CEEn 563 Pavement Design

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LIME STABILIZATION

Application

Lime works well to modify or stabilize alumino-siliceous clays with high plasticity indices (PI) to create working platforms for roadway construction and to ensure durable pavement layers with improved structural properties.

Clay Structure

Most clay particles are platy elements with high surface area and negatively charged faces and are usually less than 0.002 mm in diameter. The edges often contain positive charges as well. These charges can attract water molecules and various ions of the opposite charge and bind, or adsorb, them to the clay surface.

The crowding effect of bound water molecules creates a water layer of finite thickness around each clay particle. Thicker water layers generally cause a face-to-face orientation and reduce the effective stress, or particle-to-particle contact, in the soil system, which in turn reduces the strength. Studies in surface chemistry indicate that the thickness of the water layer can be reduced by increasing the valence and concentration of the cations within the layer. This can be accomplished through cation exchange as described by the Lyotropic Series, where a given cation will replace any cation to its left: $Li^{+} < Na^{+} < H^{+} < K^{+} < NH_4^{+} << Mg^{++} < Ca^{++} << Al^{+++}$.

Stabilization Mechanisms

When lime ($Ca(OH)_2$) and water are mixed with a soil, the Ca^{++} supplied by the lime immediately instigates cation exchange at the clay surfaces and, as indicated above, reduces the thickness of the water layer around each particle. As the distance between soil particles decreases, the positively charged particle edges are attracted by the negatively charged particle faces, creating a flocculated edge-to-face orientation with an immediate improvement in strength and a reduction in PI. This level of lime treatment is called lime modification.

Lime stabilization can occur when sufficient lime, a base, is provided to the soil to increase the pH of the lime-water system to above 12. At this point, Al and Si from the soil become soluble, or available in the soil system, for combining with water and the Ca^{++} from the lime in a long-term, pozzolanic reaction. Fly ash can be added to increase the availability of Si and Al. The cementitious products of the pozzolanic reaction are calcium-aluminate-hydrate (CAH), which forms first at the edge-to-face contacts between clay particles, and calcium-silicate-hydrates (CSH). The CSH crystals grow between particles, lacing them together through time to effect complete lime stabilization. Substantial strength gain occurs over a period of weeks and can continue over many years.

Other Reactions

If present in the soil in sufficient quantities, sulfates can combine with these same reactants to form calcium-aluminate-sulfate-hydrate (CASH). Unlike CAH and CSH, these crystals do not stop growing when they reach another pozzolanic product or soil particle, but can expand with pressures as high as 35 ksi inside the soil structure. If CASH forms after compaction of the soil layer, damage is inevitable.

Carbon dioxide also competes for Ca^{++} from the lime to create calcium carbonate. Though it may reduce the permeability of the soil system, calcium carbonate is not itself a cementitious product, and it can reduce the pH of the soil to a value below which pozzolanic reactions cannot continue. In addition, organic compounds exert a demand on Ca^{++}, necessitating clearing and grubbing to remove organic topsoil that could potentially contaminate the subgrade layer.