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MULTISCALE FORMULATION FOR MATERIALS WITH RANDOMLY DISTRIBUTED VOIDS: MINIMALLY CONSTRAINED AND MORE RESTRICTIVE MULTISCALE SUB-MODELS.

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Abstract. From a micro-mechanical viewpoint, many biological, natural and artificial materials can be described by means of two interacting and dissimilar constituents: (i) a continuum phase acting as a background matrix and (ii) a population of voids. Usually, the spatial distribution of voids is intricate and random. Accurate predictions for such class of materials, in terms of their effective properties, imply advances in the field of solid mechanics, heat transfer, bio-engineering, etc.

In this work, a variationally consistent multiscale theory is proposed, which is specially devised for materials with randomly distribution of voids. The framework exploits the concept of Representative Volume Element (RVE) and is based on the Multiscale Virtual Power Method (MVPM). Due to the random character of void population, the micro-structural domain must admit the presence of voids reaching, aleatory, the RVE boundaries. This fact represents a challenge for the formal statement of a multiscale theory. There is no geometrical correspondence in the matrix phase between opposite RVE boundaries, discarding the periodicity hypothesis commonly used. The so-called Minimally Constrained multiscale Model, as it is described in the current literature, presents debatable mechanical and physical aspects for RVEs with voids reaching their boundaries.

In our contribution, the ideas behind the Minimally Constrained multiscale approach are generalized. A novel strain homogenization formula is introduced which makes possible the formal establishment of a new Minimally Constrained Kinematical Multiscale Model (MCKMM) with the following attributes: (i) it is able to provide the effective response in micro-structures where voids do reach the RVE boundaries, (ii) it is consistent with a uniform traction model along the solid part of the RVE boundary and (iii) such traction system is self-equilibrated. The proposed framework also allows the construction of more kinematically restrictive multiscale models (obtained by considering sub-spaces of the MCKMM) as well as another alternative homogenization procedures. Potentialities and possible extensions of the present formulation are analysed by means of several numerical simulations.