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An integrated approach for modelling the tensile behaviour of steel fibre reinforced self-compacting concrete

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ABSTRACT

The present work resumes the experimental and numerical research carried out for the development of a numerical tool able of simulating the tensile behaviour of steel fibre reinforced self-compacting concrete (SFRSCC). SFRSCC is assumed as a two phase material, where the nonlinear material behaviour of SCC matrix is modelled by a 3D smeared crack model, and steel fibres are assumed as embedded short cables distributed within the SCC matrix according to a Monte Carlo method. The internal forces in the steel fibres are obtained from the stress–slip laws derived from the executed fibre pullout tests. The performance of this numerical strategy was appraised by simulating the tensile tests carried out. The numerical simulations showed a good agreement with the experimental results.

1. Introduction

In steel fibre reinforced concrete, SFRC, steel fibres and matrix are bonded together through a weak interface, which behaviour is important to understand and accurately model the mechanical behaviour of SFRC, since the properties of this composite are greatly influenced by the interface zone between fibre/matrix and, consequently, by the micro-mechanical fibre reinforcement mechanisms that are mobilized. When these composites are reinforced with low fibre volume ratios, the fibre contribution benefits arise, mainly, not to say almost exclusively, after the crack initiation.

The post-cracking behaviour of random discontinuous fibre reinforced composites can be predicted by the use of a stress–crack opening displacement relationship, $\sigma-w$. Several authors developed micro-mechanical models to obtain the $\sigma-w$ relationship, since for quasi-brittle materials, the stress–crack opening relationship that simulates the stress transfer between the faces of the crack has a significant impact on the behaviour of a structure after its cracking initiation. In the case of FRC, the $\sigma-w$ relationship can be approximated by averaging the contributions of the individual fibres bridging the matrix crack plane, defining for this purpose the probability–density functions of the centroidal distance of fibres from the matrix crack plane, and of the orientation angle [1–3]. These models, which are based on an averaging process of all the forces that are carried out by the fibres over a crack plane, can provide the general material composite behaviour with reasonable accuracy by modelling the main mechanisms of a single fibre pullout. However, in general, they do not account for some aspects, such as, fibre bending rupture and matrix spalling at the exit points of inclined fibres.

Another difficulty on the prediction of the post-cracking behaviour of a FRC in a real structure is that the material behaviour in a test specimen may differ from the behaviour of a real structural element. It is well described in literature that various casting procedures and structural shapes may result in predominant fibre orientation into parallel planes [4,5]. In the case of steel fibre reinforced self-compacting concrete, SFRSCC, the predominant fibre orientation can be along the flow itself (in the fresh state) and along the boundary surfaces due to the wall-effect [6,7]. A predefined orientation of the steel fibres parallel to the tensile direction in a test specimen may result in overestimating the post-cracking mechanical properties of the steel fibre reinforced concrete, when compared with specimens with equal amount of fibres, however with a random fibre orientation.

Having in mind the aforementioned aspects and factors that influence and contribute to the post-cracking behaviour of a FRC, approaching the FRC as a continuum material may lead to a rough estimation of the mechanical behaviour of a certain FRC structural element. Even though, material behaviour laws for FRC can be obtained with great accuracy by inverse analysis procedures of test specimens, these laws may not translate the accurate material behaviour within a specific structural element [8]. It is feasible to assume FRC as a two phase material, namely, an unreinforced concrete matrix phase and a fibre phase, with the latter one comprising information about fibre density and orientation depending on where and how the material is applied. Hence, this approach

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