Bounded rate damage plastic model for concrete failure under impulsive loadings

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ABSTRACT

This paper deals with the objective prediction of cracks in concrete structures within the framework of a local constitutive model. To reach this goal, it is necessary to overcome mesh dependency due to softening of concrete. The constitutive law for concrete is an isotropic damage plastic model already described in [1]. The model has been introduced in EUROPLEXUS, a general finite element explicit code for fast transient analysis. The Hilleborg's method used to maintain constant fracture energy regardless of element size is not able to deal with mesh-induced directional bias. In some cases, this leads to wrong failure mechanisms of the structure and to false ultimate load. Non-local models by their implicit nature are not adapted to explicit code and adversely affect its performance. This is the reason why the bounded rate concept presented in [2] has been introduced in the model. From a physical point of view, the basic idea is that the damage rate is finite because the cracking velocity is not instantaneous and from a mathematical point of view it was demonstrated in [2] that the problem remains well posed as long as damage rate is bounded and the damage not too close to 1.

The damage rate is asymptotically bounded thanks to a simple expression using a new parameter: the maximum damage rate to be fitted on experiment. The Hilleborg's method being no longer applicable, the characteristic length of the static damage model is no longer related to the size of the element mesh and has to be calibrated.

The model is very easy to implement because it leads to an explicit expression of the rate of damage at each time increment. It is also compared to classical delayed damage models and it is explained why it is much more efficient to regularize.

The new model has been verified on skewed mesh (relatively to crack) and compared to experimental results of the literature: an impacted notched beam [3] and an L-specimen [4] loaded at relatively moderate rates ($\simeq$ 1 m/s). It was shown that the bounded rate model regularizes deformations when the strain rate is larger than 1 s^{-1} and the mesh size about 1 mm. In that case, cracked zones are almost mesh-independent in size and orientation.

Nevertheless, calibration on these experiments has not led to a universal set of coefficients yet. So, a large amount of investigation remains to be done to broaden the loading rate range, to precise the lower bound rate that maintains regularization for a given mesh size, and to find a formulation with a single set of parameters.

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