MODELLING OF LUMPY CLAY FILLS

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Abstract

An extensive open cast mining of brown coal has been taking place in NW Bohemia since 1940's. During the mining process, overburden clay is placed in the form of irregularly shaped lumps of typical dimensions up to 500 mm into large spoil heaps. The total thickness of the lumpy clay landfills is usually 20-50 m. Their material has a double porosity structure: the porosity of intact clay (intragranular porosity) and the voids between clay lumps (intergranular porosity). The total porosity of the fresh fill can be up to 70%. This soil presents special challenges for geotechnical design, primarily because of its high and non-uniform settlement. Further, the progressive tranformation from the "granular" to "fine-grained" material makes the lumpy clay difficult to characterise and model.

The aim of the presented thesis is to describe the behaviour of the landfill and the change of its structure by means of field measurements, the centrifuge and numerical modelling. During site investigation for a motorway over a 20-30 years old landfill, two trial embankments were built and monitored over the period of 3 and 6 years respectively. The subsoil of the embankments was instrumented by hydrostatic levelling profiles, pore pressure transducers and depth reference points installed in boreholes. The interpretation of the field measurements revealed large settlements, which are attributed to the embankment surcharge, change of the groundwater level position during the monitoring and creep. A significant differential settlements were observed under both embankments.

Introductory modelling in a mini-centrifuge, combined with oedometer testing, demonstrated the key mechanisms in the double porosity fills: irreversible deformation at the low stresses due to rearrangement of the lumps, and reversible deformation (swelling) at higher stresses, similar to the behaviour of the reconstituted material. Two different methods of filling were analysed. Placing fill under water resulted in high initial void ratios followed by large deformations while loading. Dry filling followed by fast natural saturation may be recommended with respect to further development of the landfills.

The centrifuge modelling of the field embankment was carried out at 150 g. Two tests with different techniques of embankment construction were performed. The results confirmed that hydraulic conductivity was controlled by the complex structure of the clayfills. Similarly to the field measurements, there were significant initial settlements during the self-weight consolidation due to the compression of open macro voids. The double porosity structure in the saturated fresh fill allowed the excess pore pressures to dissipate quickly, which accelerated the consolidation process initially. Thereafter, dissipation was controlled by the low permeability of the intragranular pores in the clay, once the intergranular pores had closed.

The rapid initial settlement was observed also after the embankment surcharge. In the centrifuge higher settlements were measured in the top 10 meters of the landfill than in the field. The major part of this difference can be attributed to the reduction of the porosity due to the climate effects *in situ*, which can cause a faster degradation of the soil structure close to the surface.

A hypoplastic model for clays with meta-stable structure was chosen for the numerical modelling of both the *in situ* trial embankments. The basic hypoplastic model for clays was calibrated using isotropic compression tests and triaxial compression tests on the reconstituted clay. The three additional model parameters describing the effects of double porosity structure were calibrated using oedometer tests on the specimens prepared from the scaled down double porosity material (material with smaller size of clay lumps). The performance of the model was evaluated by a comparison with the results of the centrifuge model of self-weight consolidated landfill. Finally, the hypoplastic model was used for the simulation of both trial embankments and the results were compared with the *in situ* measurements.

The numerical model yielded bigger settlements due to the embankment surcharge than the field measurements. The degradation of the double porosity structure *in situ* due to weathering in the top landfill layer was considered as the main reason for this discrepancy. The weathering effects were modelled by a reduction of the void ratio, sensitivity and parameter κ^* in the vertical profile of the landfill. An inverse analysis of the weathering destructuration showed that the double porosity structure is degraded in the top 10 m and the effect of the weathering destructuration decreases with depth.