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IMPLICIT INTEGRATION ALGORITHM OF ELASTPLASTIC CONSTITUTIVE RELATION FOR COHESIONLESS-FRICTIONAL GEOMATERIAL

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ABSTRACT

The linear elastic perfectly plastic model based on Drucker-Prager yield criterion, which is linear in the meridional plane, is still widely used in geotechnical analysis. In computation with this model, however, difficulties arise due to the gradient discontinuities which occur at the apex area of the yield surface. These singularities often cause the stress-point integration algorithm to perform inefficiently or even fail. Recently, some advanced methods have been presented to eliminate the singularity and good results have been achieved. For cohesionless-frictional geomaterial, the singular point on the yield surface is a zero stress point, at which global stiffness matrix becomes singular in numerical analysis and the advanced methods may be not effective. In this paper, an implicit integration algorithm of constitutive relation is presented. A pseudo yield surface is introduced and the dual stress projection scheme is employed to remove the apex singularity and zero stress point on the yield surface. Based on the presented algorithm, an elastoplastic finite element procedure is developed for numerical analysis of cohesionless-frictional geomaterial. Case studies are performed to validate the proposed algorithm..

KEY WORDS: linear elastic perfectly plastic, Drucker-Prager yield criterion, implicit integration algorithm of constitutive relation, cohesionless-frictional geomaterial.

INTRODUCTION

In the elastoplastic finite element analysis of geomaterials, the linear elastic perfectly plastic constitutive model based on Drucker-Prager (D-P) criterion is extensively employed to depict the strength characteristics of the materials, for its simplicity and the fact that it permits finite element solution to be compared with a wide variety of classical plasticity solutions. The yielding surface of D-P criterion in the p-q plane and π-plane is shown in Fig.1 and Fig.2. The yielding function can be written as:

$$F = q - p\tan\beta - d = 0 \tag{1}$$

$$p = -\frac{1}{3}\,\mathrm{trace}\left(\sigma\right) \tag{2}$$

$$q = \sqrt{\frac{3}{2}\left(S : S\right)} \tag{3}$$

$$s = \sigma + pI \tag{4}$$

Where p is pressure stress; q is Mises equivalent stress, s is stress invariant; β is the inclined angle of yielding surface; d is cohesion of the material.

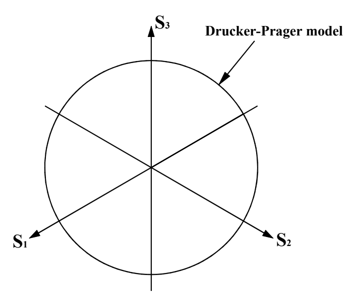

Fig. 1 Drucker-Prager yielding surface in π-plane

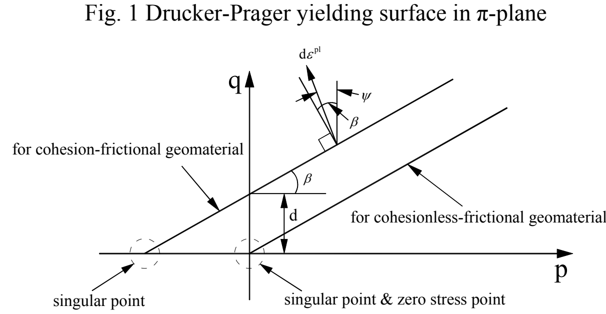

Fig. 2 Drucker-Prager yielding surface in p-q plane

On the D-P yield surface, however, there exists a singular point, i.e., the apex singularity, shown in Fig.2. In order to remove the apex