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ULTRA HIGH PERFORMANCE FIBER REINFORCED CONCRETE "I" BEAMS SUBJECTED TO SHEAR ACTION

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(Technical Note)

Abstract

In the last decade UHPC are used increasingly to fulfill the requirements of sustainable slender structures and seismic behavior. The addition of steel fibers in a reinforced concrete beam is known to increase its shear capacity and, if sufficient fibers are added, a brittle shear failure can be suppressed in favor of a more ductile behavior.This papper presents the advantage of using mixed long and short steel fibers over long steel fibers in ultra high performance concrete (UHPC) beams subjected to shear action in terms of deformations and ultimate shear force applied. We studied two fiber mixes (CL – beams reinforced with long steel fibers and CH – beams reinforced with hybrid fibers: 50% long steel fibers + 50% short steel fibers) for three different fiber percentages by volume (1.5%, 2.0% and 2.55%) for each fiber mix mentioned.The use of hybrid steel fibers in the UHPC beams proves to be more advantageos regarding the ultimate force applied and deformations, compared to beams reinforced with only long steel fibers, for all three fiber percentage by volume studied.

Rezumat

În ultimul deceniu, betoanele de ultra înaltă rezistență sunt folosite tot mai frecvent în cazul structurilor zvelte și în zonele cu seismicitate ridicată. În cazul grinzilor, adaosul de fibre de oțel crește rezistența acesteia la forfecare și evită cedarea casantă, oferind grinzii un comportament ductil.În această lucrare se prezintă avantajul utilizării armării hibride comparativ cu armarea cu fibre lungi în cazul grinzilor realizate cu betoanelor de ultra înaltă rezistență (BUIR) și supuse acțiunii forței tăietoare. Au fost studiate doua amestecuri (CL – grinzi armate numai cu fibre lungi și CH – grinzi armate cu fibre hibride: 50% fibre lungi și 50% fibre scurte) și trei procente volumice de armare cu fibre (1.5%, 2.0% and 2.55%) pentru fiecare dintre amestecurile prezentate anterior.Folosirea fibrelor hibride, în cazul grinzilor realizate din BUIR și supuse acțiunii forței tăietoare, s-a dovedit a fi mai avantajoasă în ceea ce privește forța ultima și deformațiile, comparativ cu armarea cu fibre lungi, pentru toate cele trei procente volumice studiate.

Keywords: steel, fiber, reinforced, performance, concrete, shear

1. Introduction:

Ultra high performance concrete is a new material that enhances all properties of normal and high performance concrete due to the composition and the curing treatment applied. Those factors

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increase both phisical and mechanical properties of concrete. Due to its unique properties, UHPC gives architects the posibility to create slimmer structures with bigger spans making it therefore a very atractive material.

UHPC uses steel fibers that have a major effect in the material behavior. Because the concrete bounds so well to the fibers the mix improves its behavior in tension and bending. Fibers also help resist shear, so that traditional steel shear reinforcements is unnecessary. Although primary failure in tension is still attributed to matrix cracking, it is not brittle, since the fibers assume the load and strain. Results show a more ductile behavior compared to the standard concrete and that makes UHPC a very good material for structures with high performance requirements.

2. Experimental program

The main variables studied in the experimental program were the type of fibers used and the influence of steel fiber percentage by volume on I beams subjected to shear action. This paper will show the results obtained on beams subjected to shear action by using 2 different fiber mixes and 3 different steel fiber percentages by volume for each fiber mix.

The beams have an "I" cross section as shown in Fig. 1. Longitudinal reinforcement is presented in Fig. 2:

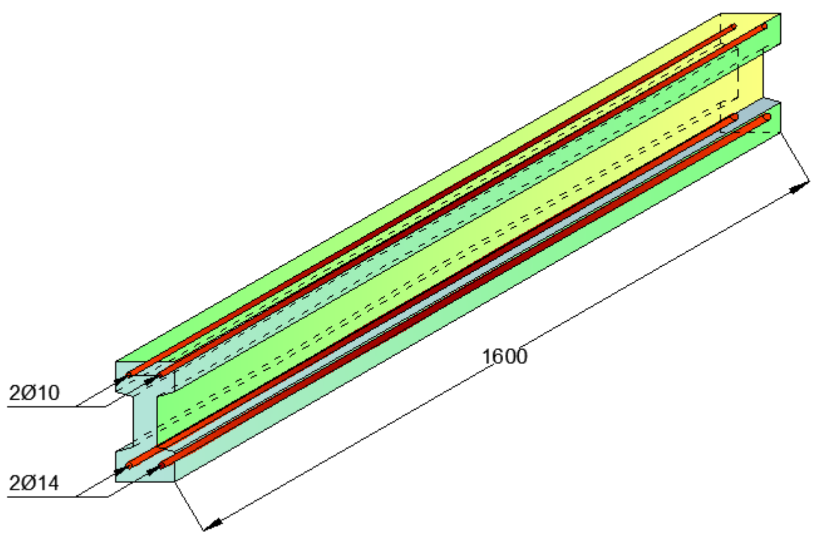

Fig.1 – General view - geometrical characteristics;

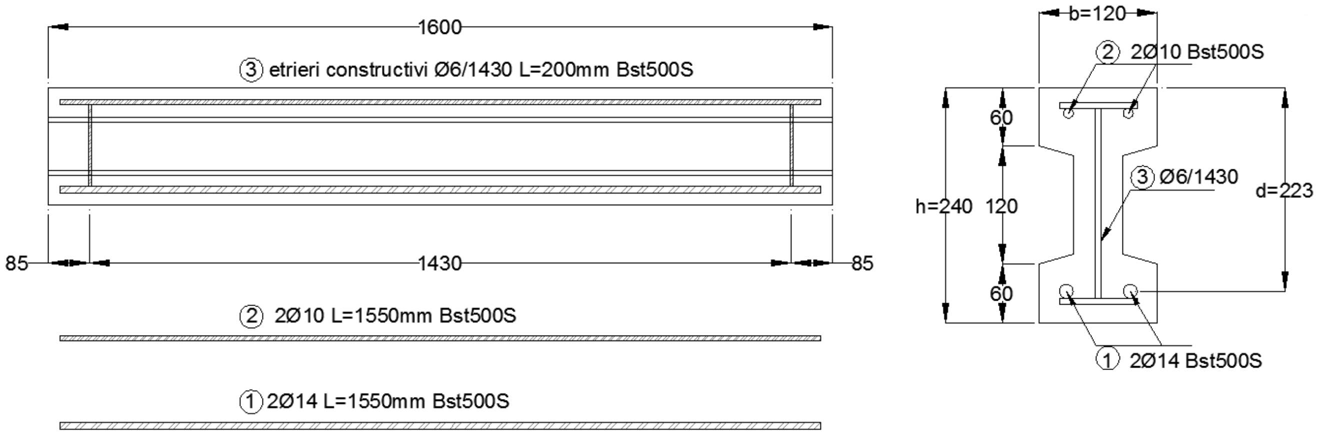

Fig. 2 - Reinforcement layout and geometric characteristics for ultra-high performance fiber reinforced concrete beam.

Testing equipment consisted of digital strain gauges with a precision of 0,001 mm (1,2,3) placed on the diagonal line in-between the support A and the application point of force V, measuring strains in real time. Deformations along the beam were measured in 3 points: F1, F2 and F3 with deformeters having a precision of 0.1 mm as shown in Fig. 3.

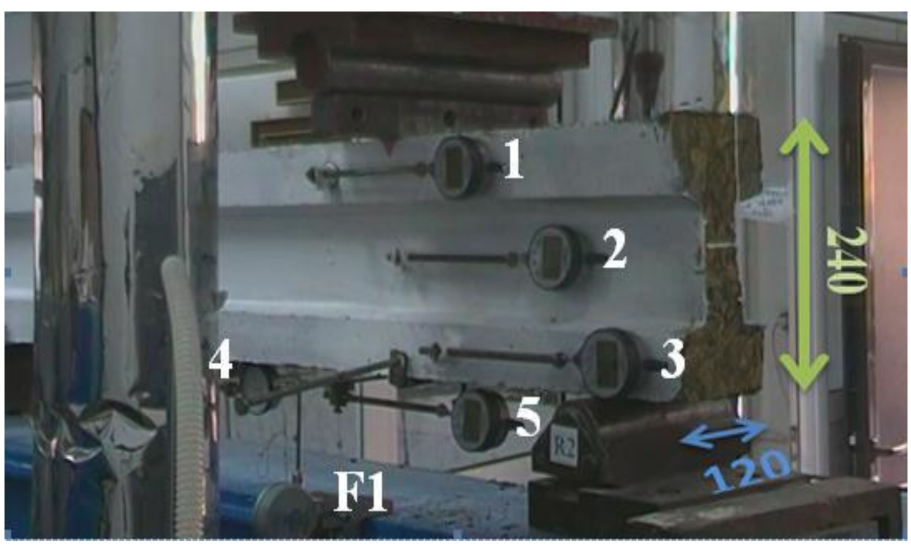

Fig. 3 – testing equipment: 1,2,3→ digital strain gauges; 4,5→ digital strain gauges measuring reinforcement deformation; F1→ deformeter for measuring Δ deformations.

The beams were subjected to shear force for a shear ratio a/d = 1.25.

Results are presented in table 1 and fig. 4, 5 and 6.

Table 1. – Maximum force and failure type

Element	$V_{U,medium}$[kN]	Failure type
CH 1-1 → 2.55% hybrid fibers	252.45	Bending moment + shear
CH 1-2 → 2.55% hybrid fibers		Bending moment + shear
CH 2-1 → 2.0% hybrid fibers	230.15	Bending moment + shear
CH 2-2 → 2.0% hybrid fibers		Bending moment + shear
CH 3-1 → 1.5% hybrid fibers	185	Shear
CH 3-2 → 1.5% hybrid fibers		Shear
CL 1-1 → 2.55% long fibers	234	Bending moment + shear
CL 1-2 → 2.55% long fibers		Bending moment + shear
CL 2-1 → 2.0% long fibers	200.1	Bending moment + shear
CL 2-2 → 2.0% long fibers		Bending moment + shear
CL 3-1 → 1.5% long fibers	160.2	Shear
CL 3-2 → 1.5% long fibers		Shear

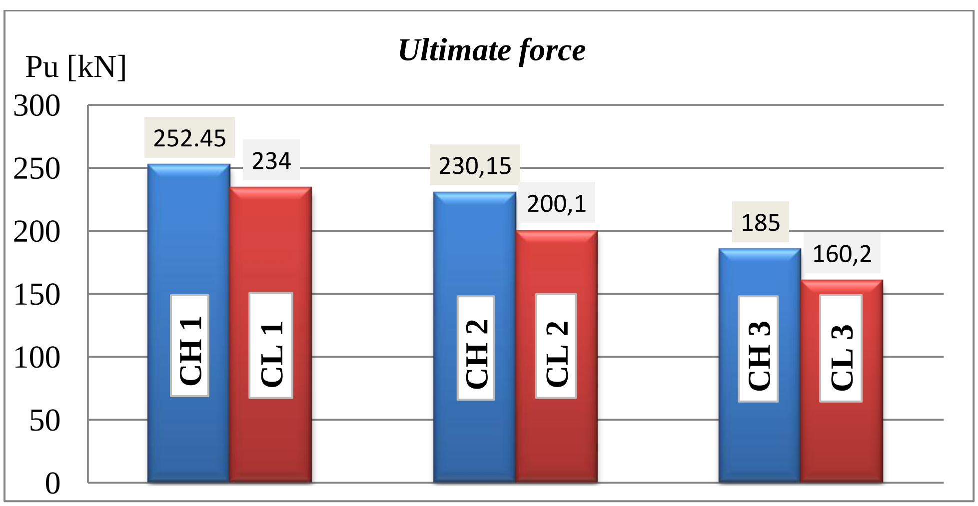

Fig. 4 – Ultimate force for both types of fiber mix studied and for each fiber percentage by volume.

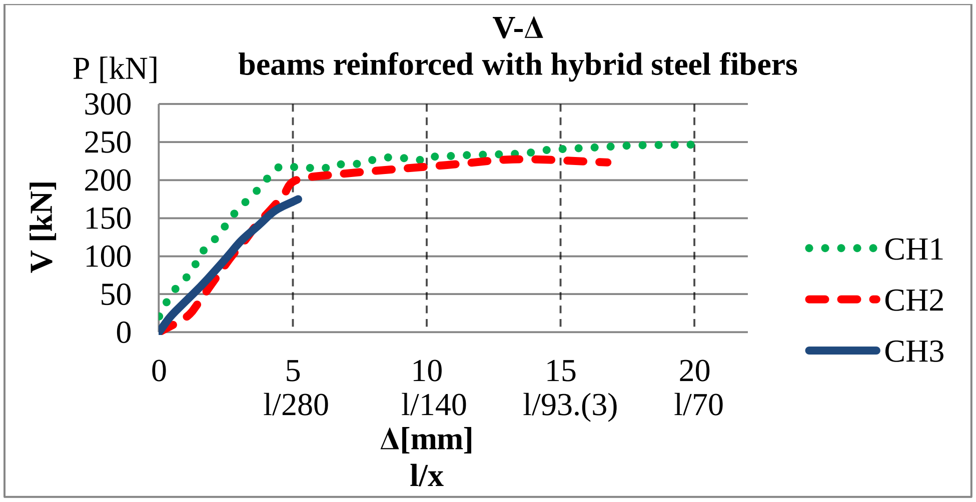

Fig. 5 – Force-deformation diagram for beams reinforced with hybrid steel fibers.

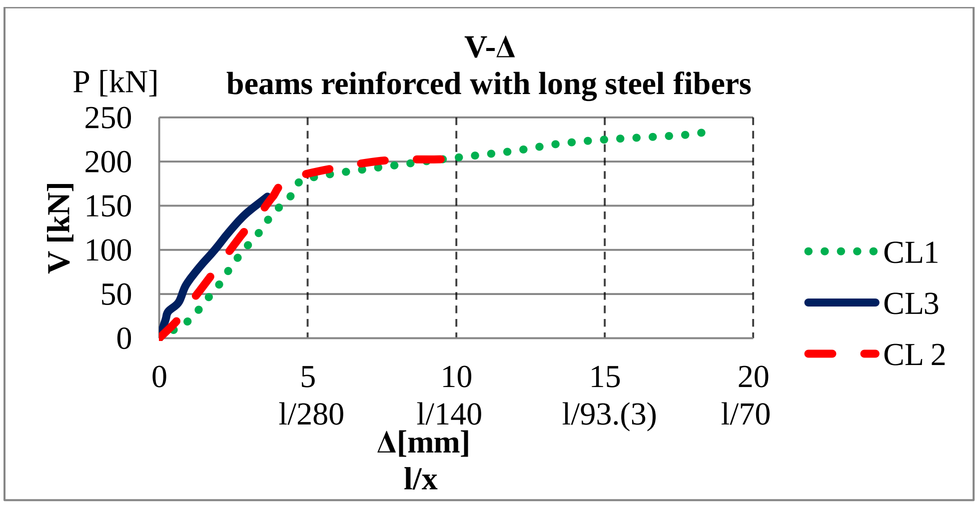

Fig. 5 – Force-deformation diagram for beams reinforced with long steel fibers.

3. Conclusions

By analyzing table 1 and fig. 4, 5 and 6 it can be said that:

- The ultimate force value is decreasing with the decrease of fiber percentage by volume;
- Beams reinforced with hybrid steel fibers show a better behavior than beams reinforced with long steel fibers in terms of the ultimate force for every fiber percentage by volume studied;
- After analysis of the failure mode for each beam we can say that it is related to fiber percentage by volume. Beams reinforced with a fiber percentage by volume of 2.55% and 2.0% failed by combined action of the bending moment and shear and beams with 1.5% failed from shear. The conclusion drawn from this fact is that steel fibers play a key role in beams subjected to shear action;

- Beams reinforced with a fiber percentage by volume of 2.0% have an increase of 25.4% of the failure force compared with beams reinforced with a fiber percentage by volume of 1.5%;
- Beams reinforced with a fiber percentage by volume of 2.55% have an increase of 36.5% of failure force compared with beams reinforced with a fiber percentage by volume of 1.5%;
- By analyzing fig. 5 and 6 we notice the increase of deformations with the increase of fiber percentage by volume and also we notice a ductile behavior on beams reinforced with a fiber percentage by volume ≥2.0% compared with beams reinforced with a fiber percentage by volume of 1.5% which had an unaware failure;
- Hybrid steel fiber reinforcement has a better deformation behavior compared to long steel fiber reinforcement.

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