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NUMERICAL MODELLING OF ENGINEERED CEMENT-BASED COMPOSITES

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Abstract: *Strain Hardening Cement-based Composite (SHCC) is a type of High Performance Concrete (HPC) that was developed to overcome the brittleness of conventional concrete. Even though there is no significant compressive strength increase compared to conventional concrete, it exhibits superior behavior in tension. The primary objective of the presented research is to develop a constitutive model that can be used to simulate structural components with SHCC under different types of loading conditions.*

Keywords: ***Strain Hardening Cement-based Composite (SHCC), rotating crack model, damage, cyclic loading, nonlinear unloading***

1. Introduction

Strain Hardening Cement-based Composite (SHCC) is a type of High Performance Concrete (HPC) that was developed to overcome the brittleness of conventional concrete. Even though there is no significant compressive strength increase compared to conventional concrete, it exhibits superior behavior in tension. It has been shown to reach a tensile strain capacity of more than 4% during a pseudo strain hardening phase (Li and Wang, 2001; Boshoff and van Zijl, 2007). This pseudo strain hardening is achieved by the formation of fine, closely spaced multiple cracks with crack widths normally not exceeding $100\mu m$ (Li and Wang, 2001). These fine cracks, compared to large (larger than $100\mu m$) localized cracks found in conventional concrete, have the advantage of increased durability. For a further discussion of the mechanical properties of SHCC, the reader is referred to (Boshoff et al., 2009*a*, b).

The primary objective of the presented research is to develop a constitutive model that can be used to simulate structural components with SHCC under different types of loading conditions. In particular, the constitutive model must be efficient and robust for large-scale simulations while restricted number of material parameters is needed. The proposed model for plane stress is outlined and the results of the preliminary implementation are shown.

2. Model definition

For the modeling of specific behavior of SHCC in tension, the application of classical constitutive material models used for quasi-brittle materials is not straightforward. The proposed numerical model is based on a rotating crack assumption to capture specific characteristics of SHCC, i.e. the strain hardening and softening, the multiple cracking and the crack localization. Multiple orthogonal crack patterns are allowed which is in accordance with the observations presented by Suryanto et al. (2008). It has to be mentioned that the rotating crack approach does not automatically include the effect of Poisson's ratio as the stress is evaluated on the basis of individual principal strains. In (Han et al., 2003) the definition of equivalent strain is used to take this effect into account. This approach is reliable when a model formulation does not permit residual deformations by cyclic loading, i.e. by changing state (tension to compression and vice versa). However, in the model presented in this study permanent (residual) deformations are allowed. Therefore, a new approach was employed to treat the effect of Poisson's ratio. The effective principal strain is used to determine the equivalent stress from the simplified uniaxial

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stress-strain diagrams, based on the mathematical representation of idealized experimental data, in compression and tension. This equivalent stress is subsequently utilized to calculate the current stress state. The described model is also adjusted for the cyclic loading when the orientation of principle stresses changes. The residual deformations are assumed to be dependant on the inelastic strain. Therefore, a simple linear definition is employed and the permissible closing (opening) strain is evaluated.

3. Conclusion

The constitutive model was implemented in the commercial available finite element code **DIANA** version 9.3 using the "User supplied subroutine" option to demonstrate its suitability for SHCC. The Newton-Raphson iterative procedure is used for the solution of nonlinear equations.

Finite element analyses of the flexural tests is performed to verify the constitutive model analyses. Namely, the three-point bending test is introduced using parameters based on the tensile tests and data presented by Boshoff (2007). The obtained results show reasonable agreement with experimental data. Nevertheless, the model must be further verified before the proposed approach will be used for larger structural components under different loading conditions.

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