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Ultra-High Performance Fiber Reinforced Concrete: "I" Beams And Prisms Subjected To Bending

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Abstract

In this article the authors will emphasize the influence of the volumetric percent of metallic fibers (2.55% and 1.5%) and the type of used fibers (hybrid or only long fibers) over the ductility of elements that are subjected to bending (beams and prisms). It is known in specific literature that such concrete has a compressive strength higher than 150MPa and a direct tensile strength higher than 5 MPa. During the experimental program were made and tested 8 samples of "I" beams of 1.10 m length(without longitudinal reinforcement) and prisms of 100x100x400mm and 150x150x600mm. All studied elements were subjected during the tests to bending in 4 points with 2 concentrated forces, applied in the middle third part of the sample. After obtaining the results there could have been determined the influence of fiber addition over the bearing capacity.

Rezumat

În acest articol autorii au incercat sa scoata in evidenţă influenţa procentului volumic de fibre metalice (2.55% şi 1.5%) şi a tipului de fibre utilizat (hibride sau numai lungi) asupra capacității portante a elementelor supuse la încovoiere (grinzi și prisme). Se cunoaşte din literature de specialitatea că aceste betoane au o rezistenţă la compresiune mai mare de 150MPa iar rezistenţa la întindere directă trebuie sa fie mai mare de 5MPa. În programul experimental s-au confecţionat şi încercat o serie de 8 grinzi "I" cu lungimea de 1.10m (fără armătură longitudinală), precum și prisme de 100x100x400mm și de 150x150x600mm. Toate elementele studiate au fost testate la încovoiere în 4 puncte cu 2 forţe concentrate aplicate în treimea mijlocie. În urma rezultatelor obtinute s-a putut determina influența adaosului de fibre asupra capacității portante.

Keywords: beams; prisms; compressive strength; UHPFRC; bending; steel fiber.

1. Introduction

The main advantage of this material consist in the highly compressive strength, that overcomes values of 150MPa, and tensile strength value over 5MPa. Because of this characteristics, the cross section of the main elements can be slender and have large spans, for this reason it can lead to decrease of self weight and to a very low consumption of material.

Due to the fact that the tensile strength has a greater value (>5MPa), many times, in the case of prestressed elements there haven't been used passive reinforcement for preventing the element cracking that appear where the prestress force is transferred, and neither the conventional

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reinforcement(consisting in stirrups) for the shear force.

By introducing steel fibers [1] in the matrix of concrete both problems can be resolved. Authors such as Lim[2], Chunxang [3] and Ashur [4] have studied the influence of the type of the used fibers in HSC elements under flexure. RILEM [5] provides specifications regarding the bending test of the fiber reinforced elements.

Besides these qualities, this type of concrete is easier to cast, has improved durability in time and it's impermeable to aggressive agents because of its dense microstructure. High ductility and capacity is obtained due to fibers that represent a link between the faces of a fissure/crack and transmit the bending stress. The most commonly used are steel fibers because of being the best in terms quality price ratio. There were proposed also few designing recommendations from AFGC [6], JSCE [7] and DAfStB [8].

2. Experimental program

The experimental program consisted in production of UHPFRC elements with different volumetric percentages of reinforcing with fibers (1.55 and 2.55%) and different type of fibers (hybrid and long fibers). Fibers used in this study were: long fibers with Lf_2/d_2=25/0.4 and short fibers with Lf_1/d_1=6/0.175 (where Lf_1- fiber length and d_1- fiber diameter) and a yield strength of 2000 (MPa).

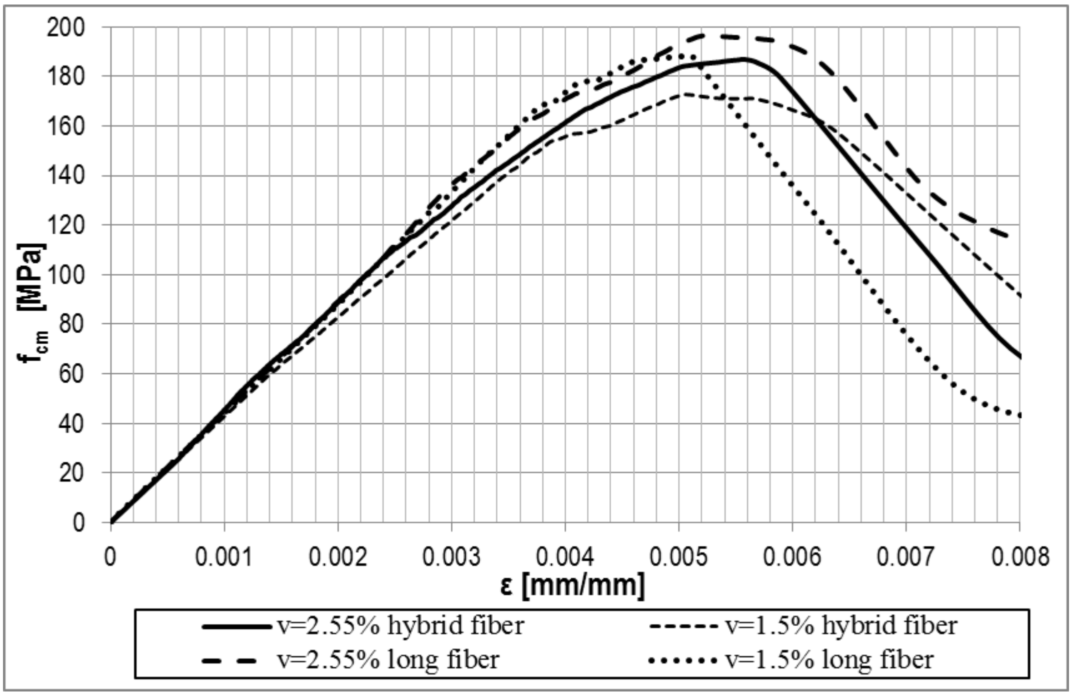

Figure 1. Compressive stress-strain curve (σ-ε) of UHPFRC.

To emphasize the influence of the fiber volume and the used type of fibers there were made and 8 samples of "I" beams of 1.10m length (without longitudinal reinforcement) and prisms of 100x100x400mm and 150x150x600mm. All studied elements were subjected during the tests to bending in 4 points (the applied forces in the middle third, which gave a central constant moment zone). The "I" beams were realized with hybrid fibers (50% long fibers and 50% short fibers) – 4 for each volumetric percent of reinforcement. The prisms were realized with hybrid fibers , and also only with long fibers for each volumetric percent separately. There were executed minimum 6 elements separately for each type of prism, reinforcing percent and type of fibers.

For each volumetric percent of fibers and type of fibers the following physical and mechanical properties were studied: compressive strength on cube samples (50mm,70.1mm,100mm), the modulus of elasticity and the indirect tensile strength by bending on prisms samples of 100x100x300mm. All tests were performed on a fully digitalized loading machine Advantest 9. The stress-strain (σ-ε) curve was determined on cubes with an edge of 100 mm and has a liniar variation almost up to failure Fig. 1. The physical and mechanical properties are presented in Table 1.

Table 1**:** Material properties of UHPFRC

The volumetric percent of fibers "v" [%]	Type of fibers used	Compressive strength f_{cm} [MPa]	Elastic moduls E_c [GPa]
2.55	Hybrid	183	43.7
1.5	Hybrid	173	42.3
2.55	Long	192	46
1.5	Long	188	44.7

In Fig. 2 and 3 is presented the testing mode of the elements: "I" beams and prisms (100x100x400mm and 150x150x600mm).

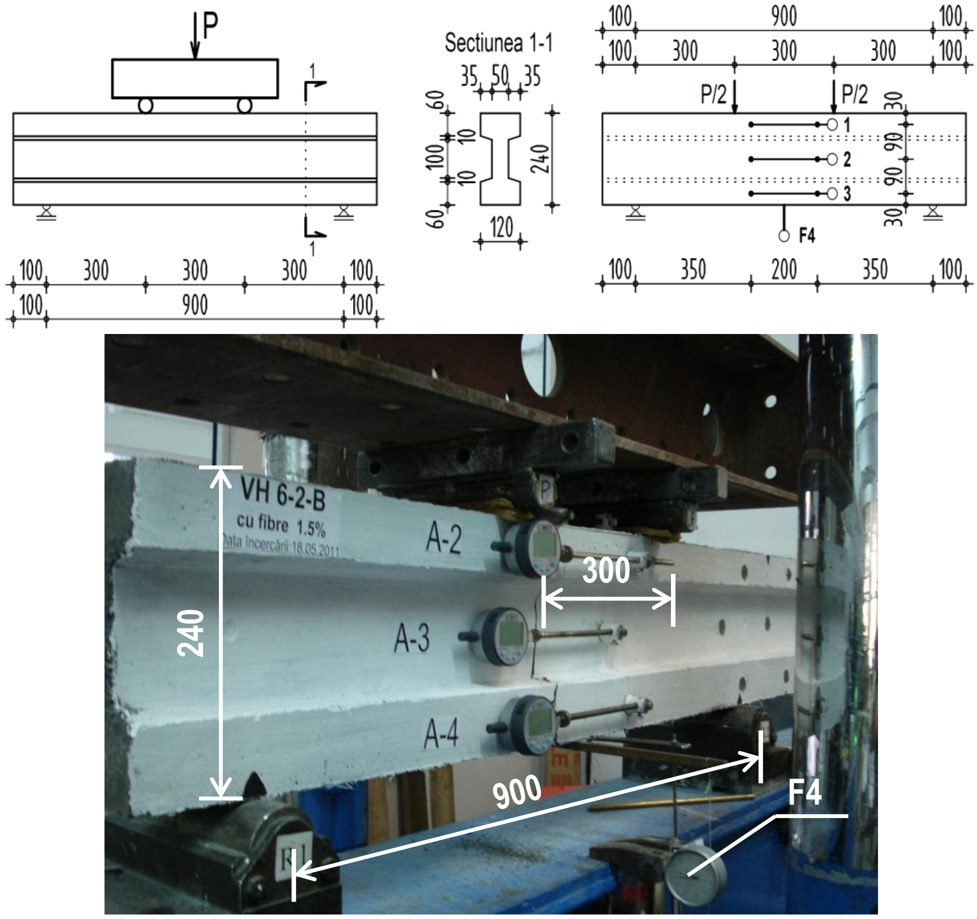

Figure 2. The characteristics of an "I" beams section and the test mode

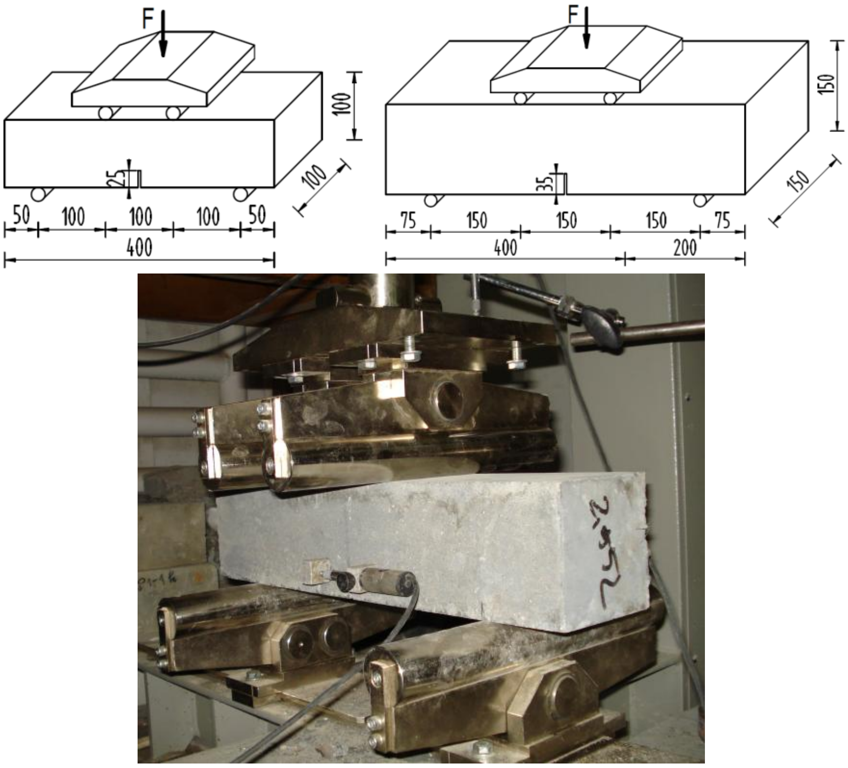

Figure 3. The characteristics of a prism section and the test mode.

3. Result and discussions

3.1. "I" Beams of 120x240x1100mm

In Fig. 4 are presented the experimental medium curves M-Δ (moment-deflection) resulted for the "I" beams of 1.10m length, for each volumetric percent of disperse reinforcement. (1.5% and 2.55%).

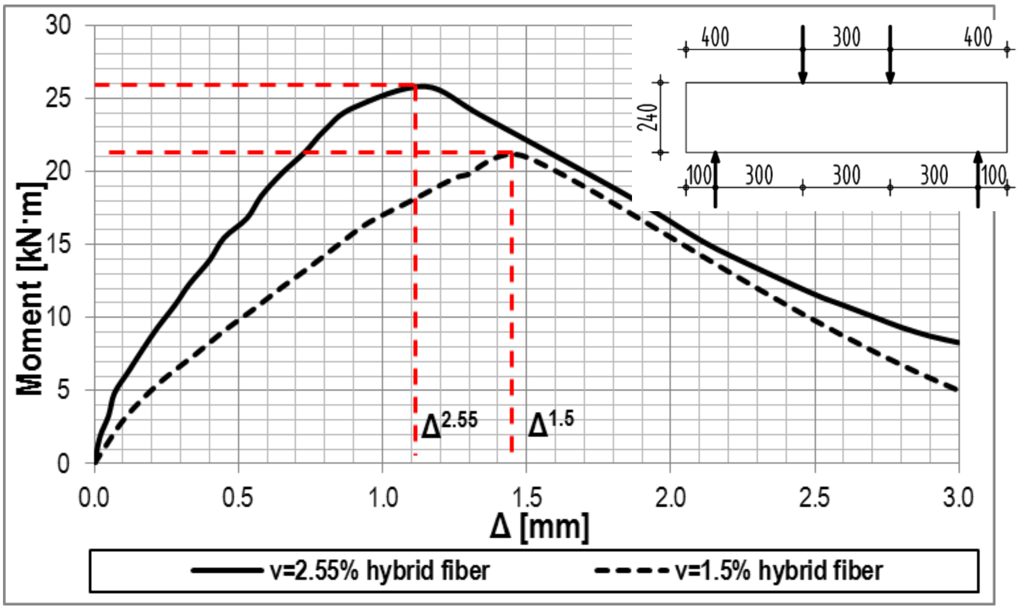

Figure 3. Characteristic curves M-Δ (moment-deflection) for "I" beams

It is observed that in the case of the elements reinforced with a volumetric percent of 2.55% hybrid fibers, the value of the breaking moment has an increase of 18%, related to the elements reinforced with a volumetric percent of hybrid fibers of 1.5%.
In what concerns the deformability of the elements, there can be distinguished the following:

- In the case of elements having v=2.55% hybrid fibers, the deformation $\Delta^{2.55}$ related to the breaking moment is decreased by approximately 28%, over the moment of the elements reinforced with a volumetric percent of hybrid fibers of v=1.5% and deformation $\Delta^{1.5}$.
- As in the case of reinforced concrete elements, the elements with smaller reinforcement percentage have a larger deformability from the other ones with a larger reinforcement percentage

3.2. Prisms of 150x150x600mm

In the case of prisms of 150x150x600mm disperse reinforced with a volumetric percent of 2.55% hybrid fibers the ultimate bending moment (M_u=6.35kN·m) has an increase of 39% over the prisms made with a volumetric percent of 1.5% fibers (M_u=4.58kN·m).
In the case of prisms of 150x150x600mm disperse reinforced with a volumetric percent of 2.55% long hybrid fibers the ultimate bending moment (M_u=7.39kN·m) has an increase of 55% over the prisms made with a volumetric percent of 1.5% fibers (M_u=4.74N·m). (Fig. 4)

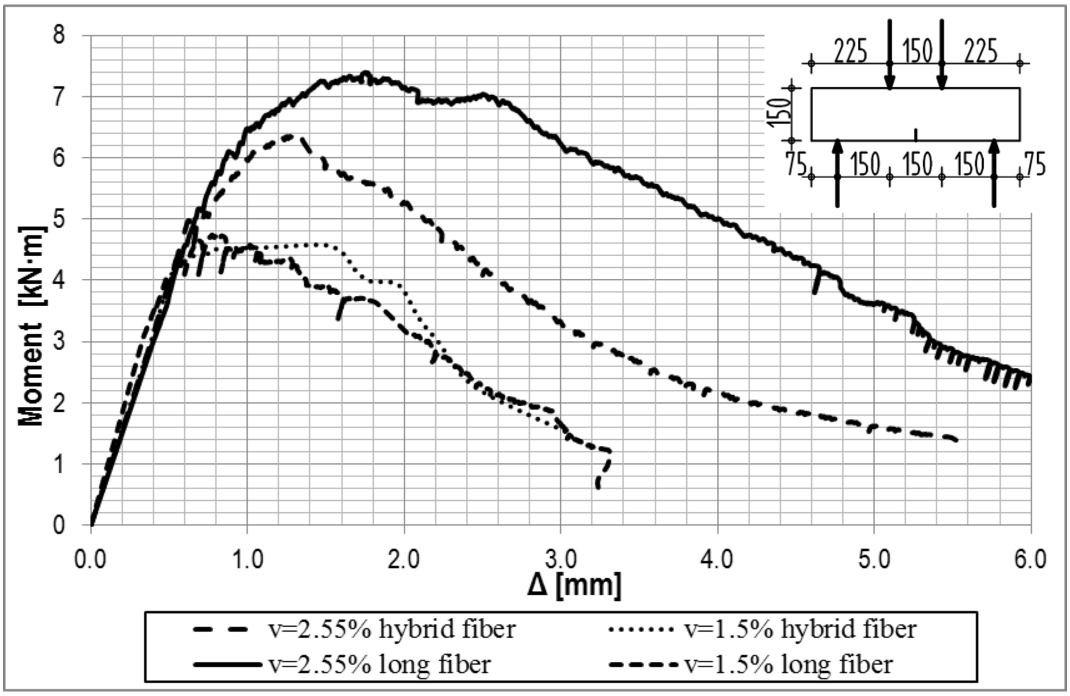

Figure 4. Characteristic curves M-Δ (moment-deflection) – prisms 150x150x600mm

3.3. Prisms of 100x100x400mm

In the case of prisms of 100x100x400mm disperse reinforced with a volumetric percent of 2.55% hybrid fibers the ultimate bending moment (M_u=2.14kN·m) has an increase of 2.7% over the prisms made with a volumetric percent of 1.5% fibers (M_u=2.04kN·m).
In the case of prisms of 100x100x400mm disperse reinforced with a volumetric percent of 2.55% long hybrid fibers the ultimate bending moment (M_u=2.33kN·m) has an increase of 16 ver the

prisms made with a volumetric percent of 1.5% fibers (M_u=2.06kN·m). (Fig. 5)

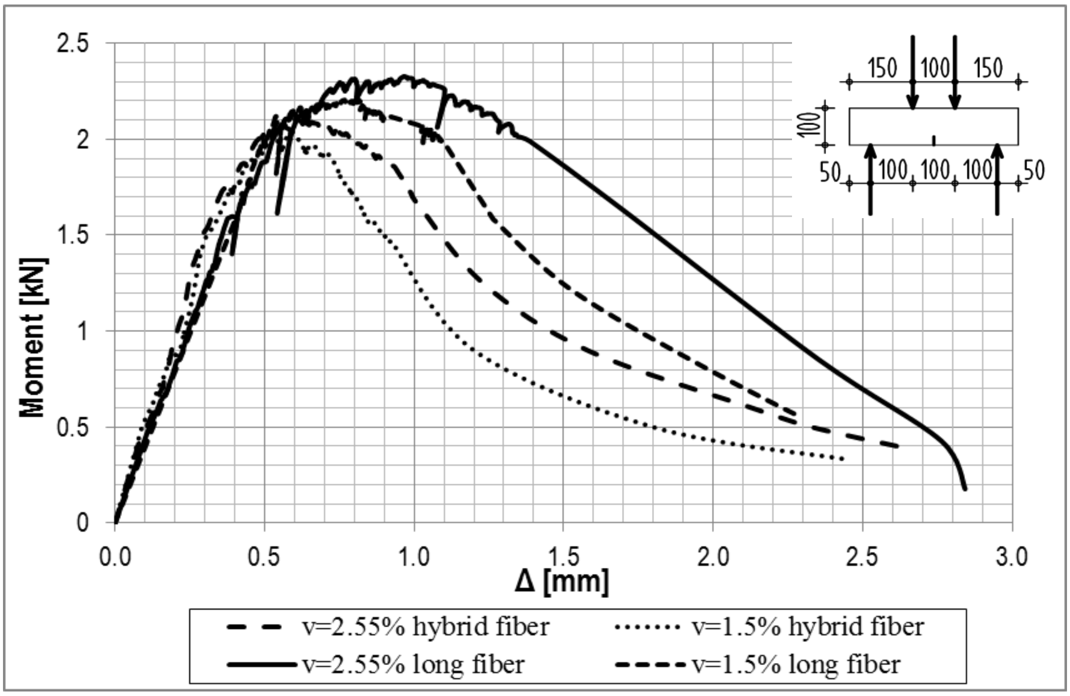

Figure 5. Characteristic curves M-Δ (moment-deflection) – prisms 100x100x400mm

4. Conclusion

The experimental testings have shown a very good behaviour during the service of the bended elements made of UHPFRC.

In the case of disperse hybrid fibers or long hybrid fibers reinforcement, the deformability of the concrete increases in tensile actions. From the performed study it can be noticed a better behaviour of the elements disperse reinforced with long fibers than the ones reinforced with hybrid fibers. Along with the increase of the volumetric percentage of fibers, the risk of fiber congestion appears, which leads to the non-homogenity of the material.

Because of the high tensile strength resistance (regarding regular concretes) of the concrete matrix, the use of the shear reinforcement is not compulsory. The use of this material is recommended to the structures situated in active seismic zones. Because of the physico-mechanical characteristics, the main structures made of UHPFRC are much slender, in this way the self weight and the total cost of the structure decrease.

5. Acknoledgments

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