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A numerical approach for modeling evolutionary problems in geomechanics

J. P. Hambleton[a*] and E. Kashizadeh[a]

[a] ARC Centre of Excellence for Geotechnical Science and Engineering, The University of Newcastle, Australia
* corresponding author: James.Hambleton@Newcastle.edu.au

Abstract:

Numerous problems in geomechanics are characterized by extremely large, predominantly plastic deformation. In plowing and cutting of soils, for example, large volumes of material accumulate ahead of the plow or cutter, and this material determines to a large extent the forces on the tool and the energy needed to displace or remove the soil as required for the application. Problems of this type, which generally involve unsteady plastic flow and evolving material boundaries, are here referred to as “evolutionary plasticity problems.” Other examples of such problems include penetrometer-based in situ testing, scratch testing, soil-structure interaction in offshore applications (e.g., pipelines), asperity-material interactions leading to friction and wear along interfaces, and crustal folding and faulting along the Earth’s surface.

Various approaches for analyzing evolutionary plasticity problems can be found in the literature. In some cases, especially for steady-state and self-similar problems, analytical solutions are possible. However, analytical methods are suitable only for relatively simple problems, and cannot be easily generalized. In contrast, numerical techniques such as the material point method and the discrete element method are unencumbered by the need for highly restrictive assumptions and can be applied to a wide variety of problems. While such methods are powerful and show increasing potential, they are not without drawbacks, the most significant being the large processing times required.

This talk presents a new numerical technique for modeling large deformation problems with evolving material boundaries. Emphasis is placed on modeling granular material and problems in which a rigid object interacts with the surface (e.g., plowing and cutting). The method rests on the assumption that deformation occurs predominantly in the form of strong discontinuities, or shear bands, and considers the full process of deformation as a sequence of incipient collapse problems[1,2,3,4]. The example of a vertical plate translating through dry sand is considered, and a comparison is made with experimental results. The example demonstrates the effectiveness and efficiency of the proposed approach as well as the physical insights that can be gleaned, including information regarding the existence and stability of steady or quasi-steady states.

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