The aim of the 3-year experimental theoretical research project is the explanation of the mechanism of cracks' initiation and propagation in concrete in a static regime depending upon its heterogeneous meso-structure and its description with the use of an advanced two-scale mathematical model, that combines fracture at the aggregate level (meso-level) with fracture at the structural level (macro-level). In simulations at the meso-level 4 the most important phases will be taken into account in concrete: aggregate, cement matrix, macro-pores and interfacial transition zones. Interfacial transition zones placed between aggregates and cement matrix play a very important role in forming the concrete properties. They are the weakest phase in concrete and are the regions of micro-crack initiation and propagation which form later discrete macro-cracks by bridging.

Research work consist of two complementary parts: experimental and theoretical ones. In the experimental part, comprehensive quasi-static laboratory tests will be performed to determine a quantitative influence of meso-structure on the global concrete behaviour. The influence of the concrete mix parameters, sieve curve, aggregate volume, size, shape and roughness of aggregate particles on macroscopic properties of concrete (strength, brittleness and cracking) will be analyzed in detail. Three point bending, splitting and uniaxial compression tests will be performed. Due to the use of the very advanced 3D x-ray micro-computed tomography system (owned by our department), the changes of meso-structure and crack geometry in concrete specimens will be observed during loading. In addition a scanning electron microscope will be also used to analyze changes of concrete meso-structure.

In the numerical part a two-scale constitutive law for concrete will be formulated that combines fracture at the aggregate level (meso-level) with fracture at the structure level (macro-level). In the first phase the usefulness of existing two-scale formulations for concrete will be analysed with respect to their complexity and reliability during the transfer of the information regarding fracture between the macro- and meso-level. In the second phase, our two-scale model will be proposed: a) in an advanced version based on the computational (full) homogenization that does not require the definition of the material model at the macro-level and b) in a simplified version based on the numerical (partial) homogenization wherein the parameters in the phenomenological constitutive law at the macro-level are to be determined at the meso-level. The meso-scale simulations will be performed with a real geometry of 4 phases in concrete on the basis of images by means of 3D x-ray micro-computed tomography. Special attention will be focused on the proper definition of a representative volume element in concrete. Two-scale numerical results 2D and 3D will be validated against laboratory outcomes.

As a result of our research, a new knowledge database on the behaviour of fractured concretes will be created by taking their real meso-structures into account. The data obtained will be useful in the design of concrete with the improved strength and brittleness and in solving different mechanical problems regarding fracture in brittle and quasi-brittle materials.