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FABRIC EVOLUTION OF SANDS AND ITS EFFECTS ON THE RESPONSE OF SURFACE FOUNDATIONS

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Summary.
This paper focuses on sand fabric evolution during loading and its effects on the response of shallow foundations in terms of settlements and ultimate bearing capacity. Sand fabric is expressed by an appropriate evolving deviatoric tensor F_{ij}, whose effects are incorporated in a constitutive model developed within the recently proposed Anisotropic Critical State Theory (ACST) [1]. It comprises a reversal surface model, e.g. [2], within the SANISAND framework of models, e.g. [3], and uses a fundamental element of ACST, namely the fabric anisotropy variable A that equals the first joint invariant of the evolving fabric and loading direction deviatoric n_{ij} tensors. The A is used for the definition of dilatancy, the plastic modulus and the evolution equation of the fabric tensor, thus simulating experimental results that show more dilative and stiff response when the loading is applied along the direction of the fabric. The model is shown to be capable of simulating the anisotropic behavior of sands, based on comparisons to Toyoura sand monotonic experiments, under both drained and undrained conditions. For example, Figure 1 presents the accurate model simulations (lines) of the undrained triaxial data on Toyoura sand (symbols) of Yoshimine et al. [4] depicting the more dilative and stiff response during compression in comparison to extension.

Then, the calibrated anisotropic model is used parametrically to study the effects of fabric evolution on the response of a rigid strip footing under vertical load resting on a thick dry sand layer using the finite difference method. It is shown that the (initial) fabric anisotropy affects the whole load-settlement curve significantly. From a practical point of view, it is shown that neglecting sand fabric anisotropy (i.e. by using an isotropic sand model with merely Lode angle dependence for different loading directions) affects considerably the predictions for settlements and the ultimate bearing capacity. Note that the foregoing differences may not be conservative from a design point of view. Hence, these results imply that the quite common assumption of isotropy for geomaterials may hide little-known pitfalls when used for the analysis of geo-structures.

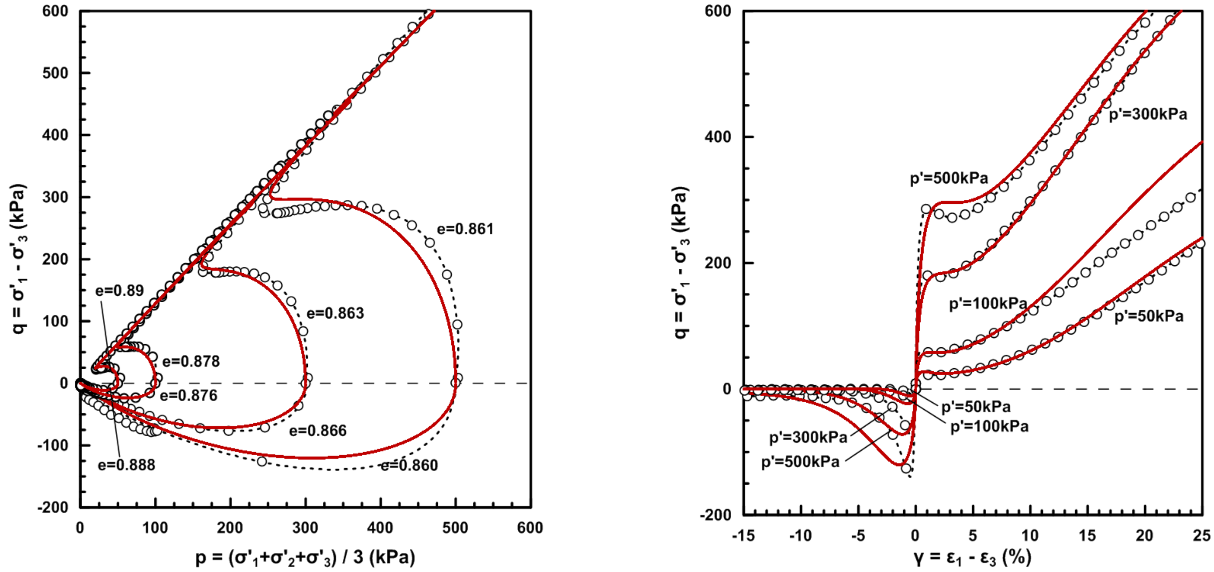

Figure 1. Comparison of model simulations to undrained triaxial (compression and extension) test data on Toyoura sand [4]

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REFERENCES

[1] X.S. Li and Y.F. Dafalias. Anisotropic critical state theory: role of fabric. *Journal of Engineering Mechanics*, *ASCE*, 138(3): 263-275, 2012.

[2] K.I. Andrianopoulos, A.G. Papadimitriou and G.D. Bouckovalas. Bounding surface plasticity model for the seismic liquefaction analysis of geostructures. *Soil Dynamics and Earthquake Engineering*, 30(10): 895-911, 2010

[3] Y.F. Dafalias and M.T. Manzari. A simple plasticity sand model accounting for fabric change effects, *Journal of Engineering Mechanics*, *ASCE*, 130(6): 622-634, 2004.

[4] M. Yoshimine, K. Ishihara and W. Vargas. Effect of principal stress direction and intermediate principal stress on undrained shear behavior of sand, *Soils and Foundations*, 38(3): 177-186, 1998.