This paper is based on a presentation made at a symposium on ‘Montmorillonites in Environmental Engineering’ held as part of the 38th Annual Meeting of The Clay Minerals Society in Madison, Wisconsin in June 2001.

MICRO-STRUCTURE AND HYDRAULIC CONDUCTIVITY OF SIMULATED SAND-BENTONITE MIXTURES

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Abstract—This paper describes the relationship between the micro-structure and hydraulic conductivity of simulated sand-bentonite mixtures (SSBMs) prepared with powdered and granular bentonite. Glass beads were used to simulate sand grains because of their superior optical properties. The micro-structure of SSBMs was observed using optical micrography and scanning electron microscopy. For mixtures prepared with powdered bentonite, the indications are that bentonite coats the particles. As the bentonite content increases, the thickness of bentonite coating increases and reduces the area available for flow. For mixtures containing granular bentonite, the dry bentonite granules occupy the space between the particles and then swell to fill the void space. As the bentonite content increases, the number of granules increases, leading to more void spaces being filled with bentonite. At higher bentonite content (>8%), flow paths devoid of bentonite are unlikely, and the hydraulic conductivity appears to be controlled by the hydraulic conductivity of bentonite. The changes in micro-structure that were observed are consistent with the decrease in hydraulic conductivity that occurs with increasing bentonite content. However, the relationship between hydraulic conductivity and bentonite content differs depending on whether a mixture contains powdered or granular bentonite.


INTRODUCTION

Sand-bentonite mixtures (SBMs) have been used successfully for construction of hydraulic barriers when clayey soils are not available. An empirical approach based on laboratory tests is commonly used to determine the amount of bentonite required to achieve the desired hydraulic conductivity (Kenney et al., 1992). Hydraulic conductivity testing, however, may take several months to perform, especially at higher bentonite contents. An alternative approach is to use mathematical models to predict the hydraulic conductivity based on the properties of the sand and the bentonite (Chapuis, 1990; Abichou, 1999).

The predictive models generally assume that the SBM is an “ideal mixture”, as reported by Chapuis (1990), Kenney et al. (1992), and Mollins et al. (1996). The SBM is assumed to be a two-phase material consisting of sand and bentonite gel (Chapuis et al., 1990). The bentonite is assumed to be distributed uniformly throughout the void space and has a swelling capacity (i.e. volume of bentonite after swelling) that is greater than or equal to the volume of the void space in the sand. Because the sand particles are effectively embedded in a matrix of hydrated bentonite, the hydraulic conductivity of an ideal mixture is controlled by the hydraulic conductivity of the bentonite (Kenney et al., 1992).

Sand-bentonite mixtures used in practice normally cannot be assumed to be ideal mixtures because they do not contain enough bentonite to fill the voids in the sand matrix. Alternatively, the bentonite is not distributed uniformly throughout the sand and thus does not swell to fill all of the available voids. Models to predict the hydraulic conductivity of these non-ideal SBMs require knowledge of how the pore-space in the sand changes as the bentonite content varies. The objective of this study was to investigate how bentonite is distributed in SBMs with low bentonite content (<10%) to elucidate how increasing the bentonite content causes the hydraulic conductivity of non-ideal SBMs to change from that of sand to that of bentonite. For simplicity, sand-bentonite mixtures were simulated with mixtures of uniformly graded glass beads and bentonite. The behavior of these mixtures is assumed to be similar to that of sand-bentonite mixtures. Future efforts will focus on how particle-size distribution affects the hydraulic conductivity of SBMs.

BACKGROUND

Graham et al. (1989) examined the particle micro-structure of SBMs with a bentonite content of 50% using scanning electron micrographs (SEMs). In this paper,