ABSTRACT

The advent of modern computing technology over the last 20 years has permitted to the researchers and engineers to solve very difficult structural problems using sophisticated techniques.
The use of finite element method (FEM) in the analysis and design of reinforced concrete structures is one of these various successful techniques.
As a matter of fact, the FEM is a powerful computational tool which can be used to simulate the response of structures, structural components and materials when submitted to a specified load.

In particular its ability to capture the nonlinear behaviour of RC has made the finite element method a very powerful tool in understanding the behaviour of structures and to quantify its load carrying capacity, stress distribution and cracking path. The fiber reinforced concrete (FRC) have been introduced recently in buildings materials to improve the durability of conventional RC structures.

Actually, it is well known that the concrete is a relatively brittle material, that could not support tensile strength. As a consequence, concrete member reinforced with continuous reinforcing bars were used to withstand tensile stresses but they don’t provide a concrete with homogeneous tensile properties.
The additional of steel reinforcement significantly increases the strength of concrete but without producing an homogeneous material due to the developments of microcracks and voids in the body.

The introduction of fibres randomly distributed throughout the concrete can overcome cracks more effectively. The formation of cracks is undoubtedly one of the most important non linear phenomena which govern the behaviour of concrete structures. Ever since the finite element method has been applied to concrete, the formation of cracks has received much attention.

The nonlinear fracture mechanics theory has been used to simulate the quasi-brittle fracture of concrete. The discrete and the smeared crack models are the most used in the literature to model the concrete fracture. The first is especially suitable to

simulate the failure in concrete structures where fracture is governed by the occurrence of a small number of cracks with a path that can be predicted.
The second crack approach is more appropriate than the first to simulate fracture in concrete structures with a reinforcement ratio that ensures crack stabilization.

The main purpose of this research is to analyze short fibres in structural concrete; in particular, according to a nonlinear fracture mechanics approach based on smeared crack models, comparisons in terms of fiber amount between concrete containing no fibres and concrete with fibres are proposed.
Starting from an investigation in the fracture mechanics frameworks (LEFM and NLFM), and on fiber reinforced concrete concepts, the work presents the results based on finite methodology, performed consistently with the distributed-crack concept and implemented Diana FE code. In particular the results of simulation of four point bending tests on polymeric and steel fiber reinforced concrete beams were presented in this work of thesis. A 2D plane stress model for analysing the development of cracks is employed; this approach, named rotating crack model, within the smeared crack concept, is based on the total strain crack model.

The total strain crack model describes the tensile and compressive behaviour of concrete beams with one stress-strain relationship. With the use of Diana FE program, a standard nonlinear, incremental, iterative approach is performed. The employed theory of the smeared crack concept describes the deterioration of simple concrete and of fiber reinforced concrete characterized by the tensile strength f_t, energy release rate G_f, crack band width h, and the shape of the stress-strain curve of the material in the crack band during softening. The smeared crack models are modelled based on concepts using linear and exponential tension-softening constitutive law.
The cracks are defined in the integration points of the elements, i.e., discrete points to compute the elemental mechanical behaviour, are numerically simulated by an adjustment of the compliance matrix at the integration point level and then are modelled according to the rotating model in which the direction of the crack may change during the loading process.
The loading process is considered as a sequence of quasi-static loading steps (increments). The theory of linearity is assumed until the maximum local principal

stress reached the strength limit of the material, whereafter initiation of mode I cracking in the plane normal to the maximum principal stress will occur.

The model is able to simulate multiple crack propagation predicted cracking processes as well as distributed crack pattern, in agreement with experimental observations. Moreover, load-deflection curves are accurately predicted and as well as these corresponding to a linear tension softening assumption of the model. The results show how the proposed approach predicts accurately the maximum loads for the two different class of beam employed as well as it is able to make reasonably good predictions of load and displacement throughout the bending tests.

The advantages provided by the short fibers to the properties of concrete improves mainly its post-cracking behaviour (ductility,cracking control and performance under dynamic loading) and can also alter tensile strength. These advantages vary according to the type and volume of fiber added to the matrix. The characteristics of the concrete are strictly dependent from the amount of fiber volume fraction. Fibres have the ability to prevent crack formation and to increase the ultimate load capacity of the concrete structures.

KEYWORDS : fracture mechanics, smeared crack models, tension-softening; fiber reinforced concrete, steel fibres, polymeric fibres; four point bending test.