Modelling of concrete fracture at aggregate level using DEM based on *x*-ray *μ*CT images of internal structure

M. Nitka and J. Tejchman

Faculty of Civil and Environmental Engineering
Gdańsk University of Technology, Gdańsk, Poland
e-mail: micnitka@pg.gda.pl, tejchmk@pg.gda.pl

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 develop an understanding of the failure process of plain concrete at the aggregate scale, the discrete element method (DEM) was used. In DEM a mechanical response of materials is governed by interactions at contacts between constituent particles and between particles and boundaries being responsible for the emergent complexity of phenomena occurring in these materials. In order to reproduce the concrete behaviour, a three-dimensional spherical discrete element model YADE was used, which was developed at University of Grenoble [2]. 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 by taking breakable cohesive inter-particle bonds between particles [3]. It included aggregate particles, cement matrix particles, interfacial transitional zones (ITZs) and macro-voids. The material constants were calibrated based on uniaxial compression and uniaxial tension [3]. The concrete micro-structure in calculations was directly taken from real concrete specimens based on 3D *x*-ray micro-computed tomography images and 2D images by the scanning electron microscope (SEM). The processes of strain localization and cracking in concrete beams were studied in 2D and 3D simulations. The simulation results with respect to the load-displacement diagram and the shape of the main crack were compared with the experimental outcomes. In addition, the evolution of contact forces, broken contacts, porosity, aggregate rotations, displacement fluctuations at the aggregate level during deformation was carefully studied. The width of a localized zone was determined based on grain displacements and compared with the width of a damage zone based on broken contacts. Moreover, the effect of properties of ITZs on fracture was studied.

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] 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)
[3] M. Nitka and J. Tejchman, "Modelling of concrete behaviour in uniaxial compression and tension with DEM", *Granular Matter*, **17**(1), 145-164 (2015).