Influence of Fiber Content on Uniaxial Tensile Behavior of UHPFRC

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1. Introduction

Ultra high performance fiber reinforced concrete (UHPFRC) combines the benefits of self-compacting concrete in the fresh state and shows an improved performance in the hardened state compared with conventional concrete due to the addition of the fibers[1)]. In this study, the uniaxial tensile tests are conducted in order to determine an appropriate tensile stress – crack width relationship for different fiber contents. Finally, the simplified analytical models for the tensile behavior of UHPFRC are drawn from the test results based on the available bilinear stress-crack width relationship[2)].

2. Materials and methods

The water to binder ratio, the amount of microsilica and the aggregate grading were kept constant for all mixtures. 3 different fiber contents have been used as the main parameter (0.8%, 1.6% and without fibers). The properties of steel fiber used are given in **Table 1**. The mechanical properties of the composites applied in the tests such as compressive and splitting tensile strength are given in **Table 2**. The uniaxial tensile tests were performed on un-notched dog-bone shaped specimens as shown in **Fig.1**. All specimens were cast in the mould with longer and higher than the final shape of specimens so the initial height of the specimens was 380 mm (**Fig.1**). The final shape for testing was obtained by cutting off the 100-mm-high pieces from both top and bottom of the initial specimen. The aim is to achieve a uniform orientation of fibers in all parts of the specimen (both in the middle and at the end of specimen). Without applying this method, the fibers in the end-zones of the specimen, at the top and bottom, would most probably be aligned horizontally to the walls of the mould. The normative tensile strength of such an end-zone will be lower than the tensile strength of the middle zone[3)]. Therefore, the fracture might occur outside the middle zone. Consequently, for cut specimens, occurrence of cracks can be expected in the middle zone where they can be measured with LVDT's. The final dog-bone shape of the specimens was 180 mm in height, 160 mm in width at the top and bottom, and 70 mm in the middle. The chosen depth of the specimen was 70 mm so the dimensions of the normative cross section is 70 × 70 mm^2. The crack opening was measured by 4 LVDT's, whose measuring length is 110 mm, attached at the front and the back of the specimen (**Fig.1**).

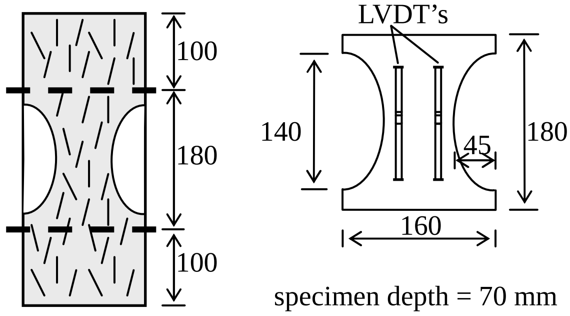

Fig.1 Initial mould and final shape of specimens

Table 1 Properties of steel fiber

Fiber type	Length (mm)	Aspect ratio	Shape	Minimum tensile strength (MPa)
OL13/0.16	13	81	Straight	2000

Table 2 Parameter, number and mechanical properties of specimens

Series	Fiber content (%)	Number of specimens	Average compressive strength (MPa)	Average splitting tensile strength (MPa)	Average direct tensile strength (MPa)
D00	0	5	139.0	11.0	4.0
D08	0.8	4	146.0	15.0	6.2
D16	1.6	4	147.0	16.5	9.0

Keywords ultra high performance fiber reinforced concrete, tension model, 3D FEM
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3. Results and discussion

Instead of the experimentally measured tensile force, all results will be presented using the equivalent tensile stress. This stress will be derived from the tensile force and full cross section in the middle zone of specimens. The tensile behavior of plain concrete specimens (D00 series) show a very brittle behavior after cracking compared to the fiber reinforced concrete (**Fig.2**). And, the softening branch could be measured only in some cases due to a slight bending of the specimen. The fiber reinforced concrete specimens (D08 and D16 series) show an increase of tensile strength compared to the reference plain concrete (**Table 2**). However, the first cracking stress is almost the same as the tensile strength of plain concrete (**Fig.2**). It can be observed from **Fig.2** that the ductility of fiber reinforced concrete is considerably larger than that of the plain concrete. And, the larger in ductility can be observed from specimens with higher fiber contents. In order to model the test results, the bilinear stress-crack width relationship[2)] was used as shown in **Fig.3**. The four points of the relationship were obtained from the test results as the following. The uniaxial tensile strength ($f_{fctm,ax}$) are between 0.4-0.5 times the splitting tensile strength determined on cubes of 100 mm (**Table 2**). The critical crack width (w_0) depended on the fiber length and the orientation number[2)]. w_0 can be considered as 0.9 (for both D08 and D16 series) times the fiber length in this study. The equivalent post-cracking strength ($f_{fctm,eq,bil}$) is about 10% of the uniaxial tensile strength for both D08 and D16 series. The characteristic crack width (w_c/w_0) at which the slope of the bilinear relation changed was 1/3-1/4 of the critical width w_0. The simplified tensile models for bot series are compared with the experimental results as shown in **Fig.4** for D08 series and **Fig.5** for D16 series. The verification of this simplified tensile model with the structural member will be the subject of continuing work.

4. Conclusion

Fiber content has a great effect on the uniaxial tensile strength and the ductility of UHPFRC. The experimental tensile behavior can be simply modeled based on the available bilinear stress-crack width relationship in this study.

References

1) Pansuk, W., Sato, Y., Shionaga, R. and Walraven, J. C., (2006). "FE analysis of ultra high performance fiber reinforced concrete." *EURO-C 2006 Computational Modelling of Concrete Structures*, Mayrhofen *27-30 March 2006*, 397-404.

2) Grunewald, S., (2004). "*Performance-based design of self-compacting fibre reinforced concrete*." PhD-thesis, Department of Structural and Building Engineering, Delft University of Technology.

3) Markovic, I., (2006). "*High-performance hybrid-fibre concrete: development and utilisation*." PhD-thesis, Department of Structural and Building Engineering, Delft University of Technology.

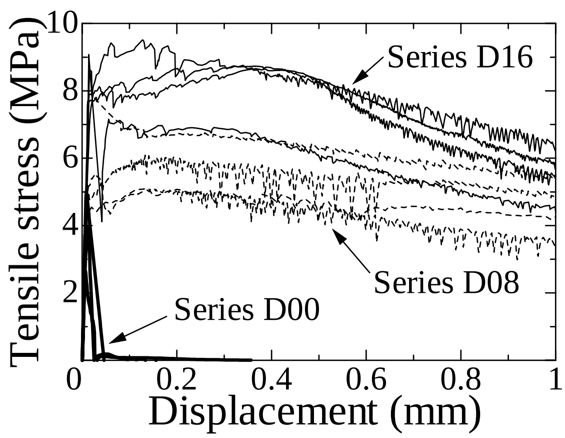

Fig.2 Comparison of the test data

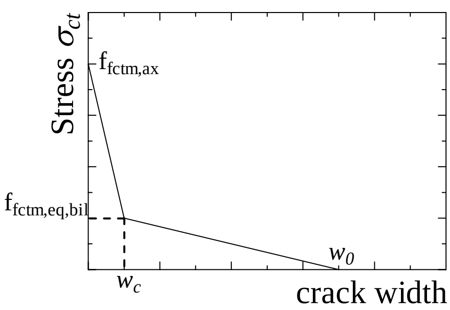

Fig.3 Bilinear stress – crack width relation[2)]

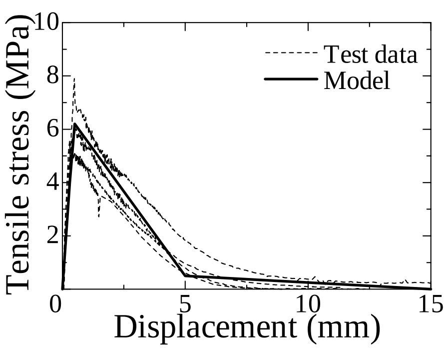

Fig.4 Comparison for D08 series

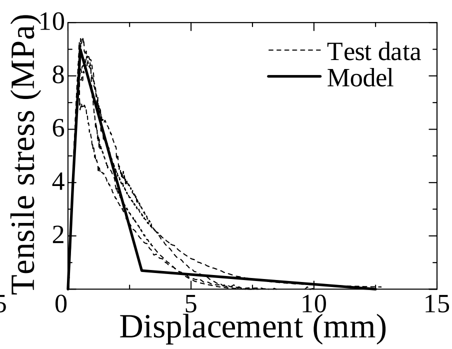

Fig.5 Comparison for D16 series