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SURFACE AND VOLUME DAMAGES

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ABSTRACT

We investigate the evolution of quasi-brittle domains, for instance pieces of concrete, glued on one another, taking into account both volume and interface damaging behaviours and their interactions, [1], [2]. The predictive theory is based on the principle of virtual power: starting from the assumption that damage results from microscopic motions, the power of these motions is taken into account in the virtual power of the interior forces. This power contribution is assumed to depend, besides on the strain rate (displacement discontinuity for interface), both on the rate of damage and gradient of damage (damage discontinuity for interface). The latter is introduced to account for the local interaction of the damage at a material point on the damage of its neighborhood. Correspondingly, also two new non classical internal forces are introduced: the internal work of damage and the flux vector of internal work of damage (adhesion energy and energy flux vector of the contact surface). On the contact surface there are local damage interactions between damage at a point and damage in its neighbourhood: thus there is interaction within the glue as well as interaction between the glue and the two concrete pieces. These interactions are defined with their virtual power involving appropriate cinematic quantities. For instance, experiments show that elongation may have damaging effects. In this setting, an elongation is a variation of the distance of two distinct points belonging to the contact surface. This is a non local quantity which introduces non local contributions in the theory. The principle of virtual power leads to three sets of equations of motion; the first one is the classical equation of motion and the others are non-standard equations for the domains and interface damage evolutions. Suitable free energies and pseudo-potentials of dissipation give the non standard internal forces conjugated to the damage rate and the gradient damage rate. The internal constraints on the values of damage quantities and on their velocities as well as the impenetrability conditions are taken into account explicitly in the expressions of the free energy and of the pseudo-potential. The predictive theory issued from this formulation is not affected by mesh inobjectivity. It correctly determines the zone affected by damage: either the interfaces

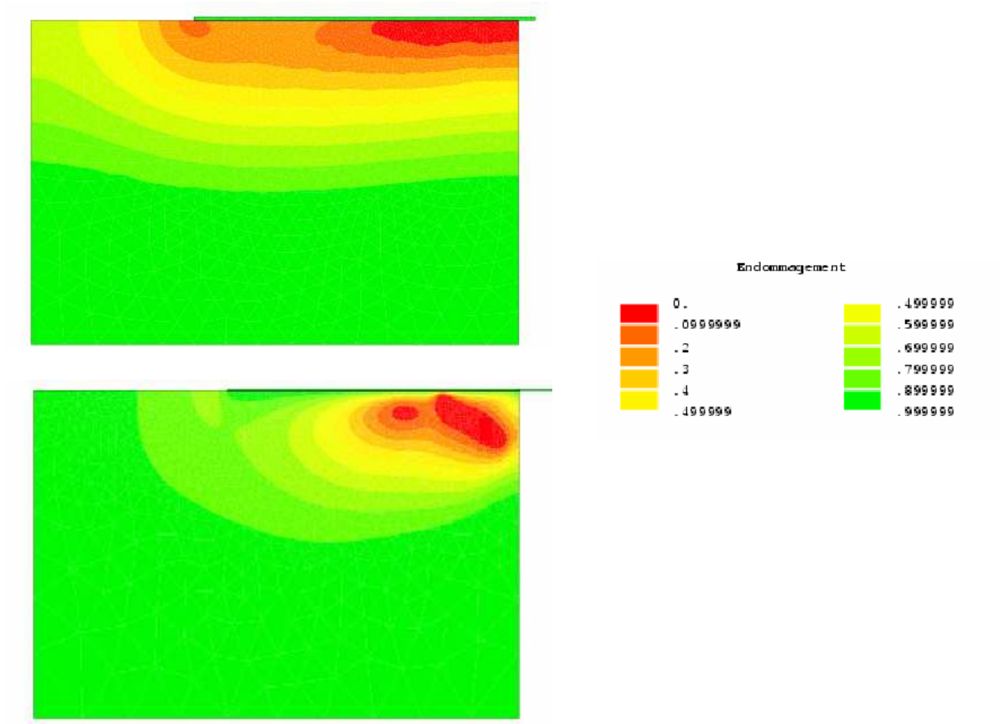

Figure 1: FRP-concrete pull-pull delamination test: damage representation in concrete for weak and strong interaction between the damage in the glue and in the concrete.

or a narrow region inside the domains. For instance evolution of concrete elements glued on one another and FRP-concrete delamination test are quantitatively and qualitatively predicted, [1].

Mathematical results for either damage domain or surface damage evolutions are reported in [3] and [5]. Thus the predictive theory is consistent both from the mechanical and mathematical point of view. Numerical results reported in [1], show that it applies correctly to engineering actual setting. For example, the proposed model has been adopted to simulate the problem of FRP-concrete debonding. In Figure (1) it is reported the damage field for standard FRP-concrete debonding test set up according to [4]. Two cases of damage interaction between the glue and the concrete substrate has been considered: weak interaction in the upper figure and strong interaction in the lower figure. It clearly appears that the strong interaction between glue and concrete induced breakage in a substrate under the interface as deeply outlined in real experiments.

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