Applying a fracture mechanics approach to material testing and structural analysis of FRC beams

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ABSTRACT

The presented work has been focused on FRC, showing a strain-softening response, and the interrelationship between material properties and structural behaviour. The main purpose of this work was to establish a procedure for structural analysis of flexural members with a combination of conventional reinforcement and steel fibres. A systematic approach for material testing and structural analysis, based on fracture mechanics, has been developed and used, this covers: (1) material testing (using the wedge-splitting test method); (2) inverse analysis; (3) adjustment of the σ-w relationship for fibre efficiency; and (4) cross-sectional and structural analysis.

A number of full-scale experiments have been conducted on beams with different amounts and types of fibres as well as different types and amounts of conventional reinforcement. To achieve a deeper understanding of the structural and fracture behaviour, non-linear fracture mechanics was applied, using the finite element method and the software DIANA. The FRC-material was modelled with 4 node quadratic elements Q8MEM and a smeared approach, total strain based and with rotating cracks, was used.. The reinforcement was modelled both as embedded reinforcement (i.e. perfect bond assumed) and as separate elements, using L2TRU elements, with interface elements describing the bond-slip relationship.

The results suggest that the approach used for the material testing provides the necessary properties to perform analyses based on non-linear fracture mechanics. Using non-linear fracture mechanics, the structural behaviour could be predicted with good agreement. The finite element model is an approach adapted for more complex structures and loading conditions, as it can provide comprehensive results regarding the structural behaviour (shear failure, crushing in the compressive zone, long-term deflections, etc.) and the crack spacing may be provided as an output as long as realistic crack localization is achieved.

When comparing with experiments, the applicability of the approach was demonstrated and, furthermore, it was shown that it is possible to adjust the σ-w relationship for any difference in fibre efficiency between the material test specimen and the structural application considered. Finally, when comparing the peak loads obtained in the experiments with the results from the analyses, the agreement was good, with a high correlation. Hence, this demonstrates the strength of the fracture-mechanical approach for material testing and structural analysis.

Key words: fibre-reinforced concrete, test method, wedge splitting test, experiments, non-linear fracture mechanics.