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# COMPUTATIONAL ESTIMATION OF MACROSCOPIC CONSTITUTIVE BEHAVIOR IN COMPOSITE MATERIALS

**D. Bruno[1], F. Greco[2], P.Lonetti[3] and P. Nevone Blasi[4]**

Dept. of Structural Engineering University of Calabria,
Via Ponte P. Bucci Cubo 39B, 87030 Arcavacata di Rende (CS), Italy.
[1]dbruno@unical.it [2]fabrizio.greco@unical.it [3]lonetti@unical.it [4]p.nevone@strutture.unical.it

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## ABSTRACT

In the present work the influence of micro-cracking and contact on the effective properties of composite materials is investigated, by using the finite element method in conjunction with interface models. Non-linear macroscopic constitutive laws are developed by taking into account changes in micro-structural configuration associated with the growth of micro-cracks and with contact between crack faces [1-2]. Numerical simulations are developed for the cases of a porous composite with edge cracks and of a debonded fiber-reinforced composite, loaded along extension/compression uniaxial macro-strain paths. In order to determine the macroscopic constitutive law as a function of damage evolution, Fracture Mechanics has been coupled to the homogenization techniques, computing macro-stress and macro-strain as a function of the energy release rate, evaluated for each damaged configuration. Micro-crack propagation is modelled by using the *J*-integral methodology [3] in conjunction with an interface model taking into account the unilateral contact of crack faces. In the context of a micro-to-macro transition obtained by controlling the macro-deformation of the micro-structure, the effects on the macroscopic constitutive law of adopting three types of boundary conditions are studied: a) uniform tractions; b) periodic deformations and antiperiodic tractions; c) linear deformation. Micro-crack and contact evolution results in a progressive loss of stiffness and may lead to failure for homogeneous macro-deformations associated with unstable crack propagation [4-5]. In order to validate the proposed homogenization procedure, the obtained macroscopic constitutive laws have been adopted in the study of a macroscopic element, subjected to an imposed displacement. Particularly, comparisons between energy release rate values obtained by means of direct analysis of a 2D macro-element, constituted by a regular arrangement of 5x5 unit cells, and those computed by means of a microscopic analysis of a single RVE driven by an imposed macro-strain obtained by a macroscopic analysis of the homogenized macro-element, are carried out.

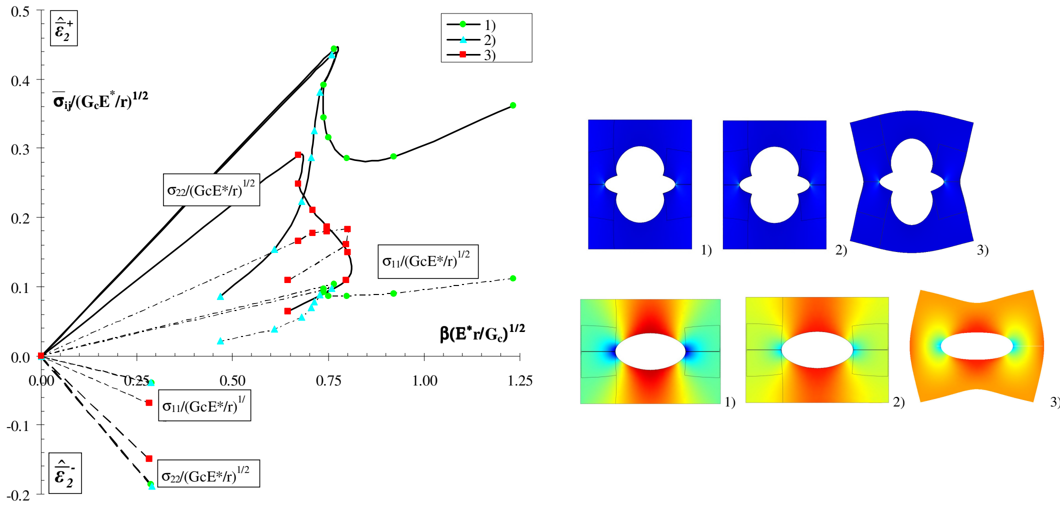


Fig. 1 Porous material: macroscopic dimensionless stress versus macroscopic strain and deformed configurations of the RVE for macro-strain paths in the $x_2$ direction and different homogenization boundary conditions.

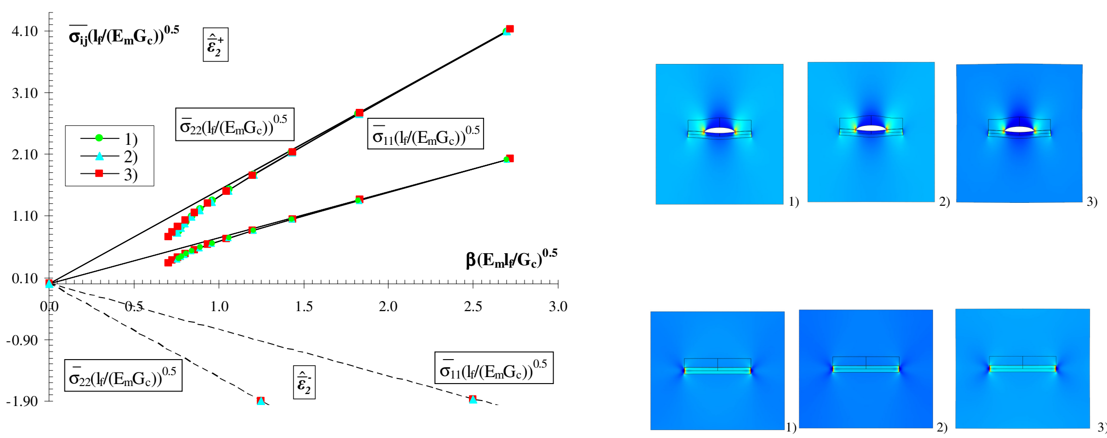


Fig. 1 Fiber-reinforced material: macroscopic dimensionless stress versus macroscopic strain and deformed configurations of the RVE for macro-strain paths in the $x_2$ direction and different homogenization boundary conditions.

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