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X-RAY OBSERVATION OF THE LOADED SILICATE COMPOSITE

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Abstract: *An intensive internal material damage evolution precedes a failure in quasi-brittle materials. Not only the existence of damage but also its quantification and the geometry of the Fracture Process Zone (FPZ) have to be identified in order to validate approaches on both numerical modelling of quasi-brittle behaviour and experimental determination of fracture properties. Radiographic techniques and Digital Image Correlation method are very appropriate for analysing of the FPZ evolution during specimen loading.*

Keywords: ***Quasi-brittle fracture, Cementitious composite, Digital radiography, Computed tomography, Digital Image Correlation***

1. Introduction

Investigation of the material failure employing X-ray imaging is presented in this paper. Specimen prepared from cementitious composite was loaded using three point bending test in a specially designed loading device. Crack and FPZ shape was analysed using digital transmission radiography and X-ray Computed Tomography (CT). Visualization of the FPZ was emphasized using tools of the Digital Image Correlation method (DIC).

As a material for the specimen preparation, a fine-grained cementitious composite was chosen to simulate the failure process of normal-sized building structures/structural members made of concrete.

Highly stiff loading compressive device was used for the notched beam specimen loaded in three point bending. This device allows very low loading velocity while it's relatively low weight and dimensions enable X-ray observation of the specimen in the radiographic cabin.

2. Experimental results

Specimen was loaded with velocity 6 μm/min. Exposure time of one X-ray radiograms was 5×0.48 seconds (it corresponds to the 0.5 μm displacement increment due to read out time). These radiograms were recorded continuously during loading while CT measurement was done in two loading levels. For the CT measurement, 240 snapshots (180° rotation) were taken.

A load−displacement diagram (LD diagram) is plotted in Figure 1. It is clearly visible that loading device enables to study processes with very high loading precision. DIC tools were used to visualize crack and FPZ which are shielded by the material structure in original radiograms. Actual and initial radiograms were subtracted (subtraction image) to find changes of the specimen density considering specimen movement during its loading.

The subtraction image in the moment where loading force dropped down is depicted in Figure 2 left (point *B* in LD diagram: 28 N at 160 μm). It was proven that subtraction image (comparing with

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CT measurement) can describe crack front position and FPZ shape thanks to the significant change of the specimen density, although boundary between crack tip and FPZ is quite blurred. Crack (surrounded by continuous line ellipse) and FPZ (surrounded by dashed line ellipse) were 2.7 and 16 mm long respectively at the loading level *B*. The subtraction image from the end of the loading experiment is depicted in Figure 2 right (point C in LD diagram: 5 N at 380 μm). The crack was 17 mm long and practically whole remaining ligament was weakened by the FPZ.

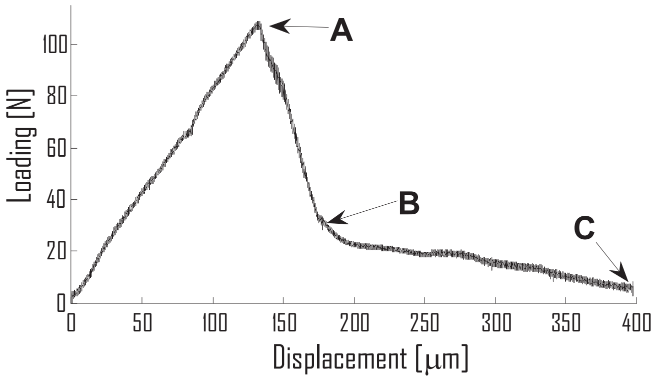

Fig. 1: LD diagram. Loading levels in which FPZ zone was detailed studied are labelled by letters.

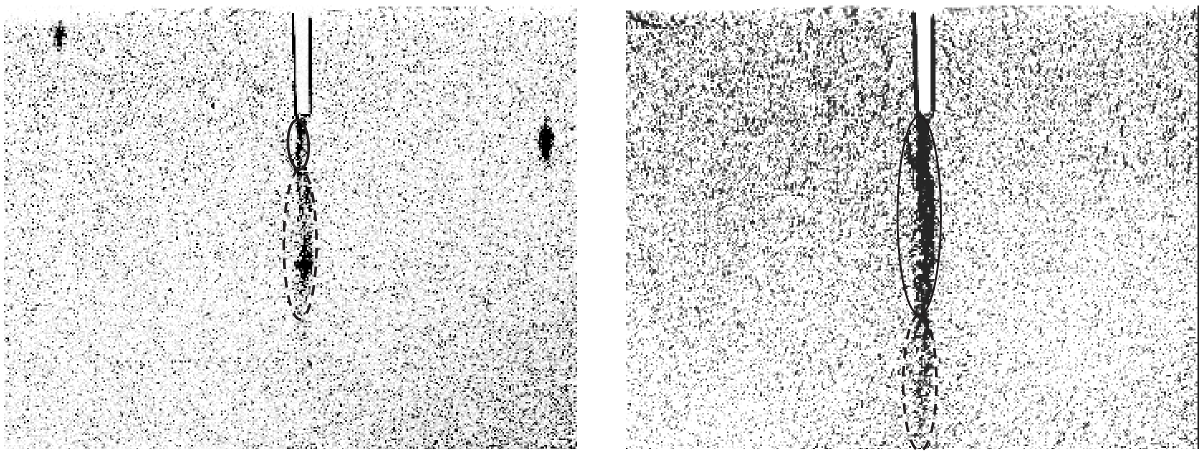

Fig. 2: Subtraction image at the loading level B left. Image of the specimen at the end of the experiment is right.

3. Conclusions

It was proven that X-ray radiography in conjunction with Digital Image Correlation and CT reconstruction are powerful tools for analysing of the crack and FPZ evolution during quasi-brittle specimen loading.

Experimental results showed that fracture process zone is generally significantly larger than macroscopic crack. Moreover, crack does not follow straight direction and its front is not sharp. It can be concluded from these reasons that linear fracture mechanics based on assumption of the continuum material can't describe such crack behaviour.

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