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FLEXURAL BEHAVIOUR OF THE CONCRETE BEAMS REINFORCED WITH THE GFRP AND CRACKS ANALYSES

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Abstract: *Concrete elements-beams reinforced with (GFRP) bars and behavior under the applied loads will be analyzing through the deflections and crack widths compared with concrete members reinforced with conventional steel. The effect of Modulus of Elasticity of GFRP will be one of the aim of this paper. Current design methods for predicting deflections at service load and crack widths developed for concrete structures reinforced with steel may not be used for concrete structures reinforced with GFRP. This paper presents methods for predicting deflections and crack widths in beams reinforced with GFRP. Based on this investigation will be proposed the predicting crack. Three beams reinforced with conventional bars and six concrete beams reinforced with different GFRP reinforcement ratios were tested. The experimental results and analytical results will lead to the predicted the modeling systems in different study cases.*

Key words: *GFRP bars; Deflections; Cracks, bearing capacity, concrete.*

1. Introduction

Fiber Reinforced Polymer (FRP) composite bars have been studied during the last three decades as alternative to traditional reinforcing steel. One of the motivation to study the effect of FRP composite bars is Corrosion resistance and behavior under the aggressive environment. The initial studies focused on retrofitting of existing concrete structural elements using FRP sheets to enhance performance under seismic forces, and in continuing process is developed in using such reinforcing bars that in process of replacing the conventional steel bars concrete structures were studied as alternative to traditional reinforcing steel. The use of fiber reinforced polymer (FRP) rebars as a longitudinal reinforcement is suggested due to its lower modulus of elasticity compared with steel, larger deflections and crack widths are expected, and therefore, the design of these elements is often governed by the limit state of serviceability.

Despite the numerous advantages exhibited by concrete structures reinforced with FRP bars, there are still many issues demanding further investigation. The concept of proposal models, the design formulae developed over the years for structures reinforced with steel bars, cannot be directly applied to FRP bars reinforced beams. It is worth considering the

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different constitutive behaviour of the FRP bars. In comparing the concept of steel bars, FRP bars behave linearly elastic up to failure, with quite different stiffness and resistance values. Moreover, concrete members reinforced with FRP bars very often exhibit a lower post-cracking bending stiffness. Consequently, the designing phase is substantially governed by limitations on serviceability (displacements and crack width).

The classical formulation in evaluating the moment of inertia of concrete beams reinforced with steel bars systematically results in excessive errors in the case of FRP reinforced beams. The analysis and modified the parameters in different used methods we achieve to compare the output results between conventional and GFRP reinforced bars.

This work aims to give a contribution to the design procedures of FRP reinforced beams by a comparison between experimental database and theoretical predictions, both at service and ultimate conditions [2,6, 10].

2. Experimental Program

The experimental tests presented here concern three sets of concrete beams reinforced: The first set with Conventional steel bars and two other sets with GFRP bars and stirrups. Each set is composed of three identical specimens cast in place with the same concrete mixture and tested according to a four point bending scheme. The cross-section of the specimens is rectangular: b = 150 mm ; h = 250 mm; the total length is equal to 1800 mm; the span, L is equal to 160 mm; Details of the specimens are reported in Figure 1.

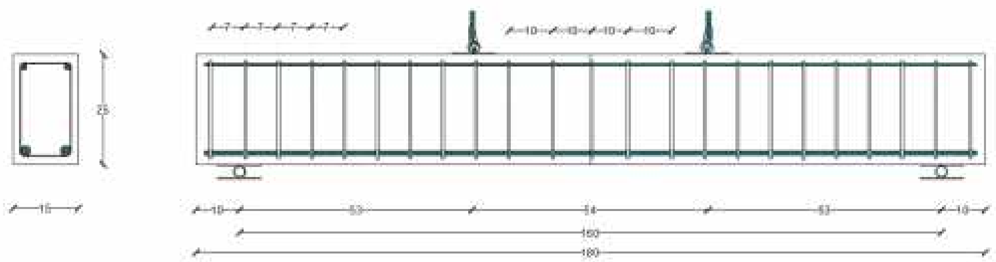

Fig. 1. *Drawing inserted within the text*

For each set are prepared the cubic concrete samples (150 mm x 150 mm x 150 mm) and were tested under compression. The mechanical properties of steel or GFRP bars are taken into consideration within the whole experimental program are given in Table 1

Sets of RC beams with conventional and GFR bars Table 1

Series	**Reinforcement**	**Type**	**Percent of reinforced (%)**	**Tensile strength (N/mm^2)**	**Modulus of elasticity (GPa)**
"A"-Etalon	Steel bars-conventional;	2 Ø10 mm	0.46	485	200
"B"	GFRP	2 Ø6 mm	0.19	1022.1	47.55
"C"	GFRP	2 Ø10 mm	0.46	1194.3	38.45

FRP mechanical properties are based on experimental test carried out at University of Prishtina, within the activity of the research project with group of master students. The tensile strength of GFRP bars is determined based on the standard procedures.

3.Test Setup, Loading and Measurements

The load was applied centrally by a 150 kN hydraulic jack- Controls MCC8, and a spreader beam was used to distribute the load to the two third-span points (Figure 2). Three linear variable displacement transducers (LVDT) were used to measure deflections at the supports. One LVDT (with extended belt) was used to measure the average strain and the crack width at the level of the reinforcement. Another LVDT is placed predictably to measure a referent crack and one LVDT is placed in midspan of the beam to measure the main deflection.

The tests were carried out in load control. The load was increased at a rate of 1 kN/min and was paused at about 5 kN intervals to mark and measure the cracks and to take notes. All of the data (force, strains and deflections) were collected by a data acquisition system, and downloaded to a PC at one second intervals Figure 3.

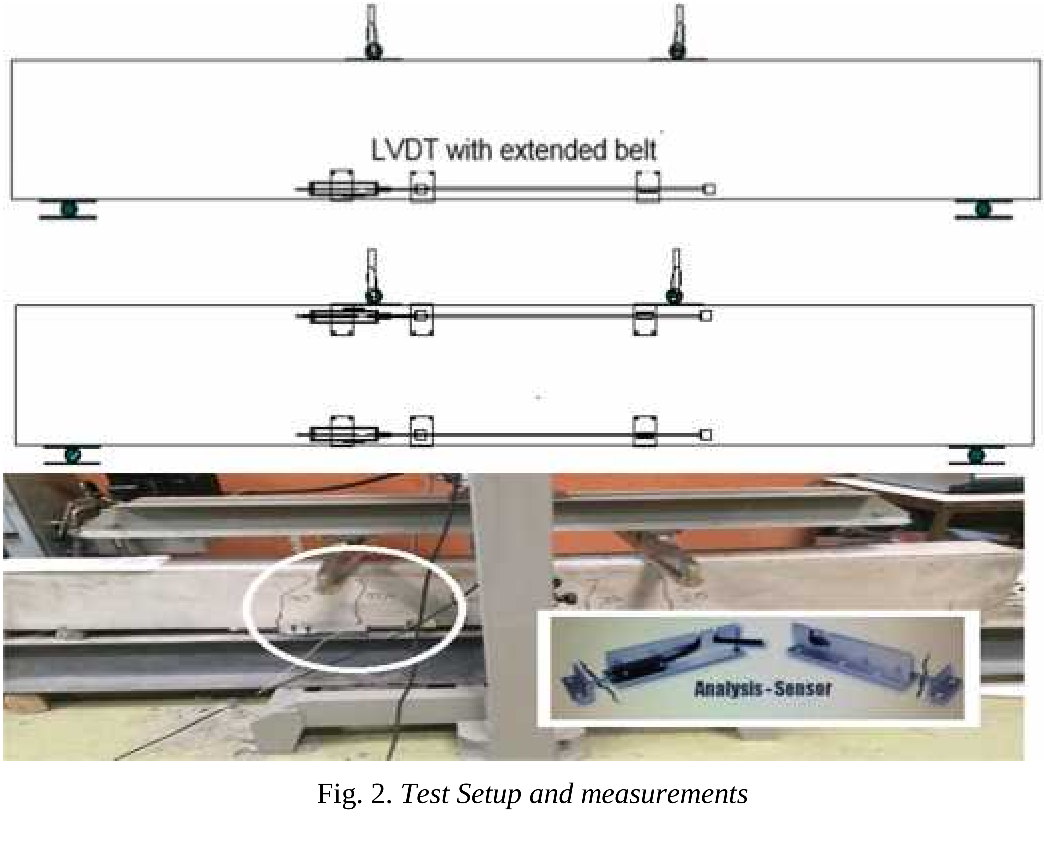

Fig. 2. *Test Setup and measurements*

Fig. 3. *Configurations and analyses of output data*

4. Results and Discussion

The experimental results regarding the three sets of RC beams are presented to highlight the peculiar features of concrete members reinforced with GFRP bars and conventional steel bars. Comparison between experimental evidence and theoretical predictions will be presented in detail for compare the two main parameter; conventional and GFRP reinforced. All the calculations will be done using the different methods or Codes to compare with experimental results. The analytical calculations is established using force equilibrium equations and strain compatibility, by assuming the following hypotheses:

- plane section preservation
- perfect reinforcement-concrete bonding
- no shear deformations
- reinforcement percent od section
- cracks analysis

FRP reinforced bars have a low elastic modulus and relatively poor bond to concrete as compared to steel bars. A direct result of these characteristics is larger crack widths and larger deflections under service loads as compared to beams reinforced similarly with steel. Set A of beams, reinforced with conventional steel bars, is determined as relation control beam which has relatively equal flexural capacity with set B and equal reinforcement area with set C.

Crack width are calculated using different methods with objective tendency to compare with experimental results which are shown in table below (Table 2).

Different Methods on the cracks analysing Table 2

S.	ULS Mr [kN m]	EC2 Function [cracks-M/Mu]	Gergely-Lutz-SLS Function [cracks-M/Mu]	Modified Gergely-Lutz [cracks-M/Mu]	ATENA Software Function [cracks-M/Mu]	Experimental results-Function [cracks-M/Mu]
A	13.22	0.201 mm-75%	0.180mm-75%	0.098mm-75%	0.192mm-75%	0.1803 mm-75%
B	11.09	2.88 mm-75%	1.49mm-75%	0.652mm-75%	1.42mm-75%	2.08 mm-75%
C	20.56	1.967 mm-75%	1.41mm-75%	1.014mm-75%	1.531mm-75%	1.739 mm-75%

The calculations is based on the percent of reinforcement and comparing with balanced reinforcement for each set, based on the equation (1); [6],[10].

$$\rho_{frp} = \alpha_1 \beta_1 \frac{\phi_c}{\phi_f} \frac{f_c}{f_{frpu}} \frac{\varepsilon_{cu}}{\varepsilon_{cu}+\varepsilon_{frpu}} \tag{1}$$

Calculations of cracks with different methods, EC 2 presented in equations (2) ,[1],[7].

$$w = \beta\, s_{rf} \frac{M}{E_f * A_f * j * d} [1 - \beta_1 \beta_2 (\frac{M_{cr} * j * d}{M * 0.9 * d})^2] \tag{2}$$

Modified Gergely-Lutz , presented in equations (3); [1,3,4, 6, 9, 10].

$$w = 2.2 k_b \frac{M - M_{cr}}{j d E_f A_f} \frac{h_2}{h_1} \sqrt[3]{d_c\ A_f} \tag{3}$$

Software –ATENA using the nonlinear analyses, and finally the experimental results during the testing RC beams.

The comparison objective will be oriented on beams reinforced with GFRP-2Ø 10 mm –Series “C” and beams reinforced with steel Bars 2Ø 10 mm-Series “A”, and the results are presented in chart, Figures 4.1 and 4.2

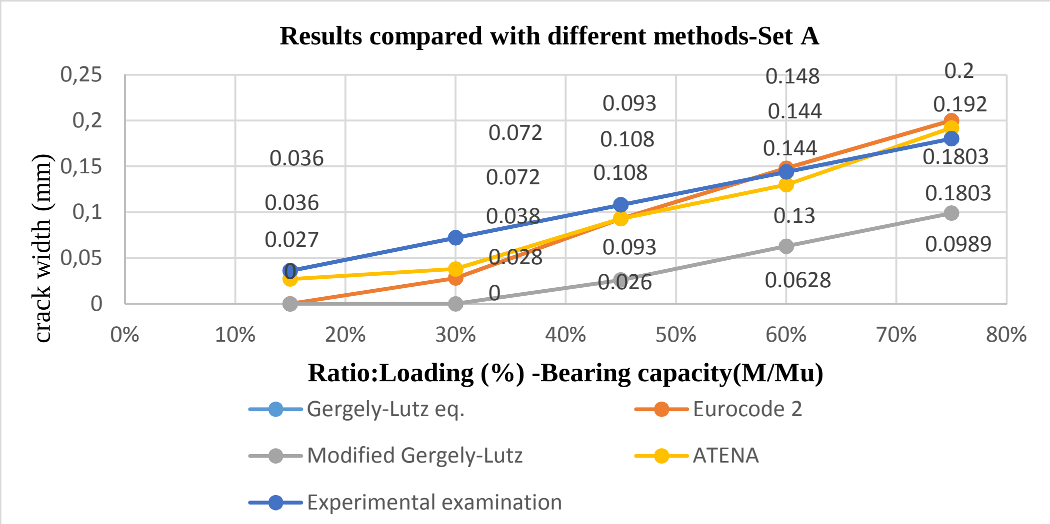

Figure 4.1. *Behaviour the beams –Set A in crack development under loading*

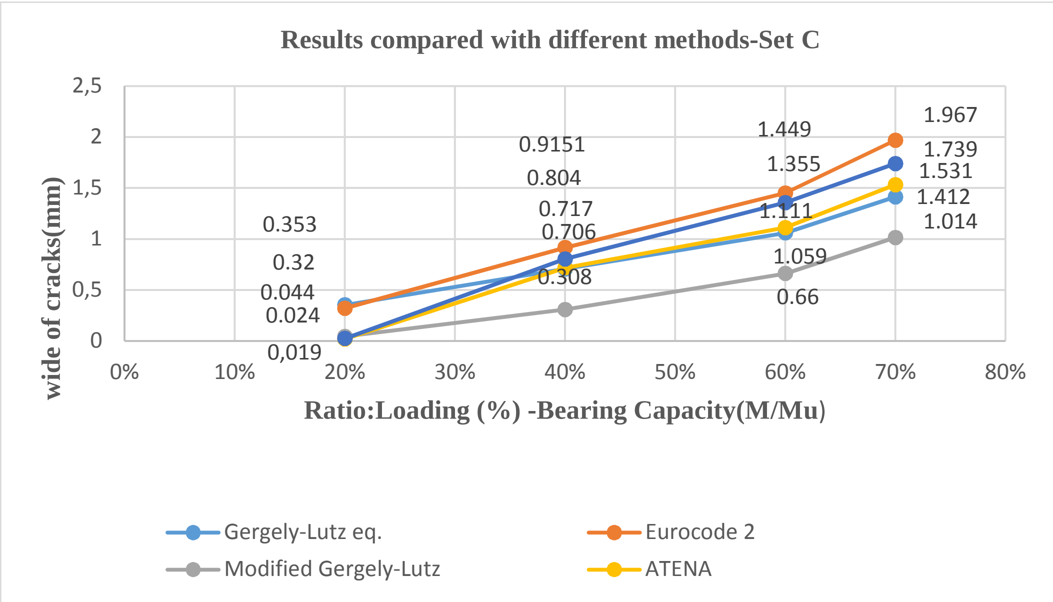

Figure 4.2. *Behaviour the beams –Set C in crack development under loading*

A large experimental program on the mechanical behaviour of concrete members with FRP internal reinforcement is still under development at the Department of Civil Engineering of University of Pristina. A part of this research, which has been recently completed, was presented and discussed in research activities.[1, 6, 8].

5. Conclusion

The predicting formula proposed by different methods or Codes for evaluating the flexural behaviour and cracks analyses during the loading of RC beams present the different values and in some of methods the overestimate the actual strength of FRP reinforced members. This point requires further investigation in order to improve and to analyse the positions of cracks, geometry of cracks and deformations of RC beams.

From the experimental and analytical work presented in this paper, the following parameters will be concluded:

- The moment-curvature relation of FRP reinforced members is basically linear in both the pre cracked and post-cracked phases during the analytical analyses and no relevant tension stiffening contributions appear.
- Experimental results substantially assess the reliability of the predicting formulae proposed in nonlinear analyse in software ATENA for both deflections and crack width.
- Neglecting effects of tension stiffening in calculating the deflection of flexural members leads to results in good accordance with experimental data.
- The crack width for ratio: max Load-Bearing comparing the conventional and GFRP reinforcement used the ATENA software results and experimental results lead to the increasing value from: 0.192mm -1.531 mm –analytical calculations-ATENA and from: 0.1803 to 1.739 –experimental examinations of RC beams.
- A non-linear finite element analysis with software “ATENA” provide similar results in ratio to experimental examinations, compared to other methods.
- Currently, the usage of the GFRP bars is limited only to a few structures, due its limitation of serviceability criteria and more depth research are in progress.

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