Geotechnics of High Water Content Materials

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EDITORS

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Foreword

This publication, *Geotechnics of High Water Content Materials*, contains papers presented at the symposium of the same name held in Memphis, Tennessee, on 28–29 January 1999. The symposium was sponsored by ASTM Committee D18 on Soil and Rock and the D18.18 Subcommittee on Peats and Organic Soils. The symposium was chaired by Tuncer B. Edil, University of Wisconsin-Madison and Patrick J. Fox, University of California-Los Angeles.

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Overview

A symposium sponsored by ASTM Subcommittee D18.18 on Peats and Organic Soils was held on 28–29 January 1999 at the Peabody Hotel in Memphis, Tennessee. The objective of the symposium was to bring together representatives of academia, government, and industry from around the world to discuss advances in research and practice involving geotechnics of high water content materials. The international flavor of the symposium and technical papers attest to the world-wide interest in such problems.

The papers contained in this volume cover a broad range of topics. Various types of high water content materials are discussed, including peats and organic soils, soft silts and clays, bentonite slurries, paper sludges, wastewater sludges, dredgings, lime wastes, and mine tailings. Several papers address contaminated materials. Geotechnical problems include handling and disposal, dewatering, stabilization, hydraulic performance, settlement, stability, in situ testing, and construction. The papers highlight recent developments in these areas with emphasis given to construction on marginal lands and dewatering and disposal of high water content waste materials.

Background

Construction on marginal lands is becoming increasingly necessary for economic reasons. Foundation soils for these projects, such as soft clays and peats, typically have high water content, high compressibility, and low shear strength. There is also considerable interest in the economic and environmentally safe disposal of high water content waste materials. Applications in which waste materials can be reused beneficially take on even more importance. The successful design, construction, operation, and in some cases reclamation of such projects involve predictions of geotechnical behavior in terms of hydraulic conduction, settlement, and shear strength, often as a function of time. This, in turn, requires reliable material characterization and modeling that accounts for differences in behavior as compared to conventional soils. Likewise, there is a need for laboratory and field tests to measure material properties and, in some cases, a need for specialized techniques of construction.

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Keynote Paper

The keynote paper provides an excellent overview of the geotechnics of high water content materials. A generation of slurried wastes is described, and material properties for a wide variety of waste materials are compared with those of natural soils. The paper identifies limitations in current knowledge and discusses a broad range of engineering concepts that are relevant to practical problems. The paper notes that current capabilities of engineering analysis far exceed the quality and/or quantity of input data in most cases and that improved methods for material and site characterization are needed.

Fundamentals, Theory, and Modeling

Large strain consolidation theory is recognized as the appropriate framework for modeling volume change due to material self-weight and applied surface loads. User-friendly computer codes and chart solutions bring this capability to engineering practice. The characterization of void ratio–effective stress and void ratio–hydraulic conductivity relationships at low effective stress and the establishment of initial void ratio for numerical analysis are still challenging problems for large strain consolidation modeling. Interesting test methods for evaluation of these relationships are proposed in this volume, and their validity is demonstrated. Use of the centrifuge for accelerated testing of sedimentation and self-weight consolidation holds special promise in this context. Instrumented columns provide insight into the process of transition from a suspension to a structured material and the development of geotechnical properties such as density, modulus, and shear strength. Currently, no ASTM standards exist for slurry sedimentation and consolidation testing.

Secondary compression and creep effects can be important for high water content materials, especially those that contain organic matter. Settlement behavior referred to as "tertiary compression" is also observed in peats, dredgings, and paper sludges. This phenomenon has been attributed to biodegradation and gas generation. However, recent studies have demonstrated that treatment of specimens for bacterial activity does not entirely remove the effect. A paper in this volume discusses the incorporation of various creep models into finite element codes. Such codes represent a needed development in the numerical simulation of field behavior.

Measurement of undrained shear strength for very soft materials and characterization of its development with consolidation remains a challenging problem. Conventional field equipment generally cannot adequately differentiate low values of shear strength. Vane shear still remains the method of choice although cone penetration is also used in sufficiently strong materials. Materials that contain fibers, such as peats and certain sludges, may exhibit internal fiber reinforcement effects, including strength anisotropy and a low coefficient of lateral earth pressure. Conventional soil strength models and testing procedures may not be applicable to such materials.

Papers are presented that deal with fundamental microstructural behavior of wastewater sludges and clay slurries. Issues of material flocculation, gas generation, and flow localization through channels are significant and require us to reevaluate basic assumptions of consolidation theory (e.g., continuum flow) for the modeling of rapidly dewatering or decomposing materials.

Laboratory Investigations

Hydraulic properties of high water content materials are important for the prediction of consolidation rate and the evaluation of potential use as a hydraulic barrier. Hydraulic conductivity testing of paper sludge may be complicated by gas generation. Refrigeration can be used to control gas during testing. As paper sludge is soft and plastic, fluid flow is not governed by macrostructure features (e.g., cracks, fissures, and clods). Consequently, hydraulic conductivity tests performed on small specimens taken from paper sludge liners can be used for quality control purposes. This material also has an effective sorptive capacity for heavy metals. Paper sludge liners may undergo significant consolidation after construction, which both improves strength and decreases hydraulic conductivity.

Dewatering is a primary concern for the disposal of high water content materials. Papers in this volume describe how to efficiently dewater slurries and estimate the quantity of exuded liquid. The quantity of water released from sludgy or pasty wastes is important in determining leaching potential and for water balance analyses associated with disposal activities. Centrifugal systems and other innovative separation techniques can produce efficient dewatering.

Chemical stabilization of high water content materials is used to increase strength and minimize leaching of contaminants. Addition of binders, typically Portland cement, to harbor dredgings and waste sludges results in solidification from both drying and hydration reactions. Significant leaching, especially of heavy metals, can occur after cement stabilization if the initial water content is high. Leaching is substantially reduced for chemical stabilization of dewatered (i.e., low water content) sludges due to their lower hydraulic conductivity.

Thermal properties of high water content materials are needed for problems involving heat transfer. Use of thermal probes is shown to be effective in characterizing the heat capacity and thermal conductivity of peats, industrial sludge, bentonite slurry, and municipal solid waste. Peat has a heat capacity similar to water and municipal solid waste has a value similar to air, illustrating that heat capacity is greatly influenced by water content. Values of thermal conductivity for high water content materials are generally less than those for sands and silts due to their high void ratio.

Field Performance

Geophysical methods have seen great advancement in recent years and their application to high water content materials holds particular promise. An in situ density and shear modulus profiling system for soft deposits, called a soil stiffness probe, is described in this volume. The probe was used to define the transition from suspension to continuous soil and the presence of gas lenses in a pond of contaminated dredge spoils. A correlation between shear modulus and undrained shear strength was also found. Geophysical methods can be used to characterize soft deposits for which conventional sampling and laboratory testing of undisturbed specimens would be difficult or impossible.

Field performance of highway embankments founded on lime waste and soft clays are described in this volume. The analyses show that conventional consolidation theory, with adjustments for large settlement and ramp loading, may give reasonable estimates of settlement but underestimates rate of pore pressure dissipation. The reason for the discrepancy in pore pressure response is not clear.

Case Histories

Construction over soft soils may encounter difficult problems of supporting equipment and structural loads. Use of low ground pressure equipment, geosynthetic reinforcement, lightweight fill, and winter construction procedures may circumvent such problems. In one case history, a sludge lagoon was capped during winter by flooding the upper crust of frozen sludge with water, thus producing a strong ice layer. A woven geotextile was then placed over the ice, followed by a lightweight cap consisting of a wood chip/soil mixture placed using low ground pressure equipment. The geotextile provided safety during construction against possible breaking of the frozen surface. After construction, the geotextile served as a separation/filter/reinforcement layer under the constructed cap.

Dredging and disposal of marine sediments in an abandoned rock quarry is described in another case history. Large strain self-weight consolidation modeling with careful characterization of material consistency from suspension to structured soil is shown to give good estimates of disposal pond capacity. Modeling of the sediment accretion process in the disposal pond was not found to have a large effect on long-term settlement estimates.

The effect of construction dewatering on soft silty clay and peat deposits and supported structures is presented in this volume. The finite element method is effectively used to optimize design of a dewatering system for a deep excavation to prevent excessive total and differential settlement. Simplified analytical approaches often result in poor predictions due to the complexity of the problem. Rapid transient drawdown of the groundwater table can result in significant compression of peat due to its high hydraulic conductivity.

Another paper describes procedures for the construction of reinforced soil walls on soft ground. Design details such as interpanel spacing joints that accommodate large total and differential settlements are presented for several walls.

Concluding Remarks

Technical papers in this volume provide state-of-the-art information for geotechnical engineering involving high water content materials. The field has evolved in terms of new material types and applications, use of geosynthetics and in situ testing, and environmental issues that must be addressed. Large-strain consolidation theory and related material characterization techniques are now used routinely. As such, ASTM standards for slurry consolidation and corresponding parameter determination are needed. ASTM standards are also needed for sample preparation of chemically stabilized materials. In situ testing will likely see increased future use for material characterization due to the difficulties of conventional undisturbed sampling and testing. Geosynthetics are also expected to play an increasing role in future projects. Progress in this field occurs as traditional soil mechanics concepts are adapted to a range of material properties and behavior that is outside that of typical natural soils. The presence of fibers, organic matter, and chemical constituents can also introduce significant complexities. Thus, the need continues for future investigations to increase our understanding of these difficult materials.

The editors wish to express their appreciation to all those who participated in the symposium. Particular thanks are extended to those who contributed papers, to the reviewers of the papers, to ASTM Committee D18 on Soil and Rock for sponsoring the symposium through Subcommittee D18.18 on Peats and Organic Soils, and to the editorial staff of ASTM.

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