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Review of the Doctoral Thesis by Mr. Jan Najser

The Doctoral Thesis of Mr. Jan Najser entitled *Modelling of lumpy clay fills* and submitted at the Charles University in Prague (Faculty of Science) can be considered as a remarkable contribution in the research of man-made soils. It deals with the mechanical behaviour of double porosity clays at different scales (laboratory tests, centrifuge model test and field tests) and attempts to apply a unifying hypoplastic framework for their constitutive description.

After a short introduction, the thesis starts with a state of the art regarding the behaviour of double porosity soils, distinguishing between the constitutive and landfill behaviour. The amount of the published results elsewher is limited and the author's review includes many relevant papers. Surprisingly, German references are missing, although the landfill problems around the city of Leipzig offer an important experience which substantially influenced the design of the trial embankments described in the thesis. It is not clear why the case of Aberfan is included. This case is related to soil liquefaction which cannot be encountered in double porosity clays. The interpretation of the results in Fig. 2.4 with respect to friction angle is also not fully tracktable. The figure presents a relationship between the landfill inclination and its height, the latter being not proportional to the vertical effective stress due to the presence of pore water pressures.

Chapter 3 gives an overview of landfills in North-Western Bohemia, including the geology of the Most Basin and the principles of filling processes. A short commented list of ground improvement techniques for landfills is presented as well. Some more details on the soil mechanical properties of the original clay material would be useful in order to understand better the features of clay lumps.

Chapter 4 deals with two trial embankments which were built on clay landfills prior to the construction of the motorway between Dresden and Prague. The construction procedure, monitoring intrumentation and groundwater oscillations are thoroughly explained. Practically no details on clayfill properties below the trial embankments are given. It is hard to believe that for such a project no site investigation was performed (in Chapter 7 core samples of the embankment subsoil are even mentioned).

The settlement trough and the ground deformation profile in vertical direction are fundamental for the interpretation of model tests and numerical simulations in the further chapters of the thesis. Thus, a critical analysis of the measured data is presented. Still, several points are difficult to follow without an additional explanation:

- Why embankment surcharge did not influence the settlement at the ends of the hydrostatic leveling profiles (p. 31)? This contradicts the principles of stress distribution in any(!) material. According to the figures, the ends of the leveling profiles were located below the embankment foot.
- The consolidation time of the embankment of approximately 100 days was estimated, followed by a pronounced creep. However, the pore water pressure measurement takes place probably in large voids. Is it not plausible to consider a longer consolidation time for clay lumps (this can be checked with a very simple calculation)? How does the creep rate coincide with the one in oedometer tests?
- The reference points at the bottom of the settlement profile B1 (Fig. 4.12a) are obviously in the active settlement zone. A larger settlement can be expected in the reality.
- The excess pore pressure dissipation under the Embankment 2 was five times longer than below the Embankment 1. The thickness of the clayfill below the Embankment 2 is only 10% larger than below th Embankment 1. The lenghth of the drainage path cannot explain the large differences in the pore pressure behaviour!

The preliminary tests in a mini centrifuge are summarized in Chapter 5. After a brief introduction to some selected topics of the centrifuge testing and a description of the applied centrifuge, the soil preparation and the testing procedure are explained. Unfortunately, there is no discussion on scale effects, comparing the artificially prepared and in situ lumps. Image analysis could certainly help in the analysis of grain shape. Moreover, one could expect a size-dependent stiffness of the lumps and further phenomena.

The results from the mini centrifuge helped with the planing of advanced centrifuge tests and provided a picture of both effects, self-weight consolidation and consolidation due to the embankment load. The limitations of the testing apparatus (stopping of the centrifuge for any measurement) made a detailed interpration of the results difficult. The author used the results for a formulation of a phenomenological model of the material behaviour which qualitatively explains structural changes in the landfill. It is strange that the author attributes the observed continuing deformation with time to creep (see Fig. 5.21). Creep rate is not scaled in centrifuge and for the short test time should be negligible!

Oedometer tests on specimens obtained from the mini centrifuge covered the compression behaviour within a large stress range. Unfortunately, the author did not use the opportunity to compare his results with those published by Herbstova and Herle (2009) which included also large scale oedometer tests on double porosity clay of the original lump size. This could contribute to the analysis of scale effects.

Chapter 6 on modelling in the geotechnical centrifuge represents one of the key parts of the thesis. The preparation, instrumentation and setup of the model are described in detail and prove a carefull approach to the physical testing. The test procedure and the difficulties with the construction of the embankment load at high acceleration are also well explained. The test results are discussed separately for the self-weight consolidation and the embankment load. In the first case, most of the deformation takes place fast (within half a year in the prototype scale) and the surface settlement is irregular due to material inhomogeneities. The observed vertical strain is almost constant within the entire fill layer (Fig. 6.23).

In the case of embankment load, a relatively large differences between the model and in situ values of pore pressures and settlements were observed. It is interesting to follow the author's reasoning about these differences. Especially the first argument (p. 96-97) on the properties of the top layer is contradictory. An increase in stiffness due to filling of voids during weathering accompanied by a higher permeability due to deep dessication cracks can be hardly accepted simultaneously. The settlement distribution with depth (Fig. 6.33) reveals that the deformation mechanisms in the centrifuge and in the field are probably qualitatively different (effect of the lump size).

Numerical modelling of the embankment boundary problem is covered by Chapter 7. An advanced hypoplastic model for structured soils after Mašín was applied. The calibration of the parameters of the basic model was based on tests with a reconstituted clay material. The parameters of the extended model followed from the oedometer tests on the specimens pre-loaded in the mini centrifuge.

The simulation results from the mini centrifuge proved the ability of the numerical model to reproduce all substantial features observed during the physical testing. Still, the initial settlement rate was not captured correctly which the author explained by the complex loading history in the centrifuge (repeated stops in order to perform measurements).

The complete numerical model of the landfill included an estimated stress-dependent permeability which takes into account a decrease of voids in deeper layers. Still, the calculations results deviated substantially from the observed settlement behaviour in the field. Introducing a further "weathering" (desctructuration) parameter, an excellent agreement with the field results was obtained. Nevertheless, many questions arise through this approach which would need more justification:

- A substantially different weathering state and distribution with depth was necessary for each of both emankments, although they were built close to each other and their large area supresses local inhomogeneities.
- The assumption of 50% weathering destructuration in the depth of 20 m is unexpected.
- If the destructuration describes weathering, it should be considered for the self-weight consolidation as well.

- The degree of weathering is the most important state parameter for the calculation. How can it be determined in situ in order to enable prediction of the clayfill behaviour.
- How the weathering concept fits to the results of the geotechnical centrifuge tests? The weathering did not take place in the model tests. Consequently, a reasonable agreement between the centrifuge results and the "non-weathered" model would be expected.

The thesis as a whole is an advanced research work which witnesses a large amount of the scientific effort and brings several important results. It shows that many features of the behaviour of clay lumpy landfills can be observed in centrifuge tests on downscaled material where the field stresses can be reproduced. If calibrating an appropriate advanced constitutive on this downscaled material, a good coincidence between physical and numerical modelling can be reached.

On the other hand, the thesis also revealed limitations of such an approach. Downscaling the size of clay lumps may change the mechanical properties of these lumps. Consequently, applying physical or numerical modelling, only a qualitative description but not a quantitative prediction of the field behaviour is possible. A missing analysis of scale effects on lumps is therefore a certain weakness of the thesis. Another topic, which would be worth to investigate in the future, is the role of structural anisotropy of the lump skeleton. In the presented physical models, the soil layers were constructed horizontally, whereas layers in the field originate at the angle of repose. At least for coarse grain soils, such anisotropy could have a substantial impact on the observed behaviour.

The style of the written text is exceptionally high and the quality of English as well. Some figures could be better — many of them are copied from different sources, even in case of simple sketches or tables which should be produced by the author himself. Still, the overall layout of the thesis is on a good level.

Conclusion

The author proves his ability to deal with actual research topics and fulfils with excellence the requirements on the doctoral degree.

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