11th. World Congress on Computational Mechanics (WCCM XI)
5th. European Conference on Computational Methods (ECCM V)
6th. European Conference on Computational Fluid Dynamics (ECFD VI)
Barcelona, July 20-25, 2014

A CONTINUUM MICROMECHANICS-LEFM MODEL FOR FIBRE REINFORCED CEMENTITIOUS MATERIALS

GÜNTHER MESCHKE* AND JITHENDER J. TIMOTHY

Institute for Structural Mechanics
Ruhr University Bochum
Universitätsstraße 150
44801 Bochum, Germany
{timothy.jithenderjaswant, guenther.meschke}@rub.de

Key words: Micromechanics, Concrete, fibre reinforced composites, LEFM

ABSTRACT

Improved mechanical properties of cementitious materials reinforced with fibres, such as higher load bearing capacity and ductility, are fundamental to performance based design of construction materials. The existence of fibres considerably improves the fracture toughness of the cementitious matrix by providing bridging stresses across opening microcracks. In the presented paper, these fibre-matrix interactions are described in the framework of a multi-scale modelling approach, adopting a combination of continuum micromechanics and Linear Elastic Fracture mechanics (LEFM). As the dominant mechanism governing the behaviour fibre reinforced composites at the scale of the individual microcrack, a penny-shaped crack, crossed by reinforcing fibres, is considered. This bridging mechanics is assumed to be the principal toughening mechanism for fibre reinforced composites.
At the scale of the individual microcrack, the local fibre stress is connected via equilibrium conditions to interfacial shear stresses, which are governed by the shear stress-slip characteristics of the fibre-concrete interface. The fibre slip controls the crack opening and, indirectly, the crack size, which, together with the bridging fibre stresses, controls the effective Mode-I stress intensity factor accounting for the bridging action of the fibres and the fibre-matrix slipping mechanism [1]. At the level of the individual microcrack, we assume that the crack growth criteria for an idealized penny shaped micro-crack according to LEFM can be applied.

Inspired by [2], the coupling of the LEFM model for micro-crack growth with fibre-bridging to micromechanics is achieved by relating the far field stresses to obtain a combined fracture-fibre-bridging-micromechanics model. In contrast to [2], however, for the unreinforced concrete, a micromechanics model is used which is directly calibrated by means of a macroscopic damage model.

The proposed LEFM-micromechanics model predicts an enhanced ultimate strength and ductility of the fibre reinforced composite depending on the fibre content. A parametric study of the model showcases the various aspects of the model. Model results are validated using experimental data.

REFERENCES

[1] K. Yanase and J. Ju. Toughening behavior of unidirectional fiber reinforced composites containing a crack-like flaw: Matrix crack without fiber break. International Journal of Damage Mechanics, 1–20, 2012.

[2] B. Pichler, C. Hellmich, and H.A. Mang, (2007), A combined fracture-micromechanics model for tensile strain-softening in brittle materials, based on propagation of interacting microcracks. Int. J. Numer. Anal. Meth. Geomech., 31: 111–132. doi: 10.1002/nag.544