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## **Discussion on “Axisymmetric Simulations of Cone Penetration in Saturated Clay” by D.M. Moug, R.W. Boulanger, J.T. DeJong, and R. Jaeger**

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The Authors presented a valuable research and case study on the axisymmetric simulation of a Cone Penetration Test (CPT) in Boston Blue Clay (BBC). The Discussers would like to raise two issues related to the calibration of the geotechnical parameters. The first considers the influence of rate effects in the numerical model, the second concerns the shearing mode and soil anisotropy.

1. The behavior of cohesive soils is generally rate-dependent (e.g., Bjerrum 1973; Casagrande and Shannon 1948; Leroueil et al. 1985). The rate-dependency of BBC was shown by

Sheahan et al. (1996). This effect seems to have not been considered by the Authors in the applied soil constitutive model and calibration procedure. The Mohr-Coulomb (MC) (reduced to the Tresca criterion in the paper) and Modified Cam Clay (MCC) models are rate-independent constitutive models. The MIT-S1 constitutive model as proposed by Pestana et al. (1999, 2002) is also rate-independent to the best of the Discussers' knowledge. The Authors use  $CK_0UC$ ,  $CK_0UE$ , and  $CK_0UDSS$  tests for constitutive model calibration, but these are performed at a relatively low axial strain rate (usually about 1 to 5 %/hour). The cone penetrates the soil with the standard rate of 2 cm/s, and, as shown by Chen and Mayne (1994), the strain rate in the cone vicinity can be as high as 200 000 %/hour. Assuming a typical 10% increase of  $s_u$  in one log cycle, the differences in rates between laboratory tests (used for model calibration) and CPT probing can result in an almost 50% increase in undrained shear strength. One might also expect a similar increase of  $q_t$ . Bearing in mind the above comments, the inclusion of rate-dependency can strongly influence the results in Fig. 10 and 11. The Discussers are interested in the Authors' opinions regarding the BBC rate-dependency and its influence on their calibration procedure.

2. The Authors calibrated the undrained shear strength on the basis of  $CK_0UC$  tests, which delivers the upper boundary of the  $s_u/\sigma'_{v0}$  ratio (e.g., Ladd and DeGroot 2003; Lefebvre et al. 1983). Three shearing modes appear in the cone vicinity (Baligh 1985; Lunne et al. 1997) as noticed by the Authors. As the MC and MCC have an isotropic yield surface, a better way to use these models in the cone penetration simulation is to calibrate them on the average value of the  $s_u/\sigma'_{v0}$  ratio (or at least on the direct simple shear mode). This will arbitrarily include the anisotropic soil behavior. Consequently, the cone factors  $N_{kt,iso}$  for MCC and MC will be closer to  $N_{kt,avg}$  for MIT-S1. The Discussers are interested in how the average shear mode in the calibration of the MC and MCC models will affect the results (with the rate-dependency taken into account).

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