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Retraction

Retraction: Comparative Study on Axial Compressive Behaviour of CFST and Externally Wrapped CFRP Columns (*IOP Conf. Ser.: Mater. Sci. Eng.* **1145** 012015)

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This article (and all articles in the proceedings volume relating to the same conference) has been retracted by IOP Publishing following an extensive investigation in line with the COPE guidelines. This investigation has uncovered evidence of systematic manipulation of the publication process and considerable citation manipulation.

IOP Publishing respectfully requests that readers consider all work within this volume potentially unreliable, as the volume has not been through a credible peer review process.

IOP Publishing regrets that our usual quality checks did not identify these issues before publication, and have since put additional measures in place to try to prevent these issues from reoccurring. IOP Publishing wishes to credit anonymous whistleblowers and the Problematic Paper Screener [1] for bringing some of the above issues to our attention, prompting us to investigate further.

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Comparative Study on Axial Compressive Behaviour of CFST and Externally Wrapped CFRP Columns

S Venkat Raman[1], S Elavarasan[1], K S Elango[1], R Saravanakumar[1], D Vivek[1], V Rajeshkumar[1] and R Gokulakrishnan[2]

[1]Department of Civil Engineering, KPR Institute of Engineering and Technology, Coimbatore.

[2]Managing Director, VR Designs, Tirupur, Tamil Nadu, India
venkat1294@gmail.com[1]

Abstract. Concrete column fails by crushing or bucking due to axial load in order to resist failure of confinement, concrete filled steel tubular column (CFST) and carbon fibre reinforced polymer (CFRP) wrapping are used. CFST member has its consecutive progression in the construction industries due to its high load carrying capacity upgraded ductile performance, need for form work is minimized and has greater confinement effect. CFRP wrapping provides resistance towards corrosion, light weight exceptional durability, increases strength over confinement. In this work, an experimental investigation between stunt and slender concrete filled steel tubular column is compared with conventional pcc strut and slender column externally wrapped by single and double layer of CFRP. Total of 8 specimen were tested under axial compression. The parameter varied is height (750mm, 1050mm). The diameter of the column is 75mm. M30 grade concrete is cast. End support condition is hinged. For short column slenderness ratio is 40, L/D is assumed to be 10 and for slender column slenderness ratio is 60 and L/D is assumed to be 14. From this study, the influence of slenderness ratio over an effect of confinement is observed. Maximum axial compressive strength of the column is recorded and it is compared with eurocode4, AS/ACI code, IS516:1959 code. The behaviour of column both experimental and analytical results is observed.

Keywords: Concrete filled steel tubular column (CFST), carbon fibre reinforced polymer (CFRP), externally wrapped columns, axial compressive strength, eurocode4, AS/ACI code, IS516:1959 code.

1. Introduction

Composite construction has an undesirable property high tensile strength and ductility, that is steel and having high compressive strength, due to concrete as it is good fire resistance at low cost. In sky scraper building, extended bridges and roof structures the composite construction is very often adopted unsettled to its maximum structural capability with enormous flexural rigidity due to strength to weight ratio [1]. In the construction of bridges composite column is attaining its position because of its inclusive applications over bridge piers exposed to influence from traffic [2].

1.1. Composite Column
Generally, there are two types of composite column they are Steel Enclosed Concrete Section and Concrete Filled Steel Tubular sections (CFST). CFST column is structure in which concrete is filled inside the hollow steel tube. CFST columns are favoured over nominal RC columns since it has greater load carrying capacity and better yielding performance. Circular cross section is preferred over all further sections due to the imprisonment of concrete [3]. CFST columns size is comparatively smaller than the nominal RC columns for the same amount of load. Even though it has a small cross-sectional area it tends to have high resistance and the useable area is reduced. The major difficulty of CFST is, when the column is exposed to ultimate load, the steel tube expands more from its definite position than that of concrete, that is due to confinement pressure that resisted by the steel tube [4].

1.2. Carbon Fibre Reinforced Polymer (CFRP) Columns
Carbon Fibre Reinforced polymer (CFRP) are widely used in rehabilitation work of reinforced concrete (RC) by its promising performance to increase its strength. In order to improve ductility and strength FRP wrapping on short RC circular columns is more reliable with its lateral confinement. It was found that there is a limited research work carried out on comparison with circular concrete filled steel tubular columns against externally wrapped CFRP columns, but investigations are necessary to understand the axial compressive behaviour of CFST columns and externally wrapped CFRP columns as it is widely applied in sky scraper buildings, long span bridges and towers [5]. Various codal provisions like Euro code, ACI, Australian codes, etc., are available to calculate the axial compressive performance of CFST columns [6]. In order to consider the effect of slenderness over confinement for relative slenderness greater than 0.5, experimental investigations were needed to be carried out.

2. Materials Used
2.1 Steel Tube
The steel tube of hollow section that has a slenderness ratio 10 to 14 confirming to IS 1161-1998 is used. It has a rounded cross section with the size of 75mm diameter, 2.5mm thickness and varying height of 750 mm and 1050 mm as shown in Figure 1, its permissible strength is given as 250MPa in the manufacturer requirement details.

2.2 Carbon Fibre Reinforced Polymer (CFRP)
Carbon Fibre reinforced polymer sheet of 2m X 2m is used for wrapping the column as single and double layer. CFRP of bi-directional with 200GSM of thickness 2mm is used as shown in Figure 2. Epoxy LY556 and Hardener HY951 is used as binding element for wrapping the CFRP along the column.

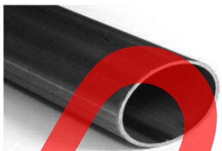

Figure 1. Hollow steel tube

Figure 2.CFRP with epoxy

2.3 Concrete Mix Proportion
The mix design quantity of 1:1.71:2.42 was used to achieve the strength of 30N/mm^2 with the water cement ratio of 0.45. Enfiq super plastic 400 was used as an admixture [7]. The average compressive strength was found to be 33N/mm^2 at the end of 28days curing.

2.4 Methodology

The main objective of this investigation is to study the compressive behaviour of circular Concrete Filled Steel Tubular sections with that of externally wrapped Carbon Fibre Reinforced Polymer. A series of eight columns of diameter 75mm with varying height of 750mm and 1050mm are tested in this study. M30 grade concrete is used as in filled material. End support condition is hinged. For short column slenderness ratio is 40, L/D is assumed to be 10 and for slender column slenderness ratio is 60 and L/D is assumed to be 14. Four sets of short columns of height 750mm and slender columns of height 1050mm are cast [8]. A conventional PCC column, CFST and columns with fully wrapped single and double layer CFRP are compared in this study. The analytical and the experimental studies are carried out.

3. Experiment Programme

3.1. Casting and curing of CFST specimens

The circular steel tube of cross section with 75mm diameter, 2.5mm thickness and 2000mm length was bought from the shop. Cut off machine is used to cut the steel tube into varying height of 750mm and 1050mm [9]. The end portion of the steel is smoothened by surface grinding machine. With the help of steel wire brush the corrode and movable debris present privileged the steel tube are removed completely throughout the entire length [10]. The bottom end is sealed with a steel plate and concrete was filled inside the steel tube, so as to avoid the seepage of slurry while compaction and to keep it free from air gaps and it is shown in Figure 3. Then the specimens were reserved below the progression of wet curing [11].

Figure 3. Placing of concrete in CFST specimens

3.2. Casting and curing of CFRP specimens

The PVC tube of circular cross section with 75mm diameter, 2.5mm thickness and 6000mm length was bought from the shop. Cut off machine is used to cut the PVC tube into varying height of 750mm and 1050mm [12]. Concrete was filled inside the steel tube, after a day PVC tube is cut using cut off machine and the PCC is removed. Then the specimens were reserved under the progression of wet curing. After 28 days specimen is removed from curing tank and kept for dry. The external surface is wiped using the salt paper. CFRP sheets are cut into required size to wrap the entire column [13]. The epoxy is mixed with hardener to required proportion and coated over the column and CFRP sheet. The wrapped column is kept for 24 hours to dry [14].

3.3. Support conditions

End conditions for the column were taken as pinned condition and the supports were created. The column is placed over the plate which is welded by a ¾ inch rod at the centre [15].

3.4. Instrumentation and Test Procedure

All the specimens were experienced under axial compression in a column tester of 500kN capacity. The columns were loaded at centre and flattened using spirit level and plumb bob and placed in the column tester [16-18]. The load cell is placed over the column and date is transferred to A 16-Channel Data Acquisition System. To initiate the test with load of 10kN was functional and unconcerned to make the column rest on their base plate. The experimental set up is shown in Figure 4. Behaviour of CFST and CFRP is given in Figure 5 and Figure 6.

Figure 4. Experimental setup

Figure 5. Behaviour of CFST

Figure 6. Behaviour of CFRP

All the specimens were experienced under axial compression in a column tester of 500kN capacity. The deflection in each specimen is recorded using LVDT which is placed along the column on both the sides. Figure 7 and Figure 8 shows the Comparative graph showing deflection of all short columns and long columns. The deflection to the corresponding load is recorded and tabulated in Table 1 and Table 2 as follows.

Table 1. Experimental results for deflection of M30 grade short specimen

S. No	**PCC short specimen**		**CFRP single layer short specimen**		**CFRP double layer short specimen**		**CFST short specimen**	
	Load (kN)	**Deflection (mm)**	**Load (kN)**	**Deflection (mm)**	**Load (kN)**	**Deflection (mm)**	**Load (kN)**	**Deflection (mm)**
1	0	0	0	0	0	0	0	0
2	60	0	65	0	63	0.1	60	0.1
3	64	0.1	77	0.3	75	0.3	75	0.3
4	75	0.1	85	0.3	85	0.3	88	0.5
5	80	0.3	99	0.3	99	0.5	100	0.9

6	95	0.3	102	0.3	106	0.5	110	0.9
7	105	0.3	125	0.4	125	0.7	125	1.2
8	120	0.4	130	0.4	131	0.7	137	1.2
9	115	0.3	155	0.4	142	0.9	150	1.7
10	-	-	170	0.5	156	0.9	165	1.9
11	-	-	198	0.5	162	0.9	184	1.9
12	-	-	185	0.5	175	0.9	210	2.1
13	-	-	-	-	200	0.9	225	2.1
14	-	-	-	-	212	1.1	237	2.5
15	-	-	-	-	225	1.2	250	2.5
16	-	-	-	-	250	1.2	268	2.7
17	-	-	-	-	232	1.2	260	2.7

Table 2. Experimental results for deflection of M30 grade long specimen

S.No	**PCC long specimen**		**CFRP single layer long specimen**		**CFRP double layer long specimen**		**CFST long specimen**	
	Load (kN)	**Deflection (mm)**	**Load (kN)**	**Deflection (mm)**	**Load (kN)**	**Deflection (mm)**	**Load (kN)**	**Deflection (mm)**
1	0	0	0	0	0	0	0	0
2	60	0.1	62	0.1	63	0.1	60	0.1
3	64	0.1	73	0.3	75	0.3	75	0.3
4	73	0.3	85	0.5	85	0.5	88	0.3
5	80	0.4	99	0.7	100	0.9	100	0.4
6	95	0.6	102	0.7	110	0.9	115	0.9
7	105	0.6	125	1.3	129	1.2	125	1.5
8	112	0.6	130	1.5	137	1.2	137	1.5
9	99	0.4	142	1.6	144	1.5	150	1.9
10	-	-	115	1.6	156	1.6	165	2.3
11	-	-	-	-	165	1.6	184	2.5
12	-	-	-	-	178	1.8	205	2.7
13	-	-	-	-	188	1.8	225	3.1
14	-	-	-	-	175	1.8	230	3.5

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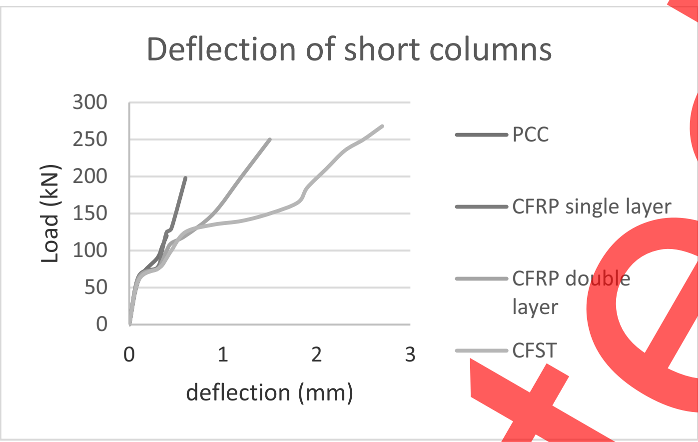

Figure 7. Comparative graph showing deflection of all short columns.

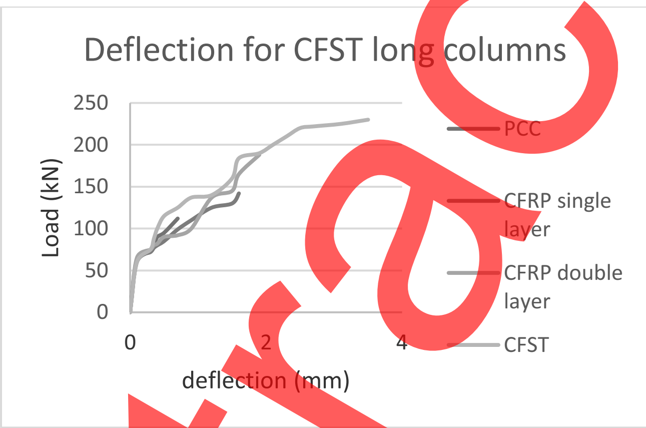

Figure 8. Comparative graph showing deflection of all long columns.

4. Analytical Investigation

4.1. Eurocode 4

The ultimate axial capacity of CFST column given by EC4 is as follows in Equation (1)

$$N_{pl,Rd} = A_a \eta 2\, f y / \gamma ma + A_c (0.8\, f_c k/\gamma_c)\,(1+\eta 1\, (tfy)/(0.8dfck)) \qquad (1)$$

Where Aa and Ac are the cross-sectional area of the structural steel and concrete respectively, t is the wall thickness of the steel tube, η1, η2coefficients calculated by following equations.

$\eta 1 = \eta 10\ (1\text{-}e/d)$

$\eta 2 = \eta 20 + (1\text{-}\eta 20)\ (10e/d)$

The theoretical capacity of CFST Columns is calculated using Eurocodes 4 and results are summarized in Table 3.

Table 3. Theoretical capacity as per Eurocode 4

Grade of concrete	Outside diameter	Thickness "t" (mm)	L/D	Effective length	λ	Nplrd

	"D" (mm)			L_e (mm)		(kN)
M30	75	2.5	10	750	0.4	165.99
	75	2.5	14	1050	0.6	134.31

4.2. AS-3600/ACI-318

Table 4 shows the Theoretical capacity. The incremental confined concrete's axial capacity which is given by Equation (2)

$$N_{\frac{AS}{ACI}} = 0.85 f_c A_c + A_s f_s \quad (2)$$

Table 4. Theoretical capacity as per AS 3600/ACI-318

Grade of concrete	Outside diameter "D" (mm)	Thickness "t" (mm)	L/D	Effective length L_e (mm)	NAS/ACI(kN)
M30	75	2.5	10	750	179.54
	75	2.5	14	1050	179.54

4.3. Comparison of Codal values

The capacity of the CFST sections is found out by using these three codes (EC4, AISC & AS/ACI) and their comparison for varying D/t ratios is given in Table 5.

Table 5. Comparative table for all codes

Grade of concrete	Outside diameter "D" (mm)	Thickness "t" (mm)	L/D	Effective length Le (mm)	Neuro (kN)	NAS/ACI (kN)
M30	75	2.5	10	750	134.31	179.54
	75	2.5	14	1050	165.99	179.54

Finally, the compressive strength of PCC, CFRP single and double layer and CFST columns are observed and compared by experimental analysis.

5. Comparison of Experimental Values and Theoretical Values

Table 6. Comparison between NEC4 Vs NACI/AS Vs Ntest results

S. No	Specimen	Slenderness Λ	Theoretical value NEC4 (kN)	Theoretical value NACI/AS (kN)	Experimental value Ntest (kN)
1	M30-CL750	0.4	134.31	179.54	268
2	M30-CL1050	0.6	165.99	179.54	230

Table 7. Experimental results for M30 grade PCC, CFST and CFRP specimens

Specimen	Outside diameter "D" (mm)	Thickness "t" (mm)	L/D	Effective length L_e (mm)	N_{test} (kN)
NL750	75	2.5	10	750	120
NL1050	75	2.5	14	1050	112
SL750	75	2.5	10	750	198
SL1050	75	2.5	14	1050	142
DL750	75	2.5	10	750	250
DL1050	75	2.5	14	1050	188
CL750	75	2.5	10	750	268
CL1050	75	2.5	14	1050	230

Table 6 and Table 7 shows the comparison of experimental values and theoretical values.

6. Conclusion

The axial compressive behaviour of eight PCC, CFRP single layer, CFRP double layer and CFST columns were tested with both ends pinned conditions by varying its slenderness ratio. The eight columns were loaded axially and its ultimate load along with deflection is recorded. The test results were compared and analysed with the codal provisions and the following conclusions were observed:

- The codal provisions generally available for predicting the axial resistance of circular CFST columns were found to be too conservative.
- The concrete filled steel tubular section showed greater load carrying capacity than the CFRP of single layered and double layered columns.
- The experimental results show that concrete filled steel tubular section of slenderness ratio 10 has a greater load carrying capacity than concrete filled steel tubular section of slenderness ratio 14.
- From the deflections recorded, CFST columns of greater slenderness ratio shows large deflection than all other columns.
- Carbon fibre reinforced polymer that is wrapped externally along the column as double layer said to carry a load which is greater and can be used for retrofitting and rehabilitation of columns.
- The effect of relative slenderness of circular CFST columns, in enhancing the compressive strength was improved by the confinement effect even for values greater than 0.5 as compared with CFRP of single and double layered columns.
- By these experimental results of PCC, CFRP which is externally wrapped as single and double layer shows lesser load carrying capacity and deflection as compared with concrete filled steel tubular sections.
- CFST is said to have 7% larger load carrying capacity as compared with column which is externally wrapped with carbon fibre reinforced polymer.

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