Engineering Structures 33 (2011) 3579–3589

Contents lists available at SciVerse ScienceDirect

Engineering Structures

journal homepage: www.elsevier.com/locate/engstruct

Numerical simulation of the nonlinear bending response of fibre-reinforced cementitious matrix beams and comparison with experimental results

K. Georgiadi-Stefanidi [a], E. Mistakidis [a,*], P. Perdikaris [b], T. Papatheocharis [b]

[a] Laboratory of Structural Analysis and Design, Department of Civil Engineering, University of Thessaly, 38334 Volos, Greece

[b] Laboratory of Concrete Technology and Reinforced Concrete Structures, Department of Civil Engineering, University of Thessaly, 38334 Volos, Greece

ARTICLE INFO

Article history:
Received 11 April 2011
Received in revised form
7 June 2011
Accepted 1 July 2011
Available online 3 September 2011

Keywords:
Fibre-reinforced cementitious mix
Numerical simulation
Reinforced concrete

ABSTRACT

The aim of this work is the efficient numerical simulation of the bending behaviour of fibre reinforced cementitious matrix (FRCM) beams. For the production of the FRCM specimens, a high-strength cementitious matrix with hooked-end steel fibres is used. Two types of FRCM beams are considered. The first type has no conventional steel reinforcement, while the second one includes longitudinal and transverse reinforcement steel bars. For comparison reasons, conventional reinforced concrete (RC) beams are also studied. The beams are tested under static and cyclic loading. The response of the tested beams is simulated by means of effective two-dimensional finite element models, in which the contribution of the FRCM is taken into account by means of two different layers of finite elements. The first one represents the cementitious matrix while the second one accounts for the contribution of the steel fibres in a homogenized manner. The presented models are able to follow the nonlinearities that appear in the corresponding physical models. The validity of the proposed methodology is established by comparing the numerical results with the corresponding experimental results.

1. Introduction

Concrete is a material with low tensile strength and tends to crack under relatively low forces. The same holds, in general, for most kinds of cementitious products. The addition of steel fibres in cementitious mixtures somewhat improves their tensile strength and stiffness and greatly improves ductility. During the past few decades, many researchers have studied the use of steel fibre-reinforced concrete or cement composites for the improvement of the performance of structural members. These studies are mostly experimental in nature; however, some analytical and numerical contributions have also been published during the past years. It has been reported that the combination of fibres and conventional steel reinforcement increases the flexural strength of beams and also changes the cracking pattern, increasing the number of cracks and decreasing their width and length [1]. Moreover, various researchers have investigated experimentally the effect of the fibre volume fraction, fibre length and fibre geometry on the flexural toughness and cracking characteristics of steel fibre reinforced concrete beams [2–4].

The addition of steel fibres to high-strength concrete has a similar effect to that observed in the case of normal strength concrete [5]. Many researchers have reported that the addition of steel fibres enhanced the strength and increased the ductility and flexural stiffness of the tested beams [6–8]. Recently, high-performance fibre-reinforced concrete mixes have been produced, mainly for the retrofitting of existing concrete structures [9–11].

Till now, several researchers have used the Finite Element Method (FEM) to predict the response of steel fibre-reinforced concrete beams. It is well known that the use of the FEM is a really useful and powerful tool for predicting the response of reinforced concrete. Numerical simulation allows the reduction of the required experimental work [12]. Also, analytical models have been proposed for the prediction of the response of fibre-reinforced materials in flexure, which are mainly based on fracture mechanics. Typical examples are the continuous and the discontinuous bridged-crack models proposed in [13,14] and the models proposed in [9–11] for the prediction of the moment resistance and load deflection response of beams retrofitted by a specific type of high-performance fibre-reinforced concrete (CARDIFRC). As it was verified by various studies, experiments are essential for the complete investigation of the response of any structural system. The development of analytical or numerical models should be based on reliable test results. Therefore, experimental and numerical analyses should complement each other in the investigation of a particular phenomenon [15,16]. With respect to the specific case of fibre-reinforced concrete, in several studies [17–20] it was treated as a uniform material, while constitutive models were proposed for the simulation of its behaviour.

* Corresponding author.
E-mail address: emistaki@uth.gr (E. Mistakidis).

0141-0296/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.engstruct.2011.07.022