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Analysis and Behaviour the Concrete Columns Strengthening with the Carbon Polymer Fibres

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Abstract In recent years using the polymer materials in strengthening and retrofitting the concrete elements is on the developing process. Fiber-reinforced polymers (FRP), have emerged as an alternative solution to traditional materials for strengthening and retrofitting structures, especially in existing structures which need to up build or to change the destinations. In attempt to increase strength and ductility of reinforced concrete (RC) load bearing elements through confining systems the FRP membranes have become a familiar solution. Extensive studies (experimental, finite element modeling and analytical modeling) were carried out on the analysis of confining effect in case of concentrically loaded RC columns. This paper investigates the prospect of strengthening deficient square columns and cycle columns with carbon fiber-reinforced polymer(CFRP) jackets. In both cases output results will compare with the etalon specimen (without strengthening). Currently, the study of RC columns confined with composite materials will be focused in centric compression, because the eccentric compression is relatively new and limited. FRP confinement systems are less effective under eccentric loading compared to concentric. Experimental program on testing the performance of centric loaded RC columns externally strengthened with CFRP membranes was carried out and results are presented in this paper.

Keywords Column, Concrete, Ductility, Fibres, Strengthening, Confinement

1. Introduction

Many studies concerned with strengthening of existing reinforced concrete columns, especially in seismic regions and in changed the destination of structure, have focused on providing additional confinement to the core concrete elements by means of external reinforcement. From the studies that have been conducted over the past several years, the advantages of using FRP materials have become more apparent. Strengthening can be achieved in a column by wrapping the column with different cross sections using fiber reinforced polymer.

Due to the increase in the ultimate compressive strain, the ductility capacity and energy absorption capacity are also considerably improved, always in comparing the different sections of columns. In all different case studies the results are compared with “etalon” without strengthening.

Using and analyzing the experimental output data, our aim is to verify the hypothesis:

- effect of fully wrapping the concrete columns
- possibility effect of partially wrapped of concrete columns
- the effect of section the concrete columns , advantages and disadvantages

Because in recent years, external CFRP systems have become widespread in field column applications despite only limited experimental research data on the seismic response of CFRP wrapped specimens

Different types of strengthening and different sections result with optimizations and orientations toward the benefits. The methodology of applying the CFRP, such wrapping was in accordance with technical specifications of materials. (L.C.Hollaway,M.K. Chryssanthopoulos and S.S.J.Moy (2004))

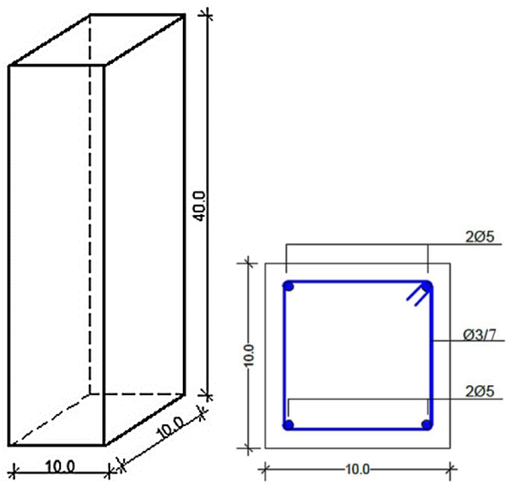

Figure 1a. Rectangular cross section

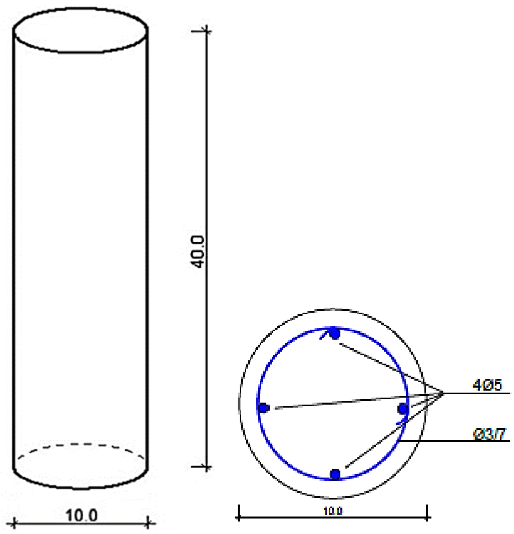

Figure1b. Circular cross section

2. Test Setup and Testing Procedures of Samples

The columns were axially loaded using a displacement control compression apparatus in the laboratory.The three different types of samples are prepared for two types of columns: Circular and Rectangular cross section in previous approved model, presenting in fig 1a and 1.b.The rectangular cross section is analysing in two types of wrapping: fully and partially wrapped. For each set of the specimens are used three samples.

2.1. Materials Properties

The concrete mix design for all the specimens is approved according to the EN-206-1, presented in table 1. The concrete mix design is based on the dimension of the models.

Table 1. Materials and properties of materials

Material	Mass(kg/m^3)	Concrete properties
Cement/CEM II 42.5	340	Compressive Strength(fc'=38.5)N/mm^2
water	180	Slump=150 mm
Coarse aggregate	780	W/C =0.53
Fine aggregate	1080	Max.Aggregate size-16 mm
additives	1.5	Air entrante 3.5 %

The CFRP, using for strengthening are from MAPEI-Italy, and properties are presented in table 2

Table 2. Materials and properties of CFRP

Description	MAPEWRAP C QUADRI-AX 760/48
Mass (gr/m2)	760
Density(gr/cm3)	1.79
Thickness (mm)	0.106
Tensile strength (N/mm2)	>4800
Tensile modulus of Elasticity (GPa)	230
Elongation (%)	2.1

2.2. Test Specimens

To determine the effect of CFRP wraps on column strength, 3 circular and 3rectangular columns were manufactured and tested (Katarina GAJDOSOVA, Juraj BILCIK). The details of the column specimens are shown in Figures 1a and 1b. The properties and dimensions of three circular columns were selected to be similar in order to obtain a reasonable mean value of the results. The rectangular column specimens were analyze in two different strengthening (wrapped) ways: full wrapped and partially wrapped (like this stirrups). The analyzing specimens were wrapped using one layer of CFRP, but in analytical analyzing are presented also for more layers, is it requested. All the geometrical and mechanical properties of CFRP are presented in table 2.

3. Testing Procedure

The columns were axially loaded using a displacement control compression apparatus in the laboratory. The first column (circular– Set D) was loaded with a speed so that the displacement increased until failure. Displacement and ultimate strength were recorded throughout the entire tests. The mode of failure for each specimen was presented in Figure 2.

The rectangular columns (two types-of wrapped -Type A and B) are also tested in same way and in same conditions.

The plain (etalon-non strengthening) specimens in both cases (Set C-rectangular and set E –circular) are tested using the same procedures.

4. Analyzing Testing Results Observation

4.1. Circle Specimens

Specimen D: Failure was sudden. It was observed through a crack which formed approximately 150mm from the top of the columns. The CFRP appeared to have burst due to the pressure or straincaused by the load.

Figure 2. Test set up and shape of failure of circular specimens

Figure 3. Test set up and shape of failure of rectangular(fully wrapped) specimens

Figure 4. Test set up and shape of failure of rectangular (partially wrapped) specimens

4.2. Square Specimens(fully wrapped)

Specimen A (fully wrapped): The columns showed warning signs of failure and cracked approximately middle of the column but in one side through edge . There were visual signals of failure such as particle debris , but not only in layer of CFRP.

4.3. Rectangular Specimens (partially wrapped)

Specimen B (partially wrapped): The columns showed warning signs of failure and cracked approximately in middle of the column but in all of surfaces . There were visual signals of failure such as totally debris, in concrete structure.(fig 4)

5. Analyzing and Comparing the Results

To be able to determine the confining effect of CFRP wrap on the behaviour of reinforced concrete columns, the axial compressive strength of concrete columns without CFRP wrap are calculated.

$$N_{Rcc,d} = \frac{1}{\gamma_{Rd}} A_c \cdot f_{ccd} + A_{sl} \cdot f_{yd} \quad (1)$$

A_c -concrete cross section area; A_s - area of longitudinal reinforcement f_{ccd} -strength of strengthening concrete

In our case study we used the different cross section, and the factor of cross section is presented in formula (3)

$$k_\alpha = \frac{1}{1+(\tan\alpha_f)^2} = \frac{1}{1(\tan 90)^2} = 0 \quad (2)$$

The calculations in our case is based also in the tensile strength of wrapped materials, presented in formula (3)

$$f_{fu,W}(R) = f_{fbd} + \langle \eta_R f_{fd} - f_{fbd} \rangle \quad (3)$$

and effective stress in our type of wrapped , presented in formula (4)

$$\sigma_{fed} \le 0.004 E_f \quad (4)$$

Analytical calculations for different cross sections specimens is presented in table 3.

Table 3. Analytical Calculated strength for different cross sections/after strengthening

Cross section	rectangulare	cicrle
Axial Strength $\mathbf{N_{Rcc,d}}$ (kN)	**175.68**	**418.00**
Shear Strength $\mathbf{V_{Rd,f}}$ (kN)	**14.02**	

The analysis of results after examinations present very wider spread results, especially in compare the results in rectangular columns were the indicate factor is very slightly in improvement of bearing capacity under axial loads. In general the results are more under of our aim for rectangular columns , but in circle columns the results are more than our aim in beginning

Comparing the results of all tested specimens , including also the plain samples is presented in table 4.

Table 4. Compare the all tested sample for different cross sections

Set	sample	Date of preparation	Date of testing	age	Cross section	Dim A x b(cm)	Height (cm)	Mass (gr)	Type of wrapped	Compression force (kN)	Compressive strength (N/mm²)
A	M_1	31.03.14	07.05.14	28	Rectang.	10x10	40	9531	Fully wrapped	331.81	33.18
	M_2	31.03.14	07.05.14	28	Rectang.	10x10	40	9508	Fully wrapped	361.20	36.12
	M_3	31.03.14	07.05.14	28	Rectang.	10x10	40	9541	Fully wrapped	368.29	36.83
B	M_1	31.03.14	07.05.14	28	Rectang.	10x10	40	9492	Partially/ stirrups	318.14	31.81
	M_2	31.03.14	07.05.14	28	Rectang.	10x10	40	9502	Partially/ stirrups	328.35	32.84
	M_3	31.03.14	07.05.14	28	Rectang.	10x10	40	9520	Partially/ stirrups	369.91	36.99
C	M_1	31.03.14	07.05.14	28	Rectang.	10x10	40	9484	No wrapped	261.75	26.18
	M_2	31.03.14	07.05.14	28	Rectang.	10x10	40	9519	No wrapped	288.61	28.86
	M_3	31.03.14	07.05.14	28	Rectang.	10x10	40	9564	No wrapped	278.45	27.85
D	M_1	31.03.14	07.05.14	28	circle	d=10	40	8295	Fully wrapped	555.13	70.72
	M_2	31.03.14	07.05.14	28	circle	d=10	40	8320	Fully wrapped	590.81	75.26
	M_3	31.03.14	07.05.14	28	circle	d=10	40	8332	Fully wrapped	518.11	66.00
E	M_1	31.03.14	07.05.14	28	circle	d=10	40	8342	No wrapped	221.58	28.23
	M_2	31.03.14	07.05.14	28	circle	d=10	40	8320	No wrapped	231.25	29.46
	M_3	31.03.14	07.05.14	28	circle	d=10	40	8344	No wrapped	236.13	30.08

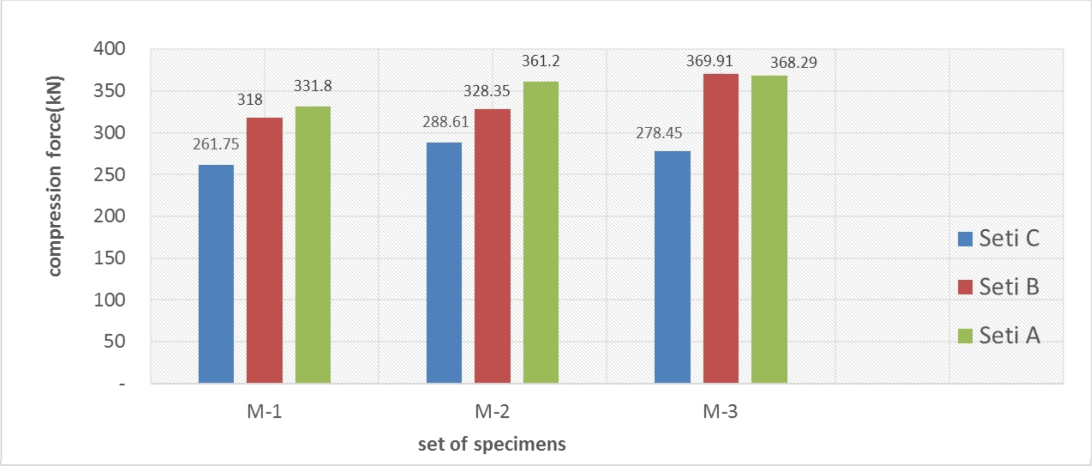

Figure 5. Comparison the different sets of rectangular columns

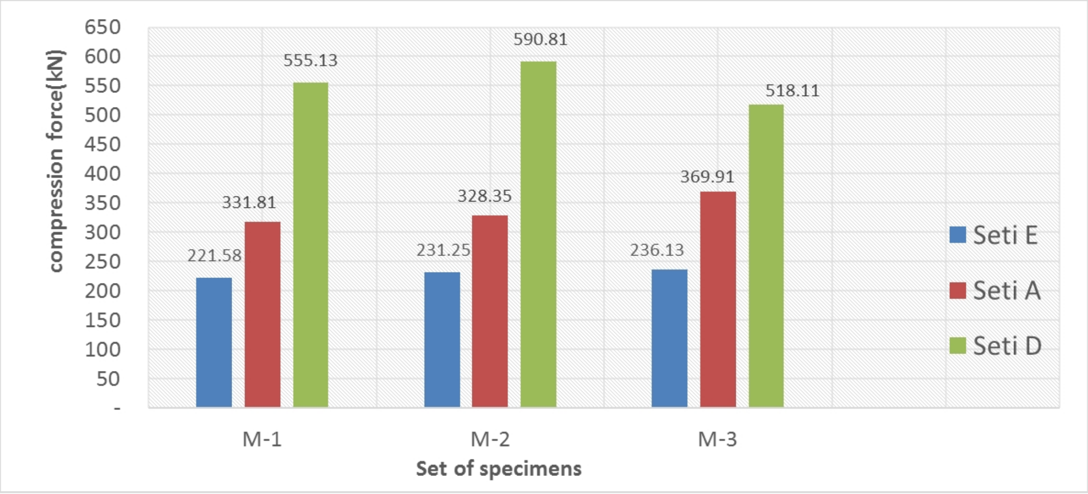

Figure 6. Comparison the different sets of circle columns

The analyze of all cases in this paper is presented in graphical form, using the charts in fig 5 and fig.6.

Comparison between the test results of wrapped rectangular columns with the calculated value express not significant changes between set A and B, and very slightly increasing compare with set A (no strengthening), presented in fig . However, if the corners of the square columns are rounded appropriately, the axial strength and ductility of columns increase considerably.

Comparison between the test results of wrapped circular columns shows that the CFRP wrap can increase the axial strength of circular columns significantly. The ductility of circular columns improves because of the application of the CFRP wrap. Comparing with set A, is significant increase the axial loads. (presented in fig. 6)

6. Conclusions

The effect of the CFRP wrap on the axial strength of reinforced concrete columns was analyzed in this paper. The study included testing two types' columns in three series. The first series comprised three similar rectangular columns fully wrapped with CFRP (set A). The second series consisted of three similar rectangular columns partially wrapped with CFRP (Set B). The third series consisted of three similar circle columns fully wrapped with CFRP (set D). Based on the test results, the following conclusions are drawn:

- Applied the strengthening of circle columns is indicated factor on increasing of axial loads and in same time creating the more ductile element.
- The applied the strengthening fully wrapped and partially wrapped is not big different, because the main indicated factor is rounded the edges, and applications in this case is limited.
- The partially wrapped it will be more applicable in positions were the shear force have the main values.
- The recent proposed equations presented for the wrapped circular columns can be used to predict the axial strength of CFRP wrapped circular columns. However, their proposed equations for square columns overestimate the axial strength of CFRP

wrapped square columns unless the corners of the square columns are rounded appropriately.

- The idea of the work was to analyze the improvement the bearing capacity of the columns under axial loads , using the preferable method , wrapped with CFRP, and the results are satisfy our aim for circle columns but not for rectangular columns.
- The main problem in rectangular columns is the edges in sections, was the stresses are concentrated, and already is the weak point.

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