Bond behaviour of steel microfibres embedded in UHPC

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ABSTRACT

New developments in materials science and especially concrete technology have provided the design and construction of slender beams with optimized cross-sections. Furthermore, the use of delicate prefabricated components guarantees a very high material quality. As a result, slender beams and slabs made of high-tech materials such as ultra-high performance fibre reinforced concrete (UHPFRC) are developed and have to be designed according to an increased susceptibility to oscillations.

This research project is focused on the detection, description and modelling of the degradation behaviour of UHPFRC subjected to cyclic tensile loading. For economical, resource-efficient and performance-optimised design, the load-bearing capacity of the additional steel microfibres as well as the cyclic deterioration of this capacity have to be investigated. Therefore, the understanding of the bond behaviour on the mesoscale between fibres and the concrete matrix provides the basis for modelling of the fatigue behaviour of UHPFRC.

Existing bond models for ribbed steel bars embedded in concrete, e.g. developed by Cox & Herrmann [3] and Lundgren [2], are not able to describe the bond behaviour of microfibres connected to ultra-high performance concrete (UHPC). For example, Lawrence [4], Gray [5] and Naaman et al. [6] analysed the bond behaviour of smooth fibres pulled out from an elastic matrix. With regard to modelling cyclic degradation effects within the bond behaviour, a new bond model is needed operating geometrically and physically non-linear on the mesoscale.

The developed bond model is discretised with two-dimensional zero-thickness interface elements in the bond zone, which act in three-dimensional space and store the deformation and stress history of the bond layer on the surface of the surrounding concrete matrix (see also [7]). Being in contact with the fibre surface, the bond response is calculated in dependency on the relative displacements of these surfaces. Simulating the full pull-out of a fibre from a concrete matrix within the theory of small strains, the mesh has to be flexible with respect to moving surfaces. Therefore, a repetitive mapping of the interacting fibre and matrix surface nodes has to be incorporated in the iterative calculation of every time step.

The creation of bond forces due to the progressive fibre pull-out is modelled according to the theories of elasto-plasticity and continuum damage mechanics and separated by the relevant bond mechanisms adhesion, micro-interlocking and friction, which were observed and described by Stengel [1], for example (see Figure 1). These bond mechanisms succeed and influence each other especially due to dilatancy which is generated within micro-interlocking and obligatory for the development of normal forces activating friction. With a relatively high stiffness due to adhesion, the debonding process of the fibre surface from the concrete matrix can be visualised, representing the transition phase from rigid to sliding bond. The accumulated bond zone damage representing inelastic relative displacements in the bond layer displays the degradation of the capable bond stresses and can be evaluated in terms of cylic tensile loading.

The verification and validation of the bond model is made by reference to numerical simulations of monotonically and cyclically loaded single fibre pull-out tests in comparison to experimental tests.

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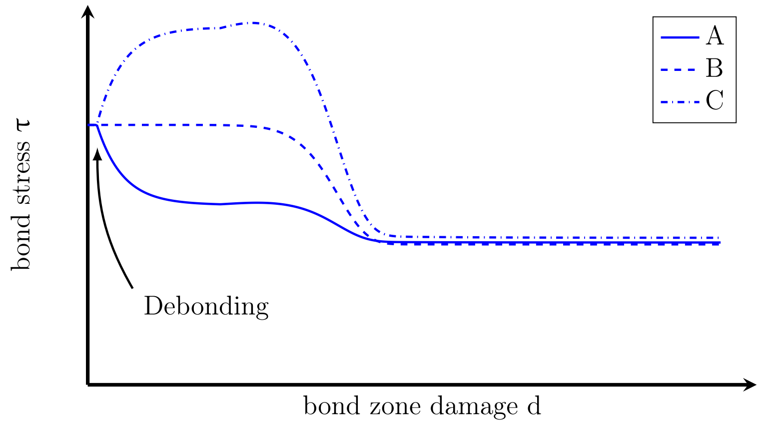

Figure 1: Development of bond stress according to bond zone damage for different parameter sets A, B and C applied to the bond model

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