EXPERIMENTAL STUDY ON FRP-PVC CONFINED CIRCULAR COLUMNS

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Abstract *- Columns are main structural components which are subjected to various threats. In the Proposed system, concrete filled PVC tubes with various thickness are wrapped with GFRP (Glass Fibre Reinforced polymer) and CFRP (Carbon Fibre Reinforced Polymer). The confinement patterns are made in a helical and circular manner with two different hoop spacing so as to reduce the amount of FRP required. This system can be used in low cost construction works as an economic alternative for steel tube columns. It also acts as a cast in place form work which solves the issue of inability of steel tubes to resist corrosion. The PVC lies at the outer perimeter where it performs most effectively in tension. FRP provides additional stiffness to the PVC tubes. Effect of confinement on concrete core due to PVC pipes of various thickness (3.7mm, 5.4mm, 8.7mm) and different hoop spacing(50mm and 25mm) of FRP wrapping are studied. Comparative study on effects of confinement resulted that the specimen with larger PVC thickness and carbon fibre circular wrapping resulted in higher strength than the other specimens.*

Key Words**: CFRP, Circular and helical wrapping, hoop spacing.**

1.INTRODUCTION

Lateral confinement by a jacket has been a proven method of increasing the strength, stiffness ductility and long term performance of concrete members. This method can be use d irrespective of the type of concrete such as self compacting concrete, recycled aggregate concrete etc. studies have been extensively done on various forms of jacketing for rehabilitation and strengthening of new as well as existing structures. The new materials used for these purposes include steel spirals, steel stirrups, hollow tubes, pre stressing strands, Fibre reinforced polymer materials, FRP tubes, shape memory alloy wraps, composite ropes etc. Past studies done on confining systems along with concrete filled tubes and steel or FRP material showed improvement in lateral load resisting system and gravitational effects. Studies have been done on concrete filled steel tubes and concrete filled FRP tube systems under static and seismic loading conditions. Studies revealed that concrete filled tube systems(CFT's) can improve the structural performance. Concrete filled systems especially steel tubes and FRP confinement has proved their load bearing capacity and lateral load resistive efficiency. The above two methods are not acceptable when considering their economic aspects. RCC members are always prone to environmental effects, PVC confinement can be an effective solution to safeguard members under severe environmental condition, especially in marine environments. The major advantages of PVC are high electrical insulation, low diffusion of humidity, resistance to water, acids and bases, workability including cutting, joining etc. The proposed system can act as a cast in place formwork ie; no additional formwork is required for the casting works and thus need not to remove it. The amount of water required for curing can be saved in this system since the water used for the concrete mix itself is enough for the hydration process. No water is getting escaped to the atmosphere since there is no exposure for the concrete surface.

Incorporation of FRP along with PVC can enhance the axial load carrying capacity and prevents local bulging of PVC tubes. In this study the variations in the axial load carrying capacity of PVC-FRP confined columns under the variation of different parameters is studied. The parameters are the variation in 1) different gauges of pipe,2) wrapping pattern of the FRP material ie; circular and helical confinement pattern,3) hoop spacing of the wrapping, 4) and the material used for wrapping(ie; GFRP and CFRP).

1.1 Objective

The objectives of the work done are as follows:

- To obtain the axial compressive strength of circular concrete columns due to FRP-PVC confinement
- To compare the effect of confinement due to different gauges (wall thickness) of pipes.
- To study the effect of variation in confinement due to GFRP and CFRP under different hoop spacing.
- To compare the confining actions of
    - GFRP on circular and helical pattern of confinement.
    - CFRP on circular and helical pattern of confinement
- To obtain the stress-strain behaviour of the specimens.

2. EXPERIMENTAL PROGRAM

2.1 Details of the specimen

A total of 72 FRP-PVC confined specimens, 3 control specimens and 9 specimens with PVC encasement only is made for the study. The samples were of height 350mm and diameter 160mm. The details of the different gauges of pipes are given in table 1.

Table -1: Pipe details.

Gauge of Pipe	Class of pipe (as per IS 4985-2000	Dimensions		Density
		Outer Dia. (mm)	Wall Thickness	
4	II	160	3.7 mm	1.45
6	III	160	5.4 mm	1.45
10	IV	160	8.7 mm	1.43

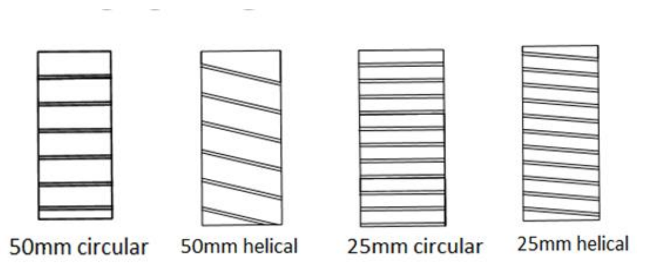

Fig -2: Hoop spacing details

2.2 Specimen Preparation

The PVC tubes were cut into a length of 350mm and externally grooved as circular and helical(Figure 2) to a width of 6mm and depth of 3mm using a centre lathe. The grooves in the PVC pipes were made to guide and to prevent the slipping of the FRP materials along the wrapping process to maintain the perfect hoop spacing and to control the amount of epoxy resin during the wrapping up. The winding process FRP material is done manually. The grooves filled with the FRP strips were continuously pressed with fingers to ensure the bonding of the material to PVC pipes with the help of epoxy resins.

Fig -3: Fibre wrapped specimens

A special stand setup as shown in figure 3 was made to maintain the pipe in position and to avoid the uplift of pipes during filling of concrete. Figure 4 shows the fibre wrapped samples.M30 grade of concrete with a strength of 37.5 MPa after 28 days of curing was used for the filling purpose.

Fig -: 4 Fibre wrapped specimens

Fig -5: concrete filled samples

2.3 Experimental Test Setup

The specimens were tested on a 3000 kN capacity compression testing machine. In order to measure the axial strain in columns, mechanical strain gauges were used. Proper care was taken to fix the pins of mechanical strain gauge using adhesives. Dial gauges were attached at the outer portion of the specimens to obtain the lateral dilation if any. Figure 6 shows the experimental setup.

3.Results and discussions

The test results for the control specimens and for the concrete specimens confined with PVC pipes only (no FRP is incorporated) is in table 2. Specimens without FRP wraps exhibited local bulging.

Fig -6: Test Setup

Table -2: Test results of control specimen

Sl.No.	Specimen	Ultimate stress(MPa)
1	Control	26
2	Gauge 4 with PVC only	28
3	Gauge 4 with PVC only	29
4	Gauge 4 with PVC only	30

The Axial compressive strength test results for the various gauge pipes confined with carbon fibre and glass fibre with different hoop type and spacing are shown in table 3. Chart 1 shows the comparison of axial compressive strength of the samples. From the comparison charts, it is clear that samples confined with gauge 10 the pipe showed improved performance than gauge 6 and gauge 4 pipes. So for further comparative studies, gauge 10 pipes are only considered Chart 2 gives the stress-strain behavior of gauge 10 samples confined with carbon fibre and glass fibre with 25 mm and 50mm helical and circular hoop spacing.

Table -3: Test results of FRP confined samples

Si. No	Pipe type	FRP Type	Hoop Type	Hoop spacing	Specimen Name	Ult. Stress (MPa)
1	Gauge 4	GFRP	circular	25	4KC25G	30
2	Gauge 4	GFRP	circular	50	4KC50G	29.85
3	Gauge 4	GFRP	helical	25	4KH25G	28.69
4	Gauge 4	GFRP	helical	50	4KH50G	30
5	Gauge 4	CFRP	circular	25	4KC25C	31.37
6	Gauge 4	CFRP	circular	50	4KC50C	31
7	Gauge 4	CFRP	helical	25	4KH25C	30.01
8	Gauge 4	CFRP	helical	50	4KH50C	25.37
9	Gauge 6	GFRP	circular	25	6KC25G	32.03
10	Gauge 6	GFRP	circular	50	6KC50G	27.6
11	Gauge 6	GFRP	helical	25	6KH25G	32
12	Gauge 6	GFRP	helical	50	6KH50G	30.5
13	Gauge 6	CFRP	circular	25	6KC25C	33
15	Gauge 6	CFRP	helical	25	6KH25C	29.74
16	Gauge 6	CFRP	helical	50	6KH50C	31
17	Gauge 10	GFRP	circular	25	10KC25G	33.2
18	Gauge 10	GFRP	circular	50	10KC50G	33
19	Gauge 10	GFRP	helical	25	10KH25G	31
20	Gauge 10	GFRP	helical	50	10KH50G	30.9
21	Gauge 10	CFRP	circular	25	10KC25C	33.5
22	Gauge 10	CFRP	circular	50	10KC50C	33.5
23	Gauge 10	CFRP	helical	25	10KH25C	32
24	Gauge 10	CFRP	helical	50	10KH50C	31.2

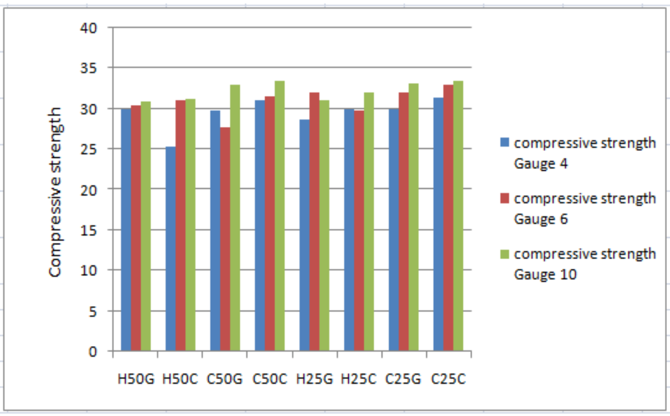

Chart -1: Comparison of axial compressive strength

From above discussions, it was observed that gauge 10 pipes acted better in confinement action than other gauge pipes. So for the comparisons of rest of the parameters, samples confined with gauge 10 pipes were only considered.

Chart 2 revealed that circular confinement pattern exhibited more compressive strength than helical confinement pattern. Chart 3 is made for the comparison of the confinement effect of different hoop spacing (25mm and 50mm} on the specimens. 25mm hoop spacing showed better performance than 50mm hoop spacing. A comparison of the FRP material used is shown in chart 4. Carbon fibre confined samples has more compressive strength than glass fibre confined sample. Since a dial gauge was used to observe lateral dilation, minute defections were only observed.

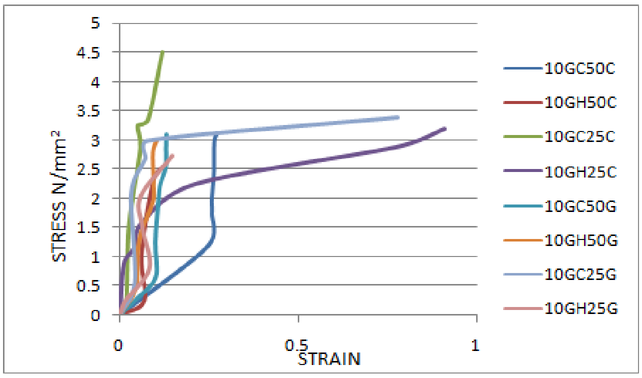

Chart -2:Stress- strain curves for gauge 10pipe samples

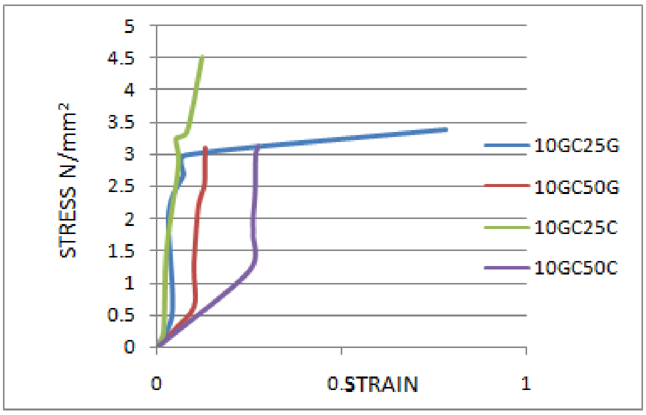

Chart -3: Stress- strain curves for confined gauge 10pipes samples with different hoop spacing

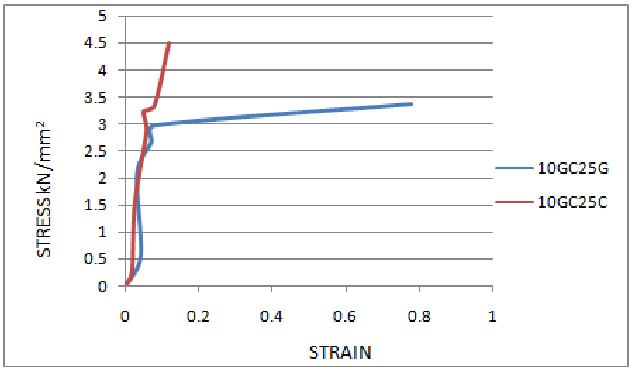

Chart -4: Stress- strain curves for CFRP and GFRP confined gauge 10 pipes

3. CONCLUSIONS

- FRP prevents the bulging of PVC pipes when loaded.
- FRP hoop failure does not occurred evenly along the length of samples
- Gauge 10 pipes confined with carbon fibre with a circular confinement of 25mm hoop spacing was found to be most efficient in confinement.
- PVC confinement results in increase in axial load carrying capacity of circular columns.
- Increase in the thickness of the PVC tube increased the confinement action.
- Gauge 4 pipe confined with circular 25mm hoop spacing carbon fibre showed 20.5% more axial compressive strength than control specimen.
- Gauge 6 pipe confined with circular 25mm hoop spacing carbon fibre showed 26% more axial compressive strength than control specimen.

- Gauge 10 pipe confined with circular 25mm hoop spacing carbon fibre showed 29 % more axial compressive strength than control specimen.
- Variation in thickness of PVC tube makes variations in the stress- strain behaviour and load carrying capacity.
- Confinement action is greater for circular wrapping than helical wrapping.
- For gauge 4 pipes, samples confined with circular confinement pattern showed 8% more axial compressive strength than helical confinement pattern.
- For gauge 6 pipes, samples confined with circular confinement pattern showed 6.7% more axial compressive strength than helical confinement pattern.
- For gauge 10 pipes, samples confined with circular confinement pattern showed 6.5% more axial compressive strength than helical confinement pattern.
- With reduced value of hoop spacing, confinement action increased.
- For gauge 4 pipes, samples confined with 25mm circular hoop spacing showed 5.5 % more compressive strength than those with 50mm helical hoop spacing.
- For gauge 6 pipes, samples confined with 25mm circular hoop spacing showed 7% more compressive strength than those confined with 50 mm helical hoop spacing.
- For gauge 10 pipes samples confined with 25mm circular hoop spacing showed 3.5% more compressive strength than those confined with 50 mm helical hoop spacing.
- Carbon fibre acted more efficiently than glass fibre.
- For gauge 4 pipes, samples confined with carbon fibre showed 2.5% more axial compressive strength than those confined with glass fibre.
- For gauge 6 pipes, samples confined with carbon fibre showed 4 % more axial compressive strength than those confined with glass fibre.
- For gauge 10 pipes, samples confined with carbon fibre showed 3% more axial compressive strength than those confined with glass fibre.

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