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An Efficient Computational Model for Fibre Reinforced Concrete Incorporating Information From Multiple Scales

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ABSTRACT

During the last years, fibre reinforced concrete has been applied increasingly. By adding fibres to the cementitious matrix the behaviour of cement can be changed from brittle to ductile. These fibre reinforced cementitious composites (FRCCs) develop first a pattern of fine distributed cracks instead of directly failing in one localised crack. This is an important feature as it allows for the design of structures that can provide a high margin of safety in case of extraordinary events like earthquakes. A well-known example of FRCCs are the engineering cementitious composites (ECCs) developed by Li et al. [1].

There exist already some tools to model FRCCs on different scales. On the macro scale, constitutive models have been developed [3] that can be used in finite element computations. On the meso scale, truss models have been used [4] to study the material behaviour. On the micro scale, the analytical approach from Lin et al. [2] has been successfully employed to develop ECCs.

In our approach, we combine the existing continuum approaches to model concrete failure with a discrete representation of fibres including the necessary information from meso- and micro-scale. This is done without addition of extra degrees of freedom and without including the fibres directly into the discretisation process. It is therefore possible to study the influence of different material parameters like for example the fibre length or the interaction between the fibre distribution and the shape of a structural member on the material properties of the composite.

The matrix material is described using a local isotropic damage model with fracture energy regularisation [5]. Fibres are directly added into our model by adding extra nodal forces at fibre ends. It is assumed that these forces can be represented by fibre pull-out forces. Fibre pull-out forces are the forces that are measured during the pull-out of a fibre from a matrix specimen. In our approach they are either directly incorporated from experimental data or by considering a micro mechanically based model developed by Lin et al. [2]. Because of the low volume fraction of fibres used in most FRCCs (two to three percent) the fibres are assumed to be active only if they bridge a damaged zone. From a computational point of view only minor changes are necessary to incorporate fibres into a standard damage finite element code. The fibre forces are added to the right hand side of the equations. Since they depend on

the damage and the displacement field of the matrix the linearisation leads to additional terms in the tangential stiffness matrix. This approach has proven to be able to represent the main features of FRCCs as increased ductility and a distributed crack pattern and still be computationally efficient. The fracture energy regularisation leads to globally mesh-independent results but suffers locally from a dependency on the mesh orientation. Since the position of the fibres with respect to the damage zone has a considerable influence on the results the local damage model is replaced by its non-local counterparts as for example described in [6]. Furthermore, this shows that the modelling approach presented here can be combined with different ways of damage modelling.

The performance of the different approaches and the influence of different numerical and material parameters are investigated. Thus, an approach to model fibre reinforced cementitious composites in a simple, realistic, and efficient way is presented.

REFERENCES

[1] V.C. Li. “On Engineered Cementitious Composites (ECC), A Review of the Material and Its Applications”. *Journal of Advanced Concrete Technology*, Vol. **1**, 215–230, 2003.

[2] Z. Lin, T. Kanda and V.C. Li. “On Interface Property Characterization and Performance of Fiber-Reinforced Cementitious Composites”. *Concrete Science and Engineering*, Vol. **1**, 173–184, 1999.

[3] A.G. Kooiman, C. van der Veen and J.C. Walraven. “Design Relation for Steel Fibre Reinforced Concrete”. *Heron*, Vol. **45**, 275–307, 2000.

[4] Z. Li, M. A. Perez Lara and J. E. Bolander. “Restraining Effects of Fibers During Non-Uniform Drying of Cement Composites”. *Cement and Concrete Research*, Vol. **36**, 1643–1652, 2006.

[5] W. A. M. Brekelmans and J. H. P. de Vree. “Reduction of Mesh Sensitivity in Continuum Damage Mechanics”. *Acta Mechanica*, Vol. **110**, 49–56, 1995.

[6] M. Jirásek and B. Patzák. “Consistent Tangent Stiffness for Nonlocal Damage Models”. *Computers and Structures*, Vol. **80**, 1279–1293, 2002.