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Strengthening of reinforced concrete circular columns using glass fibre reinforced polymers

Manish kumar Tiwari [1], Rajiv Chandak [2] , R.K. Yadav [3]
[1]Student M.E. Structural Engineering, Department of Civil Engineering Jabalpur Engineering College Jabalpur, India
[2]Professor, Department of Civil Engineering Jabalpur Engineering College Jabalpur, India
[3]Associate professor, Department of Civil Engineering Jabalpur Engineering College Jabalpur, India

Abstract: -
Seismic retrofitting of reinforced concrete members vulnerable to strong earthquakes is a great problem. It has long been recognized that confinement to concrete compression members not only increase the strength but improve ductility significantly. The present study focuses on the behavior of reinforced concrete specimens strengthened using glass fiber reinforced polymer (GFRP) subjected to axial compressive loading. In this study specimen of circular cross section having length to diameter ratio of 2.0 and 0.96% longitudinal reinforcement were prepared and tested for 28 days compressive strength. The specimens were wrapped with 0,2,4,6 and 8 layers of GFRP outside the surface of the specimens as confinement. The test results showed that there is a significant increase in the strength of specimen with the increase of confinement layers on the specimen. The 28 days compressive strength of specimen wrapped with 8 layers of GRRP was increased by 47% as compared to the strength of specimen without any confinement.
Keywords:- confinement, glass fibre ,compressive strength.

I. Introduction

Several traditional methods have been used to retrofit ,the reinforced columns damaged by earthquake forces or some other reasons. The purpose of confinement is to increase the strength and ductility of the reinforced members. The main objective of confinement is to prevent the concrete cover from spalling, to provide lateral support to longitudinal reinforcement and to enhance the strength and ductility of the member. In India it has been observed that mostly compression members of the building have been failed during earthquake due to poor lateral confinement. During a severe earthquake, the structure is likely to undergo inelastic deformation and has to depend on ductility and energy absorption capacity to avoid collapse. Such buildings need to be strengthened to increase strength, stiffness and ductility.

Fibre reinforced composite materials are becoming popular in civil engineering construction practices. One of the most practical applications of these materials is concerned with the strengthening and retrofitting of reinforced concrete compression members by means of external confinement with the GFRP sheets. The role of FRP for strengthening of existing or new reinforced concrete structures is growing at an extremely rapid pace owing mainly to the ease and speed of construction, and the possibility of application without disturbing the existing functionality of the structure.

The behavior of FRP wrapped concrete cylinders with different wrapping materials and bonding dimensions has been studied by **Lau and Zhou[1] (2001)** using the finite element method (FEM) and other analytical method. It was found that the load carrying capacity of the wrapped concrete structure is governed by mechanical properties such as tensile elasticity modulus and Poisson's ratio of the wrapping sheet**. Manuel and Carlos[2]** (**2006**) have conducted tests on modes of circular cylindrical columns of concrete with GFRP jackets subjected to axial loading for different height of cylinders and it was found that the increase in number of layers led to an increase in the maximum load carrying capacity. **Riad, et al[3] (2003)** conducted tests on square glass fibre composites. It was found that the stiffness of the applied FRP jacket was the key parameter in the design of external jacket retrofits. **Shamim, et al[4] (2002)** have investigated the seismic behavior of concrete columns confined with steel and FRP. It was concluded that the use of FRP significantly enhances strength, ductility and energy absorption capacity of columns. **Mander, et al.[5] (1988)** proposed a model to calculate the increase in concrete compressive strength due to confining pressure provided by transverse reinforcement in reinforced concrete columns. The model has been extended to the case of FRP-confined circular and square reinforced concrete by sections several researchers **Wang and Restrepo[6] (2001).**

This paper envisages the effect of lateral confinement using GFRP sheets on strength of reinforced concrete specimens.

II. EXPERIMENTAL INVESTIGATION

Test specimen Details: - Experiments were conducted on circular specimens. The specimen of height 300 mm and 150 mm in diameter were used. Reinforcement details for the column are shown in fig.1 and the details of the specimens tested are given in table 1. The ingredient used in concrete was OPC of 43 grade (JP cement), Local River sand confirming to zone II (specific gravity 2.645) and clean portable water. A design mix of M-30 (1:1.73:3.23) were used to prepare the specimens. Fe 415 grade steel is used as longitudinal reinforcement and lateral ties.

Specimens were wrapped externally by 2, 4, 6 and 8 layers of GFRP sheets. Before strengthening the specimens with GFRP sheets, a surface preparation was carried out, which included cleaning, and then epoxy adhesive was used for bonding GFRP sheets on the specimens. Additional layers of epoxy adhesive were applied between GFRP sheets.

Table-1 reinforcement and confinement details

Specimen	No.of GFRP layer	Column size (dia.) mm	Detail of Reinforcement using for columns	
			longitudinal reinforcement	stirrups
C-1	0	150	6 Nos. of 6 mm dia	5 mm dia 90 mm c/c
C-2	2	150	6 Nos. of 6 mm dia	5 mm dia 90 mm c/c
C-3	4	150	6 Nos. of 6 mm dia	5 mm dia 90 mm c/c
C-4	6	150	6 Nos. of 6 mm dia	5 mm dia 90 mm c/c
C-5	8	150	6 Nos. of 6 mm dia	5 mm dia 90 mm c/c

III. Strengthening of columns:

Before bonding the composite fabric on to the concrete surface the required region of concrete surface was made rough using a coarse. Sand paper texture and cleaned with an air blower to remove all dirt and debris. One the surface was prepared to the required standard, the epoxy resin was mixed in accordance with manufacturer's instructions mixing was carried out in a plastic container and was continued until the mixture was in uniform colour. When this was completed and the fabrics had been cut to size, the epoxy resin was applied to the concrete surface. The composite fabric was then placed on top of epoxy resin coating and the resin was squeezed through the roving of the fabric with the roller. Air bubbles entrapped at the epoxy/concrete or epoxy/fabric interface were to be eliminated. Then the second layer of the epoxy resin was applied and GFRP sheet was then placed on top of epoxy resin coating and the resin was squeezed thorough the roving of the fabric with the roller and the above process was repeated. This operation was carried out at room temperature. Concrete specimens strengthened with glass fiber fabric were tested after 24 hours at room temperature. The preparation and strengthening process of specimens is shown in figure 2, 3 and 4.

Fig.1-details of reinforcement used in specimens

Fig.2-fixing up GFRP sheet on column

Fig.3-fixing up GFRP sheet on column

Fig.4-Columns after strengthening with GFRP

IV. EXPERIMENTAL RESULTS AND DISCUSSION

Circular columns are tested for their compressive strength. In circular columns total five sets of columns C-1, C-2, C-3, C-4 and C-5 tested for compressive strength for different layer of GFRP i.e. 0,2,4,6 and 8 layers respectively. It was observed that the column C-5 has maximum strength when compared to that of the column C-1, without any confinement.

V. RESULTS

In the specimen without GFRP wrapping C-1, failure was due to concrete crushing at the column and cracks were noticed along the height of the column, for the other Glass fiber wrapped specimens, failure occurred due to the fracture of GFRP composites at the columns due to the stress concentration in those regions. In all cases, the columns failure was the results of the rupture of the FRP jacket, associated with concrete crushing of the column and marked by wraps rupturing in the circumferential direction. The test results are summarized in table-2.

Table-2 Test results:-

S. No.	Column Designation (sets)	No. of GFRP layers	Avg. compressive strength of specimen (N/mm^2)
1.	C-1	0	38.41
2.	C-2	2	42.36
3.	C-3	4	48.39
4.	C-4	6	53.29
5.	C-5	8	56.49

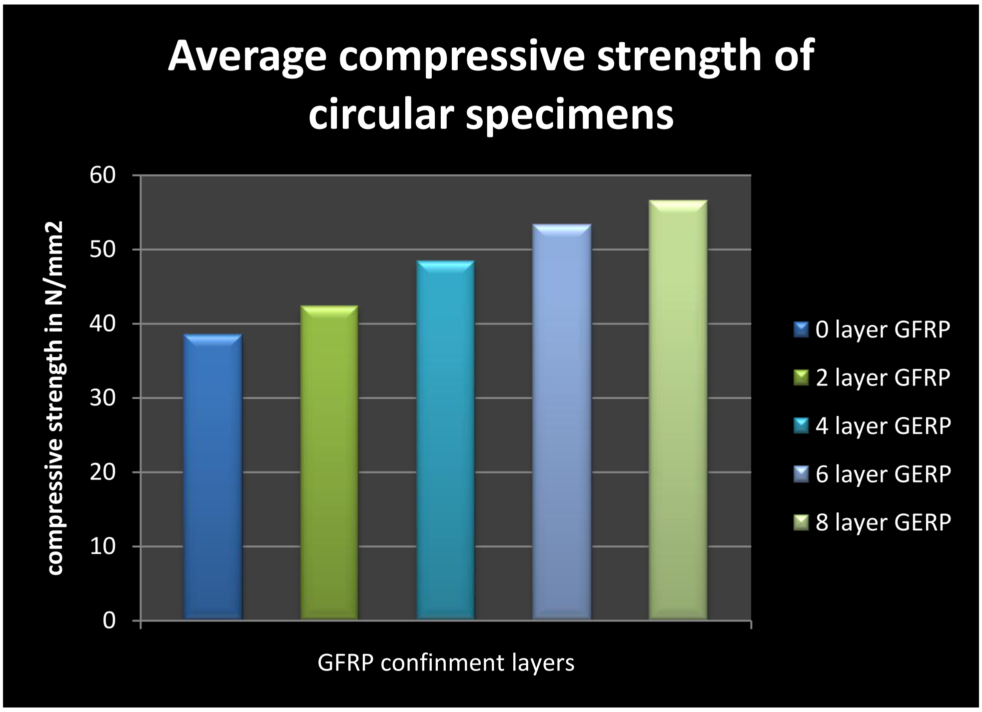

Fig.5-Average compressive strength of circular specimens with different layers of GFRP

VI. DISCUSSION

From the test result (shown in fig. 5) it is clear that there is significant increase in strength of specimens confined with GFRP layers. Specimen C-2 with 2 layer of GFRP attained an enhancement of 10.5% strength greater than the strength of specimen C-1 with zero layer of GFRP. Specimen C-3 attained an enhancement of 26% with 4 layer of GFRP, specimen C-4 attained an enhancement of 38.5% and specimen C-5 has 47% as compare to the specimen C-1 without confinement.

VII. CONCLUSIONS

From the series of tests conducted on the concrete specimens with different degree of confinement the following conclusions are drawn:

1. The confinement in the form of GFRP sheets increases the compressive strength of the specimens remarkably.
2. If the specimen is wrapped with 8 layers of GFRP sheets the strength increases to 47% of the strength without confinement.

From the study it can be concluded that the column can be confined with GFRP sheets to increase their strength to a great extent. This material (GFRP) may be used in seismic retrofitting or RCC compression members.

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