FIBRE REINFORCEMENT AND DUCTILE BEHAVIOUR OF CEMENTITIOUS COMPOSITES IN STRUCTURES

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ABSTRACT

Reinforced concrete is the most widely used material by construction industry, due to its versatility, low cost and availability of its components. Particular emphasis has been given recently to the development of concrete functionalities with greater impact in social well being. Examples are the minimisation of ecological impact of concrete production and optimisation of material use, improvement of durability and optimized life cycle design, development of ductile behaviour for seismic and impact resistant structures, among others.

In particular, the cracking behaviour of conventional concrete may be altered in a positive way. Improved durability, better seismic and impact loads resistance, reduced and optimized cross-sections of structures and the ability to recycle waste materials by its inclusion in the composite. The present work is focussed on the development of some of these functionalities, and at the same time on the development of the tools needed to support it.

INTRODUCTION

The use of fibre reinforcement in cementitious composites can contribute positively to a wide range of functional properties of cementitious composites. Decreasing brittleness in concrete results in improved durability, better seismic and impact loads resistance, reduced and optimized cross-sections of structures and the ability to recycle waste materials by its inclusion in the composite. For the last few decades a lot of research has been done for the development of Fibre Reinforced Cement Composites (FRCC). The aim has been mainly to reach strain hardening in tension, very important to attenuate one of the biggest weaknesses of cement composites: their brittleness. Among the very different proposals coming from different research groups and companies, one is ECC (Li 2003). It is known for its ability to undergo very high strains in tension (around 4%), while reaching tensile strengths between 3 MPa and 6 MPa. It mainly consists of a Portland cement based matrix, including water, mineral and chemical additions and admixtures, reinforced with polyvinyl alcohol based fibres. Structural design with these materials also requires special tools, which have been also under development in recent years (Bolander and Hikosaka 1995, Kabele 2007). It seems however that some links are still missing, both in the material and in the structural design side. In this context, the assessment of the single crack behaviour in tension brings an important input, both for material and structural design.

SINGLE CRACK TENSION TESTING

The isolation of a single crack in materials especially designed to develop multiple cracks is not straightforward (Shah 1996, Fischer et al. 2007. In this study, after some previous trial shapes and dimensions, the geometry represented in Fig.1 was used.

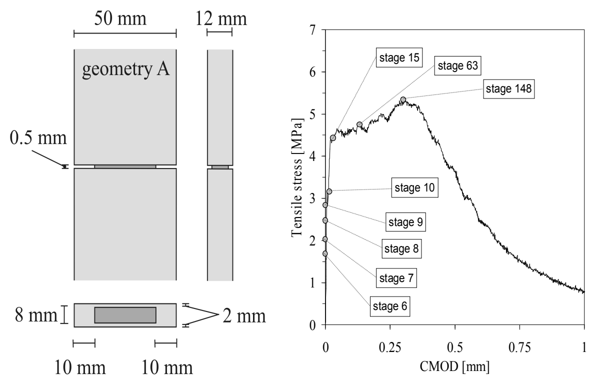

Figure 1: Single Crack Tension Specimen and Stress-CMOD Curve.

The obtained stress-CMOD (crack mouth opening displacement) curves, also represented in Figure 1, revealed consistently that a single crack in tension was possible to obtain and characterize. This geometry was further used to study the composite behaviour of different matrices reinforced with different fibres, yielding what can be called as the “footprint” of the material.

MONITORING CRACK PROPAGATION

The monitoring of crack appearance and propagation in FRCC is also very important. The fracture processing zone and the crack bridging mechanisms take place at a small scale, making them not so easy to assess and characterize. For this purpose a special technique has been under development. It is based on recent contactless monitoring techniques, which make use of high resolution photographs to interpolate the deformations and the displacement fields. In Figure 2 three of the stages identified in the Stress-CMOD curve (see Figure 1) are shown. In each case the left picture is the black and white photo of the notched area magnified, and the right picture is the interpolated strain field, based on the first.

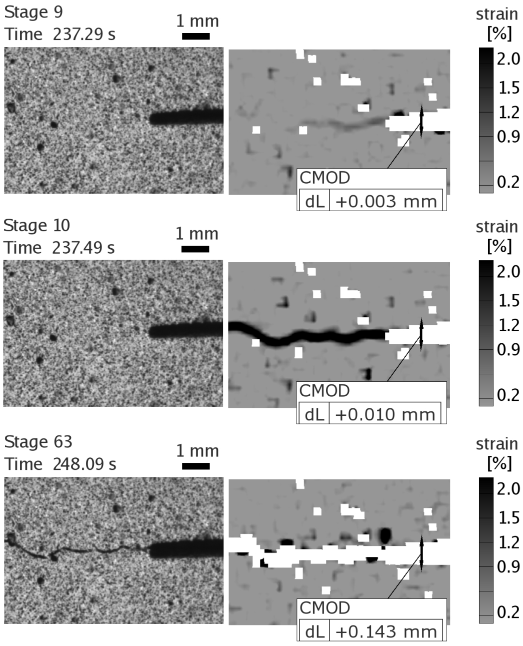

Figure 2: Monitoring of Crack Appearance and Propagation Close to the Notch.

MULTIPLE CRACKING IN TENSION

One of the main final goals of FRCC design is to attain strain hardening and multiple cracking in tension. More important than the ability to carry tensile stresses is the aptitude to develop several parallel cracks with very tight crack openings, as shown in Figure 3. The picture on the left hand side shows the cracked surface of a dogbone-shaped after tensile testing. The right hand side picture shows the interpolated strain field, using the same procedure as before. Using this test-setup the material behaviour in tension can be characterized and the appearance of the corresponding cracks can be analysed and followed in detail.

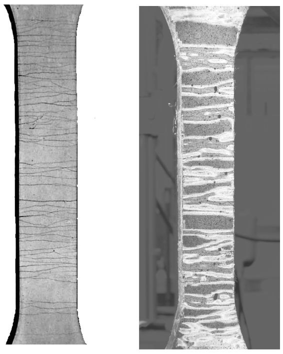

Figure 11. Dogbone-shaped Specimen after Tensile Test (Lárusson et al. 2009).

CONCLUSIONS

The ongoing research project focuses mainly on fundamental material properties of FRCC and their up scaling to the level of the structural design. These materials reveal special features, which can be used to solve a wide range of construction problems in a more safe and sustainable way. A deeper insight of their micromechanical behaviour is though needed, for which the present work can give a valuable contribution.

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