A Concurrent Multiscale Approach for Modeling Concrete and Fiber Reinforced Concrete

Osvaldo L. Manzoli[‡] , Eduardo A. Rodrigues[†*], Luís A. G. Bitencourt Jr.[†], Túlio N. Bittencourt[†]

[‡]São Paulo State University
Department of Civil Engineering, UNESP – Univ. Estadual Paulista, 17033-360, Bauru-SP, Brazil
omanzoli@feb.unesp.br

[†]Polytechnic School at the University of São Paulo
Av. Prof. Almeida Prado, trav. 2, 271, Cidade Universitária, 05508 – 900, São Paulo, Brazil
eduardoalex@usp.br / luis.bitencourt@usp.br / tbitten@usp.br

ABSTRACT

A concurrent multiscale approach of concrete is presented, in which two distinct scales are considered: the mesoscale, where the concrete is modeled as a heterogeneous material and the macroscale that treats the concrete as a homogeneous material. The mesostructure heterogeneities are idealized as three phase materials composed of coarse aggregates, mortar matrix and Interfacial Transition Zone (ITZ). Special continuum finite elements with high aspect ratio and a tensile damage model with an implicit-explicit integration scheme are used to describe the nonlinear behavior due to propagation of cracks, which initiate in the ITZ and propagate to the mortar matrix until macro-cracks formation. These solid finite elements with high aspect ratio, that work as cohesive interface elements, are introduced in between all regular elements of the original (standard) mesh. This preprocess step, here called Mesh Fragmentation Technique, allows the representation of crack initiation and propagation without the need of schemes to track crack paths. In order to make possible the concurrent multiscale analysis, where the strain localization region cannot to be previously defined, an adaptive multiscale model is proposed. In this approach the macroscale stress distribution is used as an indicator to properly change the modeling of the critical regions from the macroscale to the mesoscale one. Consequently, the macroscopic mesh is automatically replaced by a mesoscopic mesh where the nonlinear behavior occurrence is imminent. To consider the presence of discrete steel fibers, new finite elements, named Coupling Finite Elements (CFEs), are introduced to couple the originally independent meshes of the concrete and fibers. This model is very appealing, since important aspects, such as random distributions of fibers, type of fibers (hooked or straight) and the concrete-fiber interaction can also be considered. The non-rigid coupling scheme developed for modeling the fiber-concrete interaction may be calibrated using any type of shear-slip given by standard codes or from experimental tests. Numerical analyses are presented to show the ability of the proposed method to predict the behavior of cracks initiation and propagation in tensile regions. Results obtained using the adaptive approach are also compared with those obtained by the Direct Numerical Simulation method.

Keywords: Multiscale Analysis, Interface Finite Element, Continuum Damage Model, Crack Propagation, Concrete.