ABSTRACT

The knowledge of hydro-mechanical response of the two extreme clays namely, kaolin and bentonite are important due to their presence in many parts of the world and these clays are subjected to wetting cycles under external loads during the monsoon. Bentonite clays are further subjected to combined hydraulic and mechanical loading from the surrounding saturated rock mass or ground water during the placement in nuclear waste repositories and landfills, respectively. In this work, it will be shown that kaolin is a collapsible soil similar to the loess soil. The collapse mechanism in kaolin is, however, due to changes in particle association (fabric) with the interaction with different pore fluids. Collapsible soils are known to withstand high normal stresses without undergoing a significant volume change in air-dry state. The soil is, however, susceptible to a large volume change upon wetting. Several physicochemical parameters strongly influenced the particle association in kaolin by altering the charges on the particle surfaces and edges due to interaction with different pore-fluids. The collapse nature of the kaolin is investigated with great detail in this work. Wetting induced collapse behavior of kaolin was studied under the influence of pore-fluid chemistry using a multi-scale approach. The influence of pH, salt concentration, and dielectric pore-fluid environment on the clay behavior was analyzed using sedimentation and collapse tests. The collapse test results were well corroborated with the sedimentation test data, SEM images of lyophilized specimens, and edge isoelectric point (IEP_{edge}). The influence of inundation fluid and inundation pressure on the fabric changes and collapse potential was elucidated.

In contrast, bentonite clays swell due to wetting. These clays exert swelling pressure on the surroundings in isochoric conditions due to wetting. Swelling pressure evolution curve (SPEC) for different quality Indian bentonites was established under different compaction density. The effect of compaction density and bentonite quality on the pore-size distributions (PSDs) and clay fabric were analyzed for understanding the influence on SPEC behavior. The evolution of PSD and fabric during the water uptake process was analyzed for understanding the microstructural influence on the SPEC behavior. Swelling pressure of the bentonites is influenced by the initial compaction density and plasticity. The knowledge of swelling pressure variation with initial compaction density for bentonites of different plasticity is important for the design of the repository.

Theoretical models on establishing the swelling pressure vs. dry density relationship are gaining attention as the laboratory estimation of swelling pressure over a wide range of dry densities is highly time-consuming and expensive. Current theoretical models based on the surface properties of the bentonites using the diffuse double layer theory and using the water adsorption isotherm are associated with several limitations. A predictive model based on the linearization of the swelling pressure data using normalization dry density was proposed in this work. Influence of the bentonite plasticity and swelling mechanisms were well studied for establishing the appropriate model parameter and for choosing the normalization factor. The proposed model required a single experimentally measured swelling pressure data point in the dry density range varying between 1.45 – 1.7 Mg/m^3 for accurately establishing the swelling pressure curves over a wide range of dry densities. The model does not require the knowledge of surface properties and pore–fluid parameters, unlike the previous models.

The effective stresss variation in clays of different mineralogy under hydromechanical loads was studied. Three series of suction-controlled tests were considered for understanding the effective stress development using the suction stress approach. In the first series of tests, the drying behavior of slurried kaolin and mixtures of kaolin – bentonite clays were considered. Two clay mixtures were used in these tests. The Volumetric Shrinkage Curve (VSC) and drying Soil Water Characteristics Curve (SWCC) of initially slurried clays were established by conducting a series of volumetric shrinkage and suction controlled tests for understanding the effective stress development due to drying using suction stress concept. The second series of experiments consisted of suction controlled swelling pressure and SWCC tests for ascertaining wetting SWCCs in isochoric conditions. The last series consisted of suction-controlled, wetting induced collapse tests on compacted kaolin under different inundation pressures. The suction stresses and effective stresses in kaolin, bentonite, and kaolin – bentonite mixtures were analyzed under the studied hydro-mechanical conditions. The study concludes that the suction stress approach does not explain the effective stresses correctly in the collapsible and swelling clays under hydro-mechanical loading and for the studied conditions. Keyword: Kaolin, bentonite, hydro-mechanical load, nuclear waste repository, collapse, swell pressure, effective stress.