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Prediction of strain localization in granular soils

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Abstract

Strain localization is a well-known phenomenon in geomaterials. In this process, plastic deformation is observed to concentrate in narrow zones called shear bands. The accurate numerical simulation of the slope stability problems, the bearing capacity of shallow and deep foundations, and the active and passive stresses acting on retaining walls depend strongly on formation of shear bands in granular soils. In this study, an advanced plasticity model formulated within the bounding surface plasticity family and critical state soil mechanics is applied for prediction of strain localization in granular soils. It is shown that realistic predictions are obtained for states at which strain localization can take place.

Keywords: Sand, Bounding surface plasticity, Dilatancy, Hardening.

1. INTRODUCTION

Under loading conditions found in many geotechnical structures, it is common to observe failure in zone of intense localized strain called shear bands. This event which is a fundamental phenomenon in granular materials has been widely investigated during recent decades by both experimental and theoretical approaches [1-6]. As for soils and granular materials, extensive experimental results with respect to formation of shear banding have been reported in the literature [1-4]. Granular materials deform in various ways beneath the engineering structures. For small strains, deformation is nearly uniform. However, for large strains, deformation may localized in one or more narrow regions of soil mass. These regions, technically called shear bands, separate almost rigid blocks of granular media. Researchers have recently carried out systematic studies to analyze and describe the occurrence and patterns of shear bands. The theoretical studies have used bifurcation theory to predict and describe the occurrence of shear bands [5,6]. Prediction of strain localization depends strongly on the constitutive models employed to describe the mechanical behavior of soil. Thus, shear band analysis is closely coupled with the constitutive relations.
Herein, in order to investigate the stress and density dependent behavior of granular soils, a unified description of the interaction between the mean stress and the current density is necessary. As a result, a state-dependent bounding surface plasticity model is used to describe the three-dimensional stress-strain behavior of granular soils. Predictions for strain localization are compared with data of compression mode of triaxial. It is shown that a reasonable agreements exists between the model predictions and experimental data.

2. CONSTITUTIVE MODEL IN MULTIAXIAL STRESS AND STRAIN SPACES

The elastoplastic model selected here is essentially the constitutive model proposed by Manzari & Dafalias [7]. In the following lines, the model formulation is presented:
The rate of strain tensor can be decomposed into elastic and plastic parts indicated, respectively, by "e" and "p" superscripts:

$$\dot{\boldsymbol{\varepsilon}} = \dot{\boldsymbol{\varepsilon}}^{e} + \dot{\boldsymbol{\varepsilon}}^{p} \qquad (1)$$

For the elastic branch of behavior, the isotropic hypo-elasticity is defied by: