Mesoscopic Modelling of Strain Hardening Fiber Reinforced Cement Based Composites (SHCC)

Ulrich Häussler-Combe* and Alaleh Shehni*

* Institute of Concrete Structures
Technische Universität Dresden, 01062 Dresden, Germany
e-mail: ulrich.haeussler-Combe@tu-dresden.de, https://tu-dresden.de/bu/bauingenieurwesen/imb

ABSTRACT

SHCC shows high potentials to enhance the behaviour of concrete structures [1], [2]. In particular, their ductility may be increased by magnitudes which is highly relevant regarding extraordinary actions like earthquake, impact and explosions. But the properties of SHCC and its mesoscopic mechanisms are still topics under investigation. Numerical methods are required to investigate, e.g., the complex mesoscopic interaction between fibers and concrete which are decisive for the macroscopic behaviour.

This contribution discusses a mesoscopic model which explicitly distinguishes cement matrix, aggregates and randomly distributed fibers. It is based on FEM whereby cement matrix and aggregates are captured by continuum elements on the one hand, and fibers by truss elements on the other hand. Truss elements may be freely embedded in the continuum, i.e. continuum elements and truss elements each have their own nodes which don’t have to share positions. This allows for regular continuum mesh geometries combined with a random truss meshes. Truss elements and continuum elements are coupled by special bond elements which allow for flexible nonlinear bond behaviour. Continuum and fiber material behaviour may be assumed as nonlinear with their own laws, furthermore continuum distinguished between cement matrix and aggregates.

Concrete cracking behaviour needs special attention also in this setup. It is modelled with a simplified Strong Discontinuity Approach (SDA) applied for the continuum elements [3], [4]. Depending on the load history elements with continuous displacement fields are replaced with discontinuous displacement fields with the fulfilment of a Rankine criterion. This introduces additional kinematic degrees of freedom for a crack width geometry. Furthermore, crack width is connected with crack tractions and resolved on the element level without carrying additional degrees of freedom to the system level. Crack traction depending on crack width is prescribed in order to reproduce a prescribed crack energy. This covers the softening behaviour of concrete without requiring further regularization approaches.

The whole model is implemented for small displacements in 2D and 3D, and for quasi-statics and implicit dynamics. The application is demonstrated with the simulation of experiments with SHCC-specimen. This assumes multiaxial damage laws for the continuum material behaviour, uniaxial linear laws with limited tensile strength for the fibers and a nonlinear bond stress-slip law with limited bond capacity. The results reproduce the highly ductile load-displacement behaviour of SHCC and give detailed insight into, e.g., deformation characteristics and failure mechanisms of all constituents. Thus, the simulation model can be used for an efficient enhancement of SHCC compositions by performing parameter studies.

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