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# Behaviour of GFRP Wrapped RC Columns under Axial Compression

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**Abstract –** ***Retrofitting to the RC columns used to increase its strength, ductility and stiffness. For this most recent method is using of fiber reinforced polymer sheets. The external GFRP confinement to the RC members has become a more efficient and very convenient method. This type of external bonding of reinforced polymers becomes popular for infrastructure applications. The existed many short RC columns are vulnerable mainly to failure in brittle and shear nature. This type of failure demonstrated during the seismic events. So, It is becoming more important to find out the behaviour of short RC columns and making retrofit to them. The objective of this present study mainly focused on the finding of the effectiveness of gfrp retrofitting to RC columns and to evaluate the performance improvement of pre-failure columns after gfrp confinement externally. For strengthening the RC columns Chopped strand mat type of Glass fiber polymer was used. It was found experimentally that there is a possibility to enhance the resistance of brittle failure of columns by making retrofit and effective in increasing the load carrying capacity of short columns.***

***Key words : Short column, retrofitting, strengthening, glass fiber polymer, Chopped strand mat***

## I. INTRODUCTION

Column was the most important element in any type of structure. Short columns were more susceptible to fail in crushing and brittle manner. It is commonly observing failure type in earthquake prone areas is that fail in brittle shear failure. This type of shear failure occurs in columns with low shear span to depth ration. So it is important to investigate to finding the effective methods for retrofitting to this type of brittle shear failure columns. The use of FRP polymer composites in industrial and infrastructure applications has increased very rapidly. Advanced materials of composites were used to improving and enhancing the strength and performance of structural elements particularly of short RC columns [1 – 2]. An attempt has been made hereby to investigate the experimental behaviour of GFRP wrapped small scale square RC columns with varying corner radii. The results showed that smoothening of the edges of square cross-section of RC columns play a significant role in delaying the rupture of the FRP composite at the edges. Corner radius equal to concrete cover gives better results in terms of ultimate load carrying capacity than the corner radius less than cover for confined RC columns [3]. An experimental investigation was undertaken for observing the effects of continuing corrosion process on the strength and ductility aspects of differently confined reinforced concrete short columns. The study emphasizes the immediate need for proper strengthening measures to be adopted for the existing corrosion experiencing structures for improving their much-needed ductility considering any seismic event in the future [4]. Results show that as the axial load on the interaction diagram increases, the optimal FRP length increases. Also, it was concluded that greater FRP strap lengths were needed at the point of pure bending than at the balanced point [5].It is evident that the GFRP could effectively improve the unfavourable column shear failure of non-ductile columns by increasing column shear strength and concrete ductility in the plastic hinge region [6].The columns were tested under monotonic axial compressive loading up to failure. The HSC columns with GFRP wrapping exhibited improved performance in terms of stress and ductility capacity [7].The Comparisons made between theoretical calculations and experimental results show that the model can be used to estimate the ultimate strength of externally reinforced columns under concentric load with accurate degree [8].From the test result it is observed that short column specimen with double glass fibre wrapping gives better performance as compare to single wrapped and conventional concrete specimen [9]. There is a significant increase in the strength of specimen with the increase of confinement layers on the specimen [10].An attempt has been made to experimentally investigate on the performance of conventional reinforced concrete elements, strengthened and rehabilitated elements like rectangular beams [11].The ultimate strength of the columns with flexural-shear strengthening was higher than other columns. Also, the increased percentage of fiber resulted in the increased speed of ultrasonic waves [12].A significant increase of ductility and increase in energy absorption capacity of RC beam-column when strengthened by both GFRP and CFRP Jacket [13]. A total of 16 short square reinforced concrete columns wrapped with CFRP were investigated. The results have shown that wrapping column with CFRP composite increase the capacity and ductility of the column [14].The CFRP hoop wraps provide confinement to concrete and lateral support to the longitudinal fibers and thus increase the strength of the RC columns [15].When the column was retrofitted by welding of dowel rebars with longitudinal rebars near splicing region and then wrapped with CFRP sheets, its strength, ductility and energy dissipation capacity improved significantly [16]. The effectiveness of the used strengthening techniques is investigated through the comparison with the performances obtained in the case of square members [17]. Crushing and spalling of concrete on the surface area makes the possibility of internal steel corrosion. The corrosion and loss of concrete may effect in the reduction of strength, capacity and structural integrity [18].

A lot of research has been made towards the finding of effectiveness of gfrp wrapping on short columns with direct wrapping and testing. In this present study an attempt is made to finding the performance of pre cracked columns with external confinement with gfrp wrapping. This study investigates the load carrying capacity and behaviour of square short RCC columns.

## II. EXPERIMENTAL PROGRAM AND METHODOLOGY

### A. Experimental Program

Load carrying capacity of the columns assessed by regaining its strength after external confinement with glass fiber reinforced polymer sheet. Total 11 columns were casted with cross sectional dimensions of 125mm square size and length of 1500mm. All the columns reinforced with 4 no of 10mm diameter bars as longitudinal reinforcement and 6mm diameters as stirrups or lateral ties. In these 11 columns, 2 columns made unwrapped and remaining 9 columns divided into 3 sets for different types of wrapping and variation in no of layers.

**Type of Column:**
It was identified with according the code IS 456 as short or slender column. With reference to the rule corresponding to 25.1.2, the ratio of length of column to width or breadth should not exceed 12 for short column. The all columns refereed as short columns because of the ratio (1500/125) is 12.

### B. Materials and Mixing Proportions

Ordinary Portland cement (OPC) of 53 grades, ZUARI brand has been used for mixes. The cement used was free of lumps. The cement has a specific gravity of 3.13, fineness of 2% and consistency of 33%. Steel of Fe 415 grade has been used in the present work. The coarse aggregate used was of crushed stone of two sizes 20mm and 10mm nominal size. It has a specific gravity of 2.76 , Fine aggregate which was confirming to grading zone – II according code IS 383 and has specific gravity of 2.63 was used. The Water which was used free of impurities and chemicals and got from tap water.

TABLE I Mix Proportions

| W/C | Cement Kg/m$^3$ | Coarse Aggregate Kg/m$^3$ | Fine Aggregate Kg/m$^3$ | Water Kg/m$^3$ |
|---|---|---|---|---|
| 0.5 | 383.16 | 1174.16 | 686.12 | 191.58 |

**Chopped strand mat:** The Properties of used chopped strand mat listed in below

TABLE II Properties of Chopped Strand Mat[19]

| Property | Value |
|---|---|
| Glass Content % | 25 – 40 |
| Specific Gravity Kg/Cm$^3$ | 1.4 – 1.5 |
| Tensile Strength MN/m$^2$ | 63 – 140 |
| Tensile Modulus GN/m$^2$ | 6 – 12 |
| Compressive Strength MN/m$^2$ | 130 – 170 |
| Flexural Strength MN/m$^2$ | 140 – 250 |

**Resin adhesive:** This adhesive used as binding material between the mat and column specimen surface. It consists of resin, Cobalt accelerator and MEKP (Methyl Ethyl Ketone Peroxide) hardener.

Fig. 1 gfrp sheet and cobalt resin mixture

### C. Experimental methodology

#### 1. Testing Strength of Concrete

For casting the test specimens, standard size of cubes (150 × 150 × 150 mm) made with cast iron moulds were used. After 24 hours of casting, specimens are de-moulded and kept in curing tank for 28days. Compressive strength test is performed on cube specimens to determine compressive strength of concrete at 28 days curing. Nominal strength and target strength of concrete were 25N/Sq.mm and 31.6N/Sq.mm.

The test results shown that 3 cubes having strength of 32.3 N/Sq. mm, 31.8N/Sq. mm, 30.8N/Sq. mm.

Fig. 2 casting of cubes and testing

**2. Casting Columns and Creating Control damage to columns**

All the specimens were casted by using concrete mix as of proportions shown in Table -1 of concrete grade of M – 25. As per code provision of IS 456, the slump of concrete mix maintained in the range of 75 – 100mm. Clear cover for the all columns kept as 20mm. Concrete was prepared by concrete mixture. These columns reinforced by 4no of 10mm diameter bars as longitudinal reinforcement and 6mm diameter bars for stirrups spaced at 130mm c/c in transverse direction based on code IS 456 provisional. All the casted columns kept in water for curing period of 28 days.

Fig. 3 Casting of columns

After 28 days for creating control damage in columns, 9 columns were made to fail in flexure testing. This was done because of columns were short columns. They fail by crushing and spalling of concrete under compression test. So we made flexure test to create control damage by providing cracks in columns.


Fig. 4 Creating control damage to columns

### 3. GFRP wrapping and Curing

The surface of the pre cracked columns cleaned by brush and removed dust particles. Chopped strand mat was made cut into pieces as per dimensions required for columns. These gfrp sheet pieces placed on columns properly and resin mix of Cobalt and methyl ethyl ketone peroxide hardener was applied on sheet and surface of columns. These retrofitted specimens kept at room temperature for period of 7 days .

Fig. 5 gfrp wrapping

### 4. Test Setup and Testing of columns

The columns were tested on loading frame of capacity of 1000KN in the laboratory. A 1000KN servo-controlled hydraulic actuator was used to apply loads. All columns capped with steel caps to make surface parallel and make the distribution of load uniformly over the entire cross section of column. All the column specimens were tested to fail in axial compression with concentric loading.

Fig. 6 Laboratory testing setup

## III. RESULTS AND DISCUSSIONS

### A. Ultimate Axial Load

TABLE III columns description and axial load values

| Specimen Type | Description | Axial Load (KN) |
|---|---|---|
| Unwrapped | Control columns without wrapping | 236.25 (Average of 2 columns) |
| C1FWL1 | Full wrapping - 1 layer | 227.8 |
| C2FWL2 | Full wrapping - 2 layer | 284.2 |
| C3FWL3 | Full wrapping - 3 layer | 144.8 |

| | | |
|---|---|---|
| C4SL1 | Strip wrapping - 1 layer | 218.7 |
| C5SL2 | Strip wrapping - 2 layer | 248.4 |
| C6SL2 | Strip wrapping - 3 layer | 151.9 |
| C7ML1 | Mid zone wrapping – 1 layer | 216 |
| C8ML2 | Mid zone wrapping – 2 layer | 257.6 |
| C9ML3 | Mid zone wrapping – 3 layer | 157.9 |

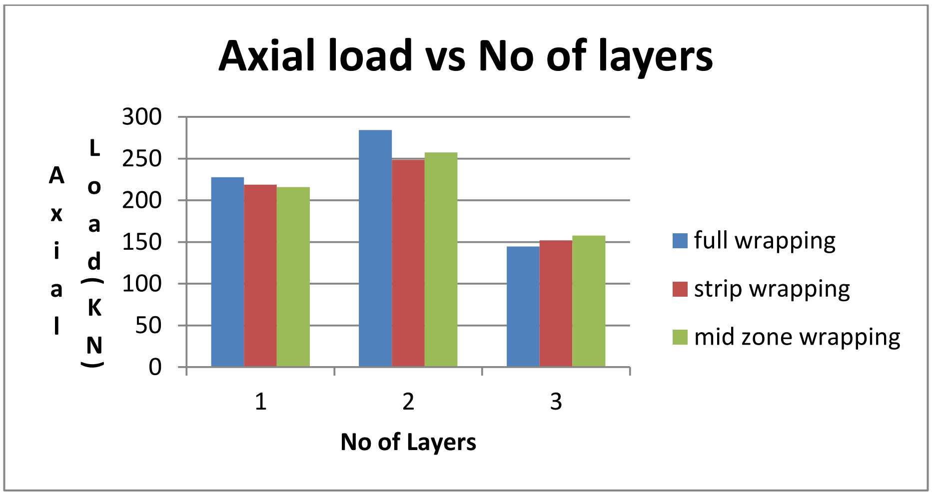



Fig. 7 variation of axial load with no of layers and type of wrapping

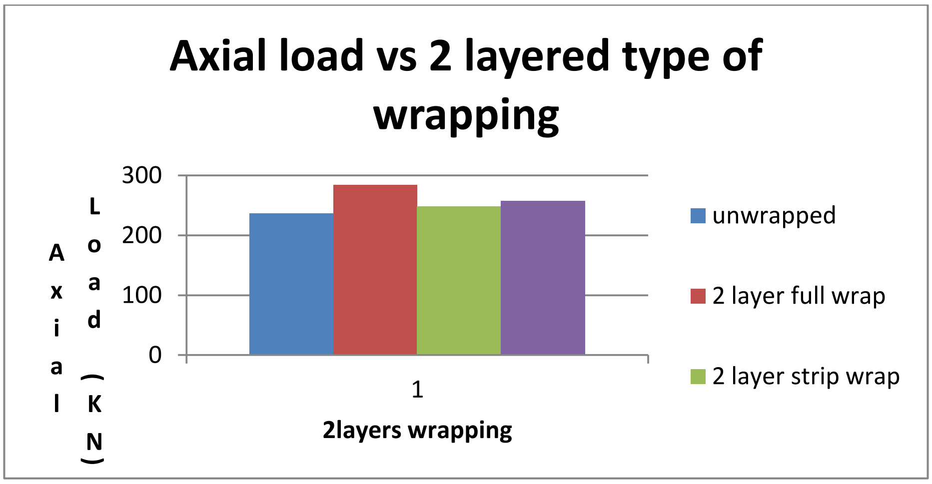
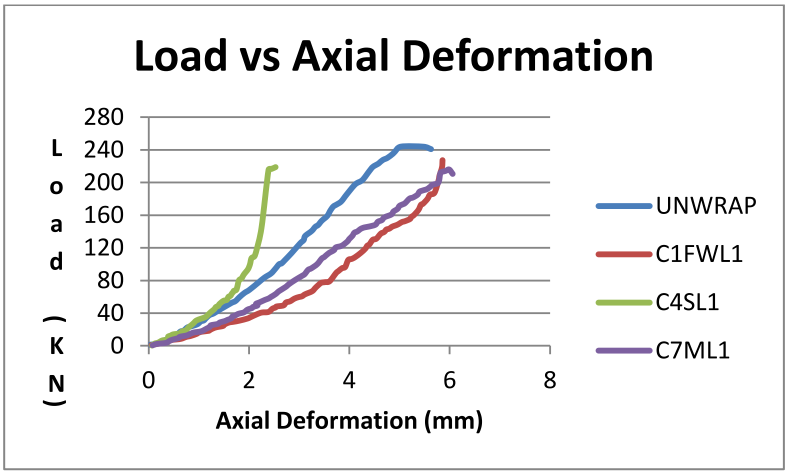



Fig. 8 variation of axial load with 2 no of layers and type of wrapping

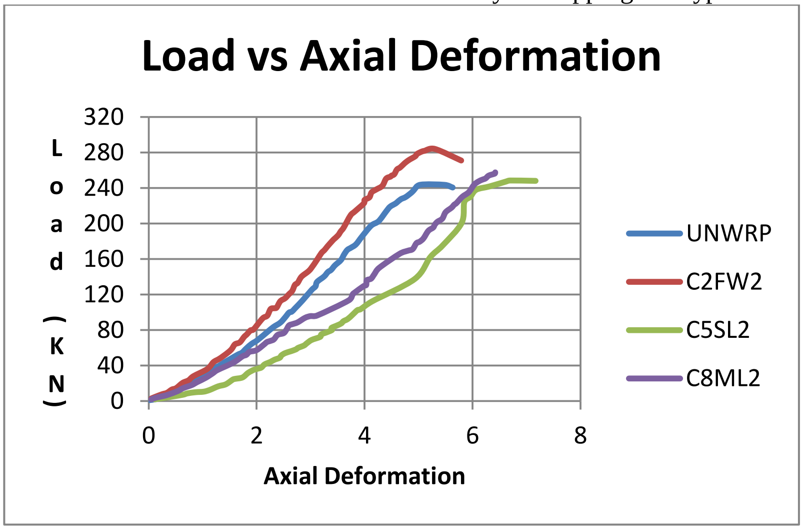
The obtained experimental results clearly demonstrate that there is a variation of load carrying capacity with change in number of layers and type of wrapping for the specimens which were made pre failure. The increase of maximum load of 20.29% for the 2layered full wrapping compared with unwrapped column. Also 5.14% increment of load for 2 layered strip wrapping and 9.03% of increment in load for 2 layered mid zone wrapping specimen compared with unwrapped columns.

B. **Axial Deformation**

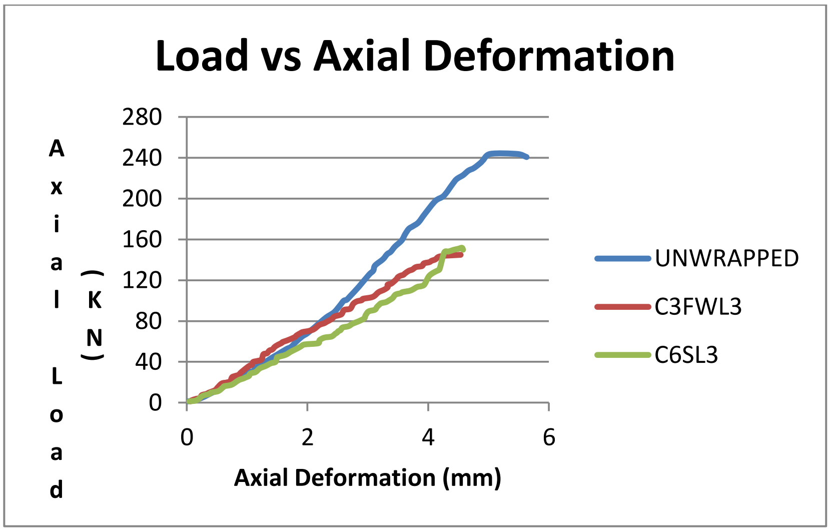
Load vs axial deformation curves for the one layered and two layered different type of wrapping shown in graph 1, graph 2 and graph 3. Comparing with unwrapped column deformation, gfrp wrapped pre cracked columns shown higher deformation. Two layered gfrp wrapped specimens shown more deformation than the unwrapped and One layered wrapped columns. Strip wrapping and mid zone wrapping also shown some effect on increment of axial deformation.




**Graph – 1** variation Axial Deformation with one layer wrapping and type of wrapping




**Graph – 2** variation Axial Deformation with Two layer wrapping and type of wrapping




**Graph – 3** variation Axial Deformation with Three layer wrapping and type of wrapping

**C. Failure Mode & Crack Pattern**

Control unwrapped RC columns failed after getting their ultimate axial load carrying capacity and failed by crushing and splitting of concrete in the top region in between the stirrups. This type of failure characterized by shearing and brittleness of concrete.

Fig. 9 Control column failure

The failure of all the wrapped columns happened by tensile failure of gfrp layers, delamination of layers and combination of both. The failure modes shown in figure 10. All these columns by failed effect of blasting at top region. Wrapped columns failure occurred at top region of columns and corners failing. Columns got failed at top and bottom but concrete and gfrp at middle portion of the columns were found intact at failure. Straining of gfrp laminate and cracking of epoxy resin was observed during failure. 1 layered column didn't reached the capacity of unwrapped column but 2 layered columns shown increment in load carrying capacity than the unwrapped columns. There was decrement of load capacity for the 3 layered columns because of columns made to pre control damage. These columns failed without failure of external confinement of gfrp. Internal core was failed and no load carried by the gfrp layers.

Fig. 10 Failure of wrapped columns

## IV. CONCLUSIONS

Based on the results following conclusion made:

- External confinement with gfrp wrapping has shown increment in load carrying capacity and axial deformation of pre cracked columns.
- Wrapped columns undergone more axial deformation comparing to unwrapped control columns.
- Two layered strip and mid zone wrapping shown more deformation than control and unwrapped control specimens.
- All columns failed by after reaching ultimate load and tensile failure of gfrp
- Two layered full wrapping column has 20.29% of load increment, Two layered strip wrapping has 5.14% of load increment and Two layered mid zone wrapping has 9.03% of load increment over the unwrapped control columns.
- All the columns were short columns so no buckling failure has been observed during control damage and under axial compression after wrapping. Spalling of concrete between stirrups was observed.

Thus it shown from present study external confinement for control damaged columns with chopped strand mat type of glass fibre polymer is an alternative for strengthening columns.

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