

In-situ x-ray tests for an image-based FE meso-model for cementitious materials

Olga Stamati ^{*1}, Emmanuel Roubin¹, Edward Andò¹, and Yann Malecot¹

¹Univ. Grenoble Alpes, CNRS, Grenoble INP[†], 3SR, F-38000 Grenoble, France

Abstract

This work aims to study the impact of the meso-scale heterogeneities of a cementitious material on its macroscopic response. More specifically, concrete is studied at meso-scale, where the local failure mechanisms are known to drive the macroscopic behaviour of the material. At this scale, concrete can be considered as a three phase geomaterial constituted of aggregates and macro-pores embedded within a mortar matrix. Therefore, development of numerical models which explicitly represent the meso-scale has become a common approach in recent years. The spirit of such an approach is to identify the impact of each phase (for example each phase's morphological properties) and the interfaces between phases on the macroscopic mechanical behaviour.

In this study, x-ray tomography of concrete specimens is used to obtain — after passing the 3D images through a set of image analysis operations — the morphologies of the meso-structure. These morphologies are then given as an input to a FE framework. On one hand, in order to account for the complex heterogeneous aspects of the meso-structure (explicit representation of aggregates and macro-pores), a projection of these morphologies into a non-adapted mesh is done that leads to discontinuities in the strain field (weak discontinuity) within an element. This discontinuity is handled by a local kinematics enhancement. On the other hand, the quasi-brittle behaviour of the material is represented at the meso-scale by another set of local discontinuities, this time in the displacement field, that account for micro-cracking (strong discontinuity). The coalescence and bridging of these micro-cracks leads to the macroscopic failure of the material. These two discontinuities are combined within the same Embedded Finite Element Method ([1] DEK-FEM).

In parallel, an x-ray compatible experimental set-up is developed allowing uniaxial tensile and compressive tests of micro-concrete specimens to be performed inside the x-ray scanner. Thus, apart from obtaining the meso-morphologies, the *in-situ* evolution of the micro-structure is followed during the tests providing information of the actual kinematics.

Comparison of experimental and numerical results reveals the capability of the meso-model to sufficiently capture the material's response, being a way for validating and enriching it. As an illustrative example, Fig.1 shows the results of a micro-concrete uniaxial tensile test. Fig.1a shows the segmented 3D image coming from the x-ray scan in the final loading step. The morphology obtained from the x-ray scan in the initial configuration (before loading) is the one used as input for the FE meso-model. Fig.1b shows the numerically computed crack patterns. The typical, for tension, mode I crack opening is obtained both experimentally and numerically.

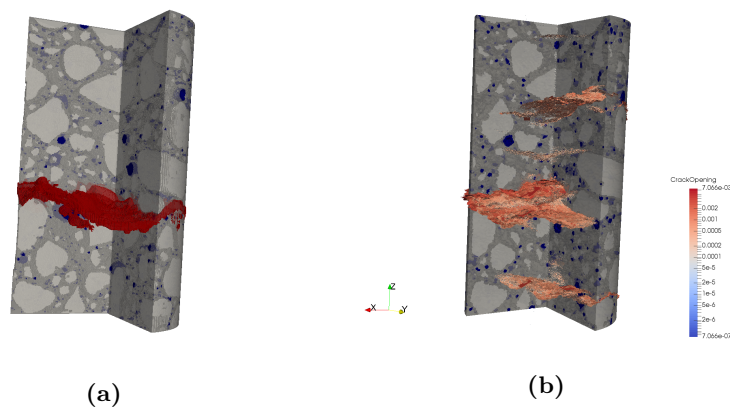


Figure 1: Comparison of experimental and numerical results for a micro-concrete uniaxial tensile test. (a): segmented 3D image of the x-ray scan in the final loading step: blue: macro-pores, grey: mortar, light grey: aggregates, red: macro-crack, (b): computed crack patterns from the numerical simulation using as an input the morphology obtained from the x-ray scan at the initial loading step.

References

- [1] E. Roubin, A. Vallade, N. Benkemoun & J.B. Colliat. Multi-scale failure of heterogeneous materials: A double kinematics enhancement for Embedded Finite Element Method. *International Journal of Solids and Structures*, 2015.

*e-mail: olga.stamati@3sr-grenoble.fr

[†]Institute of Engineering Univ. Grenoble Alpes