BEHAVIOUR OF A MEMBER WITH COMBINED REINFORCEMENT IN TENSION

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Abstract

The paper presents the test set-up for uniaxial tensile tests of a specimen with combined reinforcement (dispersed fibres and steel rebar reinforcement) and results of the tests of several types of FRC.

Keywords: Fibre reinforced concrete, cracking, uniaxial tensile test, combined reinforcement

1. Introduction

Understanding of tensile behaviour of structures from fibre reinforced concrete is fundamental both for the ultimate design and the design with respect to serviceability. Concerning investigations of ULS the enhanced tensile strength and the Load – deflection curves and stress – strain diagrams with tensile hardening and softening are well-known. There were derived and recommended design procedures for the ultimate check of FRC structures.

The approach to Serviceability Limit State is less and more empirical so far. It is approved that dispersed reinforcement improves the cracking characteristics; however the precise quantification has not been stated yet. Also the standardisation process has not proceeded much.

The investigations performed at the Department of Concrete and Masonry Structures of the Faculty o f Civil Engineering CTU in Prague shall tribute to progress in understanding of the tensile behaviour and cracking.

2. Uniaxial tensile tests of FRC

The important issue of the research program was finding of a suitable test as a basis for simple deriving of relations stress – crack width and crack spacing. The deriving of constitutive relations from direct tensile tests is clear, evident and simple. But the direct tensile test is problematic because of difficulties with executing. For testing of FRC the same test set-up as for common concrete is used. But for concretes with dispersed fibres these tests are even more problematic than for plain concrete.

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There are problems with gripping of the specimen in the test machine; one type of gripping is gluing of the specimen, the other type is screwing of the ends of the specimen.

The test specimen that is glued to testing machine has usually the shape of dogbone. The crack is expected in the narrow neck but there the fibres are directed along the specimen length and in fact the neck must not be the weakest section. The specimen usually cracks close to the glued surface as that area has less fibre reinforcement and the fibres are in the direction parallel to the glued surface.

In the test set-up where the ends of specimen are fixed in the testing machine by jaws the specimen fails due to damage caused by stress concentration under the grips and multiaxial stresses.

Lately the utilisation of FRC and cement composites in structural elements that embody dispersed and rebar reinforcement expands. In addition to determination of tensile properties of the material itself it is considerable to identify behaviour of the material in interaction with classical rebar reinforcement in a structural element. That is why a uniaxial tensile test of a specimen with combined reinforcement – longitudinal rebar reinforcement and dispersed reinforcement was proposed.

2.1 Test of a specimen with combined reinforcement

The test specimen is a rectangle block ca 75 x 75 x 800 mm from FRC; a steel bar is embedded in the longitudinal axes; the bar is ca by 400 mm longer than the specimen. The specimen is gripped in the testing machine by the free ends of the bar.

The test is performed on the universal testing machine commonly used for tensile test of steel bars. The specimen is gripped in the testing machine; the test machine is put in action and the cracking is monitored. The value of load for each crack is recorded and for given values of load the width of cracks is measured using the comparative graduated crack gauges.

After the limiting width of crack is reached the test is terminated. The cracks are marked and the spacing of cracks is measured.

The advantages of the test are no problems with fixing of the specimen and more information about tensile characteristics of the material compared to traditional set-up of tensile tests.

3. Research program

In the research programme various types of FRC were tested (see table 1) with several types of steel fibres and synthetic fibres and different volume content of fibres; two reference concrete without fibres were included. All mixes had compressive strength about 70 MPa. The steel rebar reinforcement had profile 12 mm. Two ductile classes of steel were used although no significant effect of steel ductility was expected as the testing regarded mainly elastic behaviour of steel; after the yielding was reached the cracks opened more than the limiting width and the testing was terminated.

Fig. 1: Frame of the testing machine and the tested specimen

Tab. 1 List of tested FRC

label	fibres	aspect ratio	length of fibres	strength of fibres [MPa]	volume content of fibres	Ø of the bar
PB 1	-	-	-	-	-	12
PB 2	-	-	-	-	-	12
D60 1	steel	80	60	1 225	0,5%	12
D60 2	steel	80	60	1 225	0,5%	12
D30 1	steel	80	30	2 300	0,5%	12
D30 2	steel	80	30	2 300	0,5%	12
TT 1	steel	47	50	1 000	0,5%	12
TT 2	steel	47	50	1 000	0,5%	12
D60 – α	steel	80	60	1 225	1 %	12
D30 – β	steel			1 225	1 %	12
TT – γ	steel	47	50	1 000	1 %	12
Strux – δ	synthetic macro-fibres	90	40	620	0,625%	12
FF – ε	polypropylene micro-fibres		54	570 - 660	0,5%	12
FF – φ	polypropylene micro-fibres		54	570 - 660	1 %	12

3.1 Test results

The tests were performed since October 2010 to June 2011. Now they are analysed and evaluated. This paper presents first set of results and their partial analysis.

Table 2 shows mean value of crack spacing for particular concrete or FRC respectively and average deviation.

Fig. 1: Measuring of the crack spacing

Fig. 1: A set of tested specimens

Tab. 2 Crack spacing – mean value and average deviation

Labelling of specimen	Volume content of fibres	Mean value of crack spacing	Average deviation
PB 1	-	113,1	34,5
PB 2	-	126,6	57,2
D60 1	0,5%	84,6	18,1
D60 2	0,5%	89,3	23,9
D30 1	0,5%	97,4	21,6
D30 2	0,5%	86,9	23,5
TT 1	0,5%	97,5	22,5
TT 2	0,5%	100,7	27,7
D60 – α	1 %	76,2	21,8
D30 – β	1 %	71,6	22,1
TT – γ	1 %	76,4	21,8
Strux – δ	0,625%	100,4	30,8
FF – ε	0,5%	96,7	22,3
FF – φ	1 %	89,3	17,8

Results of the test proved that fibres really favourable affect cracking. Maximum spacing of cracks had specimens from concrete without fibres. The cracks were randomly distributed; the crack spacing differs a lot. Synthetic macro fibres (Strux 0,625%) enhance the cracking a little bit; spacing of cracks is smaller than in plain concrete elements but cracks are irregularly distributed along the specimen. The fibrillated micro-fibres affect the cracking more than macro-fibres. The SFRC with 0.5% of steel fibres with smaller aspect ratio and tensile strength has similar spacing as FRC with synthetic fibres but spacing is more regular. With increasing fibre content the spacing of cracks decreases and the cracks are regularly periodically distributed.

4. Conclusions

The proposed test arrangement abolishes the problems with gripping of the specimen in testing machine common in uniaxial testing of cement based materials. On the contrary to common uniaxial tests that give the information about tensile strength, the proposed test provides further information about layout, spreading and width of cracks along the test specimen.

The test can be useful in decision which type of FRC or other cement based composite material will be the most efficient for given conditions. It can provide more information and better knowledge about behaviour of the material in structural element in terms of cracking. The feasibility of the test is high, the test is performed on common tensile test machines. The manufacturing of specimens also does not require special conditions, it is easy and cost effective.

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5. References

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