EXTERNAL STRENGTHENING OF REINFORCED CONCRETE COLUMN WITH CFRP

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Abstract- *In some buildings, when quality control is poor, the columns have a weak compressive strength, particularly in floor zone. Low compressive strength of the column member will lead to reduction in bearing capacity of column. This paper is carried out to investigate the overall actions of R.C columns, strengthened with wrapped CFRP. From the literature study One or two of them will be a control specimen and the other six specimens were strengthened with CFRP. The parameters considered are the number of composite layers and the compressive strength of unconfined concrete. The main parameters studied from the literature research were the compressive strength, and the height of CFRP wrapped part of column. The results include mode of failure, ultimate load. All the test specimens were loaded to failure in axial compression and the behavior of the specimens in the axial directions was investigated. Test results exposed that the CFRP wrap increases the strength and ductility of plain and RC cylinders expressively. The main conclusion of this paper was, strengthening of column using CFRP and which may give good results of the column carrying capacity.*

Keywords: Strengthening, CFRP, RC columns, Compressive strength.

1. INTRODUCTION

Fiber-Reinforced polymer(FRP), also is a composite material made of a polymer matrix reinforced with fibers. The fibers are usually glass, carbon, or aramid, although other fibers such as paper or wood or asbestos have been sometimes used sometimes used. The polymer is usually an epoxy, vinyl ester or polyester thermosetting plastic, and phenol formaldehyde resigns are still in use. FRPs are commonly used in the aerospace, automotive, marine, and construction industry. Composite materials are engineered or naturally occurring materials made from two or more constituent materials with significantly different physical or chemical properties which remain separate and distinct within the finished structure. Most composite has strong. Stiff fiber in a matrix which is weaker and less stiff, often with a low density. Commercial material commonly has glass or carbon fibers in matrices based on thermosetting polymer, such as epoxy or polyester resign. Sometimes, thermoplastic polymer may be preferred, since they are moldable after initial production. There are further classes of composite in which the matrix is metal or a ceramic. For the most part, these are still in a development stage, with problems of high manufacturing costs yet to be overcome. Furthermore, in these composites the reason for adding the fibers are often rather complex; fir examples, improvements may be sought in creep, wear, fracture toughness, thermal stability, etc.… [1]. Fiber reinforced polymer (FRP) are composites used in almost in every type of advanced engineering structure, with their usage ranging aircraft, helicopter and spacecraft through to boats, ships and offshore platforms and to automobiles, sports, goods, chemicals processing equipment and civil infrastructure such as bridges and buildings. The usage of FRP composites continues to grow at an impressive rate as these materials are used more in their existing markets and become established in relatively new markets such as biomedical devices and civil structures. A key factor driving the increased applications of composites over the recent years is the development of advanced forms of FRP materials. This includes development in high performance resign systems and new style of reinforcement, such as carbon nano tubes and nano particles. This paper provides an up-to-date account of the fabrication. Mechanical properties, delimitation resistance, impact tolerance and application of 3 D FRP composites.

2. SIGNIFICANCE OF THE INVESTIGATION

Research carried out in the past, and available in literature has shown that CFRP is extensively used in strengthening of structural components. However, de bonding of CFRP sheet is quite significant in such structural elements. Supposing, if beam is designed for a particular load, and if after a couple of years, it has to take revised and increased load due to revamped occupancy conditions or any such reasons, dismantling and re-casting the beam is not a feasible alternative, hence, retrofitting is a solution, which can be successfully adopted. [2] The deboning of CFRP is mainly due to failure of bond between concrete and CFRP which results in underutilization of material strength. However, CFRP can be utilized more effectively if a well-defined approach is chosen to analyze the problem and carry out strengthening operation. In the current work, efforts have been made to study, highlight and present the improvement in structural response of the beam strengthened to take revise loads and moments with the use of externally bonded CFRP strips.

3. MATERIALS

3.1 CFRP Sheet

CFRPs are composite materials. In this case the composite consists of two parts a matrix and reinforcement. In CFRP the reinforcement is carbon fiber, which provides the strength. The matrix is usually a polymer resin, such as epoxy, to bind the reinforcement together. Because CFRP consists of two distinct elements, the material properties depend on these two elements. The reinforcement will give the CFRP its strength and rigidity measured by stress and elastic modulus respectively. Unlike isotropic materials like steel and aluminum, CFRP has directional strength properties. The properties of CFRP depend on the layouts of the carbon fiber and the proportion of the carbon fibers relative to the polymer. The two different equations governing the net elastic modulus of composite materials using the properties of the carbon fibers and the polymer matrix can also be applied to carbon fiber reinforced plastics. [3] The CFRP sheet, which was applied for wrapping the specimen columns, had a fiber thickness of 0.176 mm, a modulus of elasticity of 204 GPa, an ultimate strength in tension of 3800 MPa and an ultimate strain of 1.55 %.

3.2 Coating Materials

- Epoxy-polyamine primer
- Epoxy putty
- Epoxy adhesive

This layer used for surface preparation, cleaning, forming, was used for bonding CFRP sheets on the specimens.

3.3 Cement and Aggregates

Locally available ordinary/commercial Portland cement will be used as a binding material. According to IS 8112: 2013 [4], the specific gravity of the cement is tested, and the value obtained is about 3.13. Natural river sand passing through 4.75mm is used as fine aggregate and crushed blue metal about 10mm in size will be used as a coarse aggregate. Crushed blue metal jelly is the blue-gray hard stone, bluish in color, which is crushed and used for concrete production in the southern part of India. The sieving analysis of both fine and coarse aggregate is carried out according to IS 2386(1):1963 [5] and the specific gravity of the sand and the coarse aggregate is about 2.48 and 2.67, respectively.

3.4 Super plasticizer

Conplast SP430 is a chloride free admixture based on selected sulphonated naphthalene polymers. It is used in prestressed concrete and with sulphate resisting cements and marine aggregates. It is supplied as a brown solution which instantly disperses in water. Conplast SP430 disperses the fine particles in the concrete mix, enabling the water content of concrete to perform more effectively.

3.5 Water

Water is most necessary for concrete production [6]. It is used for concrete mixing and curing of concrete material together for workability. The pH value of water should not be less than 6. Its recommendation should be as per IS 456:2000

4. MIX DESIGN

4.1 Mix Design for M30 Grade Control Mix

As per IS 10262:2009, mix design for M30 grade concrete is carried out.

Table -1: Target Mean Strength of Concrete

Target mean strength (f_t)	f_{ck}+ 1.65S
F_t	Target mean compressive strength of 28 days (N/mm^2)
F_{ck}	Characteristic compressive strength at 28 days(N/mm^2)
Standard deviation	5 N/mm^2
F_t	30 + (1.65 x 5) = 38.25 N/mm2

Table -2: Mix Ratio of M30 Control Mix

Cement	Fine Aggregate	Coarse Aggregate	Water
520 kg/m3	851.5 kg/m^3	824.7 kg/m^3	208 lit/m3
1	1.64	1.58	0.4

The ratio becomes in terms of per cubic meter of concrete is1: 1.64: 1.58: 0.4

5. EXPERIMENTAL INVESTIGATION

5.1. Specimen Description

(CFRP confined cylinder preparation) configurations of CFRP wrapping, the surface of the specimen was ground to remove loosely held powders, and was then cleaned with water and left to dry, before wrapping, the concrete surface was coated with a layer of epoxy primer; a layer of epoxy resin was next applied on the surface of the specimen 2 3 h after coating the primer when the primer was not yet completely dry, this was followed by wrapping continuous carbon/epoxy laminates around the specimen with the fibers oriented in the hoop direction, forming one to three layers (n=3) of CFRP with each layer containing a single lap of fiber sheet, as the width of a single sheet available to the authors was not sufficient to cover the entire length of a specimen, two separate sheets were used for the upper and lower parts of each specimen respectively, without overlapping at the circumferential seam, after the wrapping of each lap of fiber sheet, a layer of epoxy resin was applied and a screw roller was used to remove air voids and to allow a better impregnation of the resin.

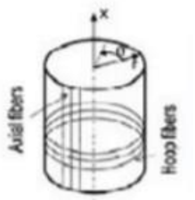

Fig-1: Fiber orientation in RC cylinder

5.2. Material Properties

To verify the mechanical properties of carbon fibers, tensile experiment was conducted on a sample of standard carbon fiber, The test coupon specimens had a length of 250mm including two 60 mm glass clips and a width of 12.5 mm shows the dimensions of the test specimens in detail, The experience of tensile fiber, samples of fiber-way single: Used in this research are three types of carbon fiber, the first type (fiber in one direction) is horizontal the second type (carbon fiber two-way), the third type (Four directions), resin used, casting cubes / 5 × 5 × 5 /cm according to the rules of Samples in the tensile character 8 according to the rules[7].

5.3. Specimen Typical Arrangement

(CFRP confined cylinder preparation) configurations of CFRP wrapping, the surface of the specimen was ground to remove loosely held powders, and was then cleaned with water and left to dry, before wrapping, the concrete surface was coated with a layer of epoxy primer; a layer of epoxy resin was next applied on the surface of the specimen 2 3 h after coating the primer when the primer was not yet completely dry, this was followed by wrapping continuous carbon/epoxy laminates around the specimen with the fibers oriented in the hoop direction, forming one to three layers (n=3) of CFRP with each layer containing a single lap of fiber sheet, as the width of a single sheet available to the authors was not sufficient to cover the entire length of a specimen, two separate sheets were used for the upper and lower parts of each specimen respectively, without overlapping at the circumferential seam, after the wrapping of each lap of fiber sheet, a layer of epoxy resin was applied and a screw roller was used to remove air voids and to allow a better impregnation of the resin. The finishing end of each sheet overlapped the starting end of the sheet by 100 mm.

5.4. Test Setup and Loading

To perform uniaxial compression and axial testing on specimens, Hydraulic testing machine was used in. Bottom jaw of the machine is adjustable in the vertical direction and it is attached to an actuator, while the top jaw is fixed. The specimens were tested using a 2,000 KN capacity compression machine and the data were monitored using an automatic data acquisition system. The tests were continued up to failure under a monotonically increasing concentric load in a displacement control mode [8]. The force and displacement data were obtained by data collecting system of the machine during the test and were stored for future reduction and analysis.

5.4.1 Compressive strength of concrete Cylinder

Compressive strength of concrete depends on many factors such as water-cement ratio, cement strength, quality of concrete material, quality control during production of concrete etc. Test for compressive strength is carried out either on cube or cylinder.

Fig-2: Compressive strength of concrete

6. RESULT AND DISCUSSION

The overall response of the wrapped concrete cylinders was superior to that of the unwrapped cylinders subjected to the same environmental conditions. The CFRP wrapped specimen showed significant improvement in terms of strength, stiffness. and ductility in comparison to a similar unwrapped cylinder.

6.1 Failure Behavior

The wrapped specimens subjected to the freeze-thaw cycles appeared to have a more catastrophic failure in comparison to the one kept at room failure modes of the specimens subjected to the freeze-thaw cycles and the room temperature conditions are

6.1.1 Axial strength

The axial strength of the unwrapped concrete subjected to freeze-thaw cycling was 46 percent lower than the unwrapped cylinders. The CFRP wrapped concrete subjected to the freeze-thaw cycles behaved as follows: one layer of wrap increased the strength by 57 percent; 2 layers of wrap increased the strength by 35 percent. The average axial strengths of the three cylinders tested in each category are given in Table. From the test results, a 2-layer wrap was found to restore the strength of a freeze-thawed cylinder to that of an unwrapped specimen kept at room temperature. Fig. 5.2 compares the axial strength versus the axial strain for all specimens tested and shows the impact of the freeze-thaw cycling on the behavior of the plain concrete. Freeze-thaw cycling significantly reduced the stiffness and strength of concrete in comparison to specimens kept at room temperature. The l-layer wrapped column at room temperature had the highest modulus of elasticity (initial tangent stiffness) and thus, sustained less axial strain in the elastic range among all tested specimens. Also, evident in Fig. 4 is the effect of CFRP wrapping in increasing the initial stiffness of wrapped specimens compared to the unwrapped specimens. The initial stiffness for l- and 2-layer wrap is very similar and thus, a second layer of wrap appears to have minor influence on stiffness.

6.1.2 Radial Strain

Under axial compressive stress, a column will experience radial expansion in addition to the axial compression strain. This radial strain is equal to the circumferential strain that was measured in the tests. The CFRP wrapping appears to enhance the axial compressive strength through confinement of the concrete in the radial direction. In fact, the results show that, at the same stress level, an unwrapped specimen exhibits larger radial strain in comparison to the wrapped specimen. Radial strain relationship. The response is similar for all tested specimens and is almost a bilinear relationship. The curves are characterized by an initially steep slope followed by a much shallower slope. The steep slope implies that a large increase in axial strain corresponds to a small radial strain. After an axial strain of about 2000, the rate of radial to-axial strain increases and a small increase in axial strain induces an extensive increase in radial strain until the column fails.

6.1.3. Plain Specimens

The axial stress-strain curves for the plain specimens are presented. This shows that the unconfined concrete strength varies between 35 and 45 MPa and the corresponding strain of the unconfined concrete strength varies between strain of 0.2 and 0.25 percent. The average unconfined concrete strength of 40 MPa and corresponding strain of 0.22 percent was calculated.

Table-3 Average values from the experimental tests of the jacketed concrete columns under Axial load.

S. No	Material	Type	No. of Samples	Axial Load In (Mpa)
C	-	UNWRAPPED	3	31
				34
				33
T1	CFRP	WRAPPED 1 LAYER	3	33
				31
				34
T2	CFRP	WRAPPED 2 LAYERS	3	89
				92
				90
T3	CFRP	WRAPPED 3 LAYER	3	140
				143
				143

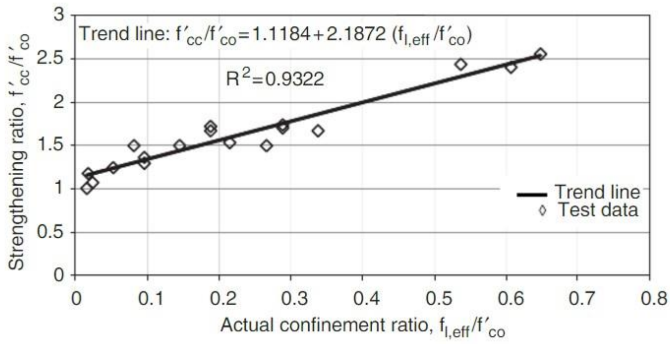

Fig-3: Behavior of Plain Specimen under Axial load condition (28 days)

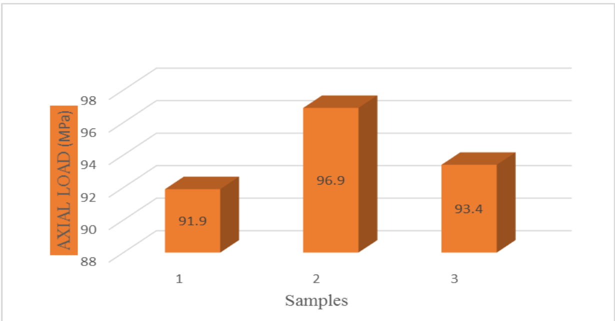

Fig -4: Behavior of two-layer CFRP Wrapped column in transverse orientation under Axial load

Fig-5: Behavior of Four layered CFRP Wrapped column in Transverse orientation under Axial load

Fig-6: Prism Test

Fig-7: Cube Test

7. CONCLUSIONS

In general, the CFRP sheets were very effective in strengthening of concrete columns after exposure to freeze-thaw cycling Based on the test results as following conclusions were drawn:

- The CFRP wraps appear efficient in strengthening concrete cylinders after exposure to freeze-thaw cycling in terms of strength, stiffness, and ductility. FRP wrap was capable of restoring the strength of cylinders exposed to freezing-thawing to that of unwrapped specimens at room temperature. l CFRP wrapped concrete exposed to freeze-thaw cycling showed a significant increase in strength (up to 57 percent) when compared to unwrapped specimens exposed to the same conditions.

- A second layer of CFRP wrap provides an extra 30 percent increase in strength. The wrapped cylinders subjected to freeze-thaw cycling failed in a more catastrophic fashion than those at room temperature.

- For the same volume of CFRP bonded to the column, the fully wrapped column is more effective than unwrapped columns in increasing axial load and moment capacities within the compression control zone. The effectiveness is more pronounced when the CFRP volumetric ratio is increased.

- The ultimate lateral strains (εlu) increases with increasing CFRP volumetric ratio, leading to a higher effective lateral confining pressure. The reported values did not reach the maximum CFRP tensile strain (or CFRP rupture) in either fully wrapped column.

- The Test Results generated in this study successfully simulated the behavior of unwrapped and fully wrapped RC columns with CFRP. There is good agreement between comparative predictions and experimental results published in the literature when comparing the confined concrete compressive stress-strain (fc $-\varepsilon c$) relationships. The results gives in a reasonable value for the column the ultimate confined concrete compressive stress (f ‘cc) and the ultimate confined concrete axial strain(εccu) corresponding to the ultimate confined concrete compressive stress.

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