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Time Dependency of Deep-sea and Island Clays at Room and Elevated Temperatures

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Results from an experimental program on creep behavior of fine-grained soils under drained, triaxial conditions are discussed. Tests were conducted at room and elevated temperatures. Soils tested included deep-sea illite and smectite, as well as a group of volcanic soils from Hawaii. The findings agree with general principles of material rate process theory with regard to temperature, but some deviations from expected behavior are observed with regard to long-term strain rate tendencies.

INTRODUCTION

The creep behavior of deep-sea Pacific clays and volcanic fine-grained soils from Hawaii has been investigated during the past 2 decades at the University of Hawaii and University of Rhode Island through an extensive set of long-term laboratory creep tests under drained triaxial conditions. These tests were conducted at room temperature and at elevated temperature using specially designed heating jackets. The purpose of the experimental program has been to understand creep phenomena in clays, and to generate the data necessary for model development. This article focuses on laboratory test results. Specimens from the deep sea were collected in the North Central Pacific Ocean, in 5000 m of water, in an abyssal plain located approximately 1000 km north of the Hawaiian Islands. The volcanic soils are from the islands of Oahu and Hawaii and were chosen to include materials with widely contrasting plasticities, as measured by their Atterberg limits. Table 1 summarizes their basic index properties. It should be noted that all the soils were thoroughly reconstituted and reconsolidated prior to testing, except as indicated in the discussion. The deep-sea soils were obtained as part of the Department of Energy's Subseabed Disposal program, which considered the long-term behavior of radioactive waste containers in certain seafloor environments under ambient and elevated temperatures (Hollister et al., 1981). The illite content of the sediments identified as illite in Table 1 was approximately 20%, while the smectite content of the smectite sediments was on the order of 13% (Jordan and Silva, 1984). The volcanic soils included various amounts of kaolinite, halloysite and smectite, as well as large proportions of amorphous material.

The room temperature equipment varied somewhat throughout the testing program, but the main components can be viewed in Fig. 1. A triaxial cell was used to pressurize the cylindrical specimens, and the deviatoric load was applied with a stationary frame balanced on top of the piston. Deviatoric stresses were reached by adding dead weights to the frame. Both cell and back pressures were applied by pneumatic regulators connected to air/water interface bottles. Axial, volume and pressure data were obtained with pressure, displacement and volumetric transducers.

Soil	W.C. (%)	LL (%)	PL (%)	Fines (%)	Specific Gravity	USCS
Pacific Illite	86	86	40	69	2.78	CH/MH
Pacific Smectite	160	230	95	69	2.87	MH
Manoa Clay	87	87	33	95	2.88	CH
Kapolei Silt	41	41	25	98	2.79	ML
Kapolei Clay	69	62	25	96	2.94	CH
Hilo Ash[1]	210	210	116	81	2.51	OH

[1]Properties of soil change dramatically upon oven drying.

Table 1 Soil index properties

Fig. 1 shows an early setup that used a system of burettes to record volume changes. Later tests used an electronic volume change device instead. For the elevated-temperature tests, a high-grade steel triaxial cell was used, which was encased in a heating jacket with a heat sink compound in between to allow for a uniform distribution of heat. A gauge extending into the cell fluid monitored the temperature, and a controller would heat up the cell as necessary to keep the temperature constant (Brandes, 1984). Drained conditions were maintained throughout, including during the period of deviatoric loading to reach constant creep stress conditions. All specimens were thoroughly saturated. An extensive set of index and strength tests was conducted on all soil types.

DEEP-SEA CLAY TESTS AT ROOM TEMPERATURE

A series of tests was conducted on deep-sea illite and smectite at various deviatoric stresses; in some cases tests lasted upwards of 1 year. All the deep-sea room temperature tests were back-pressured to 552 kPa and consolidated isotropically in stages to a confining pressure of 93 kPa, corresponding to an overburden thickness of approximately 5 m. This consolidation stress was sufficient to insure normally consolidated conditions in all the tests. In general, both volumetric and axial deformations are of interest because, when taken together, they fully describe the 3-dimensional behavior of the material. Specifically, deviatoric and volumetric quantities, which typically are used in the formulation

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