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NUMERICAL HOMOGENIZATION OF REACTIVE POWDER CONCRETE IN THE NONLINEAR RANGE

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The paper is concerned with the determination of effective material parameters of reactive powder concrete (RPC) in the range of its nonlinear response. The work is a continuation of our previous studies of RPC in the range of linear elasticity [1]. Reactive powder concrete is currently one of the most modern building materials produced on the basis of cement, and belongs to the class of Ultra-High Performance Concrete (UHPC) with its strength and high ductility comparable to steel [2]. The RPCs are also classified as cement matrix composites with ultra-high resistance properties, being often called the low-temperature ceramics. The advantageous properties of ultra-high strength and ductility of RPCs allow the designer to significantly reduce the weight and cross-sectional dimensions of constructions built from RPCs. Our investigation encompasses both development of a theoretical model of RPC and its numerical implementation as well as a series of own experimental tests which we carried out in order to validate the proposed numerical model of RPC.

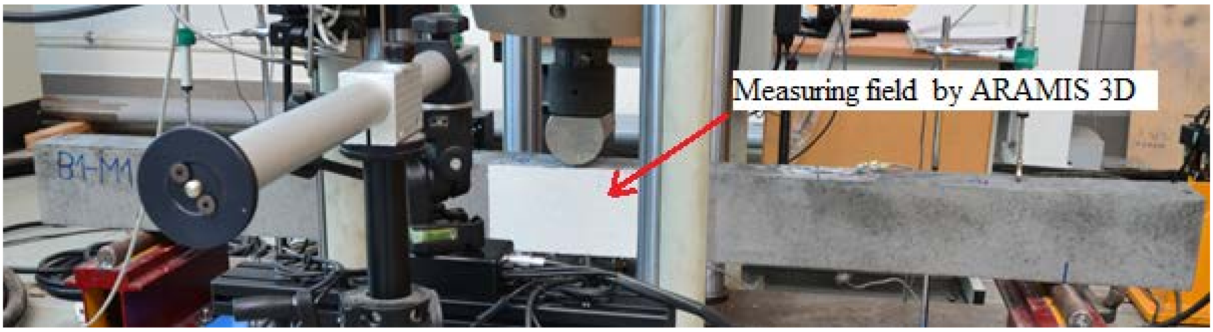

Figure 1: Testing machine (three-point bending test) and monitoring of damage zone by ARAMIS 3D

The laboratory tests were conducted on concrete cubes 15x15x15 cm (compressive strength test), small beams 10x10x46 cm (four-point bending) and beams 10x15x200 cm (three-point bending). During the laboratory tests a large amount of data was collected, related to a nonlinear working range of the tested beams and the development of damage (Fig 2). The gathered information is a base to validation of the numerical model. The tested reactive powder concrete is composed of very fine powders: sand, crushed quartz and silica fume, all with particle sizes less than 600 µm, and reinforced with dispersed steel micro-fibers and fibers. Concrete is a structural composite material and its hierarchical structure may be analysed in a multiscale approach, starting from the molecular dynamics simulation of hydrated cement solid nanoparticles [4]. In order to account for the microstructure of RPC and its evolution, the idea of a two-scale modelling technique is applied. The behavior of RPC on a macro scale (the level of phenomenological description, material point scale) is described on the basis of phenomena occurring in the microstructure of material (a micro scale). The material microstructure is taken into account by means of a representative volume element (RVE), the structure of which is generated in a stochastic way with data from the designed recipes of RPC. Creating the RVE structure consists in the random selection of an element (from a 50 × 50 grid) and also the random assignment of the component (pores, crushed quartz, sand, cement matrix) to the selected position (Fig. 3) and [1]. The issue of approximation of the random microstructures is discussed in depth in [3].

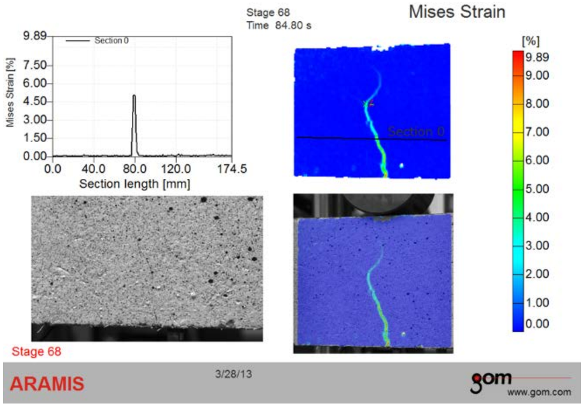

Figure 2: Beginning a damage phase: beam B2-M1 10x15x200 cm (three-point bending)

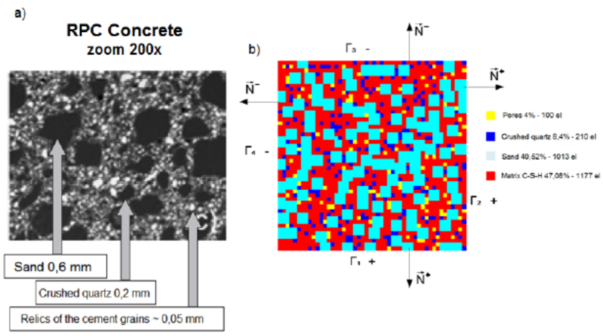

Figure 3: Representative volume element of RPC: a) microstructure [5], b) finite element model of RVE

It is assumed that the microstructure of RPC is composed of isotropic ideally-elastic-brittle constituents and at the macro scale the material is homogenized. This approach allows for the simple modelling of microcracks that cause the nonlinear behaviour of the material at the macro level. The numerical analysis is done here to the plane stress state and at each level of analysis the finite element method is applied. Results of both experimental tests and numerical simulations will be presented at the conference.

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