

**Prof. Alberto CARPINTERI**

### **SCIENTIFIC ACTIVITIES AND PROFILE**

The academic activities by Alberto Carpinteri (AC) have developed in the years towards different, although correlated, directions:

- (i) Teaching undergraduate and graduate courses on Basic Structural Mechanics, Advanced Structural Mechanics, Strength of Materials, and Fracture Mechanics;
- (ii) Organizing Workshops and Conferences at the national and international levels, in particular on topics regarding Strength of Materials and Fracture Mechanics;
- (iii) Participating, initially as a member and later with higher responsibilities, to the life of different national and international Scientific Societies, in the fields of Theoretical and Applied Mechanics, Structural Mechanics, Fracture Mechanics, Civil Engineering;
- (iv) Writing or editing volumes on different topics, reflecting various scientific interests or teaching activities;
- (v) Publishing the major results of his studies in Refereed International Journals.

As regards the last item, AC touched different specific topics, always giving them an original and personal contribution. In some cases such a contribution resulted to be also innovative, anticipating even by years the trends in cutting-edge research. Among these peculiar aspects, it is significant to remind the following ones.

- (1) Application of **Dimensional Analysis** (Buckingham's Theorem for physical similitude and scale modelling) to the scaling competition between plastic collapse and brittle fracture, which are failure mechanisms governed by generalized forces with different physical dimensions. Definition of a nondimensional number (called the *Brittleness Number*), which is a function of strength ( $FL^{-2}$ ), toughness ( $FL^{-3/2}$ ), and size-scale of the solid body, and corresponds to the Reynolds Number for fluids in the description of the transition from stable to unstable behaviour. In this context, it is possible to confirm, but also to overcome, the "small-scale yielding" condition, which is only local and related to the plastic zone around the crack tip. The innovative idea to compare the two different failure modes was firstly proposed in the papers (13, 17, 23, 31, 44).
- (2) Interpretation of brittle crack propagation in the framework of **Catastrophe Theory** by René Thom. Decreasing the fracture energy of the material, and/or increasing its tensile strength, and/or increasing the size-scale of the solid body, the structural response in terms of load versus deflection becomes more and more brittle, a cusp-catastrophe emerging in the diagram, with positive slope in the post-peak softening branch (snap-back instability). It was the first time that such a general interpretation was provided, with the possibility of analysing and realizing also the post-peak behaviour. From a numerical point of view, the crack length was selected as the monotonically increasing input parameter, as well as the input parameter in the experiments was the crack mouth opening displacement. The theoretical model and

the related numerical algorithm were called the *Cohesive Crack Model* by AC and proposed in the papers (41, 52, 56, 59, 71, 73, 74, 75, 76, 77, 78, 99, 108, 109). On the other hand, the studies on this nonlinear model confirmed the importance of the Brittleness Number in the description of the ductile-to-brittle transition by increasing the structural size. Large bodies are much more brittle than small bodies made up of the same material. Very recent applications to superplasticity in ceramic materials (369) and to plastic rotations in reinforced concrete beams (459) appear to be very successful.

- (3) Based on some experimental evidence, **fractal patterns for cracking, damage and deformation** were assumed by AC in (136, 137). This innovative conjecture led him to the definition of the renormalized (or fractal) counterparts of tensile strength, critical strain, and fracture energy, which present anomalous and noninteger physical dimensions and represent the really scale-independent material properties. On the other hand, the usual nominal quantities become scale-dependent and vary with the specimen size according to peculiar power-laws where the scaling exponent is connected to the fractal dimension of the same set over which the quantity is defined. The slope in the bi-logarithmic scaling laws, as well as the fractality itself, are maximum and equal to  $1/2$  at the smallest scales, whereas they tend to vanish at the largest scales. This homogenization effect is captured by a Multi-Fractal Scaling Law (MFSL), which is very satisfactory for initially uncracked structural elements (147, 148). The MFSL has been adopted by the European Standards for concrete and reinforced concrete structures. On the other hand, it also works for ceramic materials at the micro- and nano-scale (400).
- (4) Application of **Fractional Calculus** to field and boundary equations of an elastic body deformable only over a fractal subset (284, 285). The duality of the static and kinematic fractional operators was shown in (258, 328, 330, 403), as well as an extension of the Virtual Work Principle.
- (5) Based on rigorous conditions of equilibrium and compatibility, the problem of the propagation stability was solved for **cracks bridged by reinforcements and/or fibres**. The first two papers on the topic (21, 37) were dealing with a single reinforcement or fibre in a beam traversed by an edge crack. The stability condition is represented by a bound to a Brittleness Number where also the reinforcement percentage appears. Based on this theoretical model, numerous applications to cementitious materials followed in the years. Repeated loading and hysteretic behaviour were considered in (38, 444), as well as the problem of the minimum reinforcement in reinforced concrete members (64, 97, 98, 103, 116, 117). The model was then extended to beams with longitudinal multiple reinforcements and/or fibres (150, 168, 189, 190), as well as to reinforced concrete beams with a nonlinear matrix (309, 335).
- (6) More recently, AC provided original and innovative contributions on **fragmentation, comminution, wear, and drilling** (289, 291, 307, 314, 337, 338, 342, 357). Very interesting and new scaling laws for these phenomena were

established on the basis of fractal geometry and power laws. In the same conceptual framework, even **the phenomena of acoustic emission in cracking solids and of seismicity in the Earth's Crust** were interpreted with their scaling implications (283, 341, 412, 413, 414, 415, 437, 440, 445, 446, 494, 495, 497).

- (7) Some very recent papers deal with fundamental aspects, like the size effects on the **friction coefficient** and the criticality of rock slopes (334, 370, 476), the scaling laws in solids mechanics (360), the **nonlinear and chaotic mechanics** in cracked or damaged solids (362, 363), the mechanics of **layered or functionally graded materials** (288, 308, 371, 390, 397, 398, 399, 404, 405, 438, 439, 477, 478, 479), the mechanics of **nanostuctured or hierarchical materials** (361, 373, 403, 409, 483, 484, 486, 488, 489, 491), the **fatigue** ruptures under repeated loading in metallic materials (407, 441, 442, 480).

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2. A. Carpinteri: *Mechanical Damage and Crack Growth in Concrete: Plastic Collapse to Brittle Fracture*, Martinus Nijhoff Publishers, Dordrecht (1986), XIII + 234.
3. S.P. Shah, A. Carpinteri (Editors): *Fracture Mechanics Test Methods for Concrete*, Chapman & Hall, London (1991), XII + 287.
4. A. Carpinteri (Editor): *Applications of Fracture Mechanics to Reinforced Concrete*, Elsevier Applied Science, London (1992), XIV + 616.
5. A. Carpinteri et al. (Editors): *Localized Damage: Computer-Aided Assessment and Control*, Computational Mechanics Publications, Southampton (1994), XIV + 736.
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37. S. Bossuyt, G. Schajer, A. Carpinteri (Editors): *Residual Stress, Thermomechanics & Infrared Imaging, Hybrid Techniques and Inverse Problems*, Proceedings of the 2015 Annual Conference on Experimental and Applied Mechanics, Springer (2016), Vol. 9, IX + 380.

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45. A. Carpinteri: *Scienza delle Costruzioni 1*, Pitagora Editrice, Bologna (1992), XI + 423.
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