PLASTICITY-DAMAGE VERSUS ANISOTROPIC DAMAGE FOR IMPACT ON CONCRETE STRUCTURES

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<u>*Summary*</u> Impact problem on Reinforced Concrete structures are usually computed if the Finite Elements method is used with complex plasticity-damage models. An alternative is to extend anisotropic damage model to high strain rates applications by introducing a visco or delay-damage law. The advantages of such an approach are to represent the tensile strain rate effect encountered in concrete and to regularize the solution for a quite largerange of strain rates.

Impact problems on reinforced concrete (RC) structures are usually computed with models coupling plasticity and isotropic damage [1,2]. The induced damage anisotropy observed for quasi-brittle materials such as concrete is often reproduced considering different variables for tension and compression (not consistent with the thermodynamic framework). Introducing viscosity for both damage and plasticity evolutions enables to reproduce the strength enhancement due to rate effects. Such kinds of models present the main advantage to describe precisely each phenomenon locally observed (different rate effects in traction and compression, compaction under confined loadings ...) but require a large number of parameters.

Anisotropic damage is quite relevant to describe the micro-cracking pattern and the failure conditions of quasi-brittle materials and structures [3,4]. In concrete, a state of micro-cracks orthogonal to the loading direction in tension and parallel to it in compression is easily described by a second order damage variable (Fig. 1). Based on Mazars and coworkers [5, 6] idea of a damage rate governed by the positive extensions, an induced anisotropic damage model has been proposed [7].
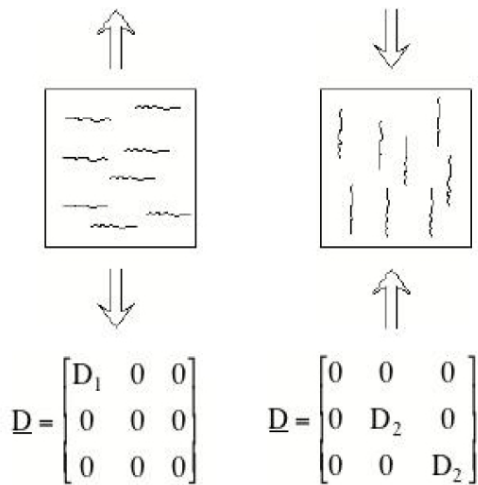

$$\underline{D} = \begin{bmatrix} D_1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \qquad \underline{D} = \begin{bmatrix} 0 & 0 & 0 \\ 0 & D_2 & 0 \\ 0 & 0 & D_2 \end{bmatrix}$$

Figure 1: Crack pattern and damage growth with the anisotropic damage model
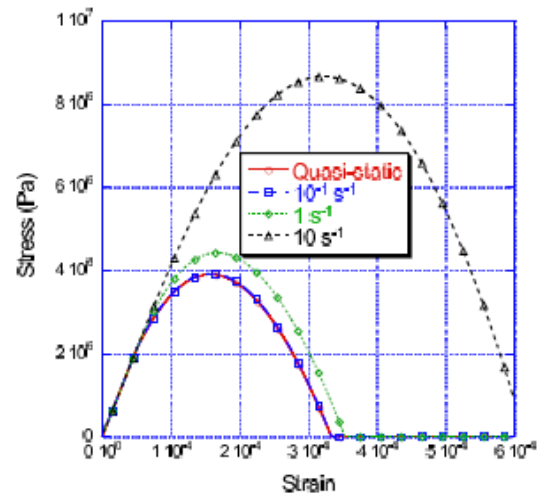

Figure 2 : Rate effect in tension for the anisotropic delay-damage model

As long as the confinement remains weak, this modelisation is an alternative to complex plasticity-damage models to deal with impact problems. A visco- or delay-damage is introduced in ttension to reproduce the strain rate effect experimentally observed and extend this model to high loading rates problems. Different viscosity laws are proposed, directly identified from dynamic tensile test to fit to the rate effect. This anisotropic delay-damage model introduces only few parameters (7 including elasticity parameters E and υ) compared to the ones mentioned higher.

The efficiency of such an approach is illustrated with its application on impacted RC beams. The same computations are perfomed with a plasticity-damage model [1] and the anisotropic delay-damage one and the results are compared.

The problem of mesh dependency is treated. One can show that delay-damage is an efficient tool – in case of damage anisotropy also- to regularize the solution of dynamics applictations.

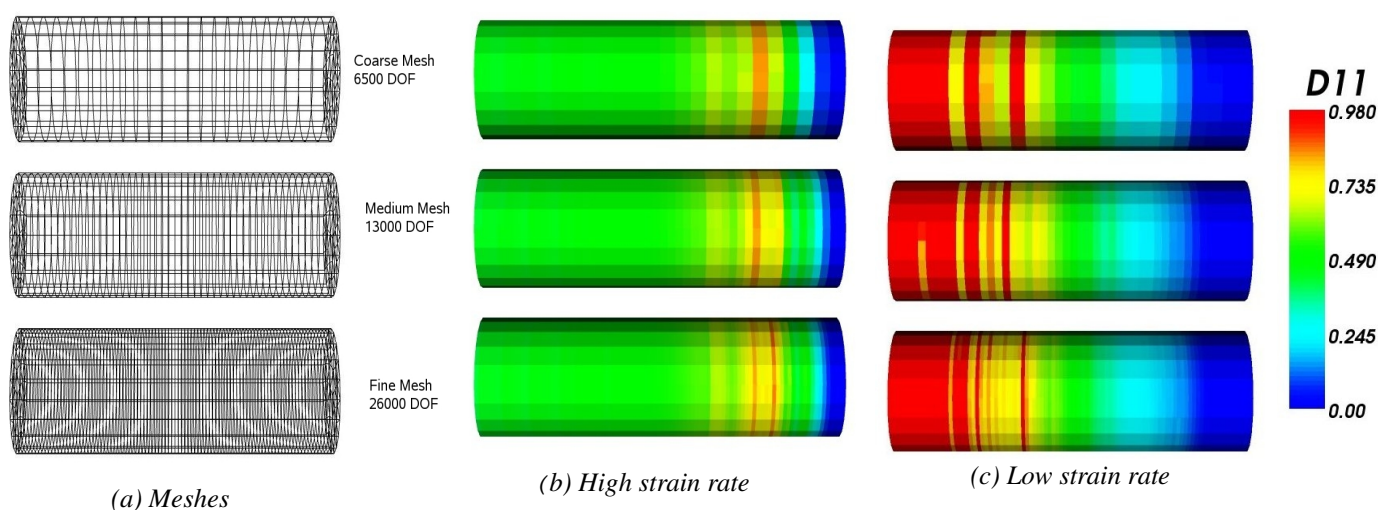(a) Meshes (b) High strain rate (c) Low strain rate

Figure 3: Damage in a concrete sample submitted to dynamic tension test : Regularization with delay damage
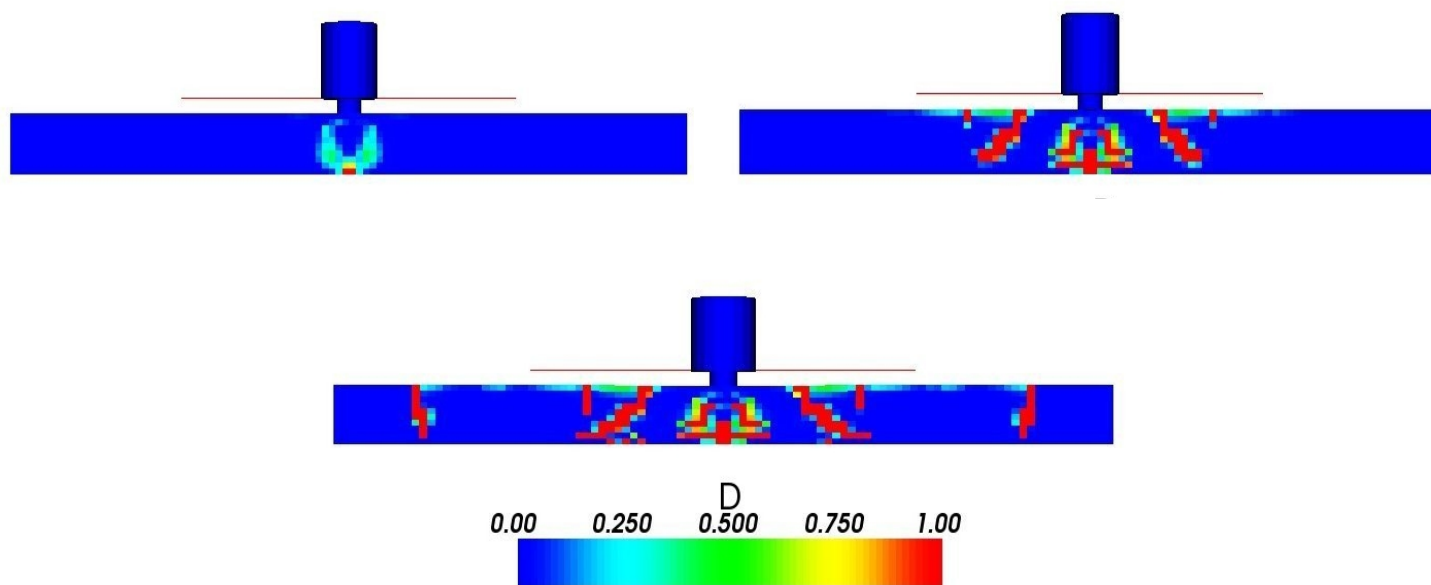

Figure 4: Damage growth in a Reinforced Concrete beam, plasticity-damage model

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