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LENGTH SCALE EFFECTS IN I_3 - PLASTICITY MODEL FOR GRANULAR MATERIALS

*** Aylin Ahadi[1] and Matti Ristinmaa[2]**

[1] Division of Mechanics
Lund University
P. O. Box 118, S-22100, Lund, Sweden
aylin.ahadi@mek.lth.se

[2] Division of Solid Mechanics
Lund University
P. O. Box 118, S-22100, Lund, Sweden
matti.ristinmaa@solid.lth.se

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ABSTRACT

The stress-strain behavior of geomaterials is of a complex nature, depending on void ratio, stress state and loading direction. The behavior is characterized by shear deformation, dilation and coupling between these. The mechanical response is further complicated by the fact that the deformation characteristics involve strain localization. A problem exhibiting localization of deformation is of an unstable nature, i.e. the load-displacement response reaches a point after which the slope is negative. This softening due to localization can not be described by classical plasticity models. There is a need to introduce length scale in order to regularize the strain field and capture the localization phenomenon and formation of shear bands.

In the present study, the non-associated plasticity model for small deformations developed by Krenk [1], has been extended and formulated to include size dependent effects. The model is a three dimensional generalization of the classical Cam-Clay model. Isotropic hardening is assumed in the model and the hardening parameter depends on both the volumetric and the deviatoric part of the stretching, in order to model the dilative behavior of geomaterials. The yield function in the model is expressed in terms of the mean pressure p and the third stress invariant I_3. The shape of the yield function is controlled by a shape function and the size is controlled by one single hardening parameter. The local yield function is modified by introducing a non-local hardening parameter. In the non-local model presented here, the softening at one material point effects the yield surfaces at all other points directly. In that way the softening is spread to neighboring points within a certain distance.

An additional balance equation, c.f. Håkansson et. al. [3], which governs the field of the non-local hardening parameter, is introduced in the model. This field equation involves the gradient of the non-local hardening parameter. The introduced length scale in the model through the additional balance equation is assumed to be a material constant. If the introduced length scale is set to zero the original local format of the model is recovered. The hardening of the loading surface depends on both plastic volumetric and deviatoric strain increments in order to model dilatancy before failure of a normally

consolidated material. The evolution of the non-local hardening parameter is therefore assumed to be a weighted sum of the volumetric and deviatoric parts of the plastic work.

The coupled problem comprising the mechanical field equation and the field equation for the non-local hardening parameter is solved by staggered method. The mechanical field equation is solved at each incitement holding the non-local hardening parameter $\tilde{p}_f$ constant and the field equation for $\tilde{p}_f$ is solved at constant configuration. For the integration of the constitutive equations the implicit integration algorithm formulated for models for granular materials in [2] is slightly modified and employed. The non-local hardening parameter is updated explicitly at each iteration. The algorithmic tangent stiffness is derived and computed at each iteration.

The implemented non-local formulation of the material model has been used to perform a multi element analysis of examples of engineering interest. In the first example a traditional geotechnical problem of a rigid strip footing resting on a surface of sand has been modelled. A strip footing may be considered as a plane strain problem, but the analysis is made using the three dimensional finite element procedure. Plane strain condition is applied by restraining the degree of freedom normal to the vertical plane. The symmetry of geometry and loading conditions allow modelling of only half the footing. The development and growth of shear bands and their influence on the bearing capacity of the foundation will be investigated.

The second example involves a conventional triaxial test on specimen of sand. A pressure is applied in the radial direction and the specimen is loaded in the axial direction. The shear band initiation is trigger by inhomogeneity in the material. The formation and development of shear bands will be simulated and results presented.

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