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THE EFFECT OF WRAPPING WITH CFRP TECHNIQUE ON CONCRETE RE-ENFORCED BEAMS

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Abstract: The use of fiber reinforced polymers (FRP) is becoming a widely accepted solution for the strengthening of reinforced concrete structures. This paper presents an experimental research on flexural behavior of carbon fiber reinforced beams. The experimental work consisted of testing to failure of four simply supported beams with rectangular cross section. One was the controlled beam and the other three were wrapped with carbon sheet. Three different wrapping techniques, U-, L- and X-wrappings were examined. We present the results of the experimental program and conclude with a discussion.

Key words: Structures, innovative materials, concrete beam, carbon fiber reinforced polymer (CFRP), consolidation, externally bonded reinforcement, wrapped.

1. INTRODUCTION

Strengthening RC beams with externally bonded fiber reinforced polymer (FRP) composite is one of the techniques developed in recent years. High strength carbon, glass and aramid composites are being promoted as an alternative to steel plates. The major advantages in using fiber reinforced polymer composites are: lightweight, high strength, corrosion resistance and the ease of application. Since 1980 many researchers studied the behavior of strengthened beams with composite materials subject to concentrated or uniformly distributed loads. This paper presents the results of a laboratory experiment performed, in order to determine the influence that the application of carbon fiber material has on beams required to a concentrated force applied at the middle opening.

2. EXPERIMENTAL PROGRAM

The experimental program consisted of testing to failure of 4 simply supported beams, G1, G2, G3, and G4 with rectangular cross section (150 x 200 mm). In the experiment, carbon fiber reinforced polymer (CFRP) was applied to strengthen 3 reinforced concrete beam but one of them (G1) remained the controlled beam. Three different wrapping schemes, U-, L-, X -wrappings were examined. After wrapping, all beams were tested to failure under three-point bending. Each component of the system: the concrete, the steel reinforcement, the wrapping material and the applied technology was studied to observe how exactly they can affect the reinforced beams under load.

The entire experiment took place in COBCO Laboratory in Brasov. Specialized and qualified staff made the concrete reinforced beams and after 28 days they completed the wrapping system with carbon material.

The loading application device was composed of: two under-circular metal rollers at both ends and a middle span upper roller supported by a transverse articulated arm. Loading was applied without shock and increased continuously until the beam could not support a higher load. Figure 1 presents the load application device used in the experiment.

Fig.1. Beam loading equipment

2.1. Cross section, reinforcing details, loading method and wrapping schemes.

The dimension of the beam cross section and reinforcement detailing are shown in figure 2: the longitudinal tension bar consisted of 2 OB 37 bars of Ø 6 mm and the longitudinal compression bar consisted of 2 PC52 bars of Ø 8 mm.The transverse stirrups consisted of OB37-Ø 4 spaced at 40 mm from center to center.

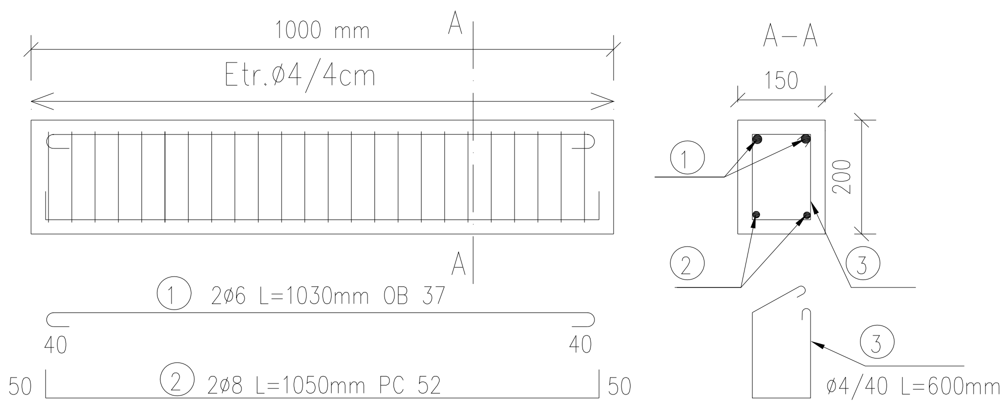

Fig.2. Cross section and reinforcement detailing of beam specimen.

The four beams were divided as follows:

- first concrete beam noted G1, etalon beam, figure 3A;
- the second beam noted G2 is represented by a concrete beam U-wrapped with carbon sheets disposed by an angle of 90º, figure 3B;
- the third beam noted G3 is represented by a concrete beam L-wrapped with carbon sheets disposed by an angle of 45º, figure 3C;
- the fourth beam noted G4 is represented by a concrete beam X-wrapped with carbon sheets disposed by an angle of ± 45º,figure 3D;

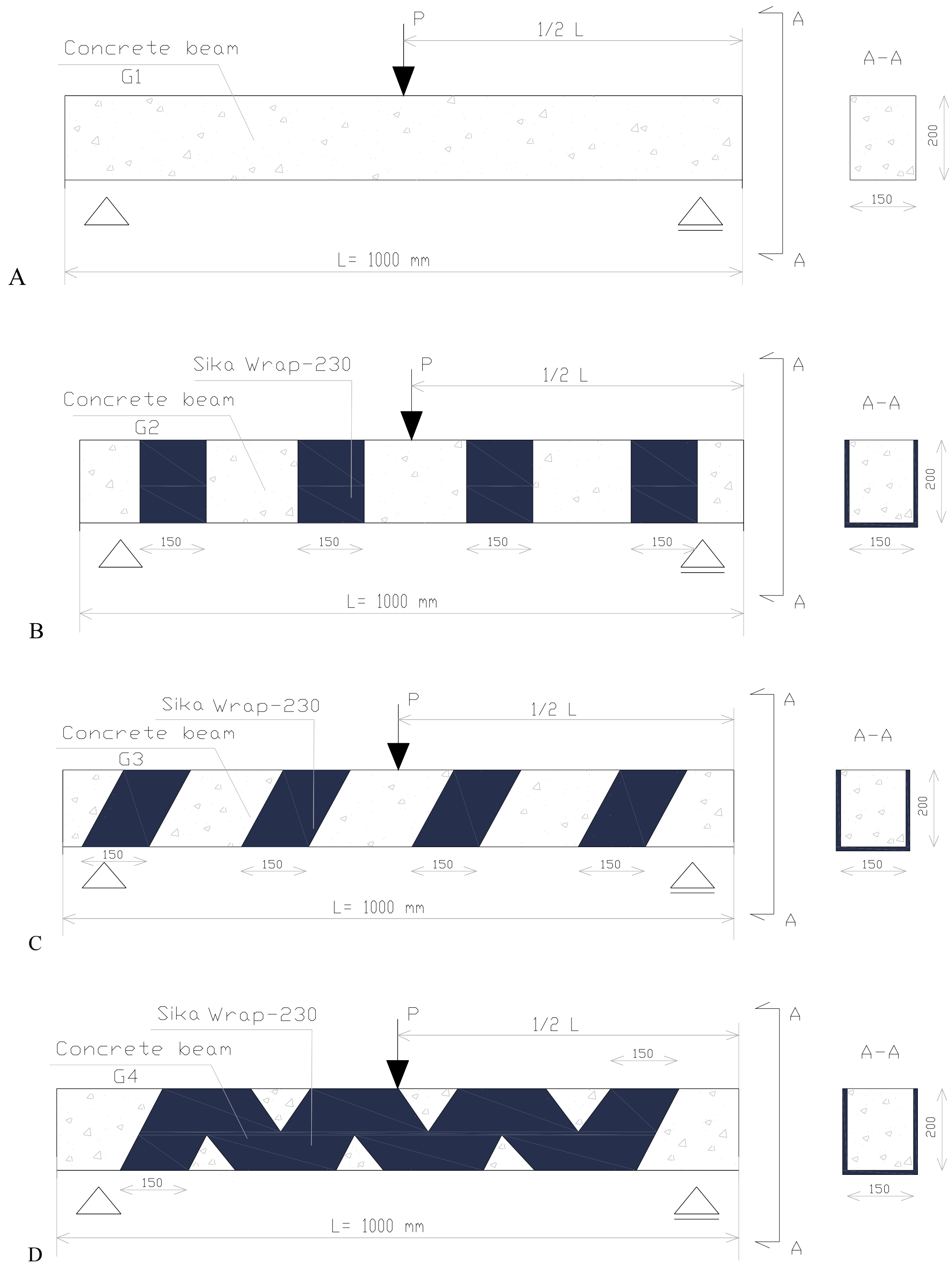

Fig.3. Detail of wrapped beams.

2.2. Material properties.

The 4 heavy concrete beams type of regular class C16/20 were obtained in laboratory under CP112-2008. SikaWrap-230C represents a carbon fiber woven fabric, unidirectional and dry, specific to the dry application process. In the following tables, table 1 and table 2, we present the properties of the carbon material and the adhesive we used.

Table1. SikaWrap-230C

Tensile strength (MPa)	Elastic modulus (Mpa)	Thickness (mm)	Fracturing strain (%)
3500	230 000	0.13	1.5

Table 2. SikaDur-330C adhesive

Compresion strength (N/ mm ^{2})	Elastic modulus (N/ mm ^{2})	Thickness (mm)	Fracturing strain (%)
30	4500	≤ 1	0.9

On a properly prepared concrete surface the adhesion force between concrete and carbon material is greater than that of concrete 4 N/ mm ^{2}, so a failure of the concrete will be expected.

2.3. The technology of wrapping.

Before applying the carbon sheets on the concrete beams, their surface must be cleaned of any traces of grease with a nitro solvent, and the irregularities of the concrete with a wire brush for smaller areas or using air or water pressure for larger areas. The surface must not contain irregularities higher than 0.5 mm. The edges of concrete beams were polished with a stone disk because the radius required for application around corners is minimum 20 mm.

We used adhesive type SikaDur-330 and the two components A and B were mixed in a ratio of 4:1. Because the usability of the adhesive is max 30 minutes, to avoid loss of quality, we prepared an adhesive portion for each beam.

2.4. Loading method.

The loading method for each beam followed precisely the schemes presented above. For each beam we started with a force P equal to zero and continually increased load until failure. During loading the beams were carefully monitored at each loading step. While testing the beams we noted and compared the first crack point, the open crack under loading, and the general appearance of the beams and sheets. All the results for testing G2, G3, and G4 were compared with the results of G1. At the end, the results were centralized and analyzed in order to find out how layout of sheets can affect the behavior of the beams.

2.5. Experimental results and conclusion.

Under loading, the behavior of beams was influenced by the orientation of the carbon material. The best results were register for beam G2 when they were applied parallel to the loading force positioned along the fiber.

Table 3 presents the results noted for load P during the occurrence of the first cracks for each beam tested. If you compare the results recorded for all beams between them, you will observe that an increase occurred for the appearing of first crack points with 70% for beam U-wrapped (90°) and 34% for beam L-wrapped (45°) and X-wrapped (± 45°).Table 3.

After the wrapping of the beams, the final load (P) increased and the layout of composite materials had a significant role. After we centralised the results, the principal conclusions are: the results for the wrapping under an angle of 90° (U-wrapped) parallel with the loading force(G2), were 29% better than the etalon beam, and for the 45° (L-wrapped) and ± 45° (X-wrapped) the results were increase with 15% .Table 4.

Table 3. The value of load P at the moment of first crack points.

Detail of wrapping beams						
No.	Beam type	U-wrapped 90°	L-wrapped 45°	L-wrapped ± 45°	Load P (N)	Increasing register
1	G1	-	-	-	23.500	-
2	G2	90°			40.000	~ 70%
3	G3		45°		32.500	~ 35%
4	G4			± 45°	31.000	~ 33%

Table 4. The value of final load P and the deformation of the beam.

Detail of wrapping beams						
No.	Beam type	U-wrapped 90°	L-wrapped 45°	L-wrapped ± 45°	Final load, P (N)	Deformation of the beam
1	G1	-	-	-	39.500	13 mm
2	G2	90°			51.000	8 mm
3	G3		45°		45.500	5 mm
4	G4			± 45°	45.250	7 mm

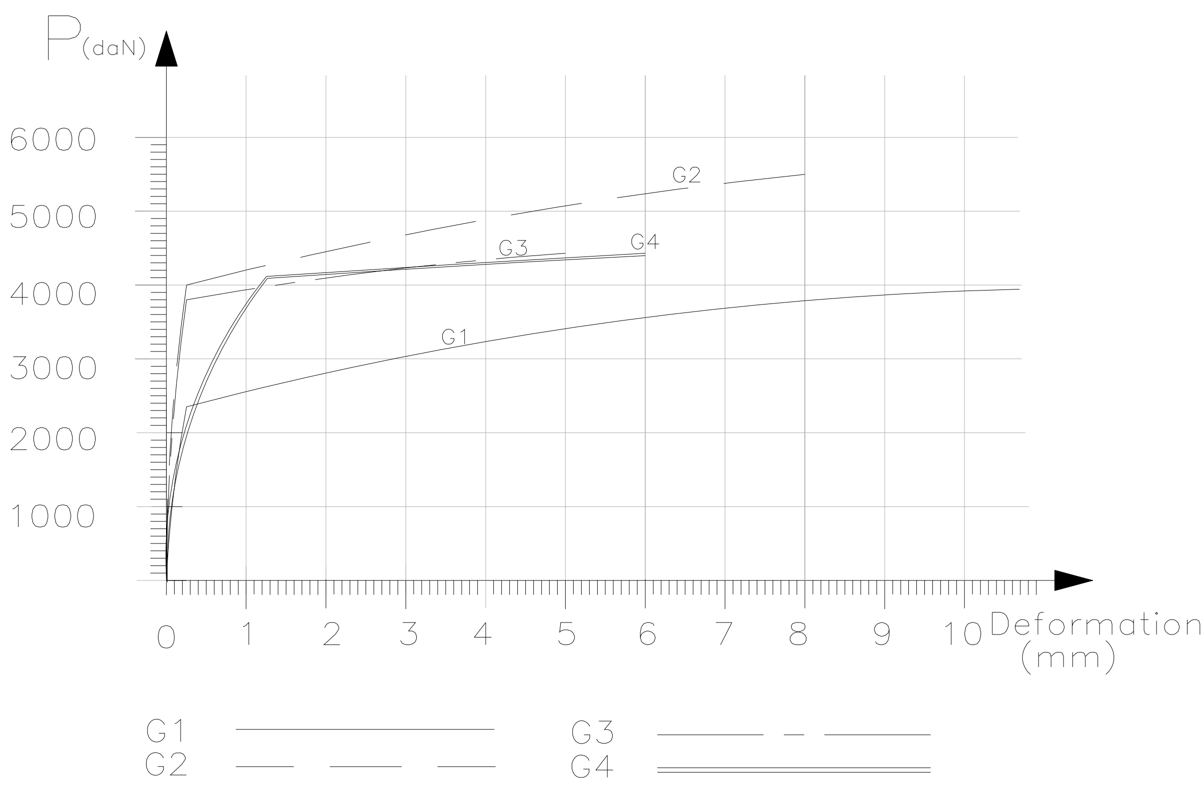

Fig.4. Deformation diagram for beam G1, G2, G3, G4.

Application of the carbon material on the concrete beams had an influence on their deformation during the loading process (figure 4). We compared the final values registered for beams G2, G3, G4 with the values measured for standard beam G1. Following the variation of the diagram presented in figure 4, we observe that beams type G2 and G4 had the highest values for final P and the deformations were similar.

Form this perspective we can say that the best way is wrapping under an angle of 90° (U-wrapped).

In all cases, the failure of the beams occurred with a warning and finally they proportionally deformed with the increase in loading and at the end of the test were being completely destroyed.

One of the most interesting issues noted during the experiment is related to the occurrence of cracks in concrete beams. The position of crack was influenced by the position of the material applied on the beam. We can say this because all cracks were registered only on the areas without carbon fiber. Generally, all the cracks occurred in the lower and tension part, between or near the carbon materials, and the general behavior of the beams was similar with the behavior of the standard beam G1. Figure 5.

Fig.5. The position of crack, beam G3

Fig.6. Position of crack for beam G3.

At the end of the experiment beam type G4 presented fewest cracks of all beams.

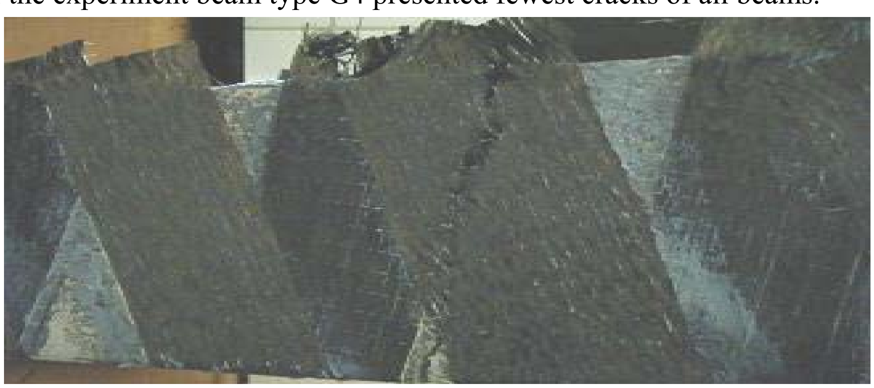

Fig.7. Position of crack for beam G4.

2.6. Final conclusion.

In my studies following this field's literature, I discovered that the most frequent objectives proposed by researchers, who are willing to obtain results through scientific research and design are:

- the development of new materials, more resistant, more durable, easy to apply and use, and also inexpensive;
- the development of new materials and construction elements that lead to reduction in the use of poor materials, avoid poor quality, and also reduce the weight of construction;
- the saving of steel and creating new materials for its replacement.

Until now, the progress in this field is substantial but we know that innovation takes time. Using FRP materials in the last decades has been challenging because there have been some inappropriate application in concrete structures. The examples are many and led to delays in their use as construction materials. The laboratory experiment I made, in addition to benefits showed a number of disadvantages, too. Some of disadvantages are present in special literature too, and can easily provoke such deductions in their use on a larger scale:

- compliance with the application technology and achieving the adhesive seems very simple, but basically has some key points that if there are not respected rigorously the whole system fails;
- it is recommended to clean well and carefully the surfaces on which you will apply the materials:
- the irregularities of the concrete surfaces must be avoided because these materials are very sensitive to sudden changes of section and can severely damage them;
- the application of this material requires workers with experience that are strictly observing and respecting the details of implementation;
- high cost and difficulty of procuring such materials in Romania constitute major disadvantages;

However, lately many other applications were made that evidence the fact that these materials have a good behavior in time and different environments. These qualities leaded to a more rapid acceptance for future applications.

In the end, I can affirm that the system used for strengthening concrete structures with composite materials represents a good alternative for strengthening reinforced concrete and the fact that it can be used in different ways is a major advantage over the other materials used up to date.

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