Addressing fundamental premises of Anisotropic Critical State Theory by means of DEM

Rui Wang*, and Yannis F. Dafalias††

* Department of Hydraulic Engineering
Tsinghua University, Beijing, 100084, China
e-mail: wangrui_05@mail.tsinghua.edu.cn.

† Department of Civil and Environmental Engineering
University of California, Davis, CA 95616, U.S.A.
e-mail: jfdafalias@ucdavis.edu

† Department of Mechanics, School of Applied Mathematical and Physical Sciences
National Technical University of Athens
Zographou Campus, Athens, Greece.

ABSTRACT

Fabric, expressed by means of a deviatoric fabric tensor **F**, plays a very important role in the mechanical response of granular materials that exhibit strong anisotropy. The recently developed Anisotropic Critical State Theory (ACST) by Li and Dafalias (2012), addressed this issue by introducing the role of fabric into the dilatancy. A key step is the formulation of the evolution equation of **F** towards its critical state value, where it defines a third fabric-related critical state condition in addition to the classical two on stress and void ratios, rendering all three conditions necessary and sufficient for reaching and maintaining critical state.

The validity of the fundamental relations of ACST for the evolution of **F** and its effect on dilatancy has only been indirectly confirmed by successful simulations of macroscopic stress-strain relationships, but not directly in terms of measured or computed grain scale quantities. Virtual numerical tests through methods such as DEM (Discrete Element Method) have become an important means complementary to physical tests in the quantification and understanding of fabric in sand. DEM has been used to comfirm the convergence of **F** towards its critical state values, but has not been applied to quantitatively validate the micromechanical assumptions for fabric evolution and its influence on dilatancy within ACST.

In this study, 3D DEM is used to address the fundamental premises of ACST, including the specific definition and evolution of **F** and its influence on the dilatancy of granular materials. DEM and ACST are used entirely independently from each other, except from inputting the DEM increasing stress ratio and shear strain in the equations of ACST as a means to compare its outcome with DEM results at same stress and strain level. The fabric tensor in ACST calculations follows its own equation of evolution as a continuum variable totally independent from the fabric tensor obtained from DEM. The results of such fabric tensor **F** evolution and analytically calculated dilatancy D and void ratio e by means of ACST relations are then compared with corresponding DEM results for fabric tensor and dilatancy. Based on this comparison it is concluded that the validity of the fundamental premises of ACST on fabric and its effect on dilatancy is confirmed for appropriate definition of the fabric tensor **F** and formulation of its evolution equation, which are crucial in achieving good description of volumetric behaviour of granular materials within ACST. Dilatancy is shown to be strongly affected by the contact normal based fabric tensor **F**, whose evolution is best described by equations within ACST that are not independent of fabric entities based on other grain-scale features, such as particle-based fabric.

REFERENCES

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