ELASTOPLASTIC GRADIENT-ENHANCED DAMAGE FORMULATION FOR QUASI-BRITTLE MATERIALS

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The mechanical behavior of the semi-brittle materials such as concrete cannot be satisfactorily modelled using either elastic damage models or elastic plastic constitutive laws. They indeed fail to reproduce the unloading slopes which are used to determine the value of the damage in the material. Combining these two approaches in a single constitutive relation is thus a requisite, if an accurate value of the damage is needed. A simple and efficient possibility for the coupling between damage and plasticity is based on the definition of the effective stress in the material and on the assumption that the material, free of damage, is elasto-plastic and the damage does not affect the growth of plastic strain (see [1] for more details).

As for conventional continuum constitutive models, a combined plastic damage formulation exhibits strain-softening and all the inherent difficulties attached to this specific material behavior, i.e., spurious strain localisation and dependence of the energy dissipation on mesh refinement. To overcome the deficiencies of the classical local modelling a number of proposals can be found in the literature. Whether they are in a gradient or in an integral form, a salient characteristic of both types is the presence of an internal length in the constitutive relation.

In the present paper, a coupled elastoplastic nonlocal damage model is proposed. The regularization technique is similar to that presented by Peerlings et al. [2]. It is based on implicit gradient definitions of the nonlocal strain tensor which is calculated for each component of the elastic strain tensor. To solve the governing equations problem i.e., equilibrium and nonlocal averaging, an iterative Newton-Raphson method is developed, in which consistent tangent stiffness matrix is derived. For the sake of simplicity, a simple Von-Mises model with isotropic hardening has been chosen for the plasic part. It is then combined with the isotropic damage model initially developed by Mazars [3].

The validation of the numerical implementation is illustrated by mean of a 3D tensile bar benchmark with imperfection in the center. We run several tests for which, in the limit, we recover for instance the non local damage response (inhibiting plasticity) or the plasticity response (inhibiting damage). Mesh independence of the results is checked and a comparison with the local version of the model is carried out. Finally, the regularizarition capabilities of the proposed model is demonstrated by a three-point bending test on a RC beam.

References

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