This article appeared in a journal published by Elsevier. The attached copy is furnished to the author for internal non-commercial research and education use, including for instruction at the authors institution and sharing with colleagues.

Other uses, including reproduction and distribution, or selling or licensing copies, or posting to personal, institutional or third party websites are prohibited.

In most cases authors are permitted to post their version of the article (e.g. in Word or Tex form) to their personal website or institutional repository. Authors requiring further information regarding Elsevier’s archiving and manuscript policies are encouraged to visit:

http://www.elsevier.com/copyright
Zero-thickness interface model formulation for failure behavior of fiber-reinforced cementitious composites

Antonio Caggiano\textsuperscript{a}, Guillermo E\textsuperscript{t}se\textsuperscript{b,\ast}, Enzo Martinelli\textsuperscript{a}

\textsuperscript{a} Department of Civil Engineering, University of Salerno, Fisciano (SA), Italy
\textsuperscript{b} CONICET and Faculty of Exact Sciences and Technology, University of Tucumán, Argentina

\textbf{A R T I C L E   I N F O}

\textbf{Article history:}
Received 8 September 2011
Accepted 26 January 2012
Available online 3 March 2012

\textbf{Keywords:}
Composite material
Fiber-reinforced concrete
Fracture-based plasticity
Mixture theory
Zero-thickness interfaces

\textbf{A B S T R A C T}

This paper deals with simulating the mechanical response of fiber-reinforced cementitious composites (FRCCs) by means of a zero-thickness interface model formulated within the framework of discrete-crack approaches. Following a similar model already available in literature for plain concrete, the formulation of the interface element is further developed and extended to capture the key mechanical phenomena controlling the FRCC behavior. An original approach is introduced for reproducing the complex influence of fibers on the cracking phenomena of the concrete/mortar matrix. Numerical analyses demonstrate the capabilities of the proposed model and show a very good agreement with experimental results on FRCC tests.

\textcopyright 2012 Elsevier Ltd. All rights reserved.

\section{1. Introduction}

Cement-based materials like concrete and most of the cohesive-frictional media are characterized by low strength and brittle response in low confinement and tensile stress states. These deficiencies can be mitigated by randomly adding short steel fibers into the cement mortar. Fibers play a relevant role in the post-cracking regime providing resistance to crack opening processes. In this sense, fiber-reinforced cementitious composites (FRCCs) may result in a less brittle and possible quasi-ductile behavior even in case of tensile loading, exhibiting strain-hardening processes with multiple cracks and relatively large energy absorption prior to failure. Composites with these relevant features take the name of high performance fiber-reinforced cementitious composites (HPFRCCs) [1].

Moreover, fibers spread up within the concrete matrix also influence its durability, as they control the crack opening and reduce the diffusion phenomena which lead to corrosion.

In the recent past, several test methods and theoretical models have been proposed for investigating the mechanical behavior of FRCCs. Most of the performed experimental analyses and proposed constitutive theories, however, focused on one or few aspects of the composite mechanical behavior. Fanella and Naaman [2] proposed a possible characterization of the stress–strain properties of fiber-reinforced mortars in compression. They proposed an analytical expression in terms of the key composite parameters (e.g. fiber types, volume fraction, etc.) that influence the stress-strain response and the toughness index of the composite.

Experimental tests aimed at investigating the FRCC failure behavior in compression and tension were performed, among others, by Ezeldin and Balaguru [3] and Barros and Figueiras [4], respectively. Abrishami and Mitchell [5] proposed an equation for predicting the tension-stiffening effect induced by fibers on steel-fiber-reinforced concrete (SFRC). They reported the importance and the fundamental influence of the fiber bond strength in the post-crack response behavior. While the benefits of fibers on strength and ductility were demonstrated in [6,7] based on direct shear test results on FRCC specimens characterized by different strength levels. Regarding the strength capacity of FRCC, Mirsayah and Banthia [8] proposed an empirical expression for the ultimate shear strength. FRCC capacity to resist fracture processes under static, dynamic or impact loads is given in [9]. The strength at first-crack of FRCC on beams under three-point bending is defined in [10]. An alternative proposal to evaluate the capacity of three-point beams is also given in [11].

The constitutive models currently available in the scientific literature for simulating the mechanical response of FRCC can be classified, as follow, on the basis of their observation scale:

\begin{itemize}
  \item \textit{Meso-scale models:} thereby the interaction among the different phases of the composite (i.e. fibers, matrix and coarse aggregates and their interfaces) is explicitly considered. Key contributions in this filed are due to Cusatis et al. [14] who considered the effect of fibers dispersed into a proposed lattice discrete particle model (LDPM), as well as in [15–20], among the others.
\end{itemize}