SYNTHETIC AND STEEL FIBRES IN PRESTRESSED, PRECAST LONG SPAN BEAMS

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Summary

Four large-scale, prismatic, T-shaped beams with 19 m span were produced without stirrups, but 2 with synthetic fibres and 2 with steel fibres. Four point bending tests were made to simulate the load bearing process of built-in beams. Three point shear tests were made in the uncracked ends of the beams to prove the shear resistance of FRC. The behaviour of beams made of synthetic and steel fibre reinforced concrete was compared. Finite element calculation was made with the fibre reinforced concrete and plain concrete as well. The material model was according to Eurocode and the effect of the fibre was according to RILEM guideline. The numerical and real test load-deflection results showed close correlation.

Keywords: synthetic fibre, steel fibre, prestress, precast, finite element analysis

1 Introduction

1.1 Beams

Four large-scale, prismatic, prestressed, T-shaped beams with 19 m span were produced: two with synthetic fibres and two with steel fibres. The height of the beam was 90 cm, the width of the flange was 50 cm, and the web thickness was 14 cm. Concrete was C50/60-XC1-16, but the first test was made only at 19 days after casting. The homogeneity of the strength was measured by Schmidt hammer.

Six stirrups were placed in the web (height is 45 cm, not reaching the flange), in one meter from the edge of the element to avoid spalling stresses due to the release of the prestressing force, but shear reinforcement was substituted by the fibres. Before the tests 10-40 cm long cracks with 0.05-0.3 mm width were appeared 45-50 cm from the soffit. There were 15-45 cm long cracks with 0.1 mm width between the web and the flange.

1.2 Tests

Four point bending test were made to model the built-in behaviour of the beams. The loads were acted in each one-fifth point of the span to be similar to the real load distribution. Force, deflection in the middle of the span, crack patter was recorded in fifteen load-steps. It was decided after reaching the 130% of the design value of the bending resistance, loading will be stopped without a break-off failure to remain the beam-end uncracked for shear tests. A crack with 1.0 mm width was declared failure.

Shear load was affected ~2.5h distance from the beam-end and it was increased until failure. Test and pictures were made by ÉMI-TÜV SÜD Kft.

Fig. 1 Spalling crack in the end of the beam

Fig. 2 Bending (left) and shear (right) tests

2 Results

2.1 Bending

Beams made of steel and synthetic fibre reinforced concrete showed similar load bearing behaviour during bending tests. Cracks appeared regularly and frequently between the two outside press, the beam end remained uncracked. As the load was increased, cracks started to open and reached the flange. Cracks with 1.0 mm width were appeared at 120% of the design value of the bending resistance, but they closed due to the high prestressing force after deloading.

In case of synthetic fibres the crack propagation process started earlier, at lower loading level, was faster and cracks were closer to each other. In the seventh load step inclined (~45°) cracks appeared at the outside loads. In case of steel fibres the same was observed only in tenth. After two loading level their width was the same as pure bending cracks'. Other new cracks' inclination was lower. In the last loading level they reached 1.0 mm width. Failure was observed at the shear-bending zone with obvious prognostic in both cases.

2.2 Shear

In the shear tests first cracks appeared at 115% of the design value of the shear resistance. Failure with 1.0 mm width was observed at 200%, the break off was at 230%. All the cracks went from the support to the load, the firsts' inclination was 35-45°, and the last was 18°. Failure was ductile in cases of both steel and synthetic fibres.

Fig. 3 Bending (left) and shear (right) failure

3 Finite element analysis

3.1 Material model of the concrete and FRC

The effect of the fibre in the concrete was investigated in previous grandstand concrete elements at the new stadium in Debrecen, Hungary [1]. Four point beam test were made on 150 mm x 150 mm and 550 mm long beams, according to RILEM TC162 [2]. After the results, inverse analysis was made and the correct added fracture energy was measured by fibre dosage. Modified fracture energy is a new and simple way to model the behaviour of FRC in tension and bending [3]. The crack-width diagram was defined until 4 mm crack opening as a limit from an engineering point of view.

3.2 Numerical and test results

The numerical calculation shows good correlation with the test result. The fibre reinforced concrete beam has the maximum bending capacity 52% higher than the plain concrete one.

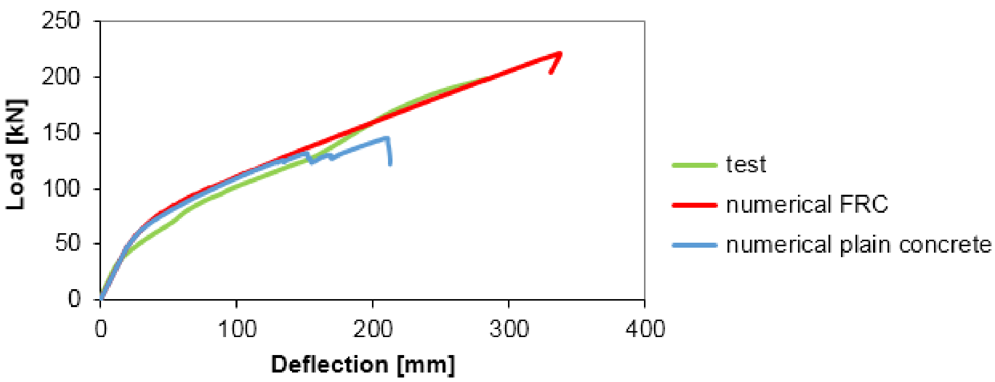

Fig. 4 Test and numerical load-deflection results

4 Conclusion

The structural behaviour was clear, but advanced statistical analysis cannot be performed due to the limited number of beams. The existence of horizontal spalling cracks on the beam ends was predicted by the verified finite element analysis. Calculation shows higher dosage of fibres or extra reinforcement is needed to avoid spalling failure, although these cracks do not influence the load bearing capacity of the beam.

There was no difference between steel and polymer fibre reinforced concrete beams in load bearing capacity. In the four-point bending test failure occurred in the bended-sheared area by inclined cracks, although the crack-width in the pure-bended zone was also remarkable. Inclined shear crack with 1.0 mm width was achieved at the same load level in the two cases. Breaking shear load was 25% higher, showing tough behaviour. Breaking was ductile with obvious prognostic. The cracked surface was examined, the fibres mostly pulled out instead of tearing. Finite element analysis shows significantly higher (52%) load bearing capacity of the fibre reinforced beam compared to plain concrete one.

References

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