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BEHAVIOR OF ULTRA SOFT CLAY-WATER SYSTEMS

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Summary. The focus of the presentation is on clay-water dispersions, a class of geomaterials characterized by mechanical properties significantly below the range typical of traditional soft clays. The behavior of these materials is relevant in a number of contexts within the geotechnical arena (e.g. dredged sediments, tailings, drilling fluids). The presentation utilizes the results of rheological tests performed on both “clean” clay-water systems, as well as on more complex systems containing organics and in some cases air, to describe select aspects of the response (e.g. solid like response to large strains, thixotropy, stress history dependence) of these geomaterials. Additional data obtained following modification of clay-water systems with salts and/or polymers are used to highlight how changes in the structure of these materials are reflected in the mechanical response. Finally, insights gained from coupling rheological measurements with techniques that allow probing molecular scale interactions are briefly discussed.

1. ULTRA-SOFT CLAYS – A CLASS OF GEOMATERIALS OF EMERGING SIGNIFICANCE

Clay-water dispersions are geomaterials, whose structure is dominated by the presence of water, and which are characterized by mechanical properties falling much below those characteristic of traditional soft clays examined in the geotechnical literature (e.g. shear stiffness G in the kPa range – see Fig.1). Within the geotechnical field, the study of these geomaterials is relevant to the behavior of dredged sediments, surficial coastal and underwater deposits, tailings generated from various mining operations, drilling fluids used in reservoir exploration and trenchless technologies, grouts for soil treatment, slurries used for cutoff walls and ground support. Moreover, clay based dispersions find application in a range of fields outside of civil engineering. These include traditional applications in the cosmetic, paint, paper, and ink sectors, as well as newer uses in electronics and biotechnology. For the same clay mineral, the structure and properties of these materials depend on a variety of factors including solid concentration, type and concentration of the cations and anions present in solution in the water, and pH. The presence of additional phases (e.g. gas or oil) and/or of additives further affects their behavior.

2. RHEOLOGICAL TECHNIQUES FOR THE CHARACTERIZATION OF ULTRA-SOFT CLAY-WATER SYSTEMS

Traditional geomechanics experimental methods are, in general, not suited for the investigation of ultra-soft clay-water systems. Instead, it is shown that rheometrical techniques, extensively used to date to study soft materials in other fields, represent an effective way of characterizing these geomaterials.

Oscillatory rheological measurements on concentrated pure clay-water systems are presented to illustrate key features of the mechanical response, including the presence of a region characterized by "solid-like" behavior that extends to very large strains, the marked sensitivity of the response to stress history, and the effects of thixotropy and aging.

Additional data are presented from rheological measurements on tailings generated from mining processes. The response of these more complex clay water systems is affected by the more complex and variable mineralogy, the presence of organics and of additives used during the mining process, and, in some cases, the existence of a gas phase deriving from bacterial activity.

Rheological measurements find also application in the development of methodologies for modifying the behavior of clay-water systems (e.g. with high molecular weight anionic polymers), as changes in the particle-to-particle interactions and the overall microstructure of these materials due to the interaction of additives with the clay particles are fingerprinted in the rheological response.

As the structure and the mechanical response of ultra-soft clay-water systems are ultimately dependent on molecular and colloidal interactions, information complementary to rheological data can be obtained from techniques capable of probing the material response at these scales. This is illustrated through a study conducted using thermal analysis and spectroscopic techniques in parallel with the rheological measurements.

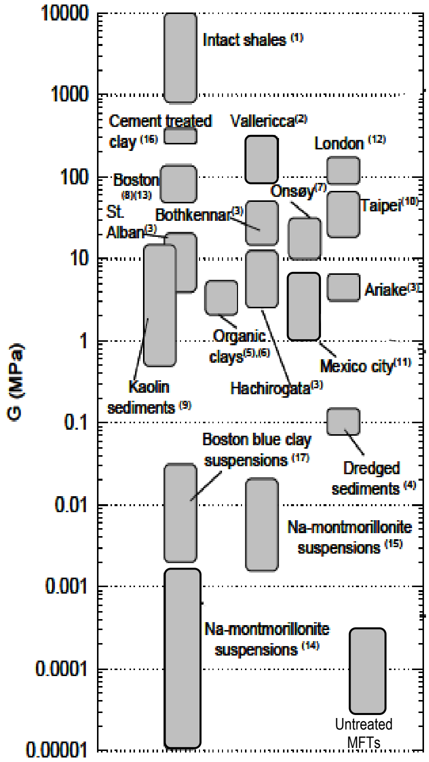

Fig. 1 Shear stiffness values for a variety of clay geomaterials [1]

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