Abstract of the dissertation

Deformation behaviour of multi-porosity soils in landfills

Two different soils may be generated from open-pit mining: lumpy soils with a granular structure and clay mixtures, depending on the length of the conveyor belt and the strength of the original soils. Lumpy soils may be created for a high strength of the excavated soils. They are dumped as landfills without any compaction, which permits the water and air flows via the inter-lump voids. As a result, a new structure consisting of the lumps and reconstituted soil within the inter-lump voids can be created. However, if the original soil has a low strength or a long transportation takes place, the material may disintegrate into small lumps and thoroughly mix soils from different layers. Landfills consisting of clay mixtures arise in this way. The stability and deformation of landfills are crucial for design of occupied area and landfill slopes. For this reason, three different landfill materials will be investigated in this thesis: (1) the lumpy granular soil from fresh landfills, (2) the lumpy composite soil corresponding to old landfills and (3) clay mixtures.

Firstly, an artificial lumpy soil was investigated. It is a transition form between the reconstituted and natural lumpy soils. Compression, permeability and strength of lumpy materials have been evaluated based on oedometer and triaxial tests. The shear strength of the normally consolidated lumpy specimens lies approximately on the Critical State Line of the reconstituted soil. The reconstituted soil, which exists in the inter-lump voids, plays a crucial role in the behaviour of artificial lumpy materials. Similarly to the artificial lumpy soil, inter-lump voids of the natural lumpy soil are mainly closed above a relatively small stress level, which is induced by the rearrangement of the lumps. However, its limit stress state is located above the Critical State Line of the reconstituted soil, which may be caused by the diagenetic soil structure in the natural lumps.

The structure transition of the lumpy granular material can be divided into three possible stages related to the stress level. Firstly, the compressibility of a fresh lumpy is relativity high due to the closure of the inter-lump voids within a low stress range. In this stage, the hydraulic conductivity is mainly controlled by the inter-lump skeleton due to the existence of macro drainage paths, while the shear strength is controlled by the reconstituted soil around the lumps. Afterwards, its compressibility decreases with the consolidation stress and the soil behaves similarly to an overconsolidated soil. The

clayfill appears to be uniform visually in this stage, but its structure is still highly heterogeneous and the hydraulic conductivity is higher than that of the reconstituted soil with the same overall specific volume. Finally, the loading reaches the preconsolidation stress of the lumps, and the whole soil volume becomes normally consolidated.

Isotropically consolidated drained triaxial shear tests were performed on artificially prepared specimens with parallel and series structures. The laboratory tests show that the specimens with the series structure have the same failure mode as the constituent with the lower strength; the specimens with the parallel structure have a failure plane which crosses both constituents. As a result, the shear strength of the series specimens is only slightly higher than that of the constituent with the lower strength and the strength of the parallel specimens lies between those of the constituents. Afterwards, the behaviour of an artificial lumpy material with randomly distributed inclusions is investigated using the Finite Element Method. The computation results show that the stress ratio, defined as the ratio of the volume-average stress between the lumps and the reconstituted soil within the inter-lump voids, is significantly affected by both the volume fraction and the preconsolidation pressure of the lumps under an isotropic compression path, while the volume fraction of the lumps plays a minor role under a triaxial compression path. Based on the simulation results and analysis of the two basic configurations, a homogenization law was proposed utilizing the secant stiffnesses.

The compression behavior of the lumpy composite soil was analyzed within the homogenization framework. Firstly, the volume of the composite soil was divided into four individual components. The inter-lump porosity was introduced to account for the evolution of the volume fractions of the constituents, and it was formulated as a function of the overall porosity and those of its constituents. A homogenization law was then proposed based on the analysis of the lumpy structure together with a numerical method, which gives a relationship for tangent stiffnesses of the lumpy soil and its constituents. Finally, a simple compression model was proposed for the composite lumpy material, which incorporates both the influence of the soil structure and the volume fraction change of the reconstituted soil. Furthermore, a general framework for the consolidation behaviour of the lumpy composite soil was proposed based on the double porosity concept and the homogenization theory.

To describe the behaviour of lumps with low stress level, a new failure line was proposed with help of the equivalent Hvorslev pressure and critical state concept. The structure effect was incorporated into the nonlinear Hvorslev surface within sensitivity framework and the generalized Cam clay model proposed by McDowell and Hau (2003) was adopted on the wet side of the critical state. A secant stiffness, defined as the ratio between the deviatoric stress and deviatoric strain, was used in the homogenization law. Finally, a simple model for the natural lumpy soil was proposed within the homogenization framework.

The physical properties, compression behaviour and remolded undrained shear strength of clay mixtures were investigated by reproducing the soils artificially in the lab. Afterwards, the models for the compression and undrained shear strength of clay mixtures were proposed. The model for the strength of the clay mixture originated from simplifying the structure of a clay mixture, in which the elements of the constituents are randomly distributed in a representative elementary volume. By defining a water content ratio (the ratio of water contents between the constituents), the undrained shear strength of each constituent was estimated separately and then combined together with corresponding volume fractions. A homogenization law was proposed afterwards based on the analysis of the randomly arranged structure. A simple compression model considering N constituents was proposed within the homogenization framework, which was evaluated by a mixture with two constituents.