

3D experimental detection and characterization of microcracking in porous cement based materials

TT. NGUYEN^{*,†}, C. CHATEAU^{*}, M. BORNERT^{*}, J. YVONNET[†]

^{*} Université Paris-Est, Laboratoire Navier (CNRS UMR 8205, ENPC, IFSTTAR)
Marne-la-Vallée, France
e-mail: {camille.chateau, michel.bornert}@enpc.fr

[†] Université Paris-Est, Laboratoire Modélisation et Simulation Multi Echelle (CNRS UMR 8208)
Marne-la-Vallée, France
e-mail: {thanh-tung.nguyen, julien.yvonnet}@univ-paris-est.fr

ABSTRACT

The mechanical description of damage caused by cracking phenomena occurring in many civil engineering materials is still an open issue, in terms of initiation, propagation or localisation leading to macroscopic ruin. Detailed experimental characterization of cracking under mechanical loading is necessary to validate 3D models of crack nucleation and propagation in heterogeneous materials [1].

A dedicated experimental set-up was used to perform in-situ compressive tests on an X-Ray Computed Tomography (XRCT) laboratory scanner available at Laboratoire Navier, on a cylindrical lightweight concrete sample (~10 mm in diameter). The material is made from quartz sand and expanded polystyrene (EPS) beads embedded in a cement matrix [2]. Its high porosity is suitable for crack initiation at relatively low compressive loads and stable propagation. Several load levels were successively applied to the specimen and CT images of the whole sample were recorded under constant load. Cracks developed progressively during the last loading steps and can be qualitatively observed directly in the CT images. In order to quantify their precise location and extension and to detect early-age cracking, a method based on Digital Volume Correlation (DVC) has been developed. Because local contrast is too low in EPS beads and sand grains, DVC routines have been run on positions in cement matrix, especially near interfaces, to obtain a sparse evaluation of the mechanical transformation. The latter can then be continuously extended throughout the whole sample, by means of an adjusted interpolation/smoothing procedure that also filters DVC measurements errors. Finally, after back-convection of the deformed image to the same frame as the reference image according to the estimated transformation, the difference between reference and deformed images is computed and defines the “subtracted image”. It reflects the local evolutions of the material, not described by the fit of the coarse evaluation of the transformation. For a brittle material, it essentially gives access to the cracks. In fact, the path of cracks is clearly visible within the almost uniform grey level of the subtracted image. Segmentation of cracked areas is thus possible, while it would have been very hard to separate cracks from porosity in the deformed XRCT images. Moreover, very tiny cracks can also be detected and their sub-voxel opening evaluated. Using this DVC-assisted subtraction for all loading steps, the crack network and its evolution (propagation, opening) through the cement matrix and sand grains can be characterized in the whole sample. These results can especially be directly compared to numerical simulations computed on realistic microstructures. Because validation of numerical tools on such a complex microstructure is problematic, similar tests were performed on samples composed of EPS beads embedded in an almost homogeneous plaster matrix. Their simpler microstructure characterized by a limited number of EPS beads is easier to model and will serve for detailed comparisons between new numerical tools and experimental results.

REFERENCES

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