EXPERIMENTAL INVESTIGATION OF I-BEAM MADE FROM UHPC

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Abstract

The experimental investigation on girder made from UHPC was provided. The results experimentally determined ultimate load possess high coefficient of variation. Its value was depending on cross section position during casting, resp. on direction of bending moment. It was proved that the ultimate bending load depends on the casting technology, on the fibre distribution and the air pore distribution in the structure member. These distributions are influenced by casting.

Keywords: concrete, UHPC, ultimate load, fibre distribution

1. Introduction

Klokner Institute cooperates with SKANSKA CZ, BASF and PONTEX companies on investigation of UHPC material. The aim of research is application of UHPC material on real structures in the future. Therefore, the I-beam made from UHPC was investigated and the loading test should prove the technological possibilities of pre-cast plant.

The cross section was 240 mm in height (Fig. 1). The girder was cast without any longitudinal and stirrup steel reinforcement. We prepared 12 testing specimens with the length 2 m. The beam was tested in bending as cantilever. The distance between the force and the rigid fixing was 1,30 m (Fig. 2).

The investigated UHPC material consists of cement CEM I 42,5 R (656 kg), slag (81 kg), microsilica (101 kg), aggregate 0/4 mm (1157 kg), superplasticizer (39,8 l), water (156 l) and steel fibres ∅0,2/20 mm (101 kg).

The mechanical properties of UHPC material were determined on prepared accompanying specimens. The cube strength in compression reached 115 MPa, strength in bending was 21,3 MPa, Young’s modulus 38,1 GPa and volume density 2400 kg/m^3.

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The casting of testing specimens was provided by two different plants of the SKANSKA company and by two different technologies. Nine specimens were cast in the I-position and three specimens were cast in the H-position. The cross section dimensions and casting positions are drawn on Fig. 1.

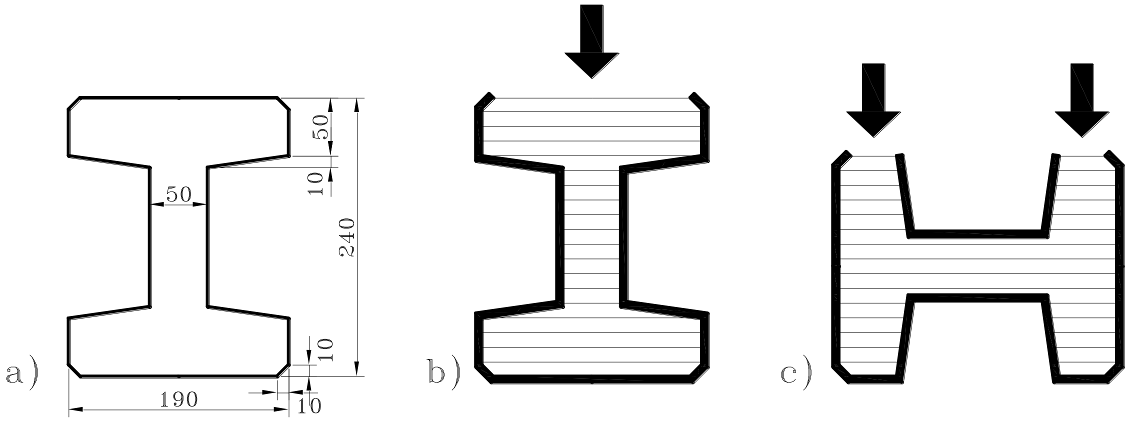

Fig. 1: The beam cross section: a) dimensions, b) casting in I-position, c) casting in H-position

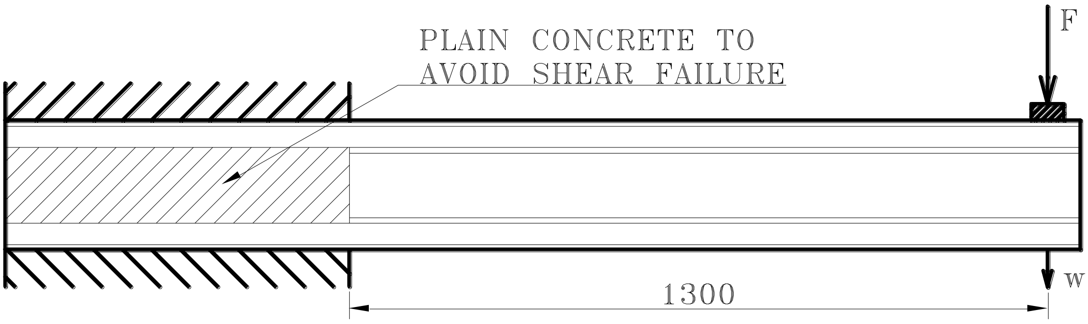

Fig. 2: The test arrangement of I-beam bending test (F – applied force, w – measured displacement)

2. Experimental results of bending tests

The cantilever I-beams were tested as was described and shown on Fig.2. Two beams casted in I-position were tested so that the tension was at upper part of cross section placed in formwork, see Fig. 1b, and these testing specimens are labelled N (normal). Three beams casted in I-position were tested so that the tension was at the lower part of cross section placed in the formwork, see Fig. 1c, labelled R (reversal). Of course, the ultimate load is assumed as independent of testing position in case if beams casted in H-position; beams were labelled H.

The typical failure of cantilever beams is presented on Fig. 3. The obtained force-deflection diagrams are presented on Fig. 1 and experimentally determined ultimate loads was from 8,84 kN to 15,21 kN, see Tab. 1.

The highest ultimate load was in sae of beams labelled R (reversal) which was much higher that in other cases. This behaviour was supposed, because of non-homogenous distribution of steel fibres in cross section due to casting technology and setting of steel fibres. This phenomenon influences not only the ultimate load but also the force-deflection relationship as is shown on Fig. 4.

Tab. 1 Table of ultimate loads from bending tests of I-beams

Testing specimen	4N	5R	6R	7N	8R	9R	10H	11H	12H
Max. load [kN]	9,74	14,24	12,98	11,26	15,21	14,93	8,84	13,43	10,43

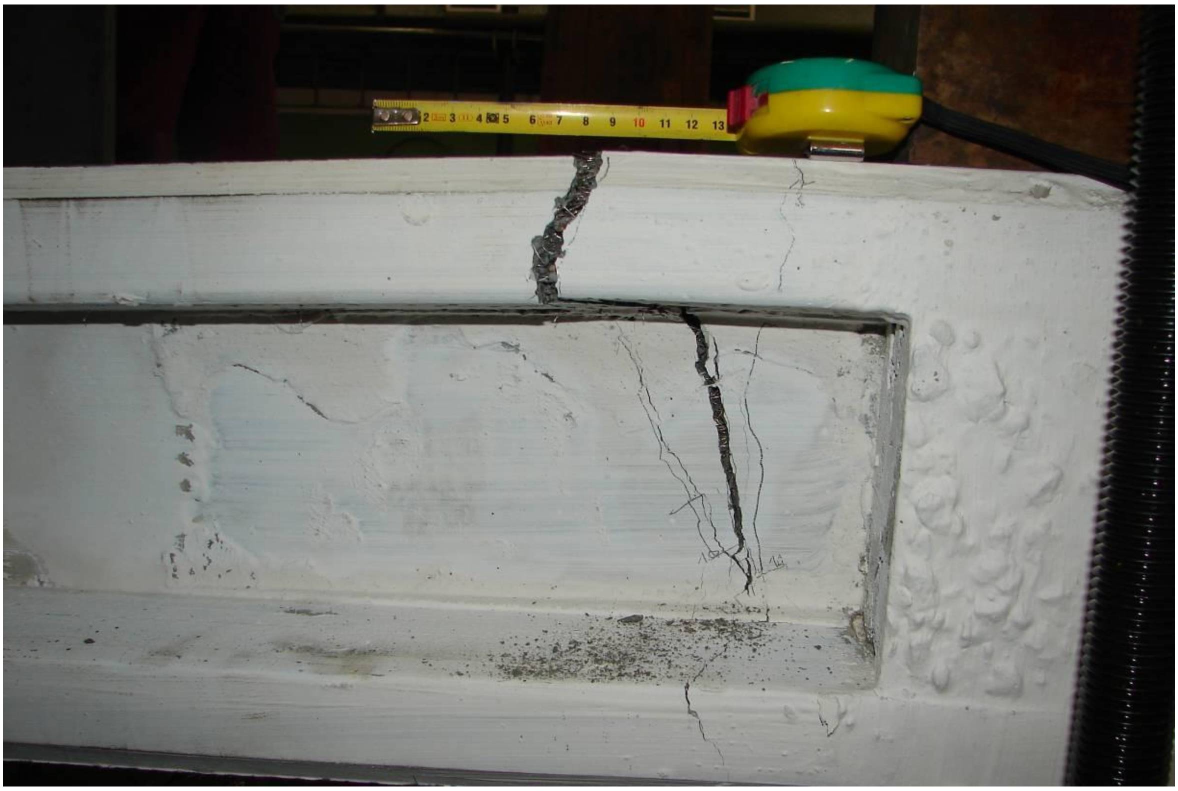

Fig. 3: The failure of cantilever beam at fixed point

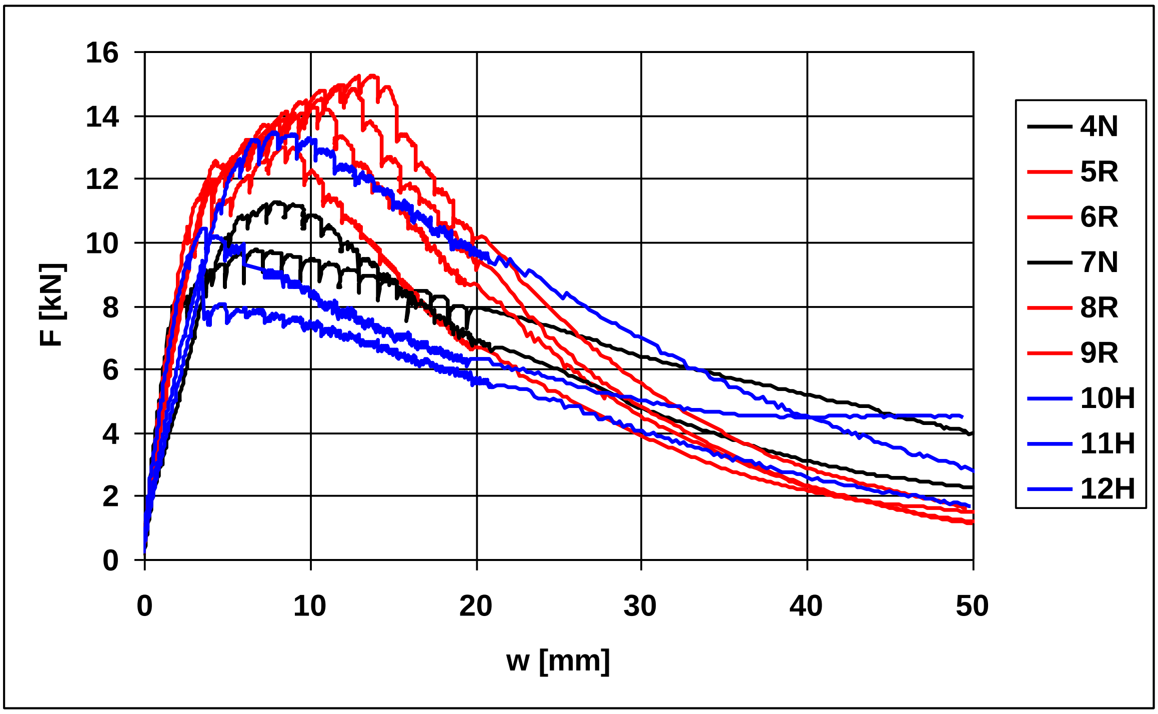

Fig. 4: The force-deflection diagram

3. Fibre distribution in cross section

The fibre distribution in the cross section was determined on cut and polished specimens by microscope method (Fig. 5). The number of steel fibres was counted in field of view with dimensions 14 x 18 mm and this field was shifted along the axes witch are drawn on Fig. 6.

Fig. 5: The fibre distribution analysis by microscope method

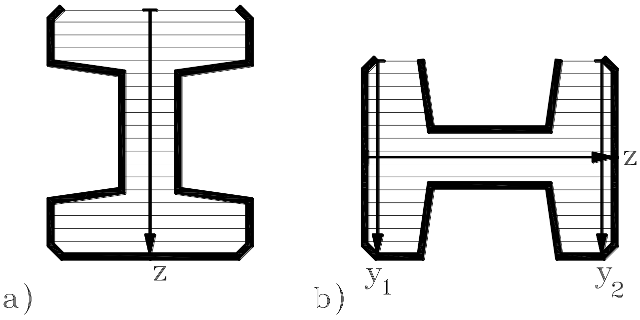

Fig. 6: The coordinates used for fibre distribution analysis – a) casting in I-position, b) casting in H-position

The picture from microscope was processed by computer, but the different light conditions did not allowed full automatic image processing. The fibre counting should be verified by man, because some badly lighted fibres were usually not counted, see Fig. 7.

The histogram on Fig. 8 shows distribution in case of beams casted in I-position depending on z coordinate. The increasing of counts with increasing z coordinate is evident. The minimum count number is only about 30 and maximum above 120.

Similar histogram for casting position H is on Fig. 9. It is supposable that this graph is closer to uniform distribution than previous. Minimum count value is 60 and maximum about 130.

The fibre distribution along axis y_1 and y_2 studied only on H series is not uniform, see Fig. 10, but it look like as some U-shape distribution. This is due to casting in 2 layers with break needed for installation of framework upper part. The minimum count number is 40 and maximum more than 120.

The pore distribution was also studied by optical microscope on several cut and polished cross-sections. The content of air pores in the upper flange was about 50 % higher than in the lower flange in case of I-position series.

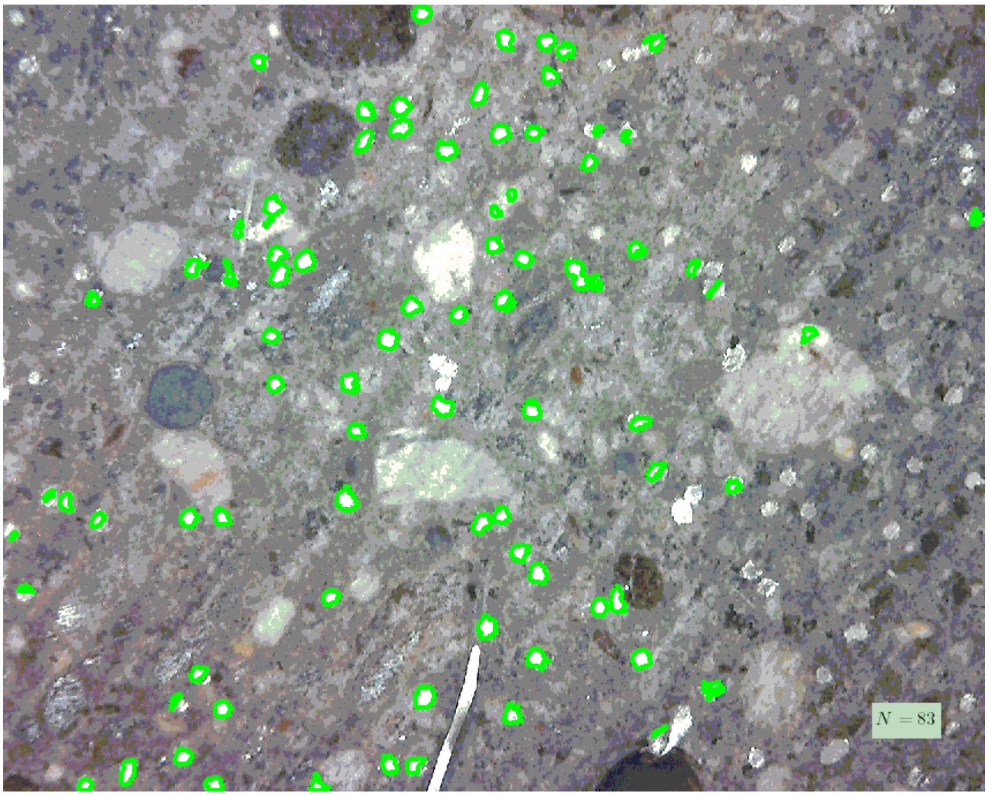

Fig. 7: The fibre counting evaluation from microscope picture should be verified by man because of different light conditions at a field

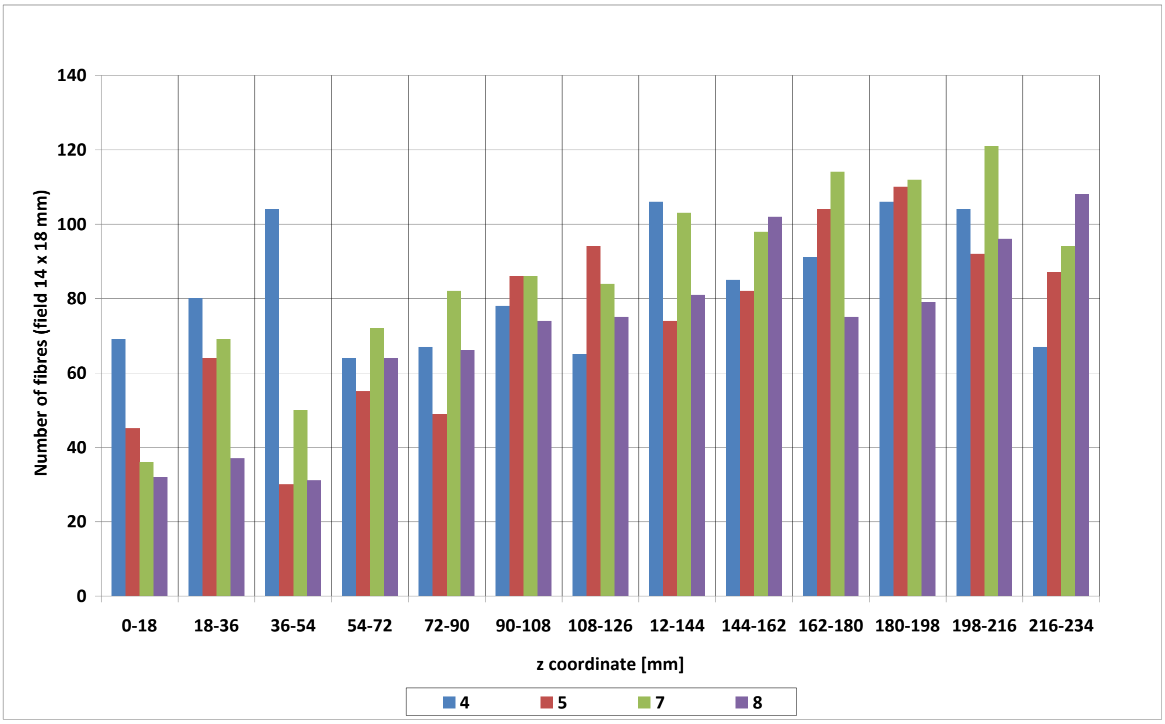

Fig. 8: The fibre distribudion in beams casted in I-position depending on z coordinate

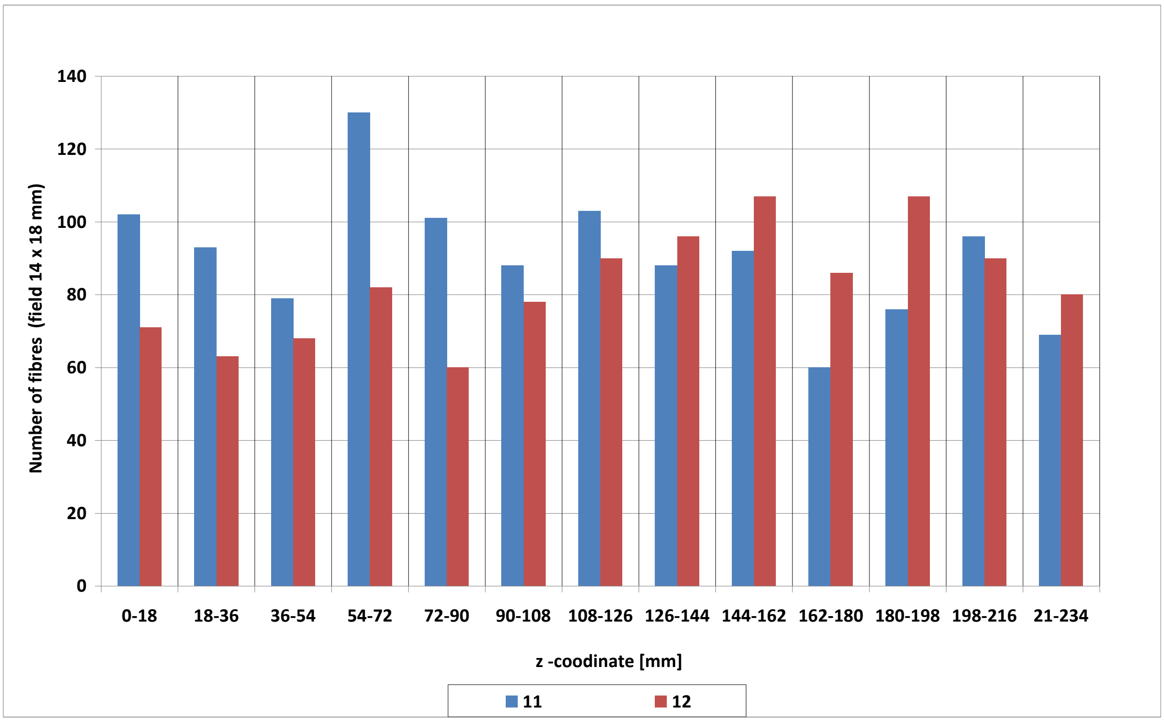

Fig. 9: The fibre distribudion in beam cross cection casted in H-position depending on z coordinate

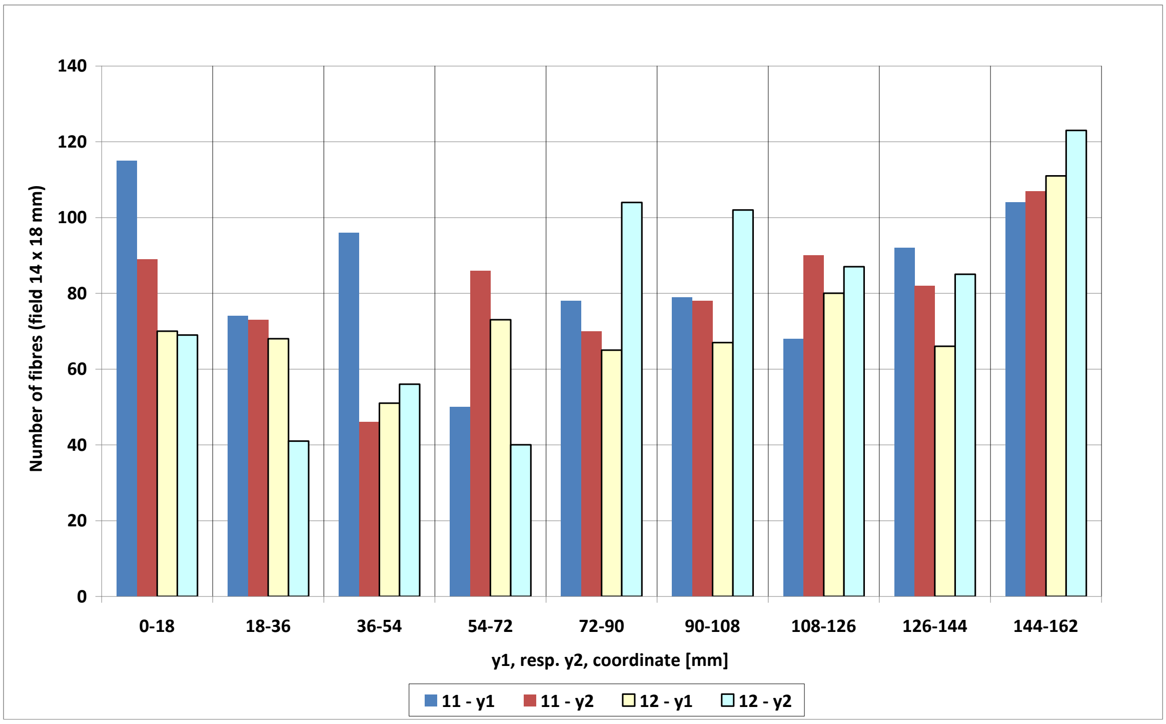

Fig. 10: The fibre distribudion in beam cross cection casted in H-position depending on y_1 and y_2 coordinate

4. Conclusions

The ultimate loads in bending were significantly variable in dependence on direction of bending moment with respect to casting position of cross section. This is caused by non-homogeneity of UHPC material in the cross section, which was proved by fibre and air pore distributions. These distributions are influenced by casting.

Acknowledgements

This study was partially supported by the project GAČR P104/10/2359 and partially by the project TAČR TA01010269. The authors wish to thank several colleagues in SKANSKA CZ, BASF and PONTEX companies for assistance with specific experiments.

5. References

[1] J. Lataste, S. Barnett, T. Parry, M. Soutsos, Determination of fibres orientation in UHPFRC and evaluation of their effect on mechanical properties, *NDTCE'09 Non-Destructive Testing in Civil Engineering*, www.ndt.net.

[2] EN 480-11. Admixtures for concrete, mortar and grout - Test methods - Part 11: Determination of air void characteristics in hardened concrete.

[3] J. Tichý et al., Další zkušenosti s ultra vysokohodnotným betonem v prefabrikaci, *17. betonářské dny* (ČBS), pp. 219-225, 2010. *(In Czech language)*