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Behavior Of Low Compressive Strength Short Columns Strengthened With External GFRP Strips/Jacket Techniques

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Abstract: This paper presents a study on behavior of short columns strengthened with GFRP techniques. Relatively recent materials like fiber reinforced polymers (FRP), have been used to strengthen circular short columns. Glass fiber external sheets were used in the circumferential direction to confine circular columns. Six specimens were tested under an axial load. The main concentric purpose of this study is to evaluate the effect of GFRP confining with different techniques in strengthening deficient columns (low compressive strength concrete). This study achieved comparison between GFRP strengthened columns (strips/jacket) and control columns. Two techniques were used external confinement, using external strips of GFRP wraps and GFRP jackets. Test results revealed that the two techniques enhances the axial load carrying capacity of the columns significantly for both reinforced and unreinforced specimens. Test results, comparisons and analysis are shown herein.

Keywords: Confinement Behavior, Strengthened RC Column, GFRP Strips and Jacket.

1. INTRODUCTION

Nowadays, some of the concrete structures those are built in the past years were inadequate to carry service loads. This insufficient load carrying capacity has resulted from poor maintenance, increasing in legal load limit, insufficient reinforcement, excessive deflections, structural damages or steel corrosion, which leads to cracks. Repair, retrofitting and rehabilitation of existing concrete structures have become a large part of the construction activity by some estimates. The money spent on retrofitting of existing structures in recent years has exceeded that spent on new structures. There is no doubt that the problem of cracked concrete structures has become one of the most pressing problems that must join hands in efforts to reach a solution. One of the most important reasons for this problem is the lack of enough awareness among engineers for reasons of cracking to be avoided, and therefore the result of lack of knowledge in necessary ways for the treatment of cracking structures. Confinement of reinforced concrete columns using externally applied FRP wraps significantly enhances the performance under axial load, bending and shear, because of the increase in concrete compressive strength, ductility, shear strength and the higher resistance against buckling of steel reinforcement in compression. Due to lateral confinement FRP confinement may be achieved by means of externally applied wraps for existing column, or as a formwork for new constructed column so that, the aim of this research was generated from this points.

2. OBJECTIVE

The objective of this research focused on the behavior, failure mechanism of RC circular short columns strengthened using external GFRP sheets/strips under effect of axial load. The study includes studies proposed parameters, which are stated as follow:

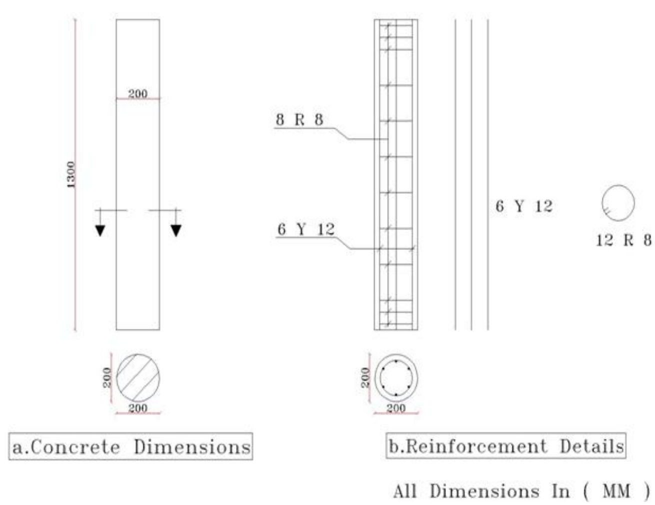
1- The effect of different techniques in strengthening of circular short columns (Strips/Jacket).
2- The effect of main reinforcement (Plain/Reinforced).
3- Compatibility of weak concrete (Fcu=200kg/cm2).
4- Strain in main reinforcement bar.
5- Type of Failure and Crack pattern.

3.1. EXPERIMENTAL WORK PROGRAM

Six circular short columns were casted. specimens were divided into two category, the first category is three specimens without main steel reinforcement, the second one is three specimens with main steel reinforcement (6Y12) and have mild steel stirrups (R8/15cm). Each group strengthened with GFRP strips and jacket. Constant parameters, like compressive strength of concrete (Fcu)=200kg/cm2 (weak concrete), crosssection of specimen is 20 cm diameter and height of 130 cm. Table (1) shows the details of test specimens and Figure (1) shows the reinforcement details for the reinforced specimens (group two).

Table (1) : Details of Circular Short Column Specimens

Specimen	Main Rfts	Stirrups	Strengthening Technique
A	Plain Concrete	-	Control
B	Plain Concrete	-	Strips
C	Plain Concrete	-	Jacket
D	6Y12 – Steel	R 8 / 15 cm	Control
E	6Y12 – Steel	R 8 / 15 cm	Strips
F	6Y12 – Steel	R 8 / 15 cm	Jacket



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3.2. MANUFACTURING PROCEDURES OF SPECIMENS

In this step, coarse aggregate firstly followed by fine aggregate then cement, finally water putted in (Rotary Mixer) which make 50 cycles per min (traditional process). Mixing process started and the time of mixing was 2 minutes. Specimens are casted vertically and to obtain a well compacting concrete a vibrator rod is used to make a good compaction and prevent segregation or honey comb to take-place. After the plastic tube mold is filled with concrete, trowel is used to get a smooth and leveled surface of column specimen. circular columns are removed 2 days after casting, then specimens are covered with wet canvas / plastic sheet for 7 days, see Figures (1), (2), (3), (4) and (5) shows the procedures of specimens manufacturing

Figure (2) : Strain Gauge on Steel Cage

Figure (3) : Steel Reinforcement Cage in Plastic Tube Form

Figure (4) : Specimen During Casting

Figure (5) : Final Caste Specimens

3.3. INSTALLATION OF GFRP STRIPS/JACKET

GFRP strips/jacket were installed on test specimens after full curing. The strips were prepared with 5cm width, 75cm perimeter length and the overlap equal approximately10cm (Strip every 15cm). GFRP jacket prepared with 75 cm perimeter length and covering full length of the specimens. GFRP strips/jacket glued with resin (polyester with peroxide) after roughing the surface of circular short column. See Figures (6), (7), (8) and (9).

Figure (6) : Cutting The GFRP Wraps to Required Strips and Jackets

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Figure (7) : Jacket Adhesion

Figure (8) : Specimen with GFRP Strips

Figure (9) : Specimen with GFRP Jacket

3.4. TEST SETUP

Specimens were tested using universal machine with capacity 200 ton. Strain meter connected with strain gauge to record stain in main reinforcement and two LVDT used to determine axial shortening. Steel column head also installed at the upper and lower of circular short column to prevent failure at the upper/lower head of specimen. See Figure (10) for final test setup.

3.5. TESTING STAGES

Specimens were carried to universal machine to start the process of testing. Load was applied in increment of 2 ton. Axial shortening and strain in main reinforcement were recorded. Also cracking and ultimate load were observed. Cracks are detected and marked. Specimens were tested as hingedhinged column.

4.1. RESULTS, ANALYSIS AND DISCUSSIONS

The cracking and ultimate load of tested specimens in addition to strain and axial shortening of circular short column tested in the experimental work are present in Table (2).

Table (2) : Summary of Test Results

Specimen	Pcr. (ton)	Pult. (ton)	Pcr/Pult (%)	Strain in Main Steel Reinforcement at Pult (µs)	Axial Shortening at Pult (mm)
C1	42	51	82%	-	7.18
C2	50	66	76%	-	9.76
C3	62	78	79%	-	11.39
C4	48	60	80%	421	11.37
C5	62	74	84%	472	11.33
C6	72	86	84%	495	13.20

With refer to Figure (11), it shown that specimens C1, C2 and C3 (plain concrete) have the strengthened with GFRP strips/jackets shows higher cracking and ultimate loads than control specimens. Although strengthened specimens showed almost the same behaviour as the control specimen (C1) on up to cracking of the control specimen (C1) but they showed better behaviour in post cracking stage and failed in better mode respect to control specimen (C1). Specimen (C3) with GFRP jackts have the highest stiffness in compare to specimens C1 and C2 due to preimeter confinement (jacket). The failure in specimen (C2/C3) started due to rupture in GFRP strips/jacket followed by debonding.

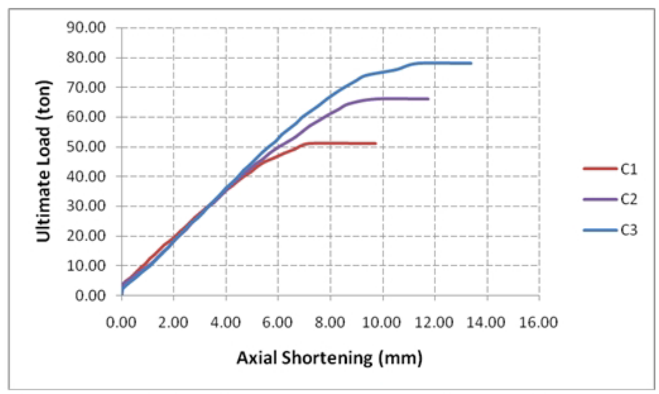

Figure (11) : Relationship Between Ultimate Load and Axial Shortening (C1,C2 and C3)

It's appear that specimens C4, C5 and C6 (reinforced concrete) tend to show the same behaviour in the elastic zone. By increasing load, the deformations in specimens increased. The main judge for ultimate capacity of specimen are deformations. Firstly, specimen (C4) missed the stiffness (young's modulus decreassed) because it's control (non strengthened specimen). Specimen (C5) with GFRP strips cling the stiffness more than control specimen (C4) but due to increasing axial load, the cracks increased so stiffness decreased. Specimen (C6) with GFRP jacks have the highest stiffness in compare to specimens (C4) and (C5) due to preimeter confinement (jacket). The failure in specimen (C5/C6) started due to rupture in GFRP strips/jacket followed by debonding. The following Figure (12) shows the relationship between load and axial shortening in three specimens (C4, C5 and C6).

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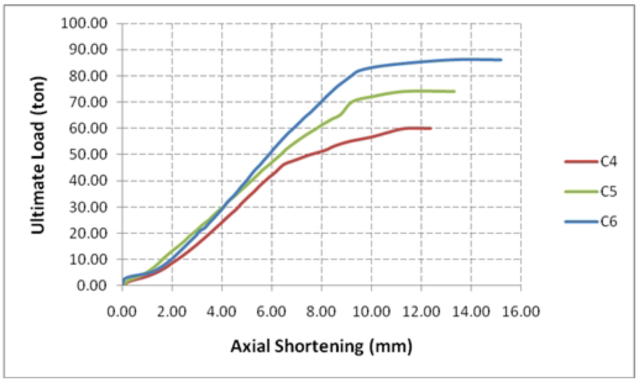

Figure (12) : Relationship Between Ultimate Load and Axial Shortening (C4,C5 and C6)

In the reinforced concrete specimens with different strengthening techniques (strips/jacket), the ultimate load in the control specimen (C4) was 70 ton and maximum strain in the main reinforcement bar was 490µs. Strengthened specimen with GFRP strips (C5) recorded ultimate load equal 77 ton with maximum strain 494µs. Specimen (C6) which is strengthened with GFRP jacket have ultimate load equal 86 ton and maximum strain equal 497µs. Strain in main reinforcement bar take the behavior of elastic zone (no yield). See Figure (13) which accentuate the relationship between ultimate load and strain in main reinforcement bar. Figure (14) shows the different crack pattern for specimens C1,C2,C3,C4,C5 and C6. The failure generally classified as brittle failure with some ductility (semi-ductile) due to the presence of GFRP sheets (

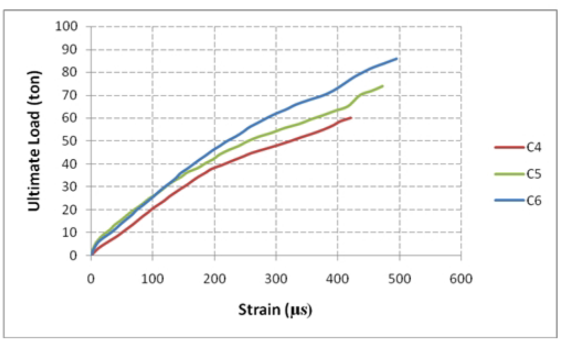

Figure (13) : Relationship Between Ultimate Load and Stain in Main Reinforcement (C4,C5 and C6)

5.1. CONCLUSIONS

Based on the test results presented herein the following conclusions are drawn:

1- For plain concrete circular short columns, Specimens with external GFRP increased capacity of column by 29% for GFRP strips and by 53% for GFRP jacket compared to control column.
2- For reinforced concrete circular short columns, Specimens with external GFRP increase capacity of column by 24% for GFRP strips and 44% for GFRP jacket compared to control column.
3- The main reinforcement in specimens increased the capacity of the circular short columns by 18% in case of non strengthened column, by 12% in case of strengthened with GFRP strips and by 10% in case of strengthened with GFRP jacket.
4- For specimens strengthened with externally glass fiber sheets (strips/jacket), the failure starts by rupture in glass fiber sheets then failure took place. It is observed that external GFRP sheets enhance the failure mode from brittle to ductile failure because the failure of these specimens gives suitable alarm before fail under compression.

6.1. ANALYTICAL ANALYSIS

The study also included verification of experimental results by using ACI code [1],[2], which is represent the design equations for both short columns without/with external GFRP strips/jackets. The following Equation (1) and (2), for nonprestressed members with tie reinforcement without/with GFRP wrapping, respectively are used to obtain the verification.

$$\varphi Pn{,}max = 0.80\varphi\ [\ 0.85fc'\ (Ag - Ast) + fyAst\ ] \quad \text{Equation (1)}$$
$$fPn = 0.80f[0.85yf\ fcc\ ¢\ (Ag - Ast) + fyAst\ ] \quad \text{Equation (2)}$$

The following Figure (14) shows that the variation between experimental and analytical results nearby the same and in the zone of acceptance.

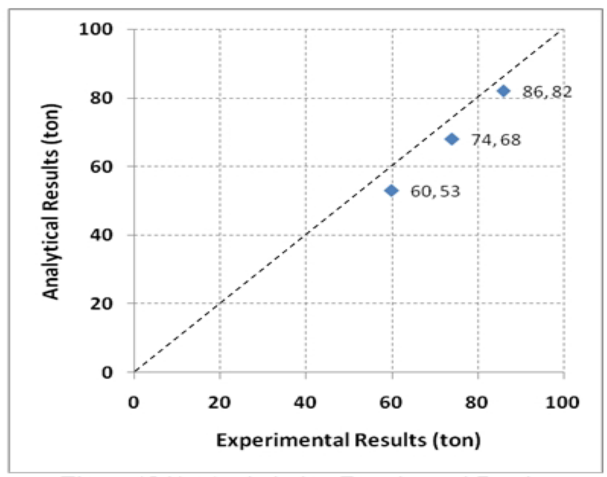

Figure (14) : Analytical to Experimental Results

7.1. RECOMMENDATIONS

It was recommended that to investigate the following parameters in the further work:

1. Usage of CFRP instead of GFRP.
2. Decrease distance between strips.
3. Using different width of strips.
4. Using epoxy resin instead of polyester resin.

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