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A NON LOCAL ANISOTROPIC DAMAGE MODEL FOR BRITTLE MATERIALS

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ABSTRACT

The mechanical behaviour of brittle materials, such as masonry and concrete, is characterized by strain-softening after a peak stress value. This phenomenon is the macroscopic manifestation of microcracking, which leads to formation of macrocracks and, possibly, to failure of the material element. This behaviour can be described through the damage mechanics using smeared crack models. These models permit the evolution of the cracking process to be reproduced, but if any region exists in the body where the strain field localizes, damage localizes as well. In other words, the results of finite element analyses made using these models are strongly mesh dependent, and an unrealistic mechanical behaviour is described. This problem can be avoided, or at least reduced, assuming that damage is spread within a region (or 'process zone') whose size is supposed to be a material property. This kind of models are generally known as 'non-local damage models'.

In this work, a non-local damage model is proposed for brittle materials, such as masonry and concrete, starting from a previous proposal of the authors [1]. The model is characterized by an anisotropic damage tensor, $\boldsymbol{D}$, which evolves differently under tensile and compressive strains. The damage process driving variable is supposed to be a 'damage force', $\boldsymbol{Y}$, obtained deriving the material Helmoltz free energy with respect to the damage variable. As the maximum eigenvalue of $\boldsymbol{Y}$ attains a critical value (y_{0T} or y_{0C}, according to the sign of the associated strain), the first damage direction is activated. An additional damage direction can activate in the plane orthogonal to the first one if the maximum direct component of $\boldsymbol{Y}$ in that plane attains the damage threshold. Eventually, the third principal damage direction necessarily forms a right-handed triad with the other two.

It is important to note that the principal directions of damage remain fixed throughout any load history, so that the model can be included in the class of the non-rotating smeared crack models.

The model overcomes some deficiencies of the previous local version, as the model

parameters are related to an internal characteristic length of the material to make the specific fracture energy mesh-independent in finite element analyses. The model was calibrated using experimental results on brittle specimens subjected to uni- and biaxial stresses. The capability of the model were assessed reproducing experimental shear tests on masonry panels subjected to horizontal monotonic and cyclic loads. In building the panels, two different height-to-width ratios were used, corresponding either to a 'slender' panel (1 m in width and 2 m in height) or to a 'squat' panel (of the same width as the slender one, but 1.35 m in height). The collapse of the squat panel is matched by growth of cracks in the central zone induced by shear stresses, whereas the failure mechanism of the slender panel is matched by a rocking behaviour. Accordingly, the plot of the horizontal force vs. the horizontal displacement for the squat panel shows a degradation in stiffness and strength in conjunction with a significant dissipation. On the contrary, the same plot for the slender panel is characterized by a smaller dissipation, due to a lower reduction in stiffness, and a lack of softening behaviour [2].

Future evolutions of the proposed model concern the possibility of encompassing also creep-induced damage, by employing different evolution laws for damage originated by increasing stresses and by sustained stresses. Also, the possibility of capturing crack-closure effects, which is a basic requirement to effectively reproduce the material behaviour under cyclic loads, could be taken into account by using different damage variables, separately accounting for damage induced by tensile and by compressive strains.

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