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with INTERNATIONAL SYMPOSIUM
ON RESEARCHING AND APPLICATION OF CONTEMPORARY ACHIEVEMENTS
IN CIVIL ENGINEERING IN THE FIELD OF MATERIALS AND STRUCTURES

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Marija Krstić[3]

VLAKNIMA ARMIRAN POLIMER KAO OJAČANJE ARMIRANOG BETONA

Rezime: *Armirano – betonske konstrukcije pokazuju izuzetne performanse u smislu konstrukcijskog ponašanja i trajnosti osim u zonama koje su izložene značajnim uticajima okoline i mehaničkim opterećenjima. Sanacija dotrajalih konstrukcija je namet i sa socio-ekonomskog stanovišta zbog značajnih troškova. Potreba za popravkom i ojačanjem AB zgrada i njihovih konstruktivnih elemenata nastaje kada zbog oštećenja nemaju dovoljnu čvrstoću, krutost i /ili duktilnost. Polimerni kompoziti ojačani vlaknima (FRP) se široko koriste za poboljšanje performansi oštećenog betona. Njihova primena može da poboljša duktilnost, čvrstoću na savijanje ili smicanje uz minimalno povećanje veličine poprečnog preseka i brzo postavljanje. Prednosti FRP su odnos čvrstoće i visine, otpornost na koroziju, otpornost na habanje, udarce i vatru. Nedostaci su visoka cena i potreba za kvalifikovanom radnom snagom. U ovom radu je prikazan uticaj FRP kompozita na povećanje nosivosti armiranobetonskih greda.*

Ključne reči: *beton, vlaknima ojačan polimer, čvrstoća pri pritisku*

THE FIBER REINFORCED POLYMER AS A STRENGTHENING OF REINFORCED CONCRETE

Summary: *Reinforced concrete structures show excellent performance in terms of structural behavior and durability except for those zones that are exposed to severe environmental and mechanical loading. Rehabilitation of deteriorated concrete structures is a heavy burden also from the socio-economic viewpoint since it also leads to significant user costs. The need to repair and strengthen RC buildings and their structural elements occurs when they do not possess sufficient strength, stiffness, and/or ductility due to damage. Fiber Reinforced Polymer composites are widely used to improve the performance of damaged concrete. Using Fiber Reinforced Polymer composites as a tool to repair damaged concrete structures could improve ductility, flexural or shear strength, with minimal increase in size and with rapid installation. The advantages of FRP are also high strength-to-weight ratio, resistance to corrosion, wear, impact, and fire. The disadvantages of Fiber Reinforced polymers are the high cost and demand for skilled labor. This paper will evaluate the influence of FRP composites on increasing the capacity of reinforced concrete beams.*

Key words: *concrete, Fiber Reinforced Polymer, compressive strength*

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1. INTRODUCTION

In this paper, the focus will be to investigate the influence of the Fiber Reinforced Polymer on strength capacity in reinforced concrete prisms. The three prisms were prefabricated having the same geometrical features. The first beam was used as a standard sample, and the second and the third beams were prefabricated having the Fiber Reinforced Polymer in different positions.

Mustafa Raheem et al [1] investigated the anchorage of externally bonded FRP sheets to improve the performance of strengthened concrete members. In this study, the use of GFRP U-wraps and flexural GFRP sheets is examined with and without the use of GFRP anchors. They developed a new method to predict the capacity of RC beams with and without strengthening. The method utilizes the truss analogy approach that is extended from the strut-and-tie model for unstrengthening beams. This method can predict the capacity of the beam specimens at the key points (yielding and ultimate).

N. F. Grace et al [2] investigated the behaviour of reinforced concrete beams strengthened with various types of Fiber-reinforced polymer (FRP) laminates. For this research 14 simply supported rectangular cross-section beams were strengthened and tested. Each beam was initially loaded above its cracking load. The cracked beams were strengthened with FRP laminates and then tested until complete failure. According to this research, FRP laminates in strengthening concrete beams reduce deflections and increase load-carrying capacity in the beams.

Saadatmanesh and Ehsani [3] studied the strengthening of beams using GFRP plates; they concluded that bonding GFRP plates to the concrete reduced the crack size at all load levels.

S.M.Mosavi and Aref Sadeghi Nik [4] investigated the Strengthening of steel-concrete composite girders using carbon fiber reinforced polymer (CFRP) plates. Regarding the high tensile strength and proper module of elasticity, CFRP plates are considered as a suitable alternative to strengthen girders. According to this research CFRP plates with epoxy adhesive increases the ultimate loading capacity of the steel-concrete composite girder. The plastic stiffness of the girders was also increased.

2. EXPERIMENTAL FACILITY

The experimental testing was conducted at "Putevi Uzice" company. The three reinforcement concrete beams were tested in a real condition with geometric similarity in scale 1:1. Compression tests were carried out by subjecting reinforcement concrete prisms under compressive load. The prisms were prefabricated and subjected to compression test up to failure to obtain the influence of Fiber Reinforced Polymer on splitting resistance in reinforced concrete beams. All reinforced concrete beams had the same geometry. The span of the beams was 3.0m, having the same concrete mixture and the same wire type GA 240/360. The compressive strength of concrete was MB20 (20N/mm^2). All beams had the same cross-section 15x30cm. For these experiments, SicaCarboDur fiber reinforced polymers were used having a tensile strength of 3500 MPa, elastic modulus of 165GPa, a thickness of 1.4mm, and a width of 50mm, with a maximum strain of 1.9%.

The type of loading was the same for all beams. The beam marked as G1 was used as a standard sample for monitoring other impacts relevant to assessing the carrying capacity. This beam was evaluated up to failure. The beam in the picture marked as G2 had a carbon-reinforced polymer in the lower zone in the length of 2.5m. The beam marked as G3 had two reinforced polymers with dimensions 2x50x1.4cm and 2.5m in length as shown in Figure 1 and Figure 2.

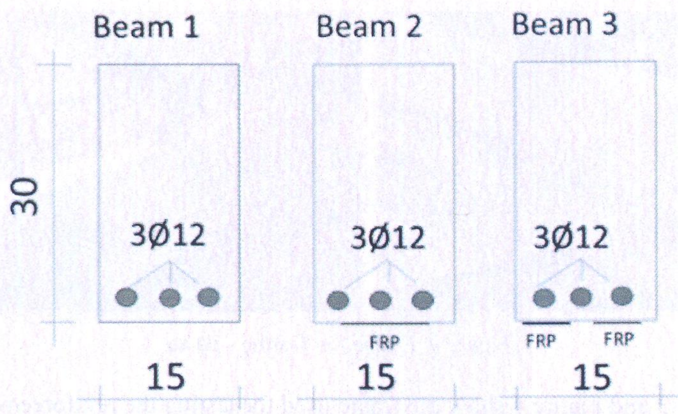

Figure 1. Beam Cross Sections

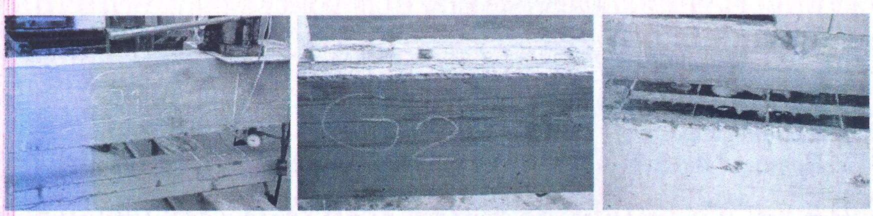

Figure 2. Positions of Fiber Reinforced Polymers on the Beams G2 and G3

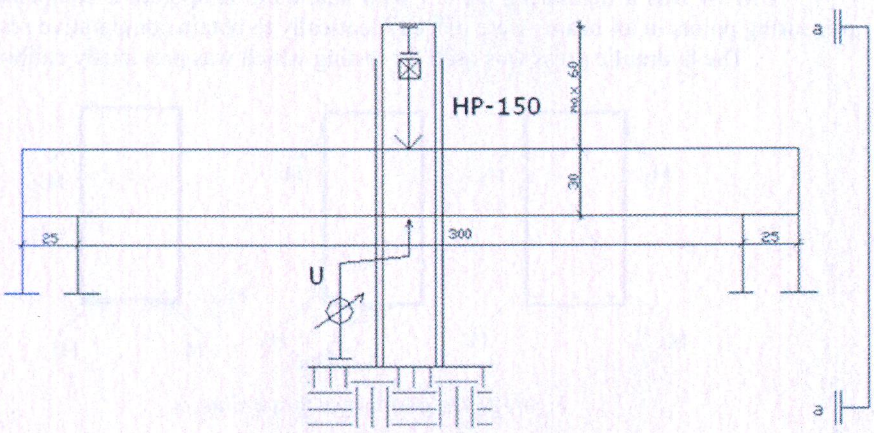

Figure 3. Frame for Testing

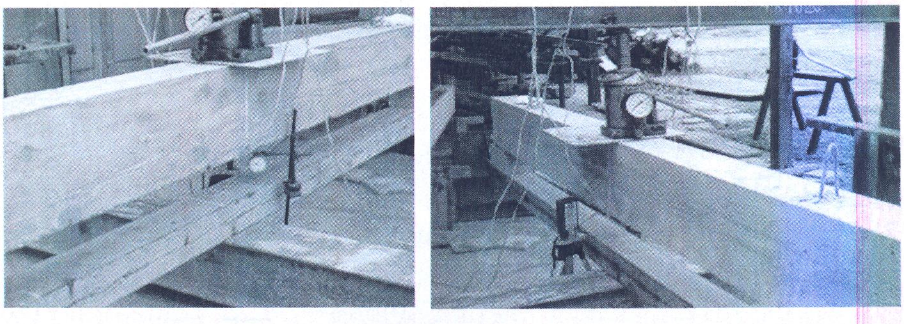

Figure 4. Frame for Testing - photo

Figure 3 and Figure 4 show the frame used for testing the reinforcement beams up to failure.

3. METHODOLOGY

For monitoring the strain of steel, concrete, and carbon fiber reinforced polymer different strain gauges were used as shown in Figure 5:

Hottinger Baldwin strain gauges type LY 100/120 were used to measure concrete strain.

The Hottinger Baldwin strain gauges type LY 10/120 was used for measuring the strains of steel and carbon fiber-reinforced polymer.

UM-74 was a measuring station with automatic temperature compensation. The measuring points in all beams were placed identically to obtain comparative results.

The hydraulic press was used for testing which was previously calibrated.

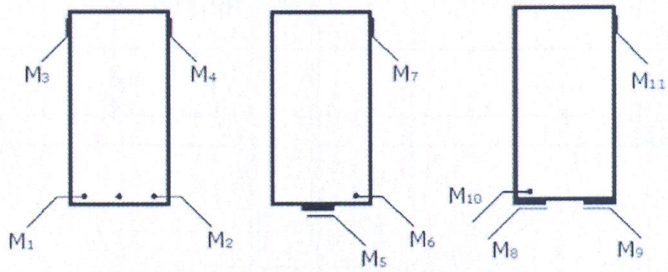

Figure 5. The positions of Strain Gauges

To achieve realistic measurements, obtaining a good connection between the elements tested and the measuring station was necessary. All strain gauges were cleaned and then glued with X-60 produced by Hottinger Baldwin.

For these experiments, SicaCarboDur fiber reinforced polymers were used having a tensile strength of 3500 MPa, elastic modulus of 165GPa, a thickness of 1.4mm, and a width of 50mm, with a maximum strain of 1.9%. Used adhesives: SicaCarboDur 30, and SicaCarboDur 31.

After placing strain gauges the zero readings were taken for all measuring points. The crack comparator was used for measuring the cracks having data of 0.05mm (Figure 6).

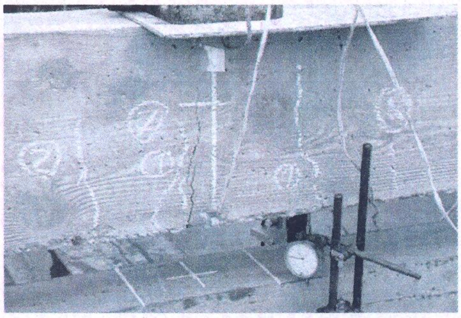

Figure 6. Picture of observed cracking

The loads were applied in four steps as shown in Figure 7.

Figure 7. Load Application

4. RESULTS

The following tables show the values of strain and deflection as a function of the different forces for each beam.

	O_1	$P_{40\text{-}4h}$	$P_{80\text{-}8h}$	$P_{100\text{-}12h}$	P_{120}
M_1	21256	21492	21699	21892	22208
M_2	23105	23385	23681	23888	23991
M_3	29506	29312	29214	29188	29056
M_4	27612	27482	27260	27081	27003
u (mm)	6.52	10.88	16.32	19.25	21.80

Table 1. Strain and deflection values for Beam 1

	O_1	P_{40-4h}	P_{80-8h}	$P_{100-12h}$	P_{120}	P_{150}
M_5	17420	17680	17892	17999	18295	18998
M_6	25305	25562	25788	25549	25976	26199
M_7	21980	21708	21605	21411	21260	21153
u (mm)	1.35	4.82	6.92	10.7	14.95	16.2

Table 2. Strain and deflection values for Beam 2

	O_1	P_{40-4h}	P_{80-8h}	$P_{100-12h}$	P_{120}	P_{150}	P_{220}
M_8	20110	20362	20488	20605	20812	21086	21453
M_9	19216	19732	19635	19888	20006	20315	20816
M_{10}	25420	25605	25712	25881	25902	26088	26452
M_{11}	27991	27814	27661	27425	27399	27291	27195
u (mm)	2.61	8.42	10.23	12.86	16.2	18.14	18.8

Table 3. Strain and deflection values for Beam 3

4.1. The Diagram of Deflections

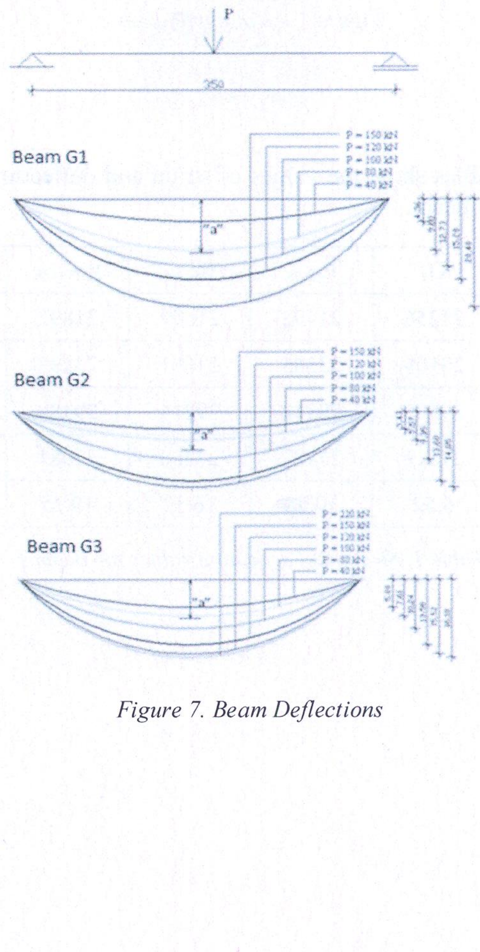

Figure 7. Beam Deflections

Figure 7 shows the diagram of deflections as a function of the different forces for each beam.

4.2. Force-deflection diagram P-u

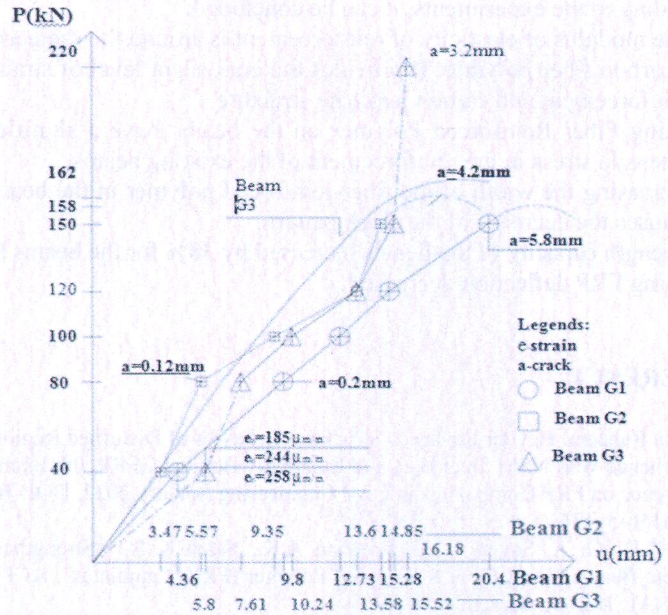

Figure 8. Force-deflection diagram

Figure 8 presents the force-deflection diagram with the values of the cracks and strains. The maximum crack opening for the beam G1 was 5.8mm under the force of 150kN and the first crack appeared under the force of 80kN. The beam G2 had the first crack of 0.12mm under the force of 80kN. The maximum crack width of 4.2mm appeared on the beam G3 under the force of 162kN.

According to the diagrams, it can be concluded that with using fiber reinforced polymer the deflection decreased, for beam without FRP deflection was 20.4mm and for beam having FRP 15.2mm. The strain for beam 1 before failure was 981.5x10-6, for beam 2 1578x10-6, and beam 3 1471.5 x10-6. The increase in capacity is around 50%. This is understandable since that is the phase of non-linearity Hook's law doesn't apply.

In the phase of exploitation in the field of elasticity, the ratio between the strains for the beam having FRP and beam G1 is 1.38 which indicates that strength capacity was increased for beams having FRP.

5. CONCLUSIONS

According to the experiments, it can be concluded:

1) The modulus of elasticity of reinforcement is around the same as the module of elasticity of carbon fiber polymer. It provides the equivalent level of strains between the embedded reinforcement and carbon laminate structure.

2) Using Fiber Reinforced Polymer on the beams have a significant impact on reducing the tensile stress in the reinforcement of the existing beams.

3) Increasing the width of the fiber-reinforced polymer in the beams from 50mm to 100mm, causes the decrease of the crack pattern.

4) Strength capacity of the beams increased by 38% for the beams having FRP.

5) Using FRP deflection decreased.

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