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Dependence of Load Bearing Capacity and Homogeneity of Steel Fiber Distribution

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Abstract. Load-bearing capacity of fine grained cement-based composite materials UHPFRC depends on the homogeneity of the steel fiber distribution at cross section. The homogeneity of the steel fiber distribution has significant effect to the mechanical properties of UHPFRC elements, especially at tensile strength in bending. The load-bearing capacity depending on the homogeneity of steel fibers at the permanent formwork slabs made from UHPFRC is shown in this paper.

Introduction

Ultra-High Performance Fiber Reinforced Concrete (UHPFRC) is a fine grained cement-based composite material such as Ultra-High Performance Concrete (UHPC) that is characterized by high mechanical resistance and by other utility properties. All of the characteristics of UHPC exceed characteristics of common used concrete.

Fig. 1. Installation of lost shuttering UHPFRC slabs.

There is no uniform terminology and classification of UHPFRC worldwide. Compressive strength is one of the determining parameters but the value of it is not determined too. There could be seen the compressive strength $f_{c,\,cyl}$ = 150 MPa in some publications [e.g. 1, 2 and 3]. Axial tensile strength exceeds 8 MPa and statics modulus of elasticity extends to 50 GPa.

Some dynamic development and investigation of UHPC can be mainly found in France, Germany, the Netherlands, the United States, Canada, Japan, Korea and Australia [4]. The first application of UHPC in the Czech Republic was at the project Reconstruction of the Bridge in Benatky nad Jizerou, the Czech Republic where the slabs presented in this paper were used. There can be shown the installation of the UHPFRC slabs in Fig. 1. The dimensions of the slabs were 1.0 m x 1.6 m and thickness only 20 mm. [5]

The results of load bearing tests of the lost shuttering slabs and tests for checking the homogeneity of the steel fibers distribution at slabs made from UHPFRC together with their dependence are also presented in this paper.

Experimental Project

The slabs were made at Skanska a.s. premises and then there were transported to the Klokner Institute CTU in Prague and tested on a loading device to find out their load-bearing capacity. The tests were controlled by the speed of movement of the loading piston that was 0.01 mm/s. However, this speed rate in the descending section, i.e. once the maximum force was reached, was gradually increased up to 0.02 - 0.03 mm/s. More than 20 load-bearing tests were done and the load-deflection relationship was recorded. Some of the results of load-bearing tests are shown in Fig. 2 where the mid-span deflection is at X-axis and loading value is in Y-axis. The arrangement of the four-point static loading test is shown in Fig. 3.

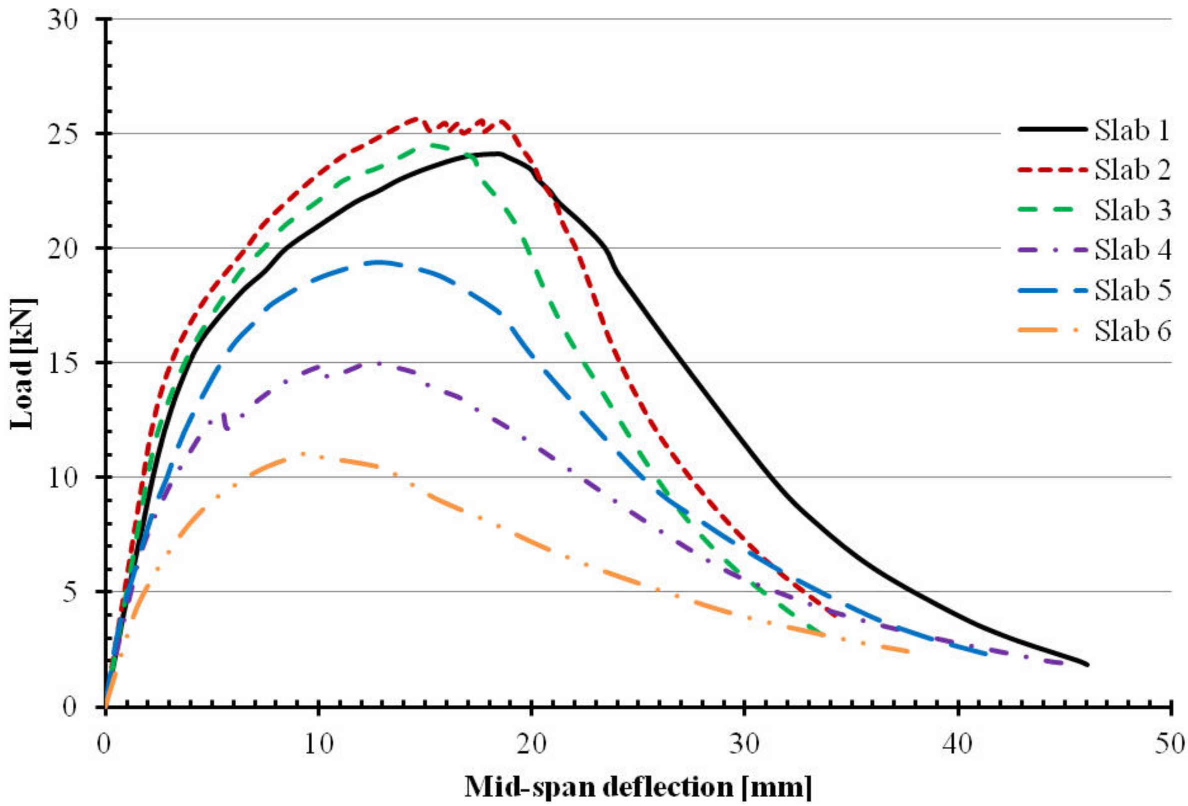
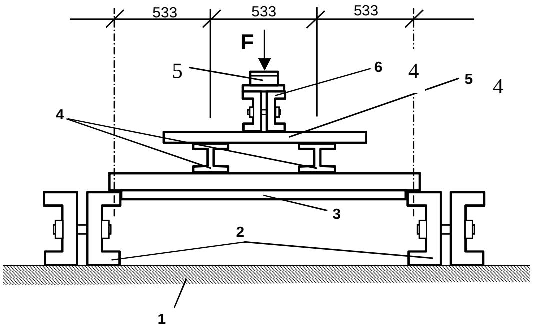


Fig. 2. Typical results of load-bearing tests for permanent formwork slabs made from UHPFRC. Mid-span deflection is at X-axis and the loading value is at Y-axis.



Legend:

1. floor
2. support beams
3. tested UHPFRC slab
4. load distributing
5. load distributing cradle hinge with steel plate pad/washer

F – direction of the load (axis of the loading piston)

Fig. 3. Scheme of arrangement of load-bearing capacity test in four-point bending on lost shuttering slabs made from UHPFRC.

Checking homogeneity. A wide variance of maximum compressive force, from 9.6 kN up to 25.7 kN, was reached. That was the one of the reason for checking the homogeneity of steel fibers distribution. Homogeneity of the steel fiber distribution was checked after four point bending tests near macro-crack. After the loading tests the slabs were cut by saw with diamond disc near macro-cracks. The cut surface area was divided to 13 sectors (from A to M) and subsectors that were scanned by a microscope and then were evaluated. The homogeneity was measured at 2/3 of the total cross section area of slabs and electronic semi-destructive microscopic method was chosen for controlling the homogeneity of the steel fiber distribution. The dimension of the subsectors is 10 mm x 10 mm in size. The subsectors segmentation and orientation of the slab at testing is show in Fig. 4. The next Figs, Fig. 5 and Fig. 6, show the results of checking the steel fiber distribution at slab thick.

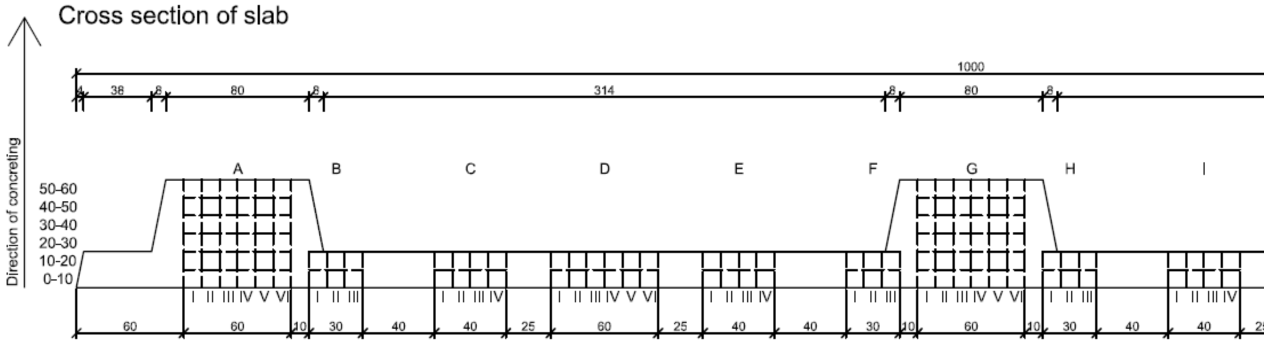


Fig. 4. Segmentation of subsectors of permanent formwork slabs. This orientation responds with orientation of slab during four point tests. Slabs were reversely oriented during the casting the fresh UHPFRC to formwork.

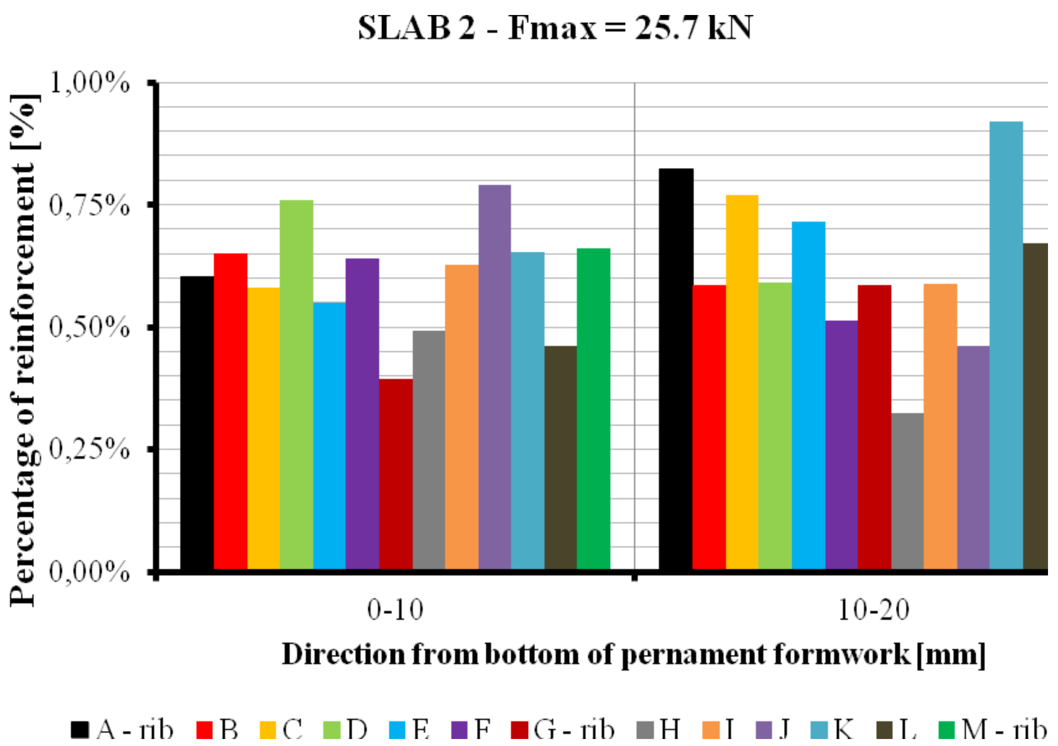


Fig. 5. Steel fiber distribution at slab 2 with F_{max} = 25.7 kN. Directions from the bottom surface of slabs are in X-axes and average value of percentage of steel fiber reinforcement at subsector (sub-sector area 1 cm^2).

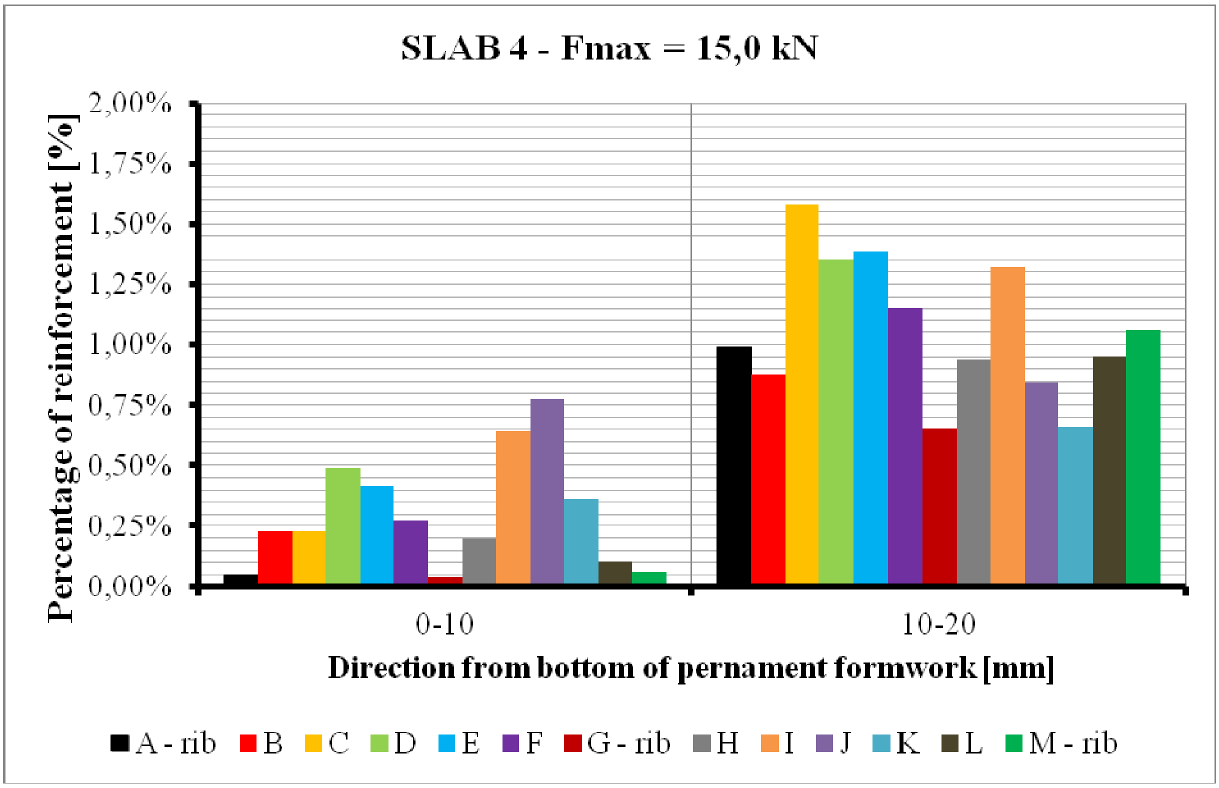


Fig. 6. Steel fiber distribution at slab 4 with F_{max} = 15.0 kN. Directions from the bottom surface of slabs are in X-axes and average value of percentage of steel fiber reinforcement at subsector (sub-sector area 1 cm^2).

The slab 2 with maximum loading value Fmax = 25.7 kN has relatively good homogeneity of the steel fibers distribution at slab part, slab thickness is 20 mm. This steel fiber distribution show Fig. 5. Fig. 6 show results of checking the steel fiber distribution at slab 4 with maximum loading value Fmax = 15.0 kN. At first layer (direction from bottom 0-10 mm) is the average value of percentage of the steel fibers approximately 0.30 % but in the second layer (direction from bottom 10-20 mm) is the average value of percentage of the steel fibers approximately 1.10 %.

Conclusions

UHPFRC is a cement-based composite material with high compressive strength, tensile strength and modulus of elasticity that has been developing in the world and in the Czech Republic too. Lot of technical and technological problems must be solved before using UHPFRC at a real construction. Segregation of the steel fibers distribution is one of the problems that affect the final mechanical properties of elements made from UHPFRC. Our practical experiences shows that this problem could be solved quit easily. Guidance for design elements established a coefficient that is used to reduce tensile capacity of elements but there are no limit values for make decisions which results are correct and which are not.

Acknowledgements

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