

A Multiscale Model for FRC Composites

Jithender J. Timothy, Yijian Zhan and Günther Meschke

Institute for Structural Mechanics
Ruhr University Bochum
Universitätsstraße 150, 44801 Bochum, Germany
Email: sd@rub.de - Web page: <http://www.sd.rub.de>

ABSTRACT

Mechanical properties such as ductility, strength and load bearing capacity of cementitious materials can be considerably improved by the addition of reinforcing fibers. These reinforcing fibers improve the fracture toughness of the unreinforced cementitious matrix by arresting micro-crack growth which, if unhindered, will coalesce and form a macro-crack eventually leading to material and structural failure. The strengthening mechanism is dependent on the properties of the fiber and its interaction with the matrix material characterized by the interface behavior.

In order to understand the macroscopic counterpart of these complex micro-mechanisms and support material design, we propose a multiscale model that is a combination of semi-analytical and computational sub-models specified at multiple scales. At the scale of the single fiber, a semi-analytical model is developed, taking the type of fiber (hooked end, straight) and the angle of the fiber w.r.t. crack direction into account. On the level of individual micro-cracks, based upon this model, the influence of fiber bundles on micro-crack evolution is taken into account within the framework of the Linear Elastic Fracture Mechanics. Upscaling to the macroscopic level is achieved by using continuum micromechanics [1]. For plain concrete, a continuum damage model is used, which can be related to the microcrack-density and the micro-crack topology. The proposed model allows to characterize the influence of the bond behavior on micro-crack evolution realistically. Selected numerical experiments provide insight into the role of the interface property, resulting – on the macroscopic level - in a brittle, softening behavior in case of weak bond and a rather ductile, hardening behavior in case of a relatively strong interface bond. Furthermore, the model predicts an increasing microcrack density and microcrack arrest with increased fiber content.

At the structural level, the Finite Element Method is used, applying the Strong Discontinuity approach [2] to capture propagating cracks. The interface behavior across opening cracks are obtained from hybrid crack bridging laws developed on the basis of the single fiber-pullout models [3].

REFERENCES

- [1] B. Pichler, C. Hellmich and H. Mang, “A combined fracture-micromechanics model for tensile strain-softening in brittle materials, based on propagation of interacting microcracks”, *Int. J. Num. An. Meth. Geomech.*, 31, 111-132 (2007).
- [2] X. Oliver, A. Huespe, M. Pulid and, E. Chaves, “From continuum mechanics to fracture mechanics: The strong discontinuity approach”, *Engrg. Frac. Mech.*, **69**, 113-136 (2002).
- [3] R. Breitenbücher, G. Meschke, F. Song and Y. Zhan “Experimental, analytical and numerical analysis of the pullout behavior of steel fibers considering different fiber types, inclinations and concrete strengths”, *Structural Concrete*, 15, 126-135 (2014).