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REPLACEMENT OF CONVENTIONAL SHEAR REINFORCEMENT IN A STEEL FIBRE REINFORCED-ULTRA HIGH PERFORMANCE CEMENT BEAM

BY

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Abstract. Due to the fact that time is wasted in the process of stirrups assembling in a concrete beam, urge the researchers to find an alternative method. The most effective solution is eliminating the stirrups by using the dispersed reinforcement. By increasing the concrete strength lightly elements can be obtained. Combining these aspects new structural solutions can be achieved, easily and rapidly. In a modern building, the utility ducts can reduce the free building height with the reason that they need to be hidden. An economical solution is to be placed through the beams. The elements needs to have web-openings and this can cause several problems to the production of the beam. By replacing conventional shear reinforcement with fibres, a sufficient reinforcement can be achieved also for the web-openings.

Key words: steel fibres; shear; UHPC; web-opening.

1. Introduction

Energy neutral buildings, hospitals, modern office buildings, etc., can benefit from web openings in the reinforced concrete beams of the bearing

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structure, to allow placement of the different types of climate control and utilities. Usually, these utility ducts or pipes are attached to the soffit of the beams, but then they need to be hidden through different methods and yield in a significant reduction of the free building height (Fig. 1).

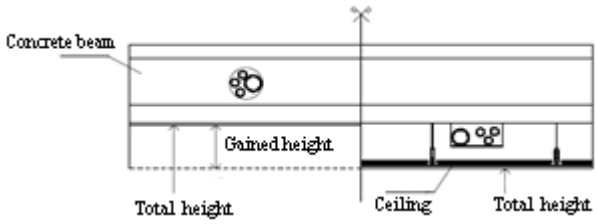

Fig. 1 – Comparison between a normal beam and a beam with web-opening.

The web-openings are modifying the normal behaviour of the beam by concentrated forces and earlier cracking of the concrete in those areas. Special reinforcement detailing normally needs to be applied for a better crack control and to prevent the failure of the beam through this section (Mansur *et al*., 1984).

During the last years the development of new materials increased considerably in the field of construction, among which evolutions in the use of SFR-UHPC (Steel Fibre Reinforced Ultra-High Performance Concrete) (Markovic, 2006).

In order to avoid the time consuming process of assembling stirrups (shear links) for RC beams, research has been performed to find alternative methods. In several cases (Mansur & Alwis, 1984; Hegger & Bertram, 2008; Voo *et al*., 2010; Narayanan & Darwish, 1987; Walraven, 2009; De Pauw *et al*., 2008; Peter *et al*., 2008; Choi *et al*., 2009; Balázs & Kovács, 2004; Gustafsson & Noghabai, 1999), the most effective solution was found to be the use of fibre reinforced concrete. With an appropriate fibre dosage and the possible use of high performance concrete, it is proven that traditional reinforcement can be replaced or reduced. Moreover, in case of a total replacement, the thickness of the web can be reduced, due to the fact that the concrete cover for the stirrups is not needed anymore. Combining these aspects new structural solutions can be achieved.

2. Experimental Program

The aim of the present study is to investigate the replacement of stirrups by steel fibres and the comparison between beams with or without web opening, for prefabricated I-shaped beams. In addition, partial replacement of shear links is investigated by comparing steel fibres with or without a single additional

diagonal rebar. A mix between short straight fibres and long hooked fibres has been chosen to ensure the best contribution to the shear resistance of the beams, due to the fact that small fibres work better on micro-cracks while long fibres are starting to work after the cracks appeared.

Due to its specific mix design, questions arise about the shear capacity of SFR-UHPC. The absence of normal aggregates and the large amount of cement and fines can have a negative influence on the shear capacity. Adding fibres in the concrete can increase the shear capacity.

This is verified by means of an experimental and analytical study. The work conducted so far demonstrates that the developed structural I-shaped prefabricated beams with SFR-UHPC are feasible, both in terms of producibility and mechanical performance. Two times five I-shaped beams made from SFR-UHPC (Fig. 2), were tested in shear until failure. 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. Each beam was tested under two different configurations, first with a shear span to depth ratio a/d = 2.5 and secondly on the opposite shear span with a/d = 2.3.

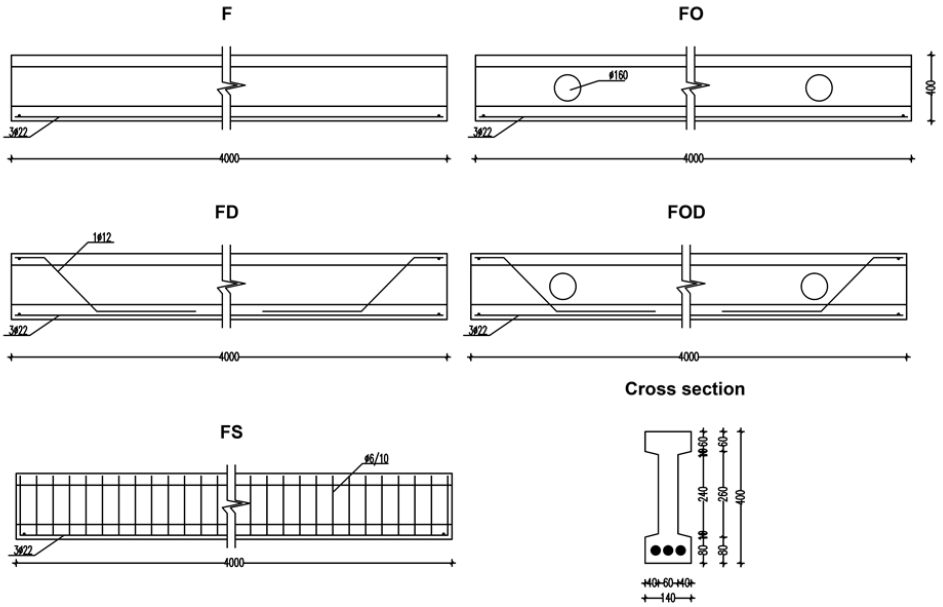

Fig. 2 – Design scheme of the beams.

The UHPC mix is based on research conducted at RWTH-Aachen University (Hegger & Bertram, 2008). The mix has been further optimized, in order to allow the use of local constituent materials and in order to upscale the concrete mix for use in an industrial mixing plant. The used fibres are a mix of 1/3 from the total quantity of short straigth fibres, and 2/3 long hooked fibres.

The SFR-UHPC mix has been fully characterized in terms of Young's modulus (E), compressive strength (f_c), splitting tensile strength (f_{sp}), bending tensile strength (f_{ctm}), as well as post-cracking behaviour of the steel fibre reinforced concrete.

All the tested beams failed in shear (to assure a shear failure, a high amount of longitudinal rebars has been applied, corresponding with a reinforcement ratio of ρ = 3.16%). The main test results are summarized in Fig. 3, demonstrating that all the beams with diagonal reinforcement collapse at a higher load, compared to the beams with only longitudinal reinforcement.

The shear cracks have been observed to form as an extension of the flexural crack, which bent over. After the cracks opened, the sound of the fibres being pull out and failing was noticeable.

In Fig. 4 it can be seen a FOD beam after the failure.

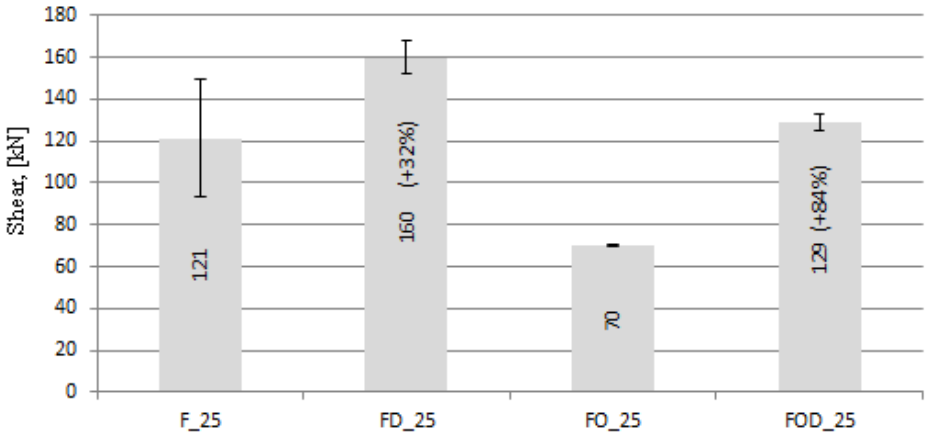

Fig. 3 – Comparison of shear capacity for a/d ratio 2.5.

Fig. 4 – FOD beam after failure.

4. Conclusions

The shear capacity of beams with web-opening equals that of the same SFR-UHPC beam without web-opening, by making use of a single additional diagonal shear link.

The experimental work presented in this paper proceed the feasibility of SFR-UHPC for I-shaped reinforced concrete beams and replacing classical stirrups by fibre reinforced concrete, with or without the combination of a single diagonal rebar.

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ÎNLOCUIREA ARMĂTURII LA FORȚĂ TĂIETOARE ÎN GRINZILE DE BETON DE ULTRA ÎNALTĂ PERFORMANȚĂ ARMATE CU FIBRE DISPERSE

(Rezumat)

Din cauza timpului pierdut în procesul de legare al etrierilor într-o grindă de beton, cercetătorii din întreaga lume sunt nevoiți să încerce să optimizeze acest procedeu. Cea mai avantajoasă soluție ar fi înlocuirea etrierilor cu armrea dispersă. Prin creşterea rezistenței betonului se pot obține elemente mai ușoare. Prin combinarea fibrelor cu clase de beton superioare, noi soluții structurale pot fi obținute într-un timp mai scurt. În clădirile moderne, conductele de instalații pot reduce foarte mult înalțimea liberă a tuturor nivelurilor construcției, ele fiind acoperite din motiv arhitectural. O soluție pentru această înălțime pierdută este trecerea lor prin grinzile de beton. În urma acestui proces pot interveni o serie de probleme la fabricarea grinzilor. Prin înlocuirea etrierilor convenționali cu armarea dispersă se poate asigura o armare corespunzătoare chiar şi pentru aceste găuri în elemente.