Ultra-High Performance Fiber-Reinforced Concrete Structural Members

2002 - 2006

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Ultra-High Performance Fiber-Reinforced Concrete (UHPFRC) is an important recent development in construction materials. Thanks to its very efficient high-tech cement-based matrix and its high fiber contents, this material is at the same time extremely strong and very durable. Its use in real-life structures remains rare, mainly because its successful and cost-effective application requires entirely new design concepts.

The cement-based matrix UHPFRC is brittle, but this brittleness is lessened by the presence of high-strength steel fibers, that bridge across cracks. This not only improves the strength of this material in tension, but also in compression, in bending, in shear, in punching shear and in zones of local introduction of forces.

The aim of the high-performance concrete project conducted by the Structural Concrete Laboratory of the Ecole Polytechnique Fédérale de Lausanne is to characterize and understand the behavior of UHPFRC structural elements, to investigate the influence of size effects and to elaborate approaches suitable for their design. In a final phase, new designs suitable for this class of materials are outlined.

The research project considers UHPFRC as a construction material, investigating its performance at the level of the material itself and at the level of structural elements. To characterize the behavior at the material level, a series of laboratory tests were performed on small-scale specimens. Two commercially available materials were investigated: Ceracem and MC2 for their behavior in compression and bending-induced tension. Crack localization was investigated on notched specimens loaded in tension.

![Figure 1: test of materials](image)

The behavior of UHPFRC structural elements was subsequently investigated in several test series including elements in tension, compression, and compression with imposed end rotations. The influence of various types of reinforcement and prestressing on cracking and on the structural behavior were studied. These tests have shown a strong influence of the reinforcement (ordinary and prestressed) and the dimensions of the element (size effect) on the mode of the failure.
A theoretical model of the behavior of UHPFRC elements in tension was developed. This model allows closely predicting the development of cracks as the microscopic, intermediate (meso) and macroscopic levels. In particular, the model allows a better understanding of the behavior of UHPFRC elements reinforced with conventional steel bars in addition to the fibers.

UHPFRC has been found to be a suitable construction material for demanding applications. The experimental and theoretical investigations of the present work show that it can be applied alone for small structural elements, in combination with ordinary steel reinforcement for larger elements, and that it requires the application of prestressing for applications to very large structures.


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