Improved Elastoplastic Bounding Surface Model for the Mathematical Modeling of Geomaterials

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Abstract : The nature of most engineering materials is quite complex. It is, therefore, difficult to devise a general mathematical model that will cover all possible ranges and types of excitation and behavior of a given material. As a result, the development of mathematical models is based upon simplifying assumptions regarding material behavior. Such simplifications result in some material idealization; for example, one of the simplest material idealization is to assume that the material behavior obeys the elasticity. However, soils are nonhomogeneous, anisotropic, path-dependent materials that exhibit nonlinear stress-strain relationships, changes in volume under shear, dilatancy, as well as time-, rate- and temperature-dependent behavior. Over the years, many constitutive models, possessing different levels of sophistication, have been developed to simulate the behavior geomaterials, particularly cohesive soils. Early in the development of constitutive models, it became evident that elastic or standard elastoplastic formulations, employing purely isotropic hardening and predicated in the existence of a yield surface surrounding a purely elastic domain, were incapable of realistically simulating the behavior of geomaterials. Accordingly, more sophisticated constitutive models have been developed; for example, the bounding surface elastoplasticity. The essence of the bounding surface concept is the hypothesis that plastic deformations can occur for stress states either within or on the bounding surface. Thus, unlike classical yield surface elastoplasticity, the plastic states are not restricted only to those lying on a surface. Elastoplastic bounding surface models have been improved; however, there is still need to improve their capabilities in simulating the response of anisotropically consolidated cohesive soils, especially the response in extension tests. Thus, in this work an improved constitutive model that can more accurately predict diverse stress-strain phenomena exhibited by cohesive soils was developed. Particularly, an improved rotational hardening rule that better simulate the response of cohesive soils in extension. The generalized definition of the bounding surface model provides a convenient and elegant framework for unifying various previous versions of the model for anisotropically consolidated cohesive soils. The Generalized Bounding Surface Model for cohesive soils is a fully three-dimensional, time-dependent model that accounts for both inherent and stress induced anisotropy employing a non-associative flow rule. The model numerical implementation in a computer code followed an adaptive multistep integration scheme in conjunction with local iteration and radial return. The one-step trapezoidal rule was used to get the stiffness matrix that defines the relationship between the stress increment and the strain increment. After testing the model in simulating the response of cohesive soils through extensive comparisons of model simulations to experimental data, it has been shown to give quite good simulations. The new model successfully simulates the response of different cohesive soils; for example, Cardiff Kaolin, Spestone Kaolin, and Lower Cromer Till. The simulated undrained stress paths, stress-strain response, and excess pore pressures are in very good agreement with the experimental values, especially in extension.

Keywords : bounding surface elastoplasticity, cohesive soils, constitutive model, modeling of geomaterials
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