STRUCTURAL USE OF ULTRA-HIGH PERFORMANCE FIBER REINFORCED CONCRETE

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A high performance concrete project currently under way at the Structural Concrete Laboratory (IS-BETON - EPFL) aims at examining new concepts and design approaches to design statically efficient and economically viable structures using ultra high performance concrete.

The scientific approach chosen is primarily to understand and characterize the behavior of UHPC by means of various laboratory experiences on material specimens and structural elements. On this basis, physical models will be subsequently developed to describe the observed behavior. Finally, design concepts will be examined, with a focus on potentially efficient structures.

Several studies have been made to establish a basis for developing design concepts:

The material characteristics were investigated by a wide experimental program studying the tensile, compressive and bending behaviors (Figure 1). In addition, tests for the bond behavior of UHPC with reinforcement bars and fibers were carried out [1].

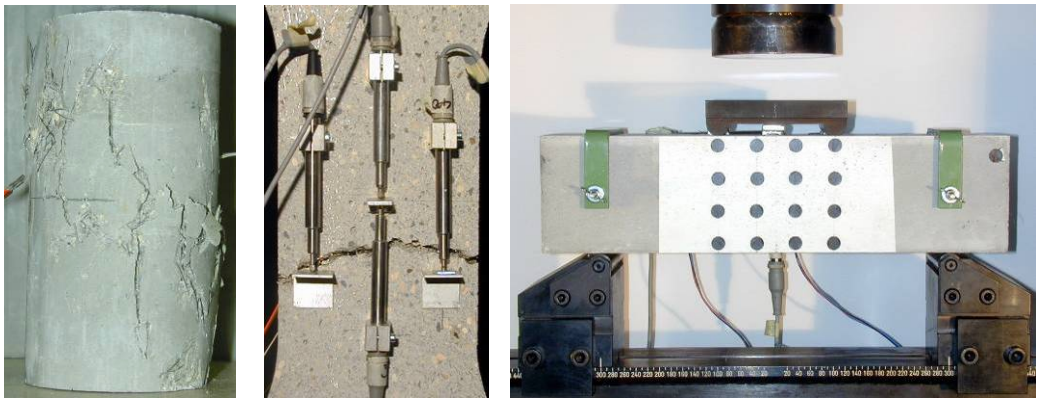

Figure 1: Material testing

Experimental results for bar reinforced structural members in compression and tension (Figure 2) have shown the particularities and advantages of UHPC compared to ordinary reinforced concrete [2].

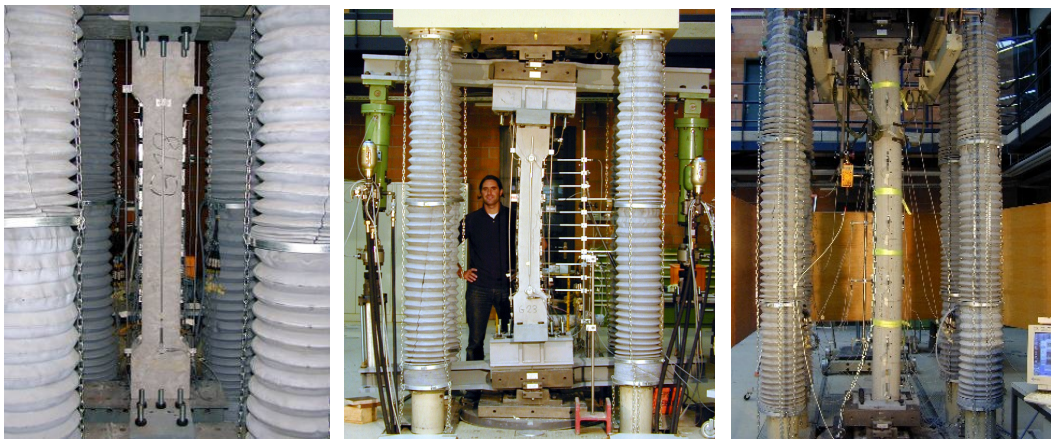

Figure 2: Testing on reinforced structural members in tension and compression

In a detailed study, the tensile behavior of bar reinforced and non reinforced structural members has been investigated [3]. To take into consideration the local effects of the crack opening, the tensile behavior of the material was characterized through two different series of tests. Unnotched specimens are used to study the uniformly distributed behavior until the crack opening occurs. The local effects of the crack opening are investigated on notched specimens (Figure 3).

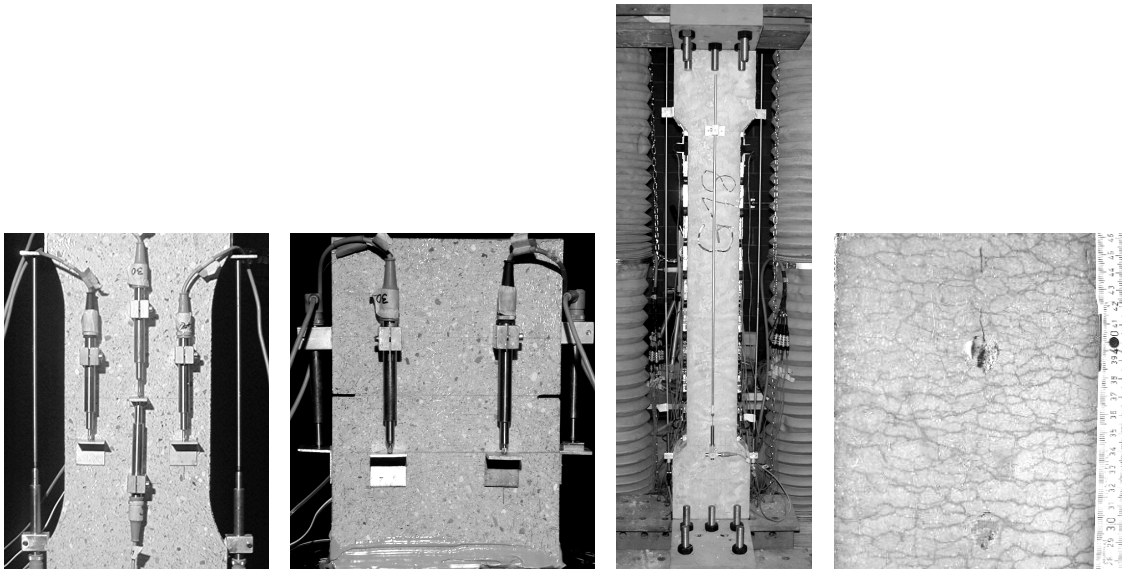

Figure 3: Material test on unnotched and notched specimens, reinforced tension member and crack pattern

The experimental work has shown that the strength of reinforced UHPC members is composed by the strength of the reinforcement bars and a contribution from the UHPC. The contribution of the UHPC to the stiffness of the element (tension stiffening) is very high. The crack pattern shows a small crack spacing and only very little crack opening.

In a recent project, conducted in cooperation with an industrial partner, full scale columns were tested (Figure 4). The possibilities of application of UHPC in buildings were investigated and basic theoretical considerations about the structural behavior have been carried out [4].

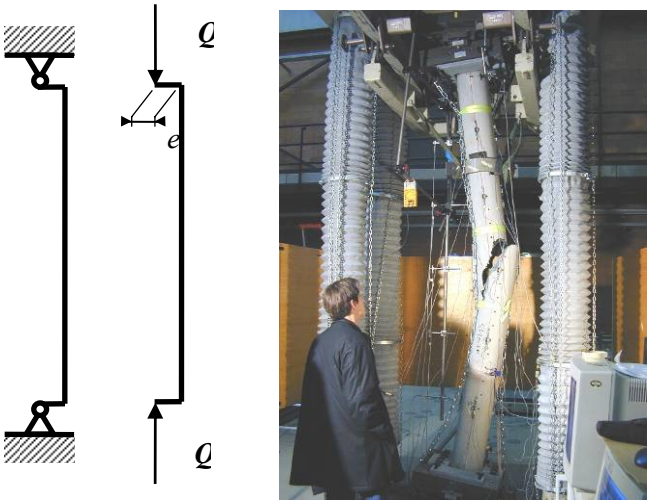

Figure 4: Testing of columns in UHPC

Based on the presented studies, the following conclusions were drawn:

- Due to the fibers and their contribution to the behavior in tension, UHPC shows a different tensile behavior than ordinary concrete.
- Major tensile stresses should be carried by reinforcement bars or pre-stressed steel to guarantee a reliable and efficient tension bearing.
- The strain hardening effect caused by the fibers leads to a well distributed multi cracking. This eliminates the need of minimal reinforcement for crack distribution.
- A good bond between the reinforcement and the matrix leads to a short development length. This should make connection of precast elements very easy.
- Shear reinforcement and reinforcement for the punching zones are not needed for minor shear stresses because of the high tensile strength respectively the high shear strength.

This means that structures can be designed only with UHPC and pre-stressing cables or passive reinforcement carrying the major tensile stresses. No other reinforcement is needed.

One possible application of UHPC in tension is its utilization as a tendon in underspanned girders [5]. Due to the high compressive strength of the UHPC, a high pre-stress ratio with a high pre-stress force can be used. This tendon has a very high cracking limit and will remain very stiff after cracking due to the fiber reinforcement. The small crack spacing and the small crack opening should also make this tendon very durable.

Figure 5: Tensile members for underspanned structures, possible replacement of a metallic tie by a UHPC pre-stressed member [5]

REFERENCES

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