Simulations of fracture in concrete beams under bending using a continuum and discrete approach

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ABSTRACT

Fracture is a fundamental phenomenon in quasi-brittle and brittle materials [1]. It is a major reason of mechanical damage under loading that contributes to a significant degradation (reduction) of the material strength. It is highly complex due to a heterogeneous structure of brittle materials over many different length scales, changing in e.g. concrete from a few nanometres (hydrated cement) to the millimetres (aggregate particles). Therefore, the material heterogeneity should be taken into account when realistically modelling the material behaviour. An understanding of a fracture process is of major importance to ensure the safety of the structure and to optimize the behaviour of material.

In the paper, in order to study a failure process in plain concrete at the aggregate scale, two different numerical approaches were used: a continuum [2] and discrete one [3]. Within continuum mechanics, the simulations at the aggregate scale were carried out with the FEM based on a damage constitutive model enhanced by a characteristic length of micro-structure by means of a non-local theory [2]. As a discrete approach, the three-dimensional spherical discrete element model YADE was used [4]. The model takes advantage of the so-called soft-particle approach (i.e. the model allows for particle deformation which is modelled as an overlap of particles).

The concrete behaviour was numerically investigated during a quasi-static 3-point bending test. Concrete was considered as a four-phase body. It included aggregate particles, cement matrix particles, interfacial transitional zones (ITZs) and voids. The concrete micro-structure was directly taken from the real specimens based on 3D images (aggregate and cement matrix) obtained with the aid of the x-ray micro-tomography and 2D images (ITZs) from the micro-scope with a very high resolution. The processes of strain localization and cracking in concrete beams were studied in detail in 2D simulations (single 3D simulations were also carried out). The simulation results were directly compared with the experimental ones. In addition, some micro-structural phenomena (force chains, grain rotations, grain fluctuation displacements, local porosity changes) occurring in concrete beams during fracture were analyzed with DEM. The advantages and limits of the both approaches were outlined.

REFERENCES

[1] J. Tejchman and J. Bobiński, *Continuous and discontinuous modelling of fracture in concrete using FEM*, Springer, Berlin-Heidelberg (eds. W. Wu and R. I. Borja) (2013).
[2] L. Skarzyński and J. Tejchman, "Calculations of fracture process zones on meso-scale in notched concrete beams subjected to three-point bending", *European Journal of Mechanics/A Solids* **29**, 746-760 (2010).
[3] M. Nitka and J. Tejchman, "Modelling of concrete behaviour in uniaxial compression and tension with DEM", *Granular Matter*, doi: 10.1007/s10035-015-0546-4 (2014).
[4] J. Kozicki and F. Donze, "A new open-source software developer for numerical simulations using discrete modeling methods", *Computer Methods in Applied Mechanics and Engineering* **197**, 4429-4443 (2008).