentucky Department of Transportation estimated a cost of $0.25 square ft for lime stabilization of 500,000 sq yds.

SINGULARITIES TO BELTSVILLE PAD

The initial mixture added to the soil at the Beltsville site contained fly ash. In retrospect, this fly ash was not needed. It was added as part of the effort at Beltsville to promote sustainable systems by using recycled by-products. Portland cement was donated to the Research Center and also put into the mixture, but it also was not a necessary ingredient for lime stabilization of the site which was located on a Christiana clay soil. It is difficult to determine what effects fly ash and Portland cement had on the final characteristics of the pad. However, an addition was made to the circumference of the pad in 1998 using just quick lime and the performance of the addition is no different than that of the original pad.

RECENT EXPERIENCES

The University of Maryland farm at Clarksville, MD enlarged their compost pad area made from concrete (actually an old barn floor) with a lime-stabilized pad. Our compost pad was enlarged about 15% to accommodate new research projects. The same technique as the original construction was used except that only quicklime was used. As mentioned earlier, the performance of the new and old pads are similar. Repair of a ‘sink’ holes was done by excavating the area to a depth of around 12 inches, mixing the excavated soil plus additional clay brought in from an outside source with quicklime, adding water, mixing the ingredients on the pad and placing the mixture into the hole. The tractor tires leveled the lime-clay mixture into place. After a few weeks of curing, the repaired area was ready for use.

CONCLUSION

Soil stabilization techniques are a suitable, affordable alternative to asphalt or concrete pads. Testing of soil to determine its suitability for lime stabilization and locating the necessary materials and equipment for stabilization are requirements for investigating the use of soil stabilization at a location. The benefits of soil stabilization is cost, endurance and repair ability.

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Footnote: Mr Francis served as Technical Manager for the National Lime Association from 1989 to 1997.