

# Dissipation due to damage for an anisotropic 3D delay-damage model

## Application to reinforced concrete structures under impact loadings

Marion Chambart <sup>1,2\*</sup>, Rodrigue Desmorat <sup>1</sup>, Fabrice Gatuingt <sup>1</sup>, Daniel Guilbaud <sup>2</sup>

<sup>1</sup>LMT-Cachan, ENS Cachan/CNRS/Université Paris 6/PRES UniverSud Paris  
61 Avenue du Président Wilson F-94230 CACHAN France  
{chambart, desmorat, gatuingt}@lmt.ens-cachan.fr

<sup>2</sup>CEA, DEN, DM2S, SEMT,DYN  
F-91191 Gif-sur-Yvette, France

### ABSTRACT

The problem of degradation of civil engineering structures under impact loading is a complex topic largely studied due to high industrial demand. Our approach consists in developing a robust Finite Elements model and the efficient algorithms associated so as to carry out 3D simulations on reinforced concrete structures.

The model is an anisotropic damage model, written in the thermodynamical background, where the damage variable is a second order tensor [1,2]. One can this way reproduce the dissymetry observed for concrete between tension and compression, and reproduce crack patterns for quasi-static and slow dynamics loadings. To extend the model to dynamics loadings it is necessary to consider the strain rate effect which introduce a relation between strain rate in tension and the maximal strength. A delay-damage [3] (viscosity) law now governs damage evolution. The effect of delay-damage on regularization in dynamics will be shown.

Experiments on a drop-weight tower have been carried out to validate the results obtained numerically. Impact tests on two different reinforced concrete beams enable to show two different failure modes (bending and shear cone). Brazilian tests on plain concrete specimens have also been performed. In both cases, numerical simulations and experimental results are compared. Image correlation is also used to interpret images recorded with an high speed numerical video camera.

So as to better understand the phenomenons observed, we also propose a way to estimate dissipation due to damage [4]. This can be done thanks to the thermodynamical background that ensure than dissipation remain positive all the time [5]. Dissipation maps can be drawn and evolution curves plotted.

### References

- [1] J. Lemaitre, R. Desmorat. Engineering Damage Mechanics : Ductile, Creep and Brittle failure Springer 2005
- [2] R. Desmorat, F. Gatuingt, F. Ragueneau. Nonlocal anisotropic damage model and related computational aspects for quasi-brittle materials. Engineering Fracture Mechanics, Vol 74. Num 10. Pages 1539-1560. 2007
- [3] O. Allix, J.F. Deü Delayed-damage modelling for fracture prediction of laminated composites under dynamic loading. Engineering Transactions, Vol 45. Pages 29-46. 1997
- [4] P. Grassl, M. Jirasek. Meso-Mechanically Motivated Nonlocal Models for Modelling of the Fracture Process Zone in Quasi-Brittle Materials. WCCM8/ECCOMAS 2008 Venise, Italie
- [5] R. Desmorat. Positivité de la dissipation intrinsèque d'une classe de modèles d'endommagement anisotropes non standards. Comptes-Rendus Mécanique, Vol 334. Num 10. Pages 587-592. 2006