MODELLING OF NATURAL STRUCTURED CLAYS USING LABORATORY AND NUMERICAL METHODS

DAVID MAŠÍN

City University, London

Introduction

The main aim of the project is a development of numerical methods for modelling of natural structured clays. The numerical model, which can describe main aspects of mechanical behaviour of reconstituted clays was developed at City University (Stallebrass, 1990). This model, named 3-SKH model, is developed in the framework of incremental, rate-independent elasto-plasticity and critical state concepts. The model introduces kinematic 'history' surface, which describes the boundary of the influence of recent stress history on soil behaviour. The model was successfully extended for the natural structured clays on the basis of the 'sensitivity' framework, proposed by Cotecchia and Chandler (2000).

According to this framework the anisotropic structure of the natural clays does not influence the shape of the state boundary surface, but significantly influence its size. The size of the state boundary surface is described by the 'sensitivity' and once 'sensitivity' is known it is possible to relate mechanical behaviour of natural and reconstituted clay.

The modelling of natural stiff clays with stable structure using the 'sensitivity' framework is convenient, since no changes in mathematical formulation of the model are necessary, only the size of the state boundary surface is controlled. Nevertheless, the advantage of the kinematic hardening models is that they can predict soil behaviour, which is dependent on the previous stress history of the soil. It was shown by Ingram (2000), that the way, how the previous stress history of the soil is numerically modelled in Finite Element Analysis influences significantly the predictions. Differences in predicted settlement of ground surface above tunnel in stiff clays is demonstrated in Figure 1. Unfortunatelly, proper development of this idea was complicated with the uncertainty in the geological history of the soil deposit.

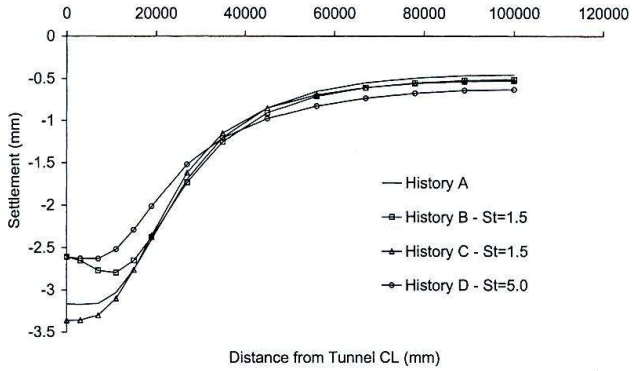

Figure 1. Influence of the calculated ground settlement on the assumed stress history of the soil deposit (Ingram, 2000)

Main aims of the project

Main aims of the project is to prepare clays with sedimentation stable structure under carefully controlled conditions in the laboratory. The stress history of such artificially prepared soil is known exactly and this process should lead to better understanding of the natural soils and to development of numerical methods for their description.

Laboratory testing

Soil is prepared by slow sedimentation from the slurry of very low initial density in the perspex tube, two meters high and ten centimetres in diameter. Soil samples are then tested in triaxial apparatus equipped with local LVDT strain transducers and bender elements. In order to ensure similarity of the stress history applied in the laboratory to that in the nature, the samples are after removing from sedimentation column consolidated under K_0 conditions in the triaxial apparatus, controlled by measurement of radial strain using local LVDT transducers. Triaxial tests on reference reconstituted samples are performed paralelly to testing sedimented samples.

In subsequent stages of the project centrifuge model tests on sedimented soil will be performed, which should allow further development of numerical methods on the basis of Finite Element analysis of boundary value problems.

Numerical modelling

Development of numerical methods for description of anisotropic clays is parallel to the laboratory testing and is based on the available data on natural and one-dimmensionally consolidated reconstituted clays. Main shortcoming of the 3-SKH model, which is of importance for current project, was defined in high overprediction of K_0 stress state. It was shown that it was possible to achieve significant improvement of the model predictions for K_0 consolidated soils by introducing non-associated flow rule with cross-anisotropic shape of the plastic potential surface into the 3-SKH model. Predictions of the K_0 stress state by the modified model are shown in Figure 2.

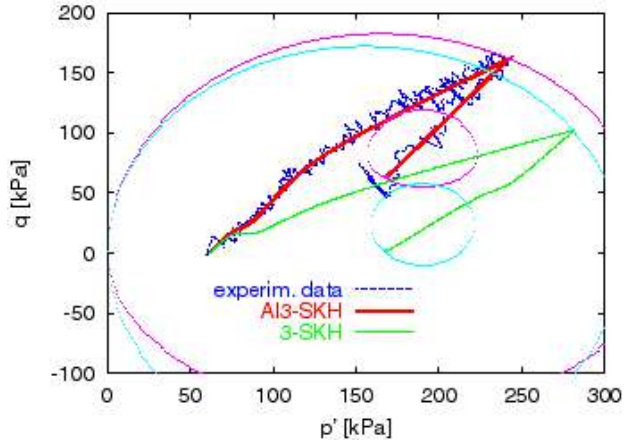

Fig. 2. Predictions of the stress state during K_0 consolidation by the 3-SKH model and modified model (AI3-SKH). Experimental data after Coop (1995).

Conclusions

Laboratory testing programme, which is designed to clarify the current knowledge about developement of structure in natural stiff clays has been running recently at City University. The numerical model for description of the anisotropic clays, based on the framework of the unique bounding surface, was developed and evaluated.

References

Coop, M. R., Atkinson, J. H. and Taylor, R. N. (1995) Strength and stiffness of structured and unstructured soils. Proc. 9th ECSMFE, No. 1, 55-62

Cotecchia, and Chandler (2000) Title of reference, Publication, volume number, page number.

Ingram, P. (2000) The application of numerical methods to natural stiff clays, PhD thesis, City University, London

Stallebrass, S. E. (1990) Modelling the effects of recent stress history on the behaviour of overconsolidated soils, PhD thesis, City University, London