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Deformation Characteristics of Glass Fiber Reinforced Polymer Wrapped Axially Loaded Short Circular HSC Column

S. Karthikraja*, P. Sasthika, A. Nandakumaar, M. Santhanakumar and K. Deventhiran

Department of Civil Engineering, Vel Tech Multi Tech Dr. Rangarajan Dr. Sakunthala Engineering College, Chennai - 600062, Tamil Nadu, India;
karthikraja015@gmail.com, srisasthika7@gmail.com,
nandahts971@gmail.com, msanthanakumar007@gmail.com, devahts1007@gmail.com

Abstract

Background/Objectives: This research is aiming to find the strength and deflection effect of external wrapping of Glass fiber in short column. **Methods/Statistical Analysis:** Usually external wrapping of glass fiber increases the strength and reduce the deflection. This study was planned to achieve this aspect to prepare thirteen columns. Entire column would be divided in to four categories. A first category is under conventional mix. Second, third and fourth is comes under Full, Unidirectional and Bi-directional wrapping. All the above categories are finally divided into single and double wrapping to find the effect of thickness of external wrapping. **Findings:** The ultimate strength found in this study was about 3.63% of the reference column for full wrapping with 2 layers of GFRP wrapping. For 4 layers, the increase is 6%. In case of horizontal strip wrapping, the increase is found to be 1.83% for 2 layers and 2.97% for 4 layers. For vertical strips, the increase is 2.74% for 2 layers and 4.61% for 4 layers. The ultimate axial strain was increased to 10% in case of full wrapping with 2 layers of GFRP Wraps and 25.9% in case of full wrapping with 4 layers. In case of horizontal strip wrapping the increase is 2.19% for 2 layers and 8.22% for 4 layers of GFRP compared to the reference column with no wrapping. For vertical strips the increase is 7.6% for 2 layers and 18.6% for 4 layers when compared to control columns. Similarly, ultimate lateral strain was increased to 12% in case of full wrapping with 2 layers of GFRP Wraps and 30.28% in case of full wrapping with 4 layers. In case of horizontal strip wrapping the increase is 1.83% for 2 layers and 9.62% for 4 layers of GFRP compared to the reference column with no wrapping. For vertical strips the increase is 3.17% for 2 layers and 19.95% for 4 layers compared to reference column. **Applications/Improvements:** The above wrapping is done by using Glass Fibre, because of the reason is to select Glass Fiber, and is economical and easily available one. Finally the load and deformation characteristics were studied.

Keywords: Deformation Characteristics, Glass Fibre Reinforced Polymer, Reinforced Concrete Column, Uni and Bi-Directional Single and Double Wrapping, Wrapping

1. Introduction

The Fibre Reinforced concrete wrapping increases the axial load carrying capacity and deformation for solid concrete columns and hollow concrete columns. But, high strength was observed in case of solid columns than hollow columns. Previous findings indicated that when using Glass Fibre Reinforced Polymer there is an improvement in strength and ductility. If the designed column specimens are short columns, then these are acting as slender columns under eccentric loads[1].

FRP concrete columns given good strength even when yield and ultimate load conditions. The increased strength is due to thickness of FRP wrap around the column[2]. Increasing of characteristic strength of concrete has substantial effect on the behaviour of tested columns with

*Author for correspondence

increase in toughness and ductility of tested columns[3]. Thus, the wrapped GFRP around the column improves the ultimate stress, axial strain and lateral strain of the concrete column[4].

For high strength concrete, more number of GFRP layers with stand the maximum load carrying capacity[5]. Further, it enhances the ductility of concrete when it is encountered with axial load. Parameters influencing the strength and ductility are wrap thickness and wrap configuration[6].

In general, the lateral deflection increased in the column with eccentricity but, due to presence of GFRP layers, lateral deflection reduced, as a results, the load carrying capacity also increases[7].

Significant strength increases can be achieved by wrapping RC wall-like columns with GFRP laminates[8]. The FRP wrap appeared to play a significant role in providing a barrier to the migration of chlorides throughout the reinforced concrete element[9]. Failure of the FRP confined RC elements depends on the failure of the FRP composite membrane[10,11].

The earlier studies reported that significant results could be achieved by wrapping of three layers of GFRP[12]. A association between longitudinal stress and strain, eccentric loads and both axial load and load eccentricity are to be considered for designing the column with GFRP layers[13]. In addition, the use of E-glass fabric provides a significant enhancement along with GFRP layers[14].

Some of studies are conducted on FRP, which shows that the performance was obviously improved as the number of FRP layers increases in the jacket[15]. The flexural strength and ductility capacity may be restored if FRP composite wraps around the concrete column[16]. The stiffness and flexural strength is also achieved with more numbers of FRP layers[17]. Clamping or wrapping combined with adhesion is effective in anchoring the FRP laminate[18]. According to authors[19], increasing the number of FRP layers yields more load capacity.

If the slenderness ratio is varied from 11 to 36, the axial and hoop strains are reduced for short column ranged between 15 and 13%[20]. Flexural strength is increased in the order of 17.9 % if Epoxy bonded GFRP retrofitted RCC beams than normal RCC Beams[21].

The compressive strength is improved by using steel fibre in the concrete. The flexural and split tensile strength may also improve by addition of silica fume with steel fibre in concrete[22]. Another study[23], indicated that partial replacement of silica fume and M-sand improves the compressive strength.

Production of concrete requires strong, sound and clean aggregates, good grade of cement and lower water-cement ratio along with super plasticizer[24,25]. In this work, the property of ductility is reached by using externally wrapped GFRP layers.

2. Experimental Details

2.1 Material

Ordinary Portland Cement (OPC) 53 grade conforming to IS 12269 and Fly ash (25%), silica fume (8%) procured from local market was used as cement replacement materials. Local natural river sand was used as fine aggregate with 50% replacement of M-sand and the coarse aggregate used was crushed granite conforming to IS 383-1970. For the concrete preparation, 20 mm size aggregate of 60% and 10 mm size aggregate of 40% was used with potable ground water. A polycarboxylate of polyethylene condensate CONPLAST 430 was used as superplasticizer. Table 1 presents the mix proportions of concrete.

Table 1. Mix proportions of concrete

Mix designation	Cement (Kg/m^3)	Sand (Kg/m^3)	Coarse aggregate (Kg/m^3)
M	450.93	611.52	1247.58

2.2 Experimental Investigations

This study was done with thirteen reinforced concrete columns having 150 mm diameter and 1500 mm height. Five rods of 10 mm diameter for longitudinal reinforcement and 8 mm diameter stirrups are used for internal lateral confinement. Out of the thirteen columns, one column serves as the reference without any wrapping. Four columns are provided with bidirectional full wrapping with varying thickness of GFRP. Four columns are provided with bidirectional wrapping as horizontal strips. Another four columns are provided with unidirectional wrapping as vertical strips (Figure 1).

2.3 Preparation and Casting of Specimens

The casting specimens are by tin sheet moulds. After clamping it to a required dimension, the moulds are placed in position with the help of a lean mix mortar. To cover the reinforcement, cover blocks are placed in desired positions. Lubricating oil is used to prevent the adhesion between the concrete and tin sheets (Figure 2). Using tin

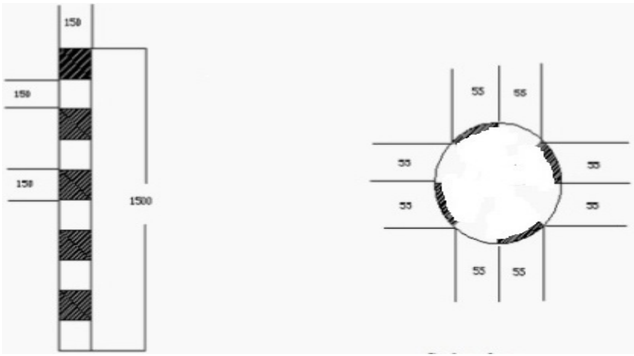

Figure 1. Different configurations of GFRP wrapping.

sheet mould casting of specimen is done. Based on design the cage for steel reinforcement is prepared. The concrete mix which is designed is poured in specimen moulds and compaction is done to prevent the formation of honey combs (Figure 3).

Figure 2. Tin sheet mould casting of specimen.

Figure 3. Demoulded specimens.

2.3.1 FRP wrapping

Wrapping of cured specimens is done by GFRP. A jet of compressed air is used to remove any dust and dirt. A rubber roller was used to confirm the proper bond between layers and distribution of resins (Figure 4).

Figure 4. Column with FRP application.

2.3.2 Experimental Set-Up

A loading frame of 200 T capacity is used to test the specimens. It also includes deflectometer of least count 0.01 mm and for dilation of column, a lateral extensometer is used. An axial compression occurs when a load of 25 kN is applied by a hydraulic jack which I measured by the dial gauges present at the top and bottom of the specimen.

3. Results and Discussion

Table 2 indicates the specimen details of GFRP wrapped columns and Table 3 shows the results due to ultimate load, axial deflection, stress and lateral deflection. The results reveal the increase of different wraps in columns.

3.1 Effect on Strength

From the Table 3, the ultimate strength was increased 3.63% of the reference column for full wrapping with 2 layers of 1mm thick GFRP Wrapping. For 4 layers, the increase is 6%. In case of horizontal strip wrapping the increase is found to be 1.83% for 2 layers and 2.97% for 4 layers. For vertical strips, the increase is 2.74% for 2 layers and 4.61% for 4 layers.

Table 2. Specimen details

Sl. No.	Specimen Designation	Diameter (mm)	Type of GFRP	Thickness of GFRP (mm)
1	CRT00	150	-	-
2	GBT21F	150	BDC	2
3	GBT22F	150	BDC	2
4	GBT41F	150	BDC	4
5	GBT42F	150	BDC	4
6	GUT21H	150	UDC	2
7	GUT22H	150	UDC	2
8	GUT41H	150	UDC	4
9	GUT42H	150	UDC	4
10	GBT21V	150	BDC	2
11	GBT22V	150	BDC	2
12	GBT41V	150	BDC	4
13	GBT42V	150	BDC	4

Table 3. Experimental results

Sl. No.	Specimen	Ultimate Load (kN)	Ultimate Axial Deflection (mm)
1	R1T100	182	1.32
2	B1T21F	668	13.40
3	B1T22F	654	13.12
4	B1T41F	1089	34.07
5	B1T42F	1096	34.29
6	U1T21H	325	2.66
7	U1T22H	343	3.13
8	U2T41H	542	10.88
9	U2T42H	539	10.82
10	B2T21V	502	10.07
11	B2T22V	497	9.97
12	B2T41V	845	27.18
13	B2T42V	833	21.91

3.2 Effect on Deformation

From the Table 3, the increase in ultimate axial strain was found to be 10% for full wrapping with 2 layers of GFRP Wraps and 25.9% for full wrapping with 4 layers. In case of horizontal strip wrapping the increase is 2.19% for 2 layers and 8.22% for 4 layers of GFRP compared to the reference column with no wrapping. For vertical strips, the increase is 7.6% for 2 layers and 18.6% for 4 layers as compared to control. The increase in ultimate lateral strain was found to be 12% for full wrapping with 2 layers of GFRP Wraps and 30.28% for full wrapping with 4 layers. In case of horizontal strip wrapping the increase is 1.83% for 2 layers and 9.62% for 4 layers of GFRP compared to the reference column with no wrapping. For vertical strips, the increase is 3.17% for 2 layers and 19.95% for 4 layers compared to reference column.

4. Conclusion

The conclusions were arrived from the studies;

- With comparison to reference column, the columns with GFRP have improved ultimate stress and ultimate axial strain.
- The maximum ultimate axial stress was increased to 6% in 4 layers of fully wrapped columns as compared to reference column without wrapping.
- Full wrapping with 4 layers of GFRP provides better confinement to concrete column.
- Vertical strip wrapping with 4 layers also give better confinement next to full wrapping with 4 layers.

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