Representative Volume for Elastic, Hardening and Softening Materials

Author: Oriol Lloberas Valls
Tutors: Harm Askes and Sonia Fernández

Abstract

One of the main challenges in solid mechanics is the transition from a heterogeneous micro-structure to an approximating continuum model. This is the case of materials such concrete which is modeled, in this study, as a three phase material: consisting of aggregates, matrix and an Interfacial Transition Zone.

For this reason a representative volume of the sample is needed. *The Representative Volume Element (RVE) is the smallest material volume element of the composite for which the usual spatially constant "overall modulus" macroscopic constitutive representation is a sufficiently accurate model to represent mean constitutive response (Drugan and Willis 1996)*.

The objective of this study is to verify the existence of RVEs in different regimes of loading and possibly to quantify the size of a RVE for brittle materials.

For this purpose a set of material samples is envisaged to be generated. This set is composed by samples with different size and aggregate density distribution. The sizes for the cell chosen in this study are 10, 15, 20 and 25 length units and the aggregate density distributions considered are 30\%, 45\% and 60\%. Five realisations are generated for each combination of the specified characteristics in order to allow later statistical analisys.

Afterwards, a mechanical test is imposed via a *Finite Element* (FE) program in order to study the mechanical response of the material. The FE program used is a computer analysis system called FEAP and the code used is a *gradient enhanced damage* code. *Damage mechanics is a branch of continuum mechanics that incorporates changes in the micro-structural level via a finite number of scalar or tensor-valued internal variables (Lemaitre and Chabosche 1990)*. These changes will contribute to the degradation of the elastic constitutive moduli allowing to reproduce the behaviour of brittle materials. For this study a tension test is made by fixing one of the sample boundaries and imposing a certain displacement to the opposite one. The result of the mechanical test is a set of "force-displacement" graphics corresponding to the mechanical response of the tested samples.

Next, certain properties of the material are chosen in order to study their statistics in different parts of the global behaviour. These properties are the global stiffness of the sample (which is studied in the elastic, hardening and softening branches of the mechanical response) and its tensile strength. The expectation and standard deviation of the mentioned properties are computed for each group of samples.

Finally, conclusions are made about the existence of an RVE in any part of the global behaviour. Further study is done for those cases that show suitable statistical results for the existence of an RVE and a Chi-square test is performed in order to construct the RVE graphs. These graphs relate the aggregate density distribution with the size of the RVE for a particular material property when a certain level of accuracy is reached. Further study is also suggested for those cases in which is not possible to quantify the size of an RVE although the results show its existence.