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Mesoscale prediction of concrete mechanical properties by random phase allocation

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ABSTRACT

Concrete is a composite structural material whose constitutive behaviour is strictly depending on the mechanical properties of its constituents. The strength and the elastic modulus of the aggregates and of the cement paste define the overall response of the material and have significant influence on the macroscopic properties. In the numerical simulation of structural problems concrete is often macroscopically characterised by assigning homogenised mechanical properties. Usually some failure criterion is selected, in the field of Plasticity, possibly with softening, or in the field of Continuum Damage Mechanics, possibly coupled with plastic irreversible strain. These approaches all depend on the accuracy of the input material parameters and in Finite Element implementation suffer of mesh dependency of the solution. However a number of strategies exists to achieve the objectivity of the solution. The correct prediction of the mechanical properties of the homogenised material can be experimentally obtained by means of standard tests. Moreover theoretical homogenisation models can be applied.

Otherwise, a variety of scientific researches is devoted to the numerical prediction of the mechanical properties of composite materials by means of mesoscale analysis. Each component of the heterogeneous composite is individually modelled and, if adequate constitutive and kinematic models are introduced, a consistent simulation of the damaging process, including crack growth and coalescence, can be achieved. The distribution of the components inside a Representative Volume Element (RVE) is randomly generated, following different approaches. Therefore, the analysis is concentrated on a finite sample, whose spatial discretisation is usually performed by a finite element mesh, following alligned or unaligned approaches [1], [3], [2], [4].

In the paper a new numerical technique for modeling the distribution of concrete components in the RVE is introduced. The numerical description of the mesoscale structure of the heterogeneous material is attained by using a random method that allocates at each Gauss point of the RVE finite element discretization a specific phase of the mixture: aggregate, cement paste, void. Specifically, the material is assigned at the Gauss point depending on a random function of the volume fractions of the mixture components, according to a Fuller grading curve. Therefore, the model does not consider the physical size of the components.

Each phase is characterised by a specific constitutive model. The evolutive behaviour of the

cement paste and of the aggregates is ruled by an elastic-plastic constitutive model coupled with damage [5].

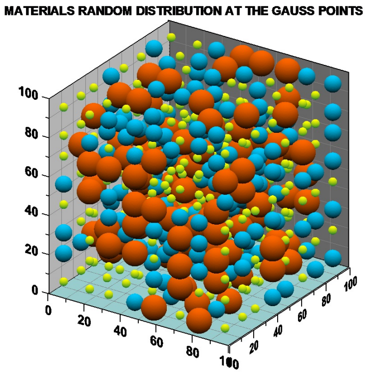

Figure 1: Phase random distribution at the Gauss point level of the RVE.

The tangent elastic modulus and the damaged Poisson ratio of the concrete mixture are accurately predicted. From uniaxial compressive tests under displacement control the secant modulus on the unloading is correctly achieved. The mesh independency is quickly obtained just by means of relatively coarse meshes of the RVE and it is not influenced by the choice of the seed value used to initialize the pseudo-random number generator. Moreover, the randomness of the generation of the micro structure does not affect the overall properties of the mixture, provided a sufficient number of finite elements is used in the dicretisation.

The method is suitable for a straightforward application in multiscale analysis of structural problems.

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