CENTER OF EXCELLENCE FOR AIRPORT TECHNOLOGY

TECHNICAL NOTE

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TITLE: ADMIXTURE STABILIZATION
(Lime Treatment of Subgrades)

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ADMIXTURE STABILIZATION
(LIME TREATMENT OF SUBGRADES)

INTRODUCTION

Admixture stabilization (mixing and blending a liquid, slurry, or powder with the soil) is a technique which has been successfully used for improving soil strength and stiffness properties, thus improving subgrade stability. In some cases, particularly with lime products, immediate (uncured) strength increases are achieved while with other admixtures a curing period is required. Those admixtures most widely used for remedial treatment of fine-grained subgrade soils are lime products (quick lime, hydrated lime, LKD-Lime Kiln Dust), fly ash, lime-fly ash, cement, and cement kiln dust (CKD). LKD, fly ash, and CKD, and are generally more economical. Lime products, cement products, and fly-ash effect many positive changes in the engineering properties of fine-grained soils.

References 1-6 include in-depth information and guidelines (selection criteria, mixture design/evaluation, and construction technique recommendations) for various admixtures. Criteria for selecting an appropriate procedure(s) are generally gradation (primarily minus #200 sieve) and plasticity index.

Construction operation limitations (mixing and pulverizing) related to high clay contents and PIs and in-situ moisture contents in excess of optimum (the most troublesome subgrade stability condition) frequently limit the use of cement. Lime products are particularly well suited and most widely utilized for these adverse conditions. Type C fly ash is a quite popular admixture in some areas. Lime treatment levels generally range from about 3% to 6% (dry weight of soil basis). Fly ash quantities are typically several percent higher.

The length of curing period required to develop acceptable strength/modulus properties in the admixture modified soil is an important consideration in the admixture selection process. In some projects it is essential to have "immediate" results while in others a short or even longer curing period (several days or greater) may be acceptable.

With the increased use of the fluidized bed combustion process for burning high sulfur coal, BED-DRAIN or BED-DRAIN + fly ash materials (by products from the combustion process) are available. Careful evaluation is required for these materials. They contain high concentrations of sulfate compounds and tend to be expansive in nature.

ADMIXTURE CONSTRUCTION

Construction specifications and procedures for subgrade soil remedial treatment are frequently less stringent than those specifications used for "stabilization" where the stabilized material is to be used as a structural pavement layer. For example, the Illinois DOT has specifications for "LIME STABILIZED SOIL MIXTURE" (for structural layer applications) and "LIME MODIFIED SOILS" (for expediting construction and providing a working platform). The Portland Cement Association (5) uses the term "cement modified soils" to describe a product not meeting "soil cement" quality requirements.

Admixtures are typically applied in a "dry" form. However, lime products are spread in the dry form or as a lime slurry (typically one ton of lime to 500 gallons of water). Slurry application is most often used when "admixture dusting" is a concern. Some admixture spreaders incorporate "skirts" and "a vacuum" to minimize dusting (See Figure 1). Obviously, when the soil is already "wet," slurry applications are not advantageous.

Several construction procedures have been utilized in "wet soil" treatment operations. Conventional rotary mixers can readily handle lifts up to approximately 12-15 inches. In some instances, discing may be adequate. Special procedures are needed to construct thicker layers. Surface soils can be removed; the exposed soil "treated;" then the removed soil is replaced and "treated". Deep plowing has been described in detail by Thompson (7). Lime-treated layers up to 24 inches in thickness have been constructed in one lift in Illinois.

In some instances, "wet borrow soils" have been "completely lime-treated" to form a stable embankment/working platform. Admixture stabilization can be accomplished using "borrow pit mixing" or the wet borrow can be spread on the embankment in a normal lift thickness and then treated.

Mixed-in-place admixture stabilization is in many instances the most cost effective remedial procedure. Undercutting and removal are not required and mixed-in-place construction procedures are relatively inexpensive. Improved job mobility, less loss of working days due to wet weather, and a general expediting of construction are frequently mentioned benefits of admixture stabilized subgrades.

The technologies associated with the various forms of admixture stabilization are well established and can be used with confidence. Careful consideration should be directed to selecting the admixture, establishing admixture treatment levels, specifying construction techniques and operations, and exercising adequate construction control. A brief summary of **LIME TREATMENT** concepts and practices relevant to considering **subgrade stability problems** is presented in the following.

LIME TREATMENT OF SUBGRADES

FAA Specification P-155 (Lime-Treated Subgrade) is fairly restrictive and not particularly adapted to lime treatment to expedite construction with wet/unstable subgrades and/or provide a "working platform" for subsequent pavement construction. Thus, P-155 is frequently modified (Special Provision) to accomodate specific job conditions.

Lime Stabilization Mechanisms

The addition of lime to a fine-grained soil in the presence of water initiates several reactions.

Cation Exchange and Flocculation/Agglomeration

Practically all fine-grained soils display **rapid** cation exchange and flocculation - agglomeration reactions when treated with lime in the presence of water. The lime addition is the calcium source. Calcium cations preferentially replace commonly present monovalent soil cations such as hydrogen and sodium (a good indicator of abnormally high swell potential). Cation exchange is very effective in reducing PI and swell potential.

Flocculation and agglomeration produce an apparent change in texture with clay particles (< 2-micron size) "clumping together" into larger-sized aggregates (more silt-sized) producing a "friable" soil structure. An apparent change in "workability" is easily noted.

The term "Lime Modification" has been used (2) to describe this treatment phase associated with cation exchange and flocculation and agglomeration. Cation exchange and flocculation cause immediate improvement in soil plasticity, swell potential, workability, and uncured strength/modulus properties.

Soil-Lime Pozzolanic Reaction

A soil-lime pozzolanic reaction may also occur to form various cementing agents that increase compacted mixture strength and durability. Pozzolanic reactions are time and temperature dependent. Ultimate cured strength development is gradual but may continue for several years.

Temperatures less than 55EF to 60EF retard the reaction. The pozzolanic reaction resumes when the temperature increases. Higher temperatures accelerate the reaction.

Lime, water, soil silica, and alumina react to form various cementitious compounds (primarily hydrated calcium silicates and calcium aluminates). Possible sources of silica and alumina in typical soils include clay minerals, quartz, feldspars, micas, and similar silicate or alumino-silicate minerals, either crystalline or amorphous in nature. When a significant quantity of lime is added to a soil, the pH of the soil-lime mixture is elevated to approximately 12.4, the pH of saturated lime water. This is a substantial pH increase for natural soils. The solubilities of silica and alumina are greatly increased at elevated pH levels and highj temperatures. A wide variety of hydrated cememtitious product forms can be obtained depending on reaction conditions (e.g., quantity and lime type, soil characteristics, curing time, and temperature).

Natural soil properties affect soil-lime pozzolanic reactions. The pozzolanic reaction is inhibited in some soils, and cementing agents are not extensively formed. Thompson (8) has termed those soils that react with lime to produce a substantial strength increase (greater than 50 psi following 28-day curing at 73EF) as reactive; those soils with lesser strength increases are called nonreactive. This terminology does not imply that lime modification does not take place.

Some of the major soil properties and characteristics that influence the lime reactivity of a soil (the ability to react with lime to produce cementitious materials) are soil pH; organic carbon content; natural drainage; presence of excessive quantities of exchangeable sodium; clay mineralogy; degree of weathering; presence of carbonates, sulfates, or both; extractable iron; silica-sesquioxide ratio; and silica-alumina ratio.

Mitchell (9) initially identified the detrimental effect of lime-treating sulfate-bearing soils. Sulfate-bearing soils are typically only encountered i regions where evapotranspiration values exceed rainfall. The formation of ettringite and thaumasite (very moisture expansive products) may produce swelling characteristics that significantly exceed those of the natural untreated soil.

A comprehensive discussion of the sulfate-bearing soil issue and recommendations are presented in Ref. 10 by the National Lime Association.

Lime-treated Soil Properties

Plasticity, swell, "workability", strength and modulus (immediate and cured), and moisture and freeze-thaw resistance properties are improved by lime treatment. Compaction properties of fine-grained soils are also modified by lime treatment. Optimum moisture content is increased, which is desirable since high moisture content is the primary reason for most unstable subgrades. The maximum dry density is decreased. Typical moisture-density-CBR relations for natural and uncured lime-treated soils are shown in Figures 2 and 3. Strengths adequate to support typical pavement construction operations can be readily achieved. The changes in compaction properties and immediate/uncured strength are achieved for all fine-grained soils with clay contents greater than about 10-15%.

With favorable curing temperature conditions, some cohesive soils (termed "lime reactive") will develop soil-lime pozzolanic reaction products and achieve high strength and modulus levels (8). Cured compressive strengths in excess of several hundred psi have been achieved.

SUMMARY

Sufficient basic understanding and field experience concerning soil-lime reactions and their effects are available to provide an adequate technology for the successful lime treatment of a large number of fine-grained soils under a wide variety of conditions.

The net effect of the LIME TREATMENT is to expedite construction in "wet soil" conditions and provide a "working platform" for the successful and timely completion of subsequent pavement construction operations.

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Figure 1. A “Dustless” Lime Spreader.

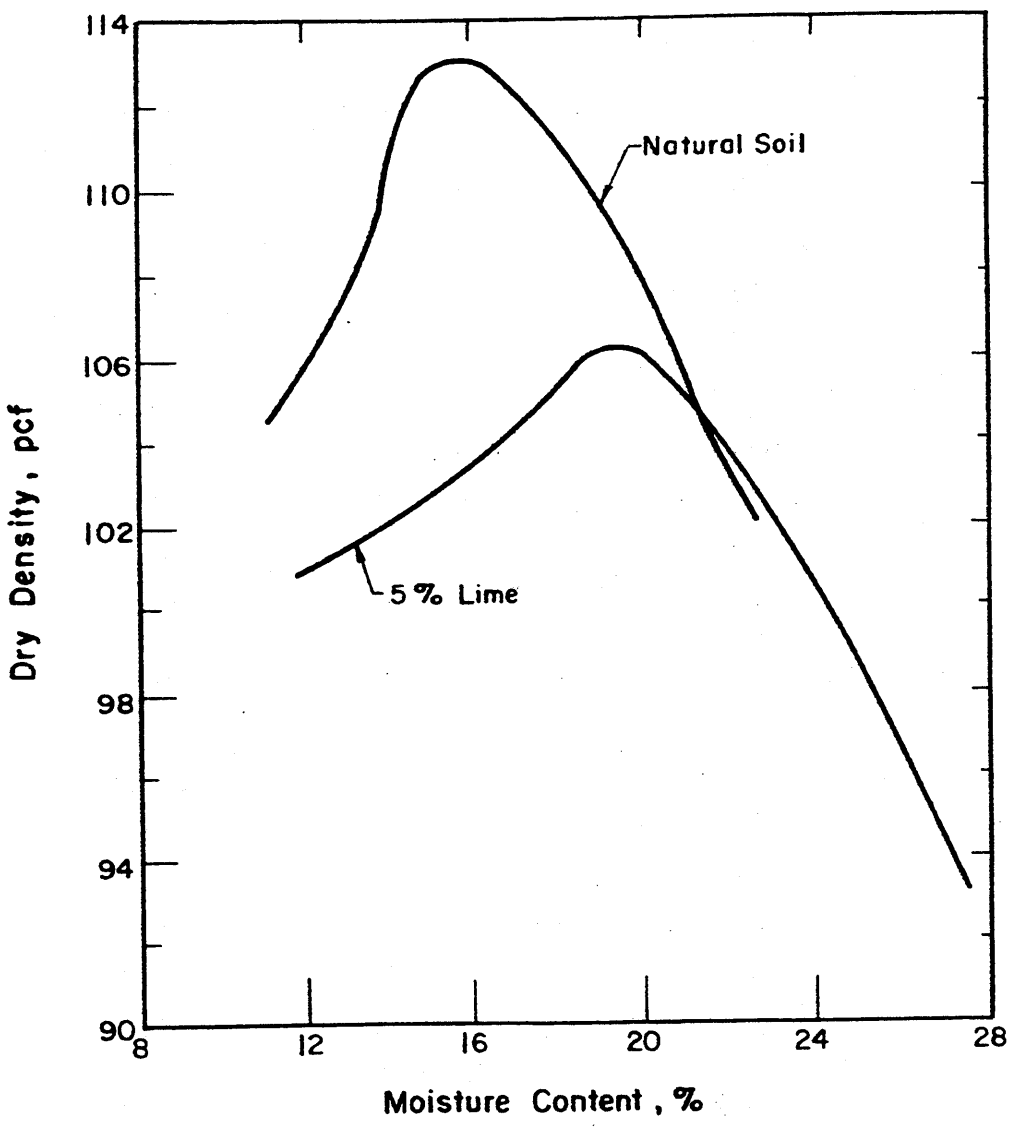

Figure 2. Moisture-Density Relations (ASTM D-698 Compactive Effort) for a Natural and Lime-Treated ML Soil.

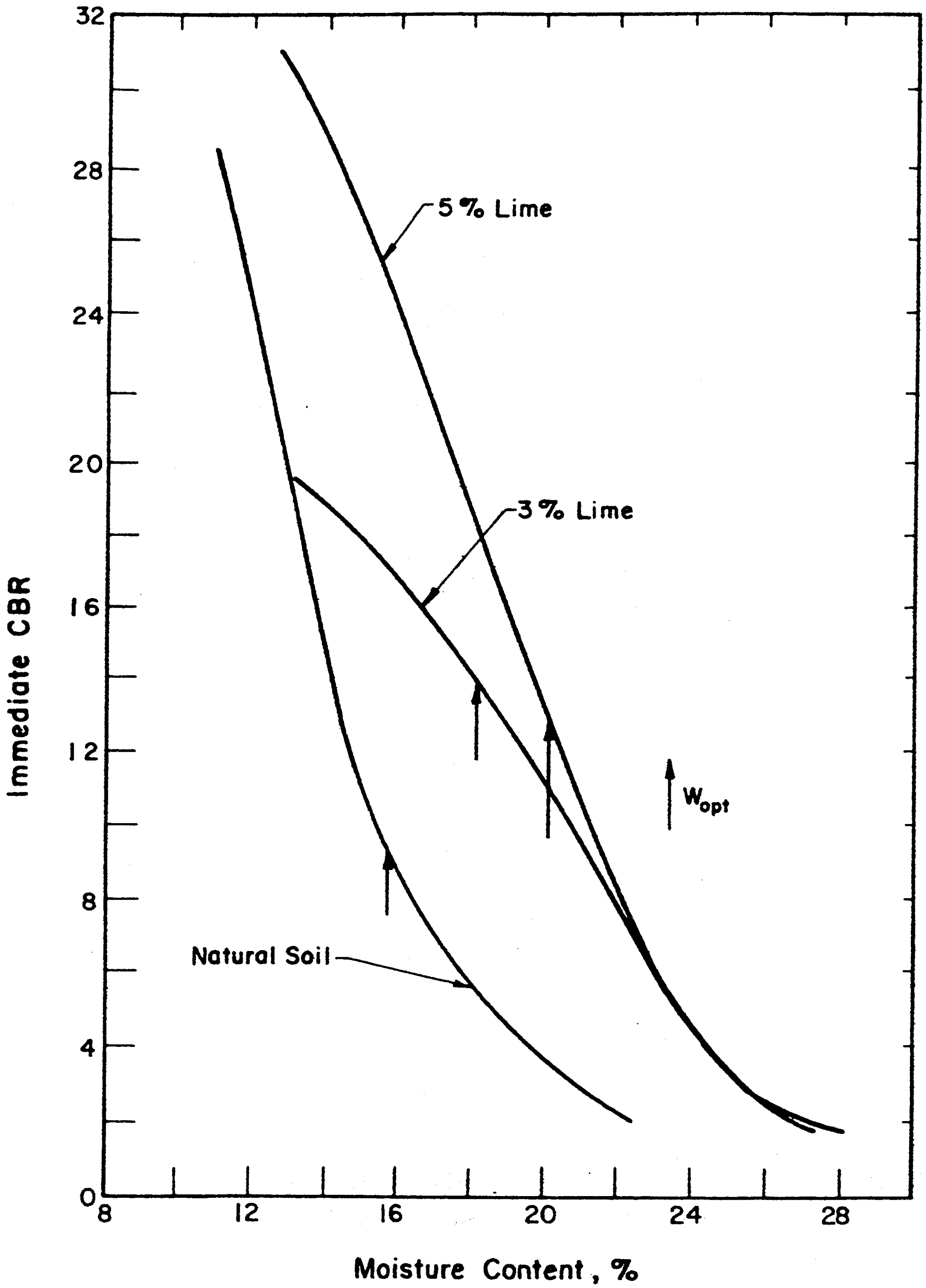

Figure 3. CBR-Moisture Content Relations for a Natural and Lime-Treated ML Soil (ASTM D-698 Compactive Effort).