
Mechanism Controlling the Volume Change Behavior of Kaolinite

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Abstract: The possible physical and chemical forces controlling the volume change behavior of kaolinite were ascertained from the sediment volume of kaolinite in various solvents under no external load condition and from conventional oedometer measurements of kaolinite in several pore fluids. The minimum sediment volume of 14.5 cm³/10 g clay occupied by kaolinite in water where repulsive (R) forces were dominant indicated that the R contribution was insignificant for kaolinite. The maximum sediment volume of 25.0 cm³/10 g clay in benzene where coulombic attraction forces were significant suggested that electrostatic attraction between silicate sheets and midplane cations and van der Waals forces were not appreciable for kaolinite. The positive edge-negative face bonding of kaolinite particles in benzene was unlikely because the protons required to impart a positive charge to the edges were not available in the nonpolar solvent. The 3688 cm⁻¹ band in the infrared spectrum of a kaolinite-dimethylamine sample decreased by 10 cm⁻¹ on H-bond formation of the solvent molecule with the exposed structural hydroxyls of the octahedral sheet. The adsorbed solvent molecules likely H-bonded with an adjacent clay particle. That such interparticle H-bonds controlled the sediment volume and interparticle attraction in kaolinite was indicated by the decrease in sediment volume with increase in dipole moment of the solvent molecule, i.e., 25.0 cm³/10 g clay in n-heptane (dipole moment, $\mu = 0$), 23.5 cm³/10 g clay in toluene ($\mu = 0.36$), 17.0 cm³/10 g clay in ethanol ($\mu = 1.67$), and 14.5 cm³/10 g clay in water ($\mu = 1.84$).

In the oedometer tests with various pore fluids, a high void ratio (i.e., volume of voids/volume of solids) of ~ 1.3 was obtained for kaolinite in n-heptane, and hexane ($\mu \simeq 0$) at an external pressure of 1 kg/cm² probably because the weakly bonded kaolinite particles were randomly oriented. At the corresponding applied pressure a lower void ratio of 0.88 resulted in water ($\mu = 1.84$) where the stronger hydrogen bond between flat layer surfaces of adjacent particles favored a parallel orientation of clay particles.

The variations in void ratio-external pressure relationship indicated that kaolinite underwent lower compressibility in a solvent with low dipole moment and *vice versa*. Thus, the interparticle H-bond did not play a significant role in controlling the shear resistance and volume change behavior. The volume change behavior was essentially controlled by frictional forces and clay fabric. In nonpolar solvents the random arrangement of kaolinite particles and the frictional forces mobilized a high shear resistance on the application of a consolidation pressure, resulting in a lower compressibility. In a solvent with high dipole moment the parallel array of clay particles mobilized less shear resistance and produced a greater compression.

Key Words: Compression • Dipole moment • Hydrogen bond • Infrared spectroscopy • Kaolinite • Organic solvents • Volume change

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