Analysis of Deformation Bands in Geomaterials Using Three-Invariant Elastoplastic Constitutive Models

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ABSTRACT

Failure of geomaterials (concrete, soils and rocks) into narrow tabular bands involves a variety of modes: shear bands accompanied by compaction or dilation, pure shear bands, pure compaction bands, and pure dilation bands. Conditions for the onset of these bands depend on the constitutive description of the material behavior prior to localization [1]. This paper deals with a class of three-invariant (isotropic) elastoplastic constitutive models suitable for the analysis of tabular deformation bands in geomaterials, their numerical implementation, and their role in determining the kind of deformation band to expect for a given material and for a given loading condition. The numerical algorithm utilizes a fully implicit return mapping algorithm in principal directions that requires the evaluation of the second derivative of the plastic potential function in terms of the principal stresses alone [2]. The upshot of this feature is that a closed-form expression for the algorithmic tangent operator is easily derivable even for complex three-invariant constitutive models commonly used for characterizing irreversible geomaterial behavior [3].

Specific constitutive plasticity models may be derived from the more general family of three-invariant models presented in this paper. Some of the models include the Drucker-Prager, Matsuoka-Nakai, and Lade-Duncan plasticity models appropriate for modeling the behavior of dilatant frictional materials as well as for predicting the onset of dilatant shear bands. With a suitable choice of material parameters, yield and plastic potential surfaces may be made to close in and intersect the hydrostatic axis to form a cap, thereby allowing the modeling of compaction shear bands as well as pure compaction bands that are known to occur in porous rock formations. Depending on the position of the stress point on the yield surface at the onset of localization, different types of deformation bands may be captured. The paper shows a numerical example demonstrating the formation of different types of deformation bands in geomaterials.

REFERENCES

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