COMPARISON OF ANISOTROPIC RATE-DEPENDENT MODELS AT ELEMENT LEVEL

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Summary: Two recently proposed anisotropic rate-dependent models, EVP-SCLAY1 and ACM are used to simulate the stress-strain behaviour of Vanttila clay. The models are identical in the way the evolution of anisotropy is simulated, but differ the in way the rate-effects are taken into account. Based on numerical simulations against element level tests, using objective parameters, suggest that EVP-SCLAY1 is able to give a better representation of the clay response at element tests than ACM in 1D loading, but the latter gives a better prediction for undrained strength.

1 Introduction

Although the geotechnical engineers have been aware of the issues related to creep and rate effects for ages, only relatively recently that comprehensive rate-dependent constitutive models capable of modelling anisotropic natural soils have been proposed (see e.g. Zhou et al. 2006, Leoni et al. 2008, Hinchberger & Qu 2009, Karstunen & Yin 2010, Yin et al. 2011). The aim of this paper is to compare objectively the predictions by two anisotropic rate-dependent models: EVP-SCLAY1 (Karstunen & Yin 2010) and ACM (Leoni et al. (2008) at element level. For the sake of simplicity, the effects of apparent bonding and destructuration of the rate-dependent behaviour are ignored, although as demonstrated e.g. by Hinchberger & Qu (2009) and Yin et al. (2010) this may be necessary for modelling certain phenomena.

2 ACM and EVP-SCLAY1 models

In ACM and EVP-SCLAY1 anisotropic surfaces, analogous to the anisotropic yield surface in the rate-independent S-CLAY1 model (Wheeler et al. 2003), represent the boundary between large irrecoverable strains and relatively small strains. Subsequent loading that produces irrecoverable strains, may change the anisotropy. In EVP-SCLAY1 (Karstunen & Yin 2010) within so-called static yield surface (see Fig. 1a) the behaviour is purely elastic. In contrast, in ACM, the bounding surface is called normal consolidation surface NCS (see Fig. 1b) and creep strains occur even in the overconsolidated range.

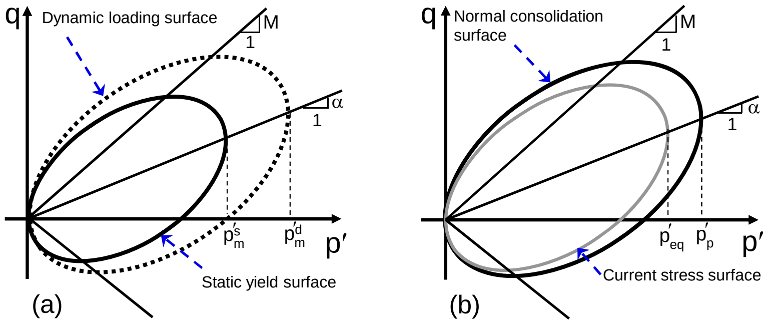

Fig. 1. a) Yield surfaces of the EVP-SCLAY1 model; b) Normal consolidation surface and current stress surface of ACM model.

The advantage of ACM over EVP-SCLAY1 is that is possible to derive the soil constants directly from the experimental tests, whilst the viscosity coefficients of EVP-SCLAY1 require some calibration. Both models have been implemented in the Plaxis 2D and 3D finite element code as user-defined soil models.

3 Simulations of Vanttila clay

The model simulations include element level tests on Vanttila Clay (Yin et al. 2010) which is a highly sensitive ($S_t > 50$) soft clay. Conventional oedometer test results, combined with the results from undrained triaxial tests have been used in-determination of average parameter values for the EVP-SCLAY1 and ACM. At a depth of 2.9 m the common parameter are: e_0=3.3, λ=0.5, κ=0.057, λ^*=0.1163, κ^*=0.0133, M=1.35, ν'=0.2; α_{K0}=0.52, ω_d= 0.91 and ω=12. For ACM μ^*=3.76E-3 and τ=1 day, and for EVP-SCLAY1 N=23 and μ = 4E-3 (day^{-1}).

Firstly, conventional 1 day oedometer tests on Vanttila clay are simulated with Plaxis 2D 2010 with the user-defined model implementation of EVP-SCLAY1 and ACM. Fig. 2 shows the model prediction against experimental data (vertical strains vs. log-time) for Vanttila clay at a depth of around 2.8-2.9 m. No attempt has been made to create a best possible match, and the soil constants have been determined independently of the test that is being modelled. For all loading stages simulated, EVP-SCLAY1 appears to give better predictions that ACM. Of course, it would be possible match ACM with the test data better than done in Fig. 2 by e.g. artificially increasing POP or OCR, τ or indeed parameter $\beta = (\lambda^* - \kappa^*)/\mu^*$. That however, would be curve-fitting rather than objective model prediction. Fig.

3 in turn shows the model predictions for an undrained shear test of Vanttila clay at constant strain rates. In this case ACM gives a better prediction of the undrained strength than EVP-SCLAY1.

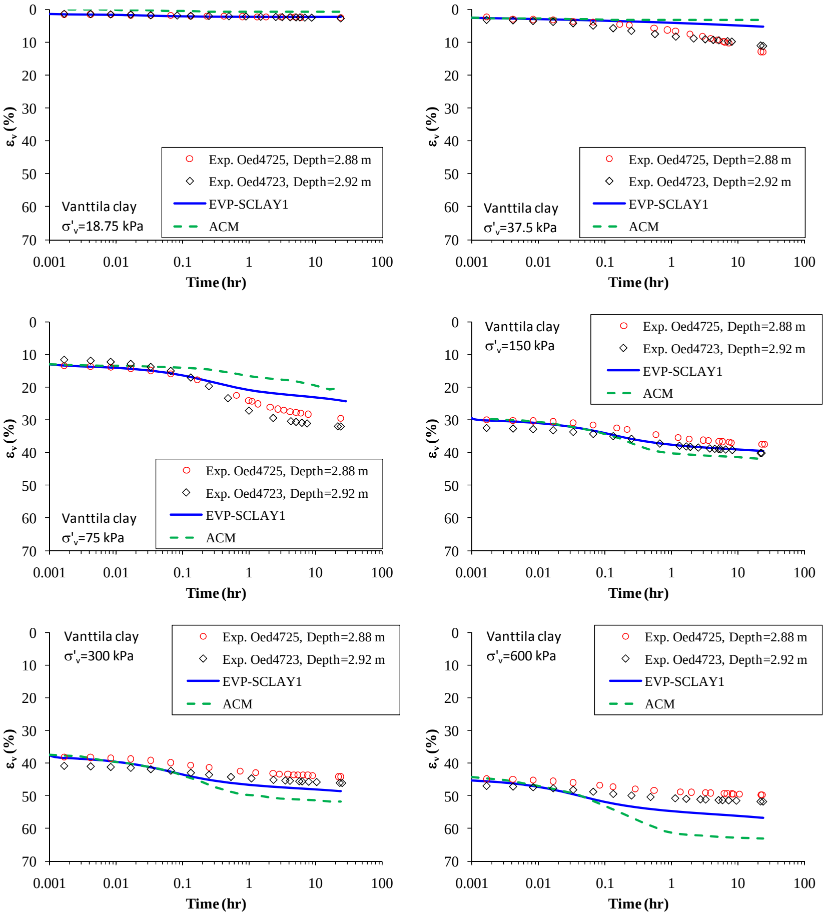

Fig. 2. Conventional oedometer test predictions of Vanttila clay.

4 Conclusions

Two anisotropic rate-dependent models, ACM (Leoni et al. 2008) and EVP-SCLAY1 (Karstunen & Yin 2010) have been used to simulate element level behaviour of Vanttila clay. EVP-SCLAY1 appears to give marginally better predictions than ACM for 1D loading, whilst ACM gives better prediction of undrained strength. The simulations ignored the effects of apparent bonding and destructuration for the sake of simplicity, which is not always appropriate. Challenge is how to make good predictions with objective parameters values. The compressibility, apparent preconsolidation stress and the tendency of a natural clay to creep is highly dependent on sample quality and further investigations on the effect of sample disturbance to the rate effects and deformations are needed.

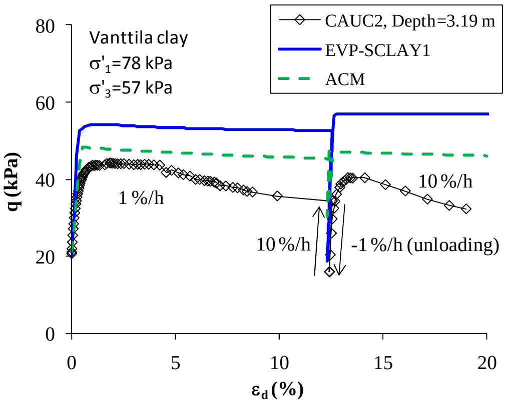

Fig. 3. Comparison of simulations of stress-strain behaviour of Vanttila clay for an undrained triaxial test with constant strain rates.

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