CHAPTER 1
INTRODUCTION

The idea of adding fibres to the concrete mixture to improve the mechanical response has been used since more than a century ago. It is from the early sixties that many researchers are trying to evaluate the mechanical properties of this material with the aim of systematizing its use.

On the other hand, High Strength Concretes are being used more often due to their superior properties but these concretes have higher brittleness, which is a disadvantage. Taking into account that Steel Fibre Reinforced Concrete (SFRC) has as one of its best properties, the increase of the toughness, it would be expected that there would be a generalized used of High strength SFRC. However, the lack of standards makes it nearly anecdotal.

1.1. SCOPE OF THE THESIS

The main objective of this thesis is to characterize the shear capacity under direct loading. An approximation to the problem is the study of the shear failure in push-off tests, following a previous work [1]. To take into account that the processes involved in full-scale elements, namely, tensile and shear behaviours are coupled, some modifications have been introduced to the test set-up defined in [1].

In order to attain this objective, the thesis has been divided in two parts, an experimental study and the numerical analysis.

The experimental study has been based on two different of experiments:

- Three point bending tests have been carried out in order to provide the parameters that govern the concrete failure in mode I (opening mode). Instead of mid-span deflection, Crack Mouth Opening Displacement (CMOD) has been measured, since it is easier to measure.
- Regarding the failure in mode II (sliding mode) and in mixed-mode (coupled mode I and II), push-off tests have been performed. In order to produce mixed-mode failure, lateral compression has been applied to the specimens. The analysis of a new set-up to apply the lateral compression is another of the important aims of the thesis.

The numerical study consists of:

- An inverse analysis programme for obtaining the parameters that govern the fracture process in mode I from the experimental load-CMOD curves of three-point bending tests.
- A numerical study of the fracture in mode II and in mixed-mode based on the utilization of a Non-Linear Finite Element software package (DIANA). Note that the mode I parameters involved in this study are given by the inverse analysis programme.

1.2. STRUCTURE OF THE THESIS

This thesis is structured in four main chapters. Firstly, in Chapter 2, after a brief introduction to fracture mechanics, going from linear elastic fracture mechanics theory to non-linear fracture mechanics and the concept of the fictitious crack, different approximations to flexural, shear and mixed-mode behaviour are described. Finally, this chapter contains an introduction about different approximations in non-linear finite element modelling.

Chapter 3 describes the experimental study carried out in this thesis. Regarding three-point bending tests, load-CMOD curves have been obtained. Different concretes have been cast in order to analyse the influence of the percentage of fibres in the concrete response. Plain concrete specimens have been cast as well. The methodology used in these tests follows the recommendations given by RILEM [2]. With regard to the push-off tests, typical stress-displacement curves have been obtained. This test has been carried out according a previous work [1]. However, the test set-up has been modified in order to restrain the lateral dilation of the crack while the specimen is being loaded. These tests were performed under constant lateral pressure.

Chapters 4 and 5 contain the numerical work carried out. Chapter 4 describes the methodology used to solve the inverse analysis problem, for obtaining the parameters that control fracture in mode I. A programme in Matlab has been implemented to get, from the load-CMOD curves of three-point bending tests, all the parameters involved in the flexural failure. Mode I failure has been modelled using a bi-linear stress crack-opening relationship and solving the explicit model of Olesen.

Chapter 5 involves non-linear finite element modelling using the commercial package DIANA. The fracture in mode II and in mixed-mode has been modelled as a discontinuity in the concrete through interface elements while the rest of the specimen has been modelled using quadrilateral and triangular linear-elastic elements.

Finally, Chapter 6 gives the general and specific conclusions that have resulted from this thesis.

Annexes A-D contain the experimental results, the set-up calibration and the inverse analysis programme code.