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Experimental Investigation On Load Carrying Capacity Of Modified Reinforced Concrete Column Wrapped With Glass Fibre Reinforced Polymer

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Abstract
In this paper, an experimental investigation was conducted to evaluate the load-carrying capacity of concrete column specimens externally wrapped with Glass Fibre Reinforced Polymer (GFRP). The study considered key variables such as the presence or absence of GFRP wrapping, as well as whether the specimens had modified or unmodified sections. For each combination of parameters, three specimens were cast, resulting in a total of 12 specimens. All specimens were subjected to axial compressive loading until failure, and their performance was monitored throughout the testing process. The results revealed that GFRP wrapping significantly improved the structural behavior and load resistance of the columns. Specifically, the specimens with both wrapping and section modification exhibited the greatest increase in strength, demonstrating the synergistic effect of geometric enhancement and external confinement. Wrapped specimens without modification also showed notable improvement compared to unwrapped ones. Failure patterns indicated a shift from brittle crushing to a more ductile response in wrapped columns. This study confirms the effectiveness of GFRP wrapping as a viable retrofitting technique for enhancing the axial load capacity of concrete columns, particularly when combined with cross-sectional modifications. The findings have potential implications for strengthening existing structures in seismic and high-load environments.

Keywords: Axial; Fibre Reinforced Polymer; Modified Section; Column

INTRODUCTION

As per the previous research findings, circular cross-section is really the most effective cross-section compared with non-circular cross-section. Due to hoop action, circular shape gives better resistance to compressive loading. Non-circular cross-sections are subjected to stress concentration at their corners leading to the ineffectual confinement of the section which leads to decrease in the load carrying capacity. Therefore, shape of column section plays a very vital role [1], [2], [3].
Rochette and Labossiere has carried out the study on how to the effectiveness better of the externally confined columns. The investigation reveals that, the modification in the non-circular sections with the help of chamfering of corners will lead to avoid the concentration of stress at corners and will make better confinement leading to increase in load carrying capacity of the cross-section. Due to presence of internal reinforcement of the reinforced concrete section, there is limitation on the chamfering of the section [2]. M. N. S. Hadi carried out the study on performance of columns wrapped with FRP composites under different

combinations of eccentricity [4], [5], use of different fibre reinforced polymer materials such Carbon and E-glass fibre [6] [7], and number of layers of fibre reinforced polymer sheets [8] [9]. Lam L and Teng J had given a model to compute the stress–strain curve of the FRP confined concrete [10]. A. Pravin and A. S. Jamwal had carried out finite element analysis to demonstrate that externally wrapped E-glass FRP is a possible solution for enhancing the strength and ductility of concrete specimens subjected to concentric loads. Parameters such wrap thickness and ply configuration were taken for the study concludes that, hoop-angle-hoop wrap configuration is recommended [11].

RESEARCH SIGNIFICANCE

An experimental investigation was carried out to evaluate the effect of the modification of the non-circular section to make it approximate elliptical cross-section on the load carrying capacity of glass fibre reinforced polymer wrapped concrete columns. Thus far, the research study carried out was on circular and non-circular cross-sections by very few researchers. There is very little research is available on the effect of shape modification on fibre reinforced polymer wrapped concrete columns. This study aims to assess the effect of shape modification on axial load carrying capacity on fibre reinforced polymer wrapped concrete columns.

EXPERIMENTAL PROGRAM

The experimental research was carried out on rectangular and elliptical (modified) cross-section externally wrapped with glass fibre reinforced polymer sheets. Unidirectional glass fibre reinforced sheets were used with an epoxy resin to glue the sheets externally around the reinforced concrete specimen. The properties of GFRP fibre and resin are mentioned in Table 2 and Table 3 as provided by the manufacturer.

The parameters investigated on a total number of 12 specimens cast in two stages. The first stage consists of testing 3 unwrapped specimens and second stage consists of testing GFRP wrapped 9 specimens under universal testing machine. GFRP sheets were wrapped in the perpendicular direction of the longitudinal direction of the column. A gap of 5 mm was kept to avoid the direct contact of the GFRP sheets to loading machine. The general properties and the dimensions of column specimen are shown in Table 1. All the column specimens were loaded axially under universal testing machine to assess the load carrying capacity of the column cross-sections.

Table 1. Details of the column specimens

Specimen ID	Strengthening	No. of Specimens	Shape of cross-section	Loading
U	Unwrapped	3	Rectangular	Axial
WNC	Non-Chamfered and GFRP Wrapped	3	Rectangular	
WC	Chamfered and GFRP Wrapped	3	Chamfered Rectangular	
WMS	Modified and GFRP Wrapped	3	Approximately Elliptical	

Note: U = unwrapped specimen; W = wrapped specimen; NC = Non-Chamfered; C = Chamfered; MS = Modified Section.1. Evolution of Sentiment Analysis Techniques.

MATERIAL PROPERTIES

Tests had been carried out to find the properties of the deign mix for concrete, tensile strength of tor-steel and mild steel. Properties of the glass fibre reinforcement polymer (GFRP) and epoxy resin were adopted as per manufacturer's specifications.

Mix design is carried out according to Indian Standard recommended method of concrete mix design i.e. IS 10262:2009. For this project a design mix of M30 grade was designed. The 28 days compressive strength of the concrete used was ranging from 32 to 35 MPa. A slump of 75 mm was maintained for all specimens.

The longitudinal reinforcement used in this study had 10 mm diameter and transverse reinforcement i.e.

stirrups had 6 mm diameter plain bars with 150 mm spacing. The ultimate strength of longitudinal and transverse reinforcement was in the range 425-455 MPa and 265-275 MPa, respectively. The reinforcement details of rectangular, elliptical (modified) and UTM test setup for columns is as shown in Figure 1, 2, and 3 respectively.

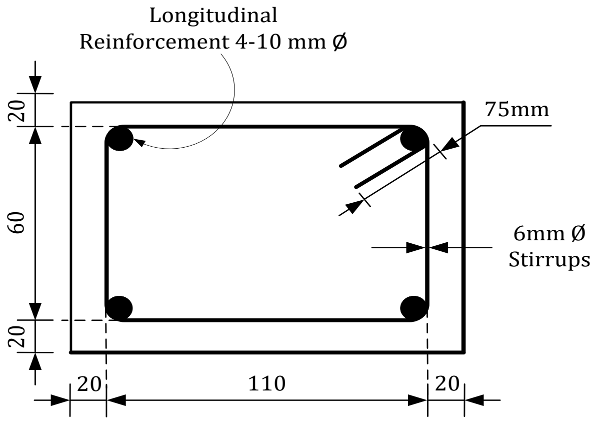

Figure 1. Reinforcement details for rectangular cross-section

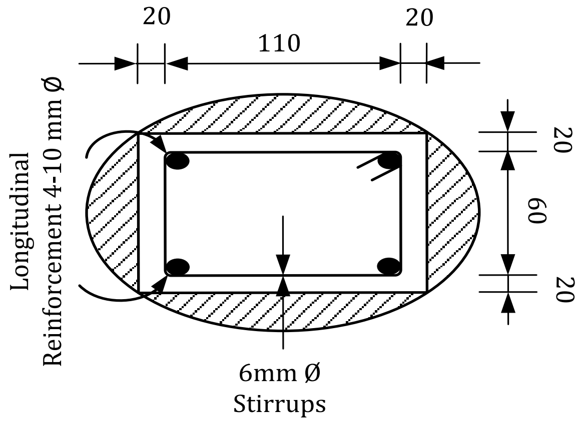

Figure 2. Reinforcement details for elliptical (modified) cross-section

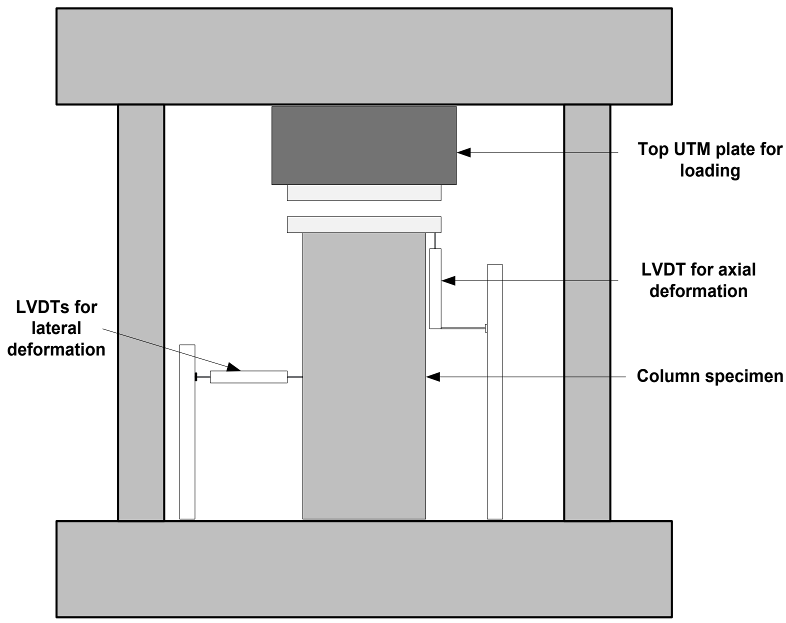

Figure 3. Instrumentation and test setup for column specimens

GLASS FIBRE REINFORCED POLYMER AND EPOXY RESIN

Properties of the glass fibre reinforcement polymer (GFRP) and epoxy resin used in this study for external strengthening of the reinforced concrete specimens are summarized in Table 2 and Table 3.

Table 2. Properties of fibre

Property	Fiber
Tensile strength, MPa	2060
Tensile modulus, MPa	75900
Elongation at break	0.04

Table 3. Properties of resin

Property	Resin
Tensile strength, MPa	875
Tensile modulus, MPa	60000
Strain	0.0146

SPECIMEN PREPARATION

The moulds for the rectangular, and elliptical (modified) cross-section were custom made to ensure the quality work during casting of the specimens as the requirement differs from traditional for modified section. Four longitudinally cut elliptical parts of which 2 with small radius and 2 with big radius were used as attachments to make the rectangular section as approximately elliptical (modified section). Specimens were then removed from the moulds after 24 hours and were kept for curing for 28 days. Refer Figure 4, 5, 6, and 7.

Figure 4. Column specimens after 28 day's curing

Figure 5. GFRP wrapped Column specimens

Figure 6. Attachments for rectangular section to make elliptical section

Figure 7. Elliptical GFRP wrapped Column specimens

EXPERIMENTAL RESULTS AND DISCUSSION

Load displayed during testing on Universal Testing Machine was taken directly as the load carrying capacity of the cross-section at respective time periods. The deflections were recorded from the LVDT attached to data acquisition system. The experimental ultimate load values and failure conditions are summarized.

Failure modes

In this section, the experimental results are given in terms of compressive load versus axial deformation values. Different types of failure modes such as concrete crushing, rupture of FRP, delamination of the FRP sheet from the surface, spalling of concrete and combination of delamination and FRP rupture may be expected. Mainly two types of failures were observed from the experimental study, namely, concrete crushing, and rupture of GFRP reinforcements under hoop tension. Refer Figure 8, 9, and 10.

Figure 8. Unwrapped Column specimens

Figure 9. Wrapped Column specimens

Figure 10. Shape Modified Wrapped Column specimens

Table 4. Summary of average experimental results for all specimens

Parameters	P (kN)	l (mm)	Failure Mode
Unwrapped Cross-section	383.70	07.20	Peeling off concrete cover
GFRP Wrapped Cross-section	536.50	08.60	FRP rupture at mid-height with noise
GFRP Wrapped Modified section	603.20	13.00	FRP rupture at mid-height with loud noise

CONCLUSION

A total of 12 RC column specimens were casted and tested under axial loading up to failure, in order to study the effect of shape modification on load carrying capacity of the GFRP wrapped column cross-section.

- External wrapping of column specimens with glass fiber reinforce polymer offer more effective confinement which leads to increase in load carrying capacity of the specimens compared to unwrapped specimens.
- For non-circular cross-sections corners should be rounded off with minimum corner radius of 10 mm to avoid stress concentration and premature failure of the specimen.
- Percentage increase in load carrying capacity of axially loaded GFRP wrapped column was about 35-45% than that of unwrapped column.
- Further the percentage increase in load carrying capacity of axially loaded GFRP wrapped with modified section column was about 10-15% than that of wrapped columns.

Thus, it can be concluded that the shape modification is a good technique to increase the load carrying capacity of the specimen.

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