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

COHESIVE CRACK MODEL DESCRIPTION OF MECHANICAL INSTABILITES IN QUASI-BRITTLE AND COMPOSITE MATERIALS

***Alberto Carpinteri and Marco Paggi**

Politecnico di Torino, Department of Structural and Geotechnical Engineering
Corso Duca degli Abruzzi 24, 10129 Torino, Italy
alberto.carpinteri@polito.it   marco.paggi@polito.it
http://staff.polito.it/alberto.carpinteri/   http://staff.polito.it/marco.paggi/

Key Words: *Cohesive model; Snap-back instability; Size-scale effects; Quasi-brittle materials; Composite materials.*

ABSTRACT

The present contribution represents a state-of-the-art review of the research works carried out at the Politecnico di Torino on the cohesive crack model description of mechanical instabilities in quasi-brittle and composite materials.

The cohesive crack model is able to describe materials that exhibit a strain-softening type behaviour. From the Continuum Mechanics viewpoint, strain softening represents a violation of the Drucker's Postulate, as pointed out by Maier and co-workers [1,2]. As a consequence, the following phenomena may occur: loss of stability in the controlled load condition (*snap-through*); loss of stability in the controlled displacement condition (*snap-back*).

The cohesive model was introduced by Dugdale [3] and Barenblatt [4] for ductile materials. Subsequently, Hillerborg et al. [5] proposed the *fictitious crack model* for the study of quasi-brittle materials. The basic assumption is the formation, as an extension of the real crack, of a fictitious crack, referred to as the process zone, where the material, albeit damaged, is still able to transfer stresses. More recently, the former terminology of *cohesive crack model* was reproposed by Carpinteri [6] for the analysis of snap-back instabilities in quasi-brittle materials and the related ductile-to-brittle size-scale transition [7,8] (see Fig. 1).

In the last few years, an extension of these studies has been carried out for the analysis of instability phenomena due to the interface mechanical problems in heterogeneous materials. Notable examples are: debonding of fiber-reinforced materials [9], where a ductile-to-brittle transition takes place by increasing the reinforcement size; delamination of externally reinforced beams in bending [10], where the process of interface crack propagation results into severe snap-back instabilities; decohesion in laminated beams with multiple micro-cracks along the interface [11], where a very complex nonlinear behaviour takes place due to coupling between interface fracture and contact problems.

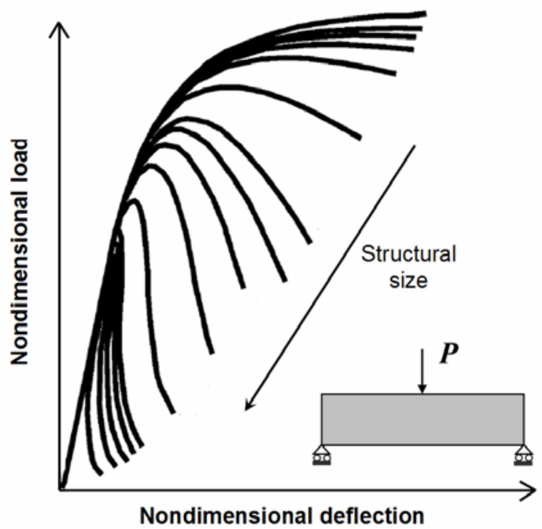

Figure 1: Ductile-to-brittle size-scale transition in quasi-brittle materials [6-8].

REFERENCES

[1] G. Maier, "Behaviour of elastic–plastic trusses with unstable bars", *ASCE J. Engng. Mech.*, Vol. **92**, pp. 67-91, (1966).

[2] G. Maier, A. Zavelani and J.C. Dotreppe, "Equilibrium branching due to flexural softening", *ASCE J. Engng. Mech.*, Vol. **89**, pp. 897-901, (1973).

[3] D.S. Dugdale, "Yielding of steel sheets containing slits", J. Mech. Phys. Solids, Vol. **8**, pp. 100-114, (1960).

[4] G.I. Barenblatt, "The mathematical theory of equilibrium cracks in brittle fracture", *Adv. Appl. Mech*., Vol. **7**, pp. 55-129, (1962).

[5] A. Hillerborg, M. Modeer and P.E. Petersson, "Analysis of crack formation and crack growth in concrete by means of fracture mechanics and finite elements", Cem. Concr. Res., Vol. **6**, pp. 773-82, (1976).

[6] A. Carpinteri, "Interpretation of the Griffith instability as a bifurcation of the global equilibrium", In S. Shah (Ed.), *Application of Fracture Mechanics to Cementitious Composites* (Proc. of a NATO Advanced Research Workshop, Evanston, USA, 1984), pp. 287-316. Martinus Nijhoff Publishers, Dordrecht.

[7] A. Carpinteri, "Cusp catastrophe interpretation of fracture instability", *J. Mech. Phys. Solids*, Vol. **37**, pp. 567-582, (1989).

[8] A. Carpinteri, "Softening and snap-back instability in cohesive solids", *Int. J. Num. Methods Engng*., Vol. **28**, pp.1521-1537, (1989).

[9] A. Carpinteri, M. Paggi and G. Zavarise, "Snap-back instability in micro-structured composites and its connection with superplasticity", *Strength, Fracture and Complexity*, Vol. 3, pp. 61-72, (2005).

[10] A. Carpinteri, G. Lacidogna and M. Paggi, "Acoustic emission monitoring and numerical modelling of FRP delamination in RC beams with non-rectangular cross-section", *RILEM Mat. Struct.*, Vol. **40**, pp. 553-566, (2007).

[11] A. Carpinteri, M. Paggi and G. Zavarise, "The effect of contact on the decohesion of laminated beams with multiple microcracks", *Int. J. Solids Struct.*, Vol. 45, pp. 129-143, (2008).