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Shear Behaviour of UHPC Concrete Beams

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Abstract

The work presented in this article aims to compare the experimental results on shear capacity of SFR-UHPC (steel fibre-reinforced ultra-high performance concrete) I-shaped beams against the modelling results. Steel fibres added to the concrete replace stirrups. The purpose of the paper is to confirm the feasibility of SFR-UHPC for I-shaped reinforced concrete beams and replacing classical stirrups by fibre reinforced concrete.

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Keywords: shear capacity; steel fibres; experiment; numerical model; ultimate strength.

1. Introduction

Ultra-high performance concrete and the use of steel fibres had a significant evolution due to the development of new materials.

In manufacturing prefabricated beams, the assembly of the reinforcement cage has a significant impact on the production, which makes replacement of stirrups by steel fibres of interest.

The aim of this study is to investigate the replacement of stirrups by steel fibres and the comparison between experimental part and modelling results.

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Nomenclature

SFRC-UHPC	steel fibre reinforced ultra-high performance concrete
a/d	shear span to depth ratio

2. Experimental program

Eight I-shaped beams made from SFR-UHPC were tested in shear until failure [1]. Each beam was tested two times, first with a shear span to depth ratio a/d=2.5 and secondly on the opposite shear span with a/d=2.3. Each element had a total length of 4 m, a cross-section of 140 mm width, 400 mm height and a web thickness of 60 mm (Fig. 1).

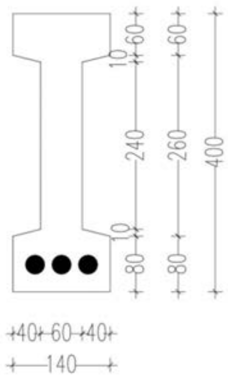

Fig. 1. Beam cross section (dimensions in mm)

Four different types of beams were used (Fig. 2):

- Type F: SFR-UHPC with longitudinal reinforcement;
- Type FD: as type F with diagonal rebar;
- Type FO: as type F with web opening;
- Type FOD: as type FO with diagonal rebar.

For each beam type 4 tests are conducted (2 times a/d=2.5 and 2 times a/d=2.3). The test setup is shown in Fig. 2. The supports allowed the horizontal movement of the tested beams. A hinge support was used at the support closed to the loading point, a roller support for the other side of the beam.

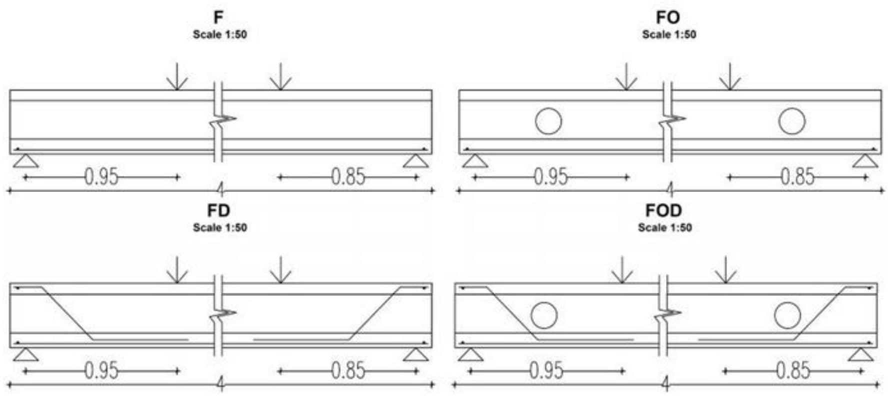

Fig. 2. Tested beams

The load was applied on a load pad (ϕ260 mm) with a spherical hinge, and between the jack and the beam a load cell with an accuracy of 0.3 kN was positioned.

In this study we will discuss only for the beams type F and FOD tested with a/d=2.5.

3. Numerical analysis

The numerical model was developed in the nonlinear computing program ATENA (Advance Tool for Engineering Nonlinear Analysis) [3]. The program is qualified on a nonlinear analysis 2D and three-dimensional problem by using the finite element modelling.

Experimental tests were carried out on beams and prisms which have been used to develop the calibration of the numerical model. Similar tests have been conducted on another experimental program [4, 5, 2]. A parametric study that is not presented in this article has been developed in which were varied various key parameters that can influence the behaviour of the ultra-high performance concrete beams subjected to shear force.

4. FE models

The first step in modelling was the beam with the longitudinal steel reinforcement bar (F). The numerical model fully reproduces the dimensions, the loading and the supports of the beams type F.

The calibration was obtained when the force-displacement diagram of the finite element model reproduced the experimental results. The analysis was made in steps by force increment of 1 KN (fig. 3).

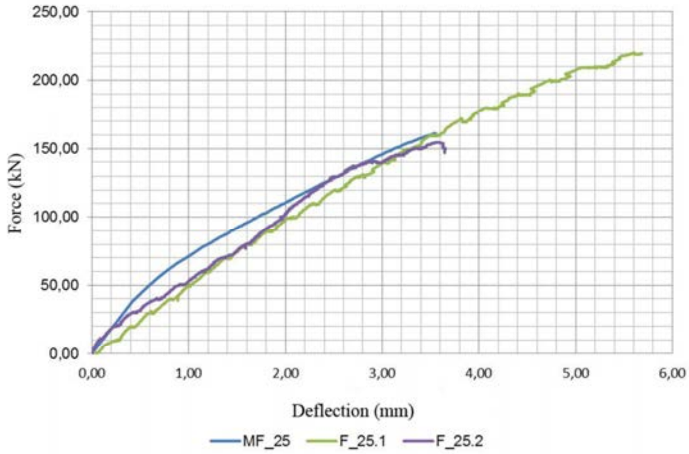

Fig. 3. MF calibrated according to beams type F

As it can be observed in fig. 3, the ultimate force according to beam F_25.2 had a small difference ($F_{u\_MF\_25}$=157 KN, $F_{u\_F\_25.2}$=154 KN). Beam F_25.1 is excluded from this study because of the major force that it has collapsed, but it can be seen how the model follows the force-deflection diagram.

The map of inclined cracking area can be observed in Fig. 4. The value of the crack opening at the maximum force was of 0.37 mm. Failure of the model was spotted in the red area, as it was in the experimental program.

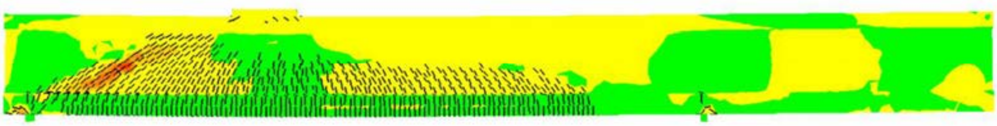

Fig. 4. Final cracking stage for MF

5. Comparison between the calibrated model and the experimental results for FOD_25

The model MFOD_25 was introduced in Atena keeping the mechanical properties of the calibrated model MF_25. Extra features introduced were the web-opening and a diagonal reinforcement.

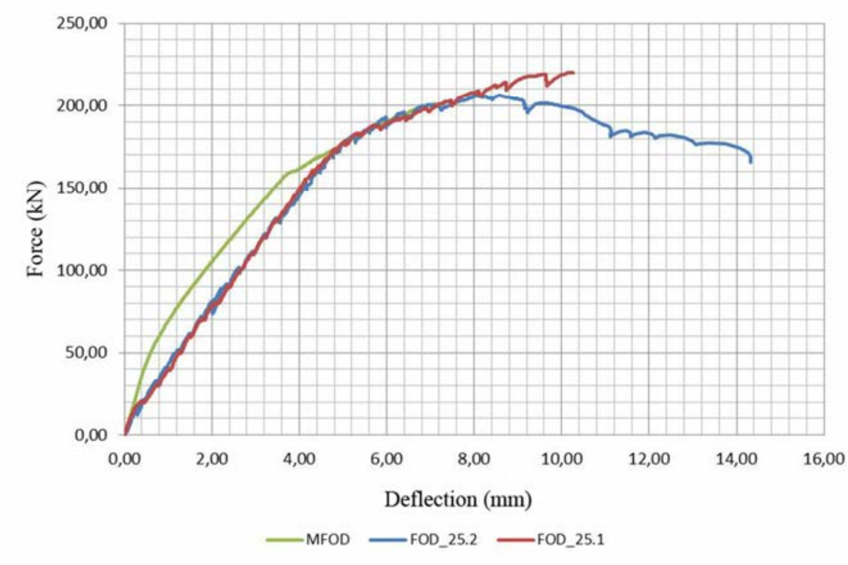

Fig. 5. MFOD calibrated according to beams type FOD

In fig.5 it can be observed that the final strength for the model MFOD is with 7% less than the average of the two experimental results.

Final cracking stage can be seen in fig.6 and where the failure will happen. The crack opening at the final strength was 0.43 mm.

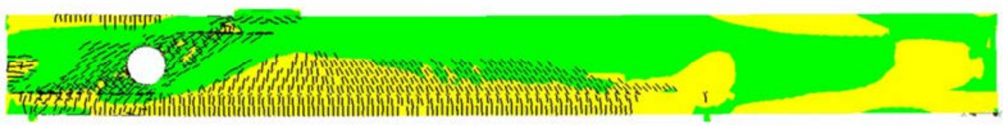

Fig. 6. Final cracking stage for MFOD

6. Conclusion of the calibration

Finite element models for UHPC-SFRC I shaped beams were created in this study. Available experimental results were used to verify the models.

- The predictions of the ultimate load capacities were fairly accurate when compared to the available experimental results for beams type F
- The failure of beams type FOD (beams with web-opening, diagonal rebar) follows the experimental failure after the rupture of the shear reinforcement.

- Between the model MFOD and MF there is an increase of 31% at the ultimate shear strength, as it was observed in the experimental program. This confirms the feasibility of using a diagonal rebar in case of beams with web-opening.

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