3rd International Conference
"Advanced Composite Materials Engineering "
COMAT 2010
27- 29 October 2010, Brasov, Romania

LONG-TERM PERFORMANCE OF HIGH-STRENGTH CONCRETE BEAMS WITH AND WITHOUT REINFORCED FIBERS

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Abstract: *The present paper presents experimental research regarding the behavior of high-strength concrete beams under long-term bending. The beams containing 2 per cent steel fiber addition were compared to the beams without fibers. All the beams were subjected to service life long term flexural loading during 5 years. The aim of the study was to analyze the time behavior of the beams in terms of deformations.*
Keywords: *high-strength concrete, beams, fibers, long-term behavior*

1. INTRODUCTION

In recent times, high strength concrete and steel have been used widely in construction. As a result, beams of smaller depths and bigger span were designed, which may be subjected to greater deflections [1]. In the design of concrete structures, deflection is an important serviceability limit state to be satisfied. Assuming that for elements subjected to tension, compression, torsion, bending or shear force, the crack formation is practically inevitable, the present norms like SR EN 1992-1-1:2004 [2] are seeking mostly to limit this phenomenon to values that do not affect the behavior of the element or structure during service life in a significant manner [3]. The cost of limiting crack widths has to be taken into account in relation to concrete strength and the reinforcement yield point. For high strength concrete elements cracking phenomenon at early ages is an important issue [4], [5], [6], [7]. The purpose of the experimental study was to find out the importance of fiber reinforcement upon high strength concrete elements.

2. CONCRETE COMPOSITION

The concrete composition is presented in Table 1. The high strength concrete contains silica fume 10% of the cement quantity. The water / binder (W / B) ratio is 0.27, where the total amount of binder contains both the cement and silica fume. The experimental study's variable parameter was the quantity of added fiber as shown in Table 2.

Table 1: High strength concrete composition

Components	Quantity for FT 5 1-2	Quantity for FT 5 2-2
Portland cement CEM I 52.5R	520 kg/m^3	520 kg/m^3
Silica fume	52 kg/m^3	52 kg/m^3
Sand (8 - 16 mm)	706 kg/m^3	706 kg/m^3
Gravel (4 – 8 mm)	530 kg/m^3	530 kg/m^3
Gravel (0 - 4 mm)	530 kg/m^3	530 kg/m^3
Water	152 l/m^3	152 l/m^3
Superplasticizer Glenium ACE 30-BASF	13.5 l/m^3	13.5 l/m^3
Steel fibers	55 kg/m^3	-

W/C	0.29	0.29
W/B	0.27	0.27

Table 2: The identification of the elements tested

Element ID	Element dimensions	f_{cm}	Significance
FT 5 1-2	125 mm X 250 mm	78 MPa	Without steel fibers addition
FT 5 2-2	125 mm X 250 mm	91 MPa	With 2% steel fibers addition

The physical – mechanical properties of the high strength concrete were determined at the age of 28 days on cube and prismatic specimens cast from the same batch as the reinforced concrete elements. The compressive stength f_{cm} determined at the age of 28 days on 150x150x150mm cubes without fiber reinforcement addition was 78 MPa and 91MPa for the elements with 2% steel fibers addition.

2. ELEMENTS DETAILING

The experimental program was conducted on rectangular beams with a cross section of 125x250mm, a length of 3200mm and a clear span of 3000mm.The reinforcement of the elements is presented in Figure 1. The concrete cover of the presented elements is c = 25 mm. The longitudinal reinforcement is 2Φ14 PC52, a locally produced steel having the characteristic yield strength f_{yk} = 355 MPa and 345MPa characteristic yield strength for 1Φ16 PC52 steel. The llongitudinal reinforcement coefficient was 2.061%. The reinforcement steel for the upper part of the beams and for the transversal reinforcement (stirrups) is OB37, with a characteristic yield strength f_{yk} = 255 MPa. The distance between stirrups was 300mm. All the elements were designed for equivalent bending capacity.

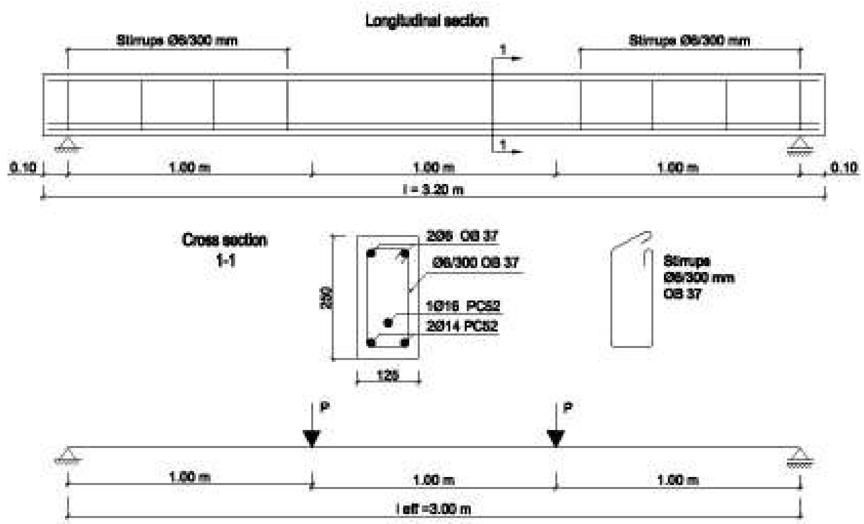

Figure 1: Longitudinal and cross section – reinforcement

A concrete mixer was used to produce the concrete admixture. A concrete vibrator was used to compact the concrete admixture in the mould. As a curing process all the beams were kept in a wet environment for 28 days. After the curing, the beams were subjected to four points load (Figure 1). The testing system was a hydraulic press of 3000kN maximum load. Two equal concentrated loads were applied at 1/3 of the clear span length l_{eff} = 3000 mm for all the beams. The static scheme was of a simply supported beam. Figure 2 presents the set-up test of the elements.

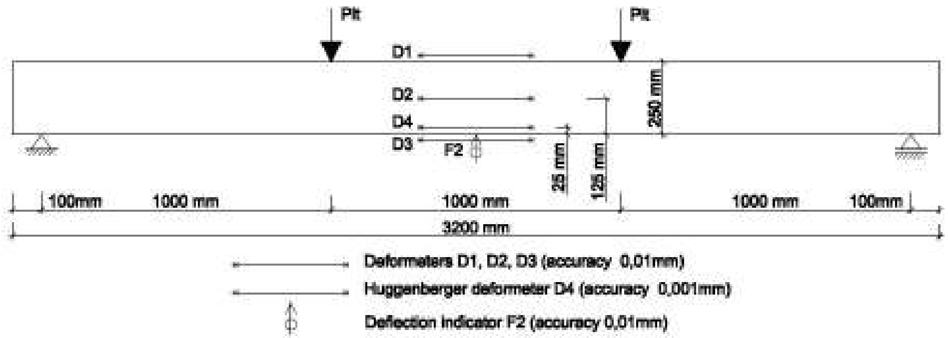

Figure 2: Test set-up

Two elements with the same geometry were subjected to short term loading. The long term loading, P_{lt}, represents 40% of the failure load: $P_{lt} / P_u = 0.40$, which consisted in a 5 years loading of $2 \cdot P_{lt} = 2 \cdot 2500N = 5000N$ for all the beams. The elements FT 5 1-2 and FT 5 2-2 subjected to long term loading were monitored to the age of 5 years.

The experimental program was conducted considering the high strength concrete class and the environmental conditions as constant parameters. After loading at 40% of the ultimate bending moment, the behavior of the beams was monitored in an environmental chamber (Figure 3), equipped with a controlling system, where the temperature was kept around 20 ºC ± 2 ºC and 60 % ± 5 % the relative humidity.

Figure 3: Environmental chamber used for storage of specimens

3. EXPERIMENTAL RESULTS

The concrete maximum strain is recorded at mid-span where strain gauges are placed on one of the beam sides in the tensile zone. Beams are subjected to a growing monotonically increasing load until failure. Each step of the applied load is equal to 1/10 of the calculated failure force. For each load increment applied on the beam the deflections at mid-span were recorded.

The following items were taken into consideration while recording the observations regarding the behavior of high strength concrete beams with and without reinforced fibers

- Load increment and ultimate load
- Strain reading
- Deflection at mid span length.

At the level of loading of $P_{lt}/P_u = 0.40$, the instantaneous deflection was Δ_i=4,57mm for FT 5 1-2 and Δ_i=5,45mm for FT 5 2-2 which represents 1/550 of the clear span l_{eff}=3000mm. The development of long term deflections until the age of 5 year shows an attenuation of the phenomenon after 210 days from the application of long term loading, as shown in Figure 4. At this time the deflection recorded was Δ=9,09mm for FT 5 1-2 and Δ=9,21mm for FT 5 2-2. After 4 years of monitoring the beams, the total deflection was 9,36mm for FT 5 1-2 and 9, 99 mm for FT 5 2-2.

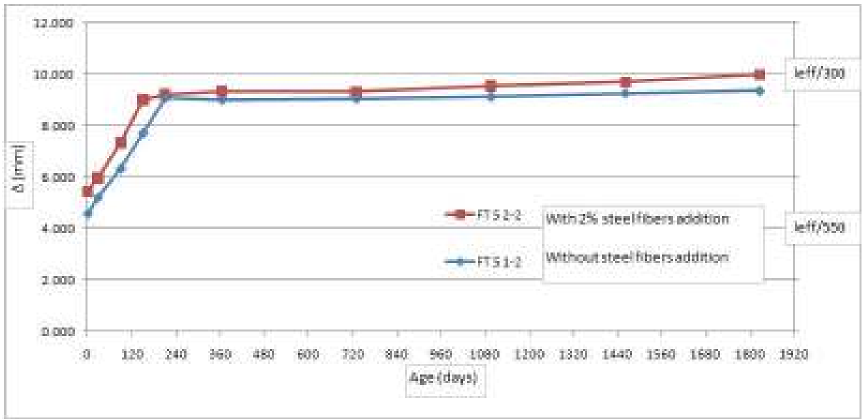

Figure 4: Time development of long-term deflections

Regarding the cracking of concrete elements, the study reveals a discrepancy between the behaviors of fiber reinforced elements to those without steel fiber addition. Therefore, without adding steel fibers, the elements had at the time of loading with long-term loads a number of 22 cracks and after five years of long-term loading, the cracks reached number 30. The beams made with addition of 2% steel fibers had at loading moment 20 cracks and after five years of subjecting the elements at long term loading the crack's number increased to 24.

4. CONCLUSIONS

The analysis of the results presented about high strength concrete elements subjected for 5 years to long term bending moment of 40% from the ultimate bending moment shows that deformations are around Δ_{lt}=9,99mm, which means l/300. The deformations depreciation took place after 210 days from the instantaneous load. The experimental results presented in this study show that the addition of steel fibers had a favorable influence on the behavior of bent elements subjected to short and long term loading.

ACKNOLDEGMENTS

Paper prepared for the Project "Doctoral studies in engineering science in order to develop a society based on knowledge - SIDOC", Contract POSDRU/88/1.5/S/60078, with the aid of a type A research grant, code CNCSIS 1036 « High Strength/High Performance Concrete with Steel and Carbon Fibers, and Rubber Powder.The Behavior in seismic areas, aggressive environments, dynamic and wear actions. Environmental Ecology », director grants Cornelia Măgureanu, Professor and Ph.D.

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