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# Experimental study of Axially Loaded Retrofitted Concrete Short Column

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**Abstract -** *The application of Carbon fibre-reinforced polymers (CFRP) to existing reinforced concrete structural elements as external reinforcement has become popular and frequently applied in recent years. An experimental study was carried out to investigate the behaviour of concrete columns bonded with Carbon Fibre Reinforced Polymer sheets. Two sets of concrete columns are prepared with square cross section of 150x150mm and circular cross section of 150mm diameter with 1m height for each columns. The testing are done to columns before and after retrofitting to ultimate failure. The behaviour of axial stress, strain and deformation due to axial loading are found out for columns before and after retrofitting. The results shows that retrofitting with externally bonded CFRP composites can restore the axial compressive strength of the columns*

**Key Words: Epoxy, Carbon fiber, RC columns**

## 1.INTRODUCTION

Many building structures constructed today are in the need of strengthening their existing civil engineering infrastructure. The reasons are deterioration by aging or corrosion caused due to environmental factors, load increase because of change of function in the structure or poor design which does not meet the present more variable design requirements in earthquake areas. The low probability of major seismic events and the high cost of structural rehabilitation make it difficult to justify economically. Strengthening or retrofitting of older structures to resist higher design loads or increase ductility has been accomplished with traditional materials such as externally bonded steel plates and steel jackets since in the 1960s. Concrete columns are important structural elements which are highly vulnerable for exceptional loads. In older structures, columns often have insufficient transverse reinforcement which is unable to provide sufficient confinement to the concrete core or to prevent buckling of the longitudinal reinforcement. This can lead to unacceptable premature strength degradation.

Cracking and spalling of concrete columns leads to the corrosion of internal steel reinforcements. The loss of cementitious material, as well as the corrosion-induced reduction in cross-section areas of a steel reinforcement, leads to drastic reductions in the structural integrity and load-carrying capacity of columnar supporting elements. The most common method of strengthening is done by installing reinforced steel jackets around column sections. The use of a steel encasement to provide the lateral confinement to concrete in compression has been extensively studied and has been shown to be able to significantly increase the compression load-carrying capacity and deformation of the columns.

The major disadvantages of using steel jackets are low resistance to corrosion, high cost, and high dead-weight. Fibre reinforced composites, due to their high strength-to-weight and stiffness-to-weight ratios, large deformation capacity, corrosion resistance to environmental degradation, and tailor ability present an attractive option as an alternative and extremely efficient retrofitting technique through the use of composite wraps around a deteriorated column. Carbon Fibre sheets have been applied to increase concrete confinement and loading resistance of reinforced concrete columns. The retrofitting of concrete columns using CFRP is shown in fig 1.

**Fig -1**. RCC column retrofitting

The confinement effect of externally bonded wraps depends on certain parameters,based on the type of concrete, steel reinforcement, the thickness of the FRP jackets and stiffness and loading conditions. The influences of the type and the amount of confining FRP on the behaviors of confined columns under concentric load are well characterized; however, the deformation capacity and energy dissipation capacity of FRP-retrofitted columns under simulated seismic load are still not very clear.

## 2. TEST SPECIMENS

Two sets of concrete columns are prepared with a square cross section of 150x150mm and circular cross section of 150mm diameter with 1m height for each column. The testing is done to columns before and after retrofitting which are subjected to ultimate failure. The behavior of axial stress, strain, and deformation due to axial loading are found out for columns before and after retrofitting.

## 3. MATERIALS AND PROPERTIES

### 3.1 Cement

The cement used for this project work is portland pozzolana cement. The various physical properties of cement used are tabulated in Table 1.

**Table 1:** Properties Of Cement

| Sl. No | Property | Values |
|---|---|---|
| 1 | Specific Gravity | 2.9 |
| 2 | Standard Consistency | 35% |
| 3 | Setting Time<br>a) Initial<br>b) Final | <br>150 min<br>564 min |

### 3.2 Fine Aggregate

Manufactured sand was used for this project. The specific gravity of sand used in this project is 2.63. The various properties of sand are tabulated in Table 2.

**Table 2:** Properties of fine aggregate

| Sl. No | Property | Values |
|---|---|---|
| 1 | Specific Gravity | 2.66 |
| 2 | Water Absorption | 0.87% |
| 3 | Fineness Modulus | 4.2 |

### 3.3 Coarse Aggregate

The crushed aggregate of nominal size 20mm is used as coarse aggregate. The various properties of coarse aggregate are presented in Table 3.

**Table 3: Properties Of Coarse Aggregate**

| Sl. No | Property | Values |
|---|---|---|
| 1 | Specific Gravity | 2.68 |
| 2 | Water Absorption | 0.43 |
| 3 | Finess Modulus | 10.89 |

### 3.4 CFRP sheets

Carbon Tow Sheet is a flexible, woven, unidirectional carbon fiber textile with a lightweight scrim on both sides designed for use as an externally applied reinforcement for strengthening concrete,timber and masonry structures.CFRP sheets used are of 2mm thickness.

## 4. TEST SETUP

In this study, all columns were tested under a concentric axial loading using a testing machine with a capacity of 50 tons.Strain gauges were used to record the axial displacement of columns. Fig 2 shows the test setup of the experimental study. The load was applied until complete failure took place. Axial deformation of column noted down at equal interval with help of dial gauge. Then ultimate load and corresponding deformation noted down. The load deformation curve was plotted.

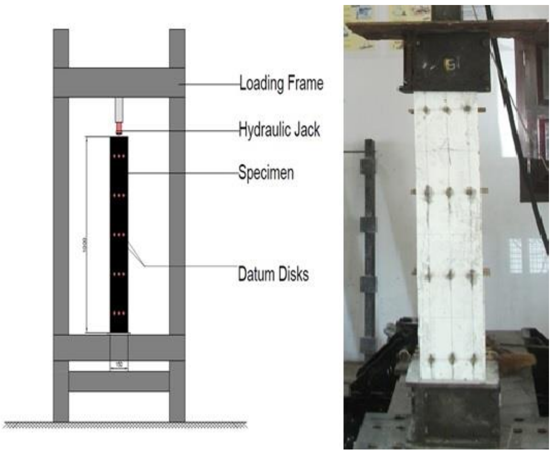


**Fig -2.** Loading of columns before retrofitting

## 5. RESULTS AND DISCUSSION

### 5.1 Loading data

Two sets of columns are tested for their ultimate strengths before and after retrofitting. In SET I columns C1 and C2 of circular cross section and in SET II columns S1and S2 of square cross section are tested. The columns are loaded to failure and then these specimens are again retrofitted and loaded to failure. The columns behavior before and after retrofitting are found out using the test results.Table IV and V shows loading value for columns before and after retrofitting.

**Table 4**: Load data for columns before retrofitting

| Sl No | Type of Column | Column Designation | Load at initial crack(kN) | Ultimate Load (kN) |
|---|---|---|---|---|
| 1 | Square Cross section | S1 | 224 | 250 |
| | | S2 | 250 | 347 |
| 2 | Circular cross section | C1 | 260 | 350 |
| | | C2 | 260 | 355 |

**Table 5.** Load data of retrofitted column

| Sl No. | Type of Column | Column designation | Ultimate load (kN) | Nature of Failure |
|---|---|---|---|---|
| 1 | Square Cross-section | S1 | 370 | BondFailure top |
| | | S2 | 375 | BondFailure at bottom |
| 2 | Circular cross section | C1 | 380 | Bond Failure on top |
| | | C2 | 390 | Bond Failure on top |

Retrofitting with CFRP sheets circular columns attain a strength enhancement in axial load of 8.5%. Thus CFRP sheets can be used as strength enhancing material for retrofitting of damaged columns. the square columns also attain a strength enhancement in axial resistance of 8%. Due to the increase in load-carrying capacity CFRP sheets can be used as retrofitting material for damaged columns.

## 6. AXIAL LOAD – DEFORMATION DATA

Load verses deformation history of all columns are noted. The deformations are noted from the strain gauge values obtained from the experiment. From the results the column deformation is higher when wrapped with CFRP. The graphs showing deformation verses Load are shown below. The axial deformation for each columns are compared by the values obtained before and after retrofitting. It can be noted that the behavior of the columns when retrofitting with CFRP sheets are better than columns without CFRP sheets. The deformations are greater when bonded externally with CFRP sheets. The use of CFRP sheet has effect in delaying the growth of crack formation.

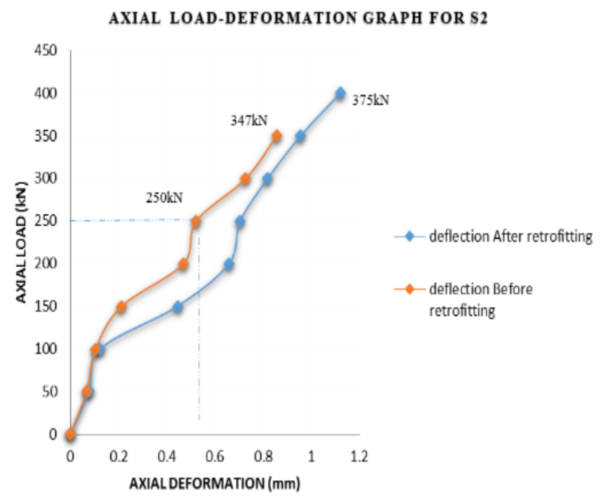


**Chart 1.** Axial load deformation graph for square column

For S1 column due to the confinement failure, the load deformation graph cannot be drawn due to inaccuracy in values. From the above axial load deformation graph, when increasing load the deformation occurs linearly up to the first crack on square columns. Chart 1 shows the load deformation graph for S2 column.

The deformation for S2 column is 0.96 mm before retrofitting and 0.85 mm after retrofitting for load 350 kN which are obtained from the strain gauge reading. Thus there is an increase of 11.4% in deformation for retrofitted square columns.

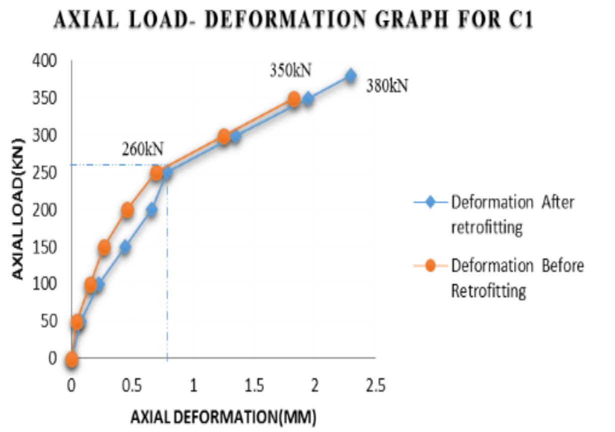


**Chart 2.** Axial load deformation graph for circular column

From the above axial load deformation graph with increasing load the deformation occurs linearly up to the first crack on columns. Chart 2 shows the load deformation graph for Cl column. The deformation for C1 column is 1.95mm before retrofitting and 1.85mm after retrofitting for load 350kN obtained from the strain gauge readings. Thus there is an increase in deformation of 6% for retrofitted C1 columns. Thus from the results, when a circular column was subjected to axial load the deformation increased to 7.5% for retrofitted circular columns.

## 7. AXIAL STRESS-STRAIN DATA

The axial stress-strain data for all columns are recorded. The axial stress-strain of each column are compared with columns before retrofitting and after retrofitting. The strain values are calculated from data obtained from strain gauge using datum disks. The use of CFRP sheet had effect in delaying the growth of crack formation.

For S1 column due to the confinement failure, the axial stress-strain graph cannot be drawn due to inaccuracy in values. From the axial stress-strain graph with increasing load, the strain occurs uniformly up to the first crack on square columns. Chart 3 shows the load deformation graph for square column. The axial strain for square column is 0.00223mm before retrofitting and 0.00359mm after retrofitting for load 350 kN obtained from the strain gauge readings.

From the results when the column was subjected to axial load, the axial strain increase to 6 % for retrofitted square columns.

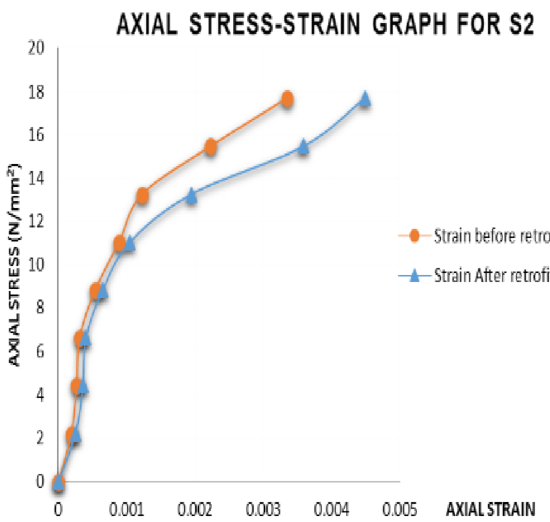


**Chart 3.** Axial stress strain graph for square column

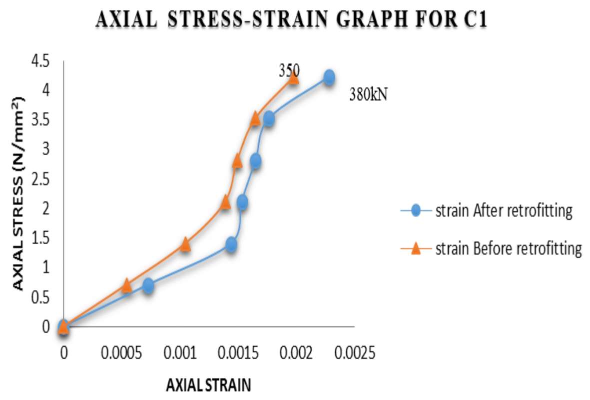


**Chart 4.** Axial stress strain graph for circular column

From the axial stress - strain graph with increasing load the strain occurs uniformly up to first crack on circular columns. Chart 4 shows the axial stress-strain graph for circular column. The axial strain for circular column is 0.00198mm before retrofitting and 0.00218mm after retrofitting for load 350 kN obtained from the strain gauge readings. There is an increase in strain of 10% for retrofitted C1 column. From the results when a circular column is subjected to axial load, the axial strain increase to 9.8 % for retrofitted circular columns.

## 8. CONCLUSIONS

Based on the experimental investigations the following conclusions can be drawn:

1. While retrofitting with CFRP sheets circular columns attain a strength enhancement in axial load of 8.5%. Thus CFRP sheets can be used as strength enhancing material for retrofitting of damaged columns.
2. While retrofitting with CFRP sheets the square columns also attain a strength enhancement in axial resistance of 8%. Due to the increase in load-carrying capacity CFRP sheets can be used as retrofitting material for damaged columns.
3. Restoring or upgrading the axial strength of columns using CFRP sheet can result in increased axial resistance and load carrying capacity with no visible cracks. Restoring columns with the CFRP is a highly effective technique.
4. When columns are retrofitted with CFRP initial cracks developed are not seen up to higher load. Due to the invisibility of cracks, no adequate warnings are provided before the collapse of columns.
5. Deformation verses load curve shows higher deformation corresponding to increasing load for columns. The axial load deformation graph shows that the deformation increases to 7.5% for retrofitted circular columns and 11.4% increase for retrofitted square columns.
6. Axial stress-strain graph shows higher stress-strain behavior with 6% increase for retrofitted square columns and 9.8% for retrofitted circular columns.

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