FINITE ELEMENT MODELING OF STRAIN-HARDENING FIBER-REINFORCED CEMENTITIOUS COMPOSITES (SHCC)

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Abstract:

This paper reviews some recent advances in finite element modeling and analysis of strain hardening fiber reinforced cementitious composites. We focus, in particular, on behavior under non-proportional stressing, which induces shear on cracks and response under uniaxial tension, which is strongly affected by mesoscopic inhomogeneity of the material.

Keywords: non-proportional stressing, individual crack model, mesoscopic inhomogeneity, stochastic fields

1. Introduction

Fiber reinforced strain hardening cementitious composites (SHCC) have a characteristic ability to sustain increasing tensile load with increasing overall elongation even after cracking. The inelastic deformation is mostly attributed to formation and opening of a large number of distributed fine cracks, which are bridged by fibers – so-called multiple cracking. These properties of SHCC are being utilized in various structural applications where the material has to accommodate large deformations without losing macroscopic integrity (e.g. anti-seismic elements, link-slab in a bridge deck) or where crack width has to be controlled for structural durability reasons (e.g. dam or waterway surface repairs). Engineered Cementitious Composite (ECC) is perhaps the most widely used representative of SHCC materials. It is typical by micromechanically optimized composition with relatively low fiber content (~2% by vol.), which lends the hardened material an excellent tensile ductility while not compromising its workability in the fresh state.

Implementation of SHCC materials in engineering practice brings forth a need for their reliable numerical modeling. Considering limited empirical knowledge about SHCC materials (as compared to concrete), numerical analysis can serve not only as an aid for design and verification of SHCC structures, but it can also efficiently complement experimental testing.

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2. Modeling of SHCC under non-proportional stressing

In structural members such as coupling beams in earthquake-resistant structures, SHCC is used in combination with conventional steel reinforcement (R/SHCC). In order to utilize the tensile capacity of SHCC, the material has to undergo extensive multiple cracking before the structural member fails. The cracking induces significant anisotropy in the material, which, in turn, causes rotation of the principal stress direction. As a result, the material failure is governed by response of fiber-bridged cracks to combination of opening and sliding.

Some existing finite element models for SHCC have idealized the material in multiple cracking state as equivalent homogeneous continuum (for brief review see [1]). But, it has been found recently that this approach leads to overestimation of the load capacity of SHCC members, especially when the SHCC material is exposed to non-proportional loading. Against this background, a methodology based on a treatment of individual cracks has been proposed [1]. This method has been shown to provide more accurate reproduction of experimental results. Analytical results also indicate that when a multiply cracked SHCC is exposed to shearing, it may lose some of its strength and deformational capacity, probably due to shearing-induced damage of fiber bridging.

3. Modeling of SHCC by finite elements with stochastic fields

Comparative experimental studies [2] have indicated that uniaxial tension tests, which are often used to determine tensile characteristics of SHCC, exhibit a large scatter depending on a particular test configuration (specimen shape, size, attachment etc.). In ref. [3] it has been argued that these phenomena can be attributed to mesoscopic inhomogeneity of SHCC material. To capture the mentioned effects numerically, the individual-crack based approach is used in conjunction with stochastic fields, which describe the non-uniform mesostructure of SHCC.

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4. References

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