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A Comparative Study On CFRP Confined RC Capsule Column With Varying Reinforcement Ratio

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Abstract

The extensive study of FRP confined concrete in Square, rectangular, circular column related to behavioural aspect, but much less is known about FRP confined RCC capsule column. The effectiveness of confinement is much increased.
In this present study, the experimental program was undertaken testing three groups of columns designed with varying reinforcement ratio 2.5%, 3%, 3.5% total nine RC columns of cross section 230x150mm and height 600mm. Further the column is provided with corner radius of 75mm on both side of the cross section, because of providing this cornering (radius) further strengthening of column can reduce the delamination of the laminate and to increase the ultimate load carrying capacity. Each group one of them was a control specimen and the other six specimens were strengthened with Carbon Fiber Reinforced Polymer laminates with varying spacing and no of layer and then tested under axial loading. The experimental results including mode of failure, ultimate load, concrete strain were analysed.

Keywords: Fiber, Column, Strengthening, CFRP, Concrete.

1. Introduction

FRP composites have found increasingly wide applications in civil engineering due to their high strength-to weight ratio and high corrosion resistance. As a result of FRP confinement, both the compressive strength and ultimate strain of concrete can be greatly enhanced. Most researches have mainly concentrated on the stress–strain model, the compressive strength and the shape of cross-section of short columns. The behaviour of FRP wrapped concrete cylinders with different wrapping materials and bonding dimensions has been studied by Lau an d Zhou using finite element (FEM) and analytical method s [3]. It was found that, the load carrying capacity of the wrapped concrete structure is governed by the mechanical properties such as modulus and Poisson's ratio, of the wrapping sheet. An analytical equation was provided to estimate the shear stress distribution of an adhesive material for different wrapping geometries. A study on the compressive behaviour and strength of elliptical concrete specimens wrapped with CFRP has been described by Teng and Lam [4]. From the study it was found that, the axial compressive strength of FRP confined concrete in elliptical specimens is controlled by the amount of confining FRP and the major to minor axis length ratio a/b of the column section. The confining FRP becomes increasingly less effective as the section becomes more elliptical but substantial strength gains from FRP confinement can still be achieved even for strongly elliptical sections. The ultimate axial strain of the confined concrete was also shown to increase as the FRP confinement becomes larger. Based on the test results, a simple compressive strength model for FRP confined concrete in elliptical columns was proposed, in which the effect of the section shape is taken into account by a shape factor. The confinement model describing the behaviour of rectangular concrete columns retrofitted with externally bonded fiber-reinforced polymer material and subjected to axial stress was presented by Omar Chaallal et al. [5]. The derivation of the proposed model was based on the findings of an extensive experimental investigation involving the testing of 90 rectangular specimens representing three cross-sectional aspect ratios, two concrete strengths and five different numbers of FRP layers. It was found that the stiffness of the applied FRP jacket is the key parameter in the design of external jacket retrofits. In a study by Toutanji [6], tests were performed to evaluate the durability performance of concrete columns confined with fibre reinforced polymer composite sheets. The influence of wet/dry exposure using salt water on the strength and ductility of FRP wrapped concrete columns was evaluated. It was found that confinement of concrete cylinders with FRP sheets improves the compressive strength and ductility and the improvement in strength and ductility is dependent on the type of FRP composite sheets. The technique of wrapping thin, flexible high strength fiber composite straps around the columns for seismic strengthening, to improve the confinement and thereby its ductility and strength has been presented by Saadhatmanesh et al. [7]. Analytical models that quantify the strength and ductility of concrete columns externally confined by means of high strength fibre composite straps were presented. The results indicate that the strength and ductility of concrete columns can be significantly increased by wrapping high strength fibre composite wraps around the columns. Thus, FRP wrapping of circular columns has proven to be an effective retrofitting technique. In contrast very limited data have been reported on rectangular columns retrofitted with FRP wrap, even though rectangular columns in need of retrofit are very common. The objective of the present paper is to study the behaviour of reinforced concrete capsule shaped columns with three different reinforcement ratios strengthened with externally applied unidirectional CFRP sheets and subjected to axial compressive loading.

1.1 Objective of study

The following parameters were considered in this experimental investigation:

(a) The reinforcement ratio: Three reinforcement ratios 3.5%, 3%, 2.5% were studied.

(b) The number of CFRP layers: Specimens with zero, one and two layers of CFRP wrap were investigated.

2. Experimental Program

2.1. Materials

Ordinary locally available Portland cement having a specific gravity of 3.15 was made use of, in the casting of the specimens. Locally available river sand having a specific gravity of 2.54 was used. Crushed granite coarse aggregate of 20 mm maximum size having a specific gravity of 2.58 was used. Water conforming to the requirements of water for concreting and curing as per IS: 456–2000 was used throughout. Mix ratio of cement: sand: gravel: water 1:1.33:3.14:0.5. Concrete columns were confined by wrap ping them with carbon fiber sheets. The resin system used in this work was general purpose polyester resin made of two-parts, resin and hardener. The various reinforcement ratio details used in this project as shown in fig1-3.

SPECIMEN DESIGNATION	REINFORCEMENT RATIO	WIDTH OF WRAPPING	NO OF LAYERS
CF1(Controlled)	3.5 %	-	-
CF2	3.5 %	100	1
CF3	3 .5 %	100	2
CF4(Controlled)	3 %	-	-
CF5	3 %	120	1
CF6	3 %	120	2
CF7(Controlled)	2.5 %	-	-
CF8	2.5 %	140	1
CF9	2.5 %	140	2

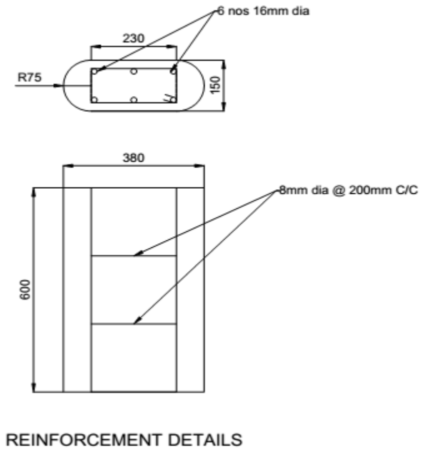

Fig.1 Reinforcement ratio details for 3.5%

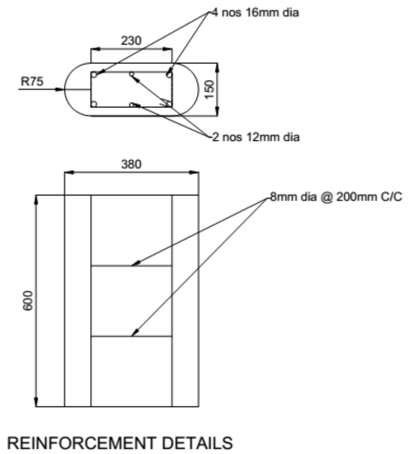

Fig.1 Reinforcement ratio details for 3%

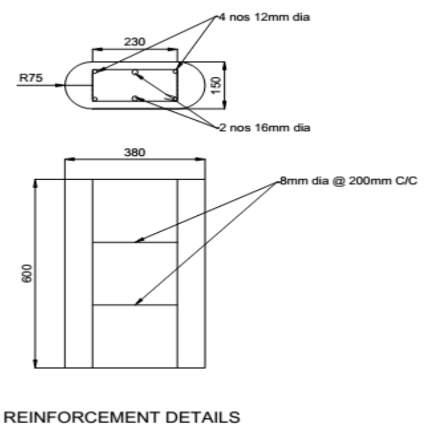

Fig.3 Reinforcement ratio details for 2.5%

2.2 Specimen Details

Totally nine reinforced concrete columns were tested under concentric compression in testing frame. The length (600 mm) and the cross sectional areas (52171.46 mm2) were kept constant for all the specimens and the reprofiling of mould as shown in fig 4. All columns had longitudinal reinforcement as shown fig 1-3. Column specimens were divided into three groups: 3 columns confined with 1 layer of CFRP, 3 confined with 2 layers of CFRP and 3 unconfined (control). The specimen ID and wrapping configurations as shown in the Table 1.

Table 1 Wrapping Configurations

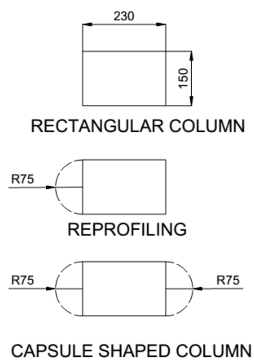

Fig 4 Reprofiling of Mould

2.3. Fibre-reinforced polymer wrapping procedure

The resin system used in this work was made of two parts namely resin and hardener. The components were thoroughly hand mixed for at least 5 min. The concrete columns were cleaned and completely dried before the resin was applied. A first coat of thin layer of resin was applied and CFRP sheet was then wrapped directly on the surface. Special attention was taken to ensure that there was no void between the CFRP sheet and concrete surface. After the application of the first wrap of the CFRP sheet, a second layer of resin was applied on the surface of the first layer to allow the impregnation of the second layer of the GFRP sheet. Finally, a layer of resin was applied on the surface of wrapped columns. In all cases, the outside layer was extended by an overlap of 50 mm to ensure the development of full composite strength. The detailed wrapping pattern as shown in fig 5-7.

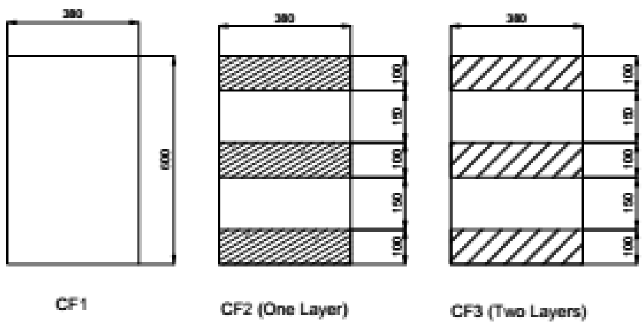

Fig.5 Wrapping Pattern for 3.5%

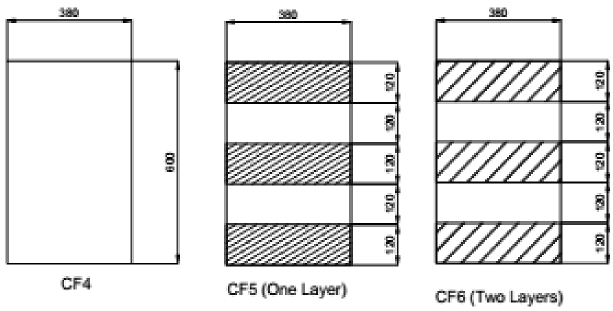

Fig.6 Wrapping Pattern for 3%

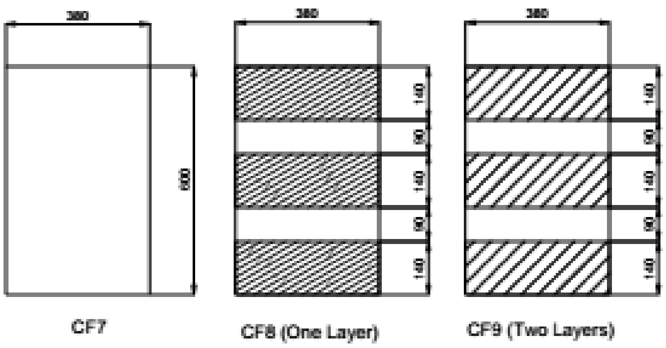

Fig.7 Wrapping Pattern for 2.5%

2.5. Instrumentation and testing procedure

All specimens were loaded until failure under axial compression in a testing frame. All the nine columns were tested under similar conditions. Strain gauges were fixed in the reinforcement and strains were noted down for every 50 kN increment of load.

3. Result and Discussion

3.1 Effect of load – displacement

The load – displacement curves of the tested columns were recorded and are presented herein.

The following graph shows that decreasing the reinforcement ratio with increase the wrapping width attained lower displacement with higher load.

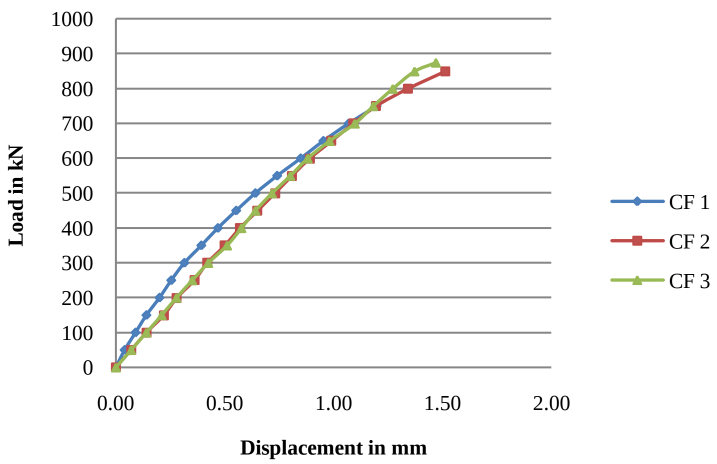

Fig 8 Load – Displacement for Specimen CF1, CF2, CF3

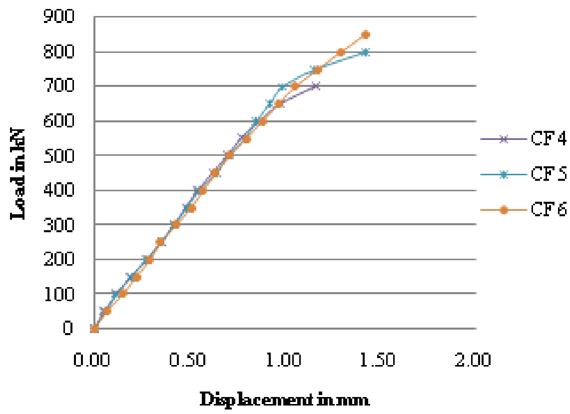

Fig 9 Load – Displacement for Specimen CF4, CF5, CF6

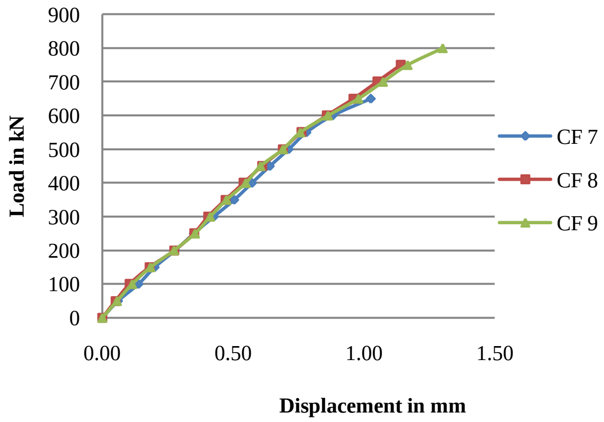

Fig 10 Load – Displacement for Specimen CF7, CF8, CF9

3.2 Effect of load – strain

The following graph shows that lower the the reinforcement ratio with increase the wrapping width attained higher the strain values with higher the load.

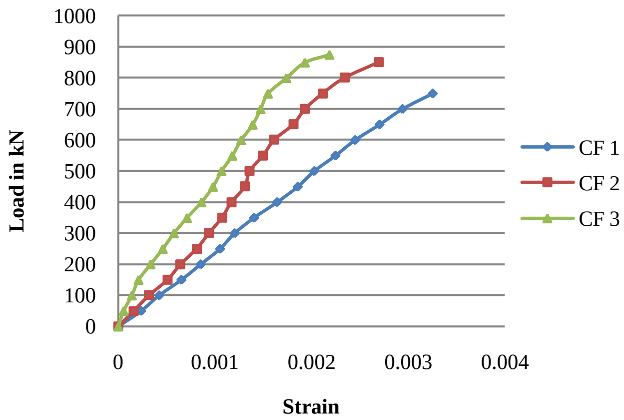

Fig 11 Load – Strain for Specimen CF1, CF2, CF3

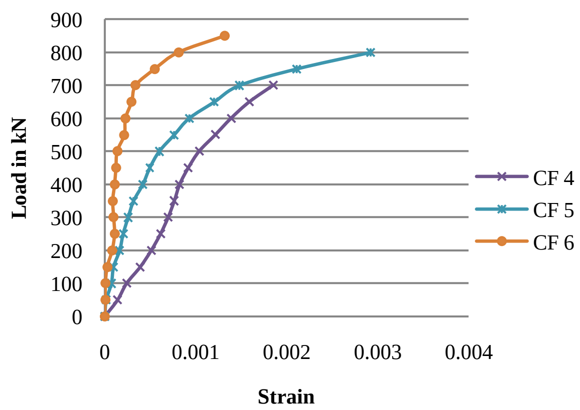

Fig 12 Load – Strain for Specimen CF4, CF5, CF6

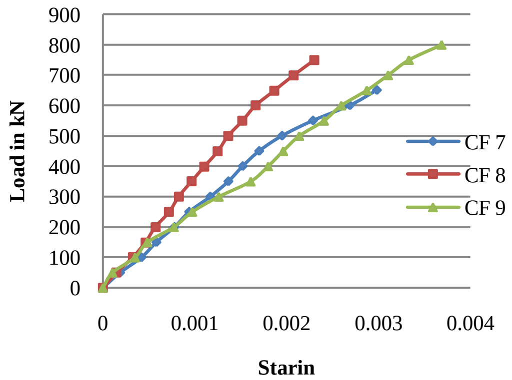

Fig 13 Load – Strain for Specimen CF7, CF8, CF9

3.3 Comparison of Compressive Strength

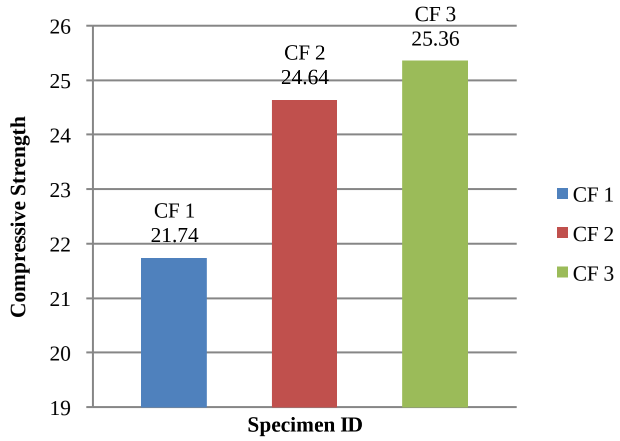

Fig 14 Reinforcement Ratio 3.5%

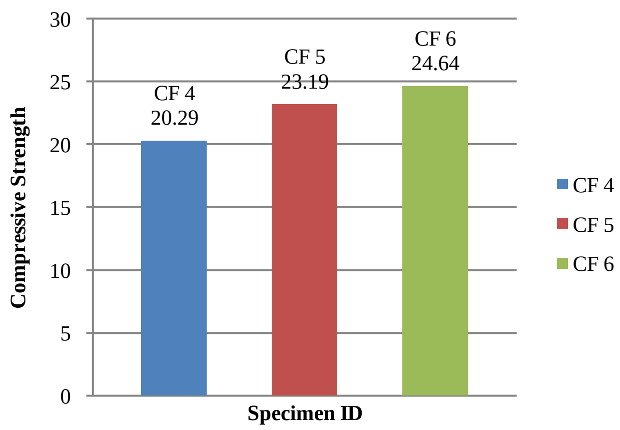

Fig 15 Reinforcement Ratio 3%

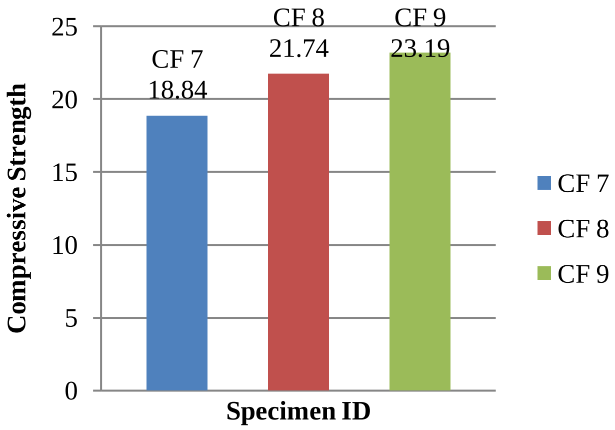

Fig 16 Reinforcement Ratio 2.5%

4. Conclusions

This study used nine internally reinforced with externally CFRP wrapping in capsule shaped columns. The following conclusions are obtained from the experimental work:

Effective confinement with CFRP composite sheets resulted in improving the compressive strength. Better confinement was achieved when the number of layers of CFRP wrap was increased, resulting in enhanced load carrying capacity of the column.

The specimen CF3 (reinforcement ratio 3.5%) with double layer of CFRP has increased compressive strength about 16.65% compared with controlled specimen.

The specimen CF6 (reinforcement ratio 3%) with double layer of CFRP has increased compressive strength about 21.44% compared with controlled specimen.

The specimen CF9 (reinforcement ratio 2.5%) with double layer of CFRP has increased compressive strength about 23.09% compared with controlled specimen.

The result shows that the wrapping of CFRP gives the high confined strength to the axial loaded column with the lower the reinforcement ratio.

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