Overview

In today's changing world, the properties of the environment are interconnected. Changes which occur or are brought to occur in one property can result in vast modifications or transformations in other properties. Some of these secondary effects are known and can be predicted, others cannot. In the field of soil mechanics, these linked reactions can have devastating results. For example, it has long been known that the compressive strength of marine clays and fine silt can change drastically after the soil is disrupted. The change in physical strength results from the replacement of divalent cations between the clay particles by monovalent ions which do not have sufficient charge sites to bond to two soil particles at the same time. Like a rusty machine, the weakened bonds between the soil particles hold until they are disturbed, then they collapse. This is an example of a change in the chemical makeup of the fluids flowing through the soil having a marked influence in the physical nature (behavior) of that soil. With such drastic potential results, discovering and quantifying these changes is an important concern of professionals who work in this field.

Discovery of these interconnected relationships is the responsibility of the researchers. However, being able to predict the outcome of these relationships reproducibly requires standardization of the testing procedures for these soil properties. To this end The American Society for Testing and Materials (ASTM), through its Committee D-18 on Soil and Rock, sponsored a symposium on the Physico-Chemical aspects of Soil, Rock and Related Materials. Physico-chemical properties are those attributes that are affected by changes in other properties.

Papers in this STP were selected from the symposium submittals based upon pertinency, originality, and technical quality. All underwent peer review and most were extensively revised between presentation and publication. In this STP, papers were selected in the following categories:

1. Lime and lime-like materials.
2. Bentonite/natural clays.
3. General soil tests.

The papers included herein, which have undergone peer review and extensive revision since their original presentation, provide state-of-the-art information on physico-chemical interactions and their test methods and will be useful to those undertaking projects which involve such testing.

Lime and Lime-like Materials

It has long been known that lime additions rapidly improve the mechanical characteristics of soil. Additions of calcium or magnesium carbonates displace and neutralize soil acidity. This, in turn, promotes interparticulate bonding, leading to a stabile soil matrix.

Verhasselt discusses the mechanism of lime reaction in soil. He also compares lime additions to other additions of combinations of various cations and basic anions. His goal was to find other mineral additions which could produce the same immediate effects as those produced by incorporating agricultural lime ($CaCO_3$).

Choquet, Ista, and Verhasselt present a method to determine the content of calcium and magnesium carbonates in soils and aggregates. The current methods are based on loss by ignition, which does not allow discrimination between calcium carbonate, magnesium carbonate, and the double carbonates of calcium and magnesium (dolomite). Such determinations are the central focus of his methodology.

Lamb focuses on the reaction of loess soil to losses of carbonates. His discussion covers the mechanism of leaching and its effects on the geotechnical aspects of soil behavior.

Bentonite/Natural Clays

Clay-size particles are, at least in part, responsible for all of the behavior known as soil properties. Bentonite (commercial sodium saturated montmorillonite) and other clay particles are naturally negatively charged. Together with positively charged cations, they give the soil structure and the ability to chemically react. Understanding the nature of this behavior is basic to understanding the reaction of a soil to chemical additions or mechanical disruption.

Wu and Khera describe the changes of properties in a soil bentonite mixture caused by additions of a simulated chemical leachate. Their research proposes a four-phase soil diagram to replace the conventional three-phased model.

Sridharan, Rao, and Gajarajan report on the influence of the sulfate ion on the index characteristics, swelling behavior, and compressibility of a bentonite clay. They chose the sulfate ion for its environmental significance as the main ionic constituent of acid rain.

Yong and Warith used leach columns to study the variable nature of the dispersion coefficient of some typical contaminant ions. Their experiments use leachate from an operating landfill to compare the reactions between a natural clay and a laboratory-prepared illite-kaolinite mixture.

Khera and Thilliyar discuss the effect of desiccation on the integrity of a slurry wall backfill. Their research stemmed from observations that the upper reaches of the backfill undergo cycles of wetting and drying while the lower regions remain saturated.

Pamukcu, Tuncan, and Fang describe the dynamic influence of temperature, pH, salinity, and degree of saturation on the mechanical behavior of clays. Their work presents some empirical correlations between mechanical behavior and the environmental factors mentioned above.

Thomas and Lentz outline the possible changes in soil properties resulting from the use of electroosmosis. Moving ions electronically through the soil changes the pH and thickness of the double layer. Their work studies the reaction of soil plasticity and swell as influenced by electroosmotis migration of ions.

Chatterji and Morganstern propose a modified shear strength formulation which utilizes an extension of the classical Terzaghi effective stress equation. The extension incorporates physico-chemical forces into the original equation.

General Soil Tests

A wide range of papers on soil properties affected by changes in physico-chemical characteristics were submitted for this symposium. Some of them, however, did not fit well into a common theme. Their incorporation in the symposium and in this technical publication is indicative of their relevance in physico-chemical testing.

Wang, Benway, and Arayssi explain the effect of sample heating on the engineering properties of two clay soils: a montmorillonite and a kaolinite. The collaboration heated specimens to a range of temperature up to a maximum of 600°C. They focused on changes in the specific gravity, consistency limit, grain-size distribution, swelling, and strength. The authors discuss the results of each test, selecting a range of heating temperatures effective for stabilizing each clay soil. They also address the possible field applications of heating soil to stabilize soft clay deposits.

Iyer inferred that a study of the influence of the chemical environment on the engineering behavior of clayey soils warrants an understanding of the chemistry of the pore water, together with the physico-chemical properties of the soil minerals. His work provided a comparison of the different techniques available to extract soil pore water from a specimen.

Stuede et al. describe the use of computed tomography as a nondestructive test method for determining a number of soil properties including bulk density, water content, and porosity. His method correlates the pattern of X-ray attenuation to the soil properties. Compared to the typical laboratory procedures, computed tomography provides accurate, reproducible data in a fraction of the time.

Picornell, El-Jurf, and Abd Rahim illustrate the need to clean soil samples of soluble salts before performing the hydrometer analysis. Their research showed that salt concentrations on the order of a hundredth of a millimole per liter leads to an overestimation of the silt size fraction.

In addition to the authors of the individual papers, any success of this publication reflects the contributions of many people.

The symposium committee worked diligently in soliciting abstract submittals, in selecting promising presentations, and in chairing the sessions. The committee was composed of the following people: Robert Lamb, Trinity Engineering; Keith Hoddinott, U.S. Army Environmental Hygiene Agency; Larry P. Jackson, GTEL Environmental Labs; and William C. B. Gates, Kleinfelder Associates.

The continued support of this symposium by the officers of ASTM Committee D-18 on Soil and Rock also was vital, since time from a more than full committee meeting schedule needed to be allocated for this endeavor.

Critical to maintaining the technical quality of this STP was the diligent work of the reviewers of the technical papers. Three reviewers were obtained for each paper to help ensure that the work reported was accurate, reproducible, and meaningful.

Considerable staff support was also required for the completion of this effort. The help of the symposium committee, the D-18 officers, the paper reviewers, and the ASTM staff is most appreciated. We trust that the papers in this STP, which the contributors labored hard to develop, will aid the efforts of industry towards the reliable prediction and quantification of these properties.

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