8th. World Congress on Computational Mechanics (WCCM8)
5th European Congress on Computational Methods in Applied Sciences and Engineeering (ECCOMAS 2008)
June 30 –July 5, 2008
Venice, Italy

EXTRACTION OF A CRACK OPENING FROM A CONTINUOUS APPROACH USING REGULARIZED DAMAGE MODELS

*** Frédéric Dufour[1], Gilles Pijaudier-Cabot[2], Marta Choinska[3] and Antonio Huerta[4]**

[1] Ecole Centrale de Nantes, GeM
1 rue de la noe
44321 Nantes, France
frederic.dufour@ec-nantes.fr

[2] Univ. de Pau et des Pays de l'Adour,
Lab. des Fluides Complexes, Allée du Parc Montaury, 64600 Anglet, France
Gilles.Pijaudier-Cabot@univ-pau.fr

[3] Université de Nantes, GeM
58 rue Michel Ange
44606 St Nazaire, France
Marta.Choinska@univ-nantes.fr

[4] Univ. Politècnica de Catalunya,
Lab. de Càlcul Numèric, Dept de Matemàtica Aplicada III, Jordi Girona 1, E-08034 Barcelona, SPAIN
antonio.huerta@upc.edu

Key Words: *Crack opening, damage model, strong discontinuity, fracture.*

ABSTRACT

For most structures, crack opening is a key parameter needed in order to estimate durability. Similarly, and for structures such as confinement vessels, tightness to gas or liquids is a major serviceability criterion that is governed by Darcy's relation in which permeability of the material is involved. Again, the material permeability is strongly related to the amount of cracking in concrete. Applying Poiseuille's law, one can easily see that the permeability of a cracked structure (with a single crack) is proportional to the square of the crack opening. Therefore, failure analysis should not only be capable of describing the distributed damage, the onset of failure, crack initiation and crack propagation, but also it should provide crack opening in order to be complete and useful in serviceability analyses.

Integral damage models [1] and enhanced continuum [2] are capable to represent diffuse damage, crack initiation and propagation. They regard cracking as an ultimate consequence of a gradual loss of material integrity. These models, however, do not predict crack opening. Fictitious crack models are based on an explicit description of the discontinuity within the material (e.g. cohesive crack model [3]). They relate the crack opening to the stress level and they are based on the linear elastic (or plastic) fracture mechanics. However cohesive crack models are not capable of describing crack initiation.

Both approaches (continuum damage and discrete crack model) complete each other, Instead of trying to combine continuum and discrete models in computational analyses, it may be attractive to derive from the continuum approach an estimate of crack opening. This is the objective of the present paper which combines non local modelling with strong discontinuity analysis.

Let us consider the case of a 1D bar loaded in tension. The strong discontinuity approach [4] gives upon failure a displacement profile of the shape of a Heaviside function and a strain profile of the shape of

a Dirac function both with an amplitude of $[U]$, i.e. the displacement jump or crack opening. After an integral-type regularization, a regularized strain profile is obtained with the same shape as the weight function and still with $[U]$ as an amplitude. Besides, a regularized strain profile can also be derived from a FE modelling of the failure of the same 1D bar using a non local damage model.

Therefore, we propose to estimate the crack opening saying that both regularized strain profiles are equal at the failure (i.e. crack) location and we estimate the error from the distance between both profiles. For large damage values (i.e., when the bar is almost fully unloaded), the estimated crack opening tends to the end displacement of the bar. The corresponding error asymptotically reaches a value smaller than 5% depending on the type of non local (integral or gradient) damage model (linear or exponetial softening) used in the FE computations.

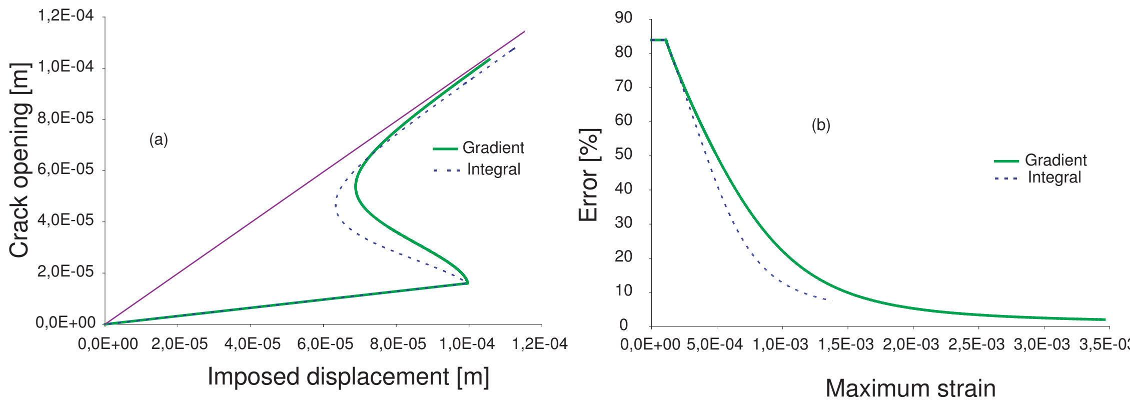

Figure 1: (a) Crack opening and (b) associated error as functions of maximal strain

Assuming that cracks are perpendicular to the largest positive eigenvalue of the strain tensor and using the method developped in [5] to estimate the direction of propagation of a crack, the cracks can be located from non local FE computations and the method presented hereby has been extended to 3D structures.

In conclusion, the proposed method is capable, from a FE computation of the failure of a 3D structure using a regularized damage model, to locate cracks and to estimate their opening along themselves.

REFERENCES

[1] G. Pijaudier-Cabot and Z. Bazant. “Nonlocal damage theory”. *J. of Eng. Mech.*, Vol. **113**, 1512–1533, 1987.

[2] R. H. J. Peerlings, R. de Borst, W. A. M. Brekelmans, J. H. P. de Vree, and I. Spee. “Some observations on localisation in non-local and gradient damage models”. *Eur. J. of Mech. A/Solids*, Vol. **15**, 937–953, 1996.

[3] A. Hillerborg, M. Modeer, and P. E. Pertersson. “Analysis of crack formation and crack growth in concrete by means of fracture mechanics and finite elements”. *CCR*, Vol. **6**, 773–782, 1976.

[4] J. Oliver. “On the discrete constitutive models induced by strong discontinuity kinematics and continuum constitutive equations”. *Int. J. of Solids and Struct.*, Vol. **37**, 7207–7229, 2000.

[5] J. Oliver, A. E. Huespe, E. Samaniego, and E.W. V. Chaves. “Continuum approach to the numerical simulation of material failure in concrete”. *Int. J. for Num. and Anal. Meth. in Geomech.*, Vol. **28**, 609–632, 2004.