CHAPTER 1

INTRODUCTION

The use of fibers in building materials to improve their behavior is an old and intuitive concept. Examples include adding straw fibers to sun-dried mud bricks (adobe) and asbestos fibers to pottery to create a composite with a better performance. Moreover, the use of strong and discrete fibers as concrete reinforcement has been a challenge to many material engineers. Adding the reinforcement to the mixer in the form of fibers, like adding the aggregates, to create a homogeneous, isotropic and moldable material is a task that started more than a century ago and nowadays can be considered a reality. The successful employment of fiber reinforced concrete started in the early sixties, and since then, many researchers are trying to evaluate the potential properties of this material for a broader use.

An increase in strength of concrete from normal strength to high strength is directly associated with an enhancement of almost all the properties of the material but, at the same time, produces an increase in its brittleness, leading to limitations in their application. This is especially critical in sections where, because of construction constraints, a small amount of reinforcing bars can be placed or where the failure is dominated by sudden crack propagation, such as in shear failures.

If steel fiber reinforced concrete (SFRC) has such important characteristics, a logical question would be based on why it is nearly not used for a safer structural design. This is explained considering the total lack of standards contemplating steel fiber reinforced concrete structural design.

The most fundamental approach to study the brittleness reduction, or rather the toughness increase, is based on the uniaxial tension test. This has, however, some practical drawbacks, which have led to the use of the flexural test for the determination of the material toughness parameters based on experimentally determined load-deflection response of prismatic specimens. The objective of the test is often to determine parameters that can be used in general structural design against brittle failure, which is the main task to achieve if SFRCs have to be widespread used.

1.1. OBJECTIVES OF THE THESIS

The philosophical objective of the thesis is to contribute to the knowledge of the properties of steel fiber reinforced concrete (SFRC), helping to extend the use of the material to structural design.

The general objective will be the definition of material-scale test methods that would permit the obtention of a complete and reliable response (pre- and post-peak) of SFRCs under uniaxial tension and direct shear. Furthermore, from the response of these test methods it must also be possible to calculate toughness-based parameters for its use in structural design, which will also be examined.

In order to attain the above general aims, the following are the specific objectives proposed:

- To study a uniaxial tension test methodology for normal and high strength SFRCs, applicable to notched molded specimens and cores extracted from existing structures.

- To completely define, through a parametric study, a uniaxial tension test for SFRC and to outline a representative toughness behavior.
- To study the push-off shear test and propose toughness factors to obtain from its complete response.
- To study the shear-loading capacity of full-scale structural SFRC elements and compare experimental data with design values that incorporate the toughness parameters previously obtained. To propose a methodology for taking into account the contribution of the fibers in shear design.

1.2. STRUCTURE OF THE THESIS

The thesis will be structured around four main chapters. First, in Chapter 2 an experimental analysis is performed in order to study a general uniaxial tension test methodology from which a stable load-displacement response can be obtained. A general test setup using a notched cylinder is presented and tests are performed on normal and high strength concrete, with and without fibers. Additionally, the configuration is applied to tests of cores of different strength levels and fiber quantities.

With the aim of defining a reliable uniaxial tension test configuration, Chapter 3 of the thesis deals with the evaluation of the effects of different test variables that could affect the test response**.** Possibilities related to the geometry of the specimen and fiber orientation are experimentally studied, including the slenderness of the specimen, its notch depth, its shape (testing panel-type specimens) and the direction of extraction of cores. Moreover, the stress-crack opening response, toughness parameters and equivalent tensile strengths are analyzed for the different variables**.** Details concerning the development of the fracture process are also considered based on the analysis of the readings of transducers placed around the notch. Also, in order to study the influence of the number of fibers present in the fracture plane on the toughness of the material, the relationship between the calculated stress and toughness parameters versus the number of fibers is studied for different fiber dosages. Further, the experimentally obtained stress-crack opening curves are used as input in a back-analysis method developed by Dr. Jose Luis Antunez de Oliveira e Sousa at

UPC. This fracture mechanics-based method is able to give the load-crack opening response in flexure from the stress-crack opening behavior in uniaxial tension.

Due to the catastrophic nature of the shear failure of concrete, fibers can be expected to improve sudden crack propagation, leading to practical advantages in elements such as thin web structural elements. Chapter 4 of the thesis treats specifically the shear-type failure. In this sense, the direct shear push-off test on prisms is exhaustively studied. Strength and toughness-based parameters for possible design use, such as equivalent shear strengths, are calculated and its variation and sensitiveness due to the strength level and fiber content analyzed.

Finally, Chapter 5 of the thesis involves tests on full-scale structural elements: rectangular and T beams were subjected to shear loading. The load-load point deflection response is analyzed and the results compared with those given by current design recommendations for fiber concrete. Further, a design method using toughness parameters from the shear stress-slip relationship in the push-off configuration is proposed.

General and specific conclusions are given in Chapter 6, together with recommendations for further research. This is followed by an extensive list of references.

The Annexes A to F give the results of the individual tests treated in Chapters 2 to 5, and other relevant data.