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# Analytical and Experimental Study on FRP Confined Concrete

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**ABSTRACT:** Fiber reinforced polymer (FRP) is a composite material made up of polymer matrix and fiber reinforcement. Glass, carbon, and aramid fibers are common, and the polymer is typically an epoxy, vinyl ester, or polyester thermosetting plastic, as well as phenol formaldehyde resins. FRP has been shown to be particularly appealing for structural strengthening and rehabilitation applications.

Using the ABAQUS program, an attempt was made to construct a 3-D finite element model of a FRP constrained concrete column. For concrete, a Drucker-Prager plasticity model is used, while for FRP, an orthotropic elasticity model is used. A parametric analysis was also conducted to assess the impact of the number of FRP layers and corner radius on the ultimate strength of concrete short columns, as well as to validate the analytical study. A research was conducted on a square column with a cross section of 125 x 125 mm and a height of 300 mm with changing corner radius of 15mm, 25mm, 35mm, and 62.5mm, as well as a control column, all of which were cast using M20 grade concrete. Using E-Glass, confinement is supplied as a single layer and a double layer for the column.

**KEYWORDS:** fibre reinforced polymer, Drucker-Prager plasticity, concrete short columns

## 1.1 INTRODUCTION

Structures are often built to survive a long period. However, due to an increase in the applied load or damaged structural parts, such as Reinforced concrete columns that have deteriorated due to reinforcing steel corrosion, structures may need to be strengthened. To this purpose, concrete jackets and fiber reinforced polymer (FRP) wraps can be used to increase the load-bearing capacity of columns. FRP is perfect for retrofitting because of its light weight, superior corrosion resistance, simplicity of sites handling, and other characteristic FRP qualities. As a result, FRP has become increasingly popular in building and structural repair.

## 1.2 FIBRE REINFORCED POLYMER (FRP)

Fibre-reinforced polymer (FRP) is a composite material made up of a polymer matrix and fibers. Glass, carbon, or aramid fibers are commonly employed, although other fibers such as paper, wood, or asbestos have also been used. Epoxy, vinyl ester, or polyester thermosetting plastics, as well as phenol formaldehyde resins, are commonly used. FRPs have been utilized effectively in a variety of construction applications, including load bearing and infill panels, pressure pipes, tank liners, roofing, and entire structures in which FRP pieces are joined to form a whole system in which the shape provides the stiffness. Polymer composites have found use in the construction industry in fields including bridge repair, bridge design, mooring cables, structural strengthening.

## 1.3 GFRP

Steel or RC jacketing, FRP improvement, and other methods can be used to strengthen the structure. Steel jacketing (SJ) is now only employed as a temporary support in post-earthquake emergency measures, rather than as a repair or strengthening intervention. In any event, this approach can only achieve passive Confinement's effects, as it becomes effective only when concrete suffers severe cracking. Fibre reinforced polymer (FRP) has emerged as a competitive steel substitute. Fibre Reinforced Polymer (FRP) is a relatively recent sophisticated composite material in civil engineering.



#### 1.4 FRP CONFINED CONCRETE

In recent years, the use of fibre reinforced polymer (FRP) composites in the retrofitting and strengthening of reinforced concrete columns has gotten a lot of attention. The concrete column is the most important structural part in the building since its failure can result in the entire structure failing. Concrete square columns are extensively used in the building of concrete structures, and one of the most important challenges related to the strengthening, repairing, and retrofitting of concrete structures is the strengthening of concrete square columns. FRP jacketing outperforms steel in terms of strength, stiffness, and weight, as well as ductility, corrosion resistance, and ease of installation and repair. FRP jackets have gained a lot of traction in the world of civil engineering in this respect.

### II. LITERATURE REVIEW

The beam-column junction is one of the most critical parts of a structure. Several researchers looked for ways to enhance the beam-column junction. Adding fibers is one way to increase the strength. This chapter gave a broad evaluation of journals related to Fiber reinforced concrete, beam column joint, steel fiber reinforced beam column joint, and hybrid fiber reinforced beam column joint, and they are listed in the report's references section.

#### 2.1 REVIEWS ON CONFINEMENT MODELS

**Lei-Ming Wang, Yu-Fei Wu (2007)**, have discussed the effects of corner radius on the performance of CFRP-confined square concrete column. The corner radius (0, 15, 30, 45, 60, 75 mm), the thickness of the CFRP jackets, and concrete grades M30 and M50 were examined as the main factors in the study. In this work, 108 CFRP-confined concrete short columns with a cross section of 150x150 mm and a height of 300 mm were examined. Jacketing enhances the strength and ductility of jacketed columns by confining the concrete. The effectiveness of confinement is greatly reduced in FRP-confined rectangular/square columns because the concrete is not uniformly confined. However, most published research suggests that a jacket with sharp edges can provide some effective confinement. This study used compressive testing to explore the influence of corner radius on the strength and ductility of FRP-confined concrete columns in order to learn more about the issue.

**Jijin V.1, Preetha Prabhakaran (2015)** described the comparative study on GFRP jacketed RC columns and CFRP jacketed RC columns of different shapes. The efficiency of external GFRP strengthening for RC Columns of circular, square, and rectangular forms with the same cross sectional area is the focus of this experimental study. A total of 15 1 meter tall RC columns were cast. One layer of GFRP wrap with a 20 mm corner radius was applied to a circular column (diameter 170 mm), a square column (150x150 mm), and a rectangle column (110x210 mm). In axial compression, all of the test specimens were loaded to failure. The test results clearly revealed that the axial load bearing capability of restricted RC columns rises as the form changes from rectangular to square to circular.

**S. Mathys; H. Toutanji; L. Taerwe (2006)** studied the stress-strain behaviour of large scale circular columns confined with FRP composites. In this paper, the stress-strain response of axially loaded large-scale circular column (diameter 400 mm and height 2000 mm) confined with FRP wrapping reinforcement is investigated. Concrete confinement with FRP wrapping is an effective method for increasing strength and ductility. The tensile strength of the FRP covering determines the strength. The stiffness of FRP wrapping is inversely related to increasing ductility. FRP operates like linear elastic and increases confinement pressure as lateral expansion of concrete increases. The first portion (unconfined portion of the curve) and the initiation of the second branch of the stress strain curves were accurately predicted by the Lam and Teng model, according to a comparison between the experimental stress-strain response recorded in this study and those predicted by the existing models. The stiffness of the second branch of the curve, on the other hand, is significantly smaller than that of the experimental.

**Manuel A. G. Silva and Carlos C. Rodrigues (2006)** studied the size and relative stiffness effects on compressive failure of concrete column wrapped with GFRP. The test was carried out on cylinders having a height of 300 mm and a diameter of 150 mm, with a slenderness ratio of  $H/D=2$ . The maximum load increased when the number of GFRP layers was increased for a particular size  $H/D$ . Even if the  $H/D$  ratio is kept constant and the thickness of the outside reinforcement is not altered, increasing the diameter of the specimens from 150 mm to 250 mm produces a considerable drop in the strength of the cylinders. In reality, as the diameter of the composite outer shell grows larger, the confinement offered by the composite outer shell gets weaker.





**S.H. Lo a, A.K.H. Kwan a, Y. Ouyang a, J.C.M. Ho b, (2015)** finite element analysis of axially loaded FRP-confined rectangular concrete columns Fibre-reinforced polymer (FRP) offers an effective and convenient means to strengthen the existing RC columns. In this paper, we present a finite element model for the nonlinear analysis of FRP-confined concrete columns, in which concrete elements are formulated using advanced constitutive models that have recently been developed, and it is validated using specimens with rectangular sections from previous experimental studies. As a consequence, the non-uniform and anisotropic confinement effects inside rectangular sections of various shapes have been identified, and their impact on the overall behavior of axially laden concrete columns has been determined. The findings of the research also show that the confinement effect is substantially better at the corners and towards the center of rectangular sections than elsewhere, and that increasing the corner roundness can result in bigger regions of well confined concrete across the cross-section.

**G. Mazzucco, V.A. Salomoni, C.E. Majorana, C. Pellegrino, C. Ceccato (2016)** studied the Numerical investigation of concrete columns with external FRP jackets subjected to axial loads The use of fibre reinforced polymer (FRP) composites as an external reinforcement for concrete columns has shown to be an effective means of strengthening and confining the structure. In this paper, a damage model was developed to simulate and predict the response of concrete columns under uniaxial loading, externally confined with carbon fiber reinforced polymer (CFRP) jackets, with a focus on the role of cross-section shape and internal steel bars in the effectiveness of strengthening interventions. Comparisons of numerical and experimental results show that such an approach can accurately predict the axial and transversal response of circular and square confined columns under monotonic compressive loading, reproducing the non-linear behavior of confined concrete members with and without internal steel bars. Retrofitting existing buildings necessitates a performance-based approach.

**Kinjal V Ranoliaa, B K Thakkarb, J D Rathodb (2012)** studied the effect of different patterns and cracking in FRP wrapping on compressive strength of confined concrete The FRP strips serve as longitudinal and hoop reinforcement as well as permanent formwork for the concrete core. In exchange, the concrete core adds to the composite system's overall stability and rigidity. A parametric analysis was conducted to determine the impact of the number of FRP wrap layers, wrap position, and fracture location on the compressive strength of concrete. E In this study, glass fibre wrapping is used. Cylinders with a height of 300 mm and a diameter of 150 mm were cast with M20 and M40 grade concrete and tested in both unconfined and confined conditions with various FRP wrap patterns, including one layer full wrap, two layers full wrap, 100 mm centre wrap, and two strips wrap

**Sushil S. Sharmaa, Urmil V. Daveb, Himat Solankic (2012)** described the FRP wrapping for RC columns with varying corner radii. Carbon/Glass fibre reinforced polymer (FRP) confinement can be effectively used for strengthening the deficient RC columns. The efficiency of FRP wrapping for RC columns is mostly determined by the specimens' corner radius and the amount of FRP layers employed for confinement. The purpose of this study is to look at the experimental behavior of GFRP wrapped small scale square RC columns with different corner radii. The performance of GFRP wrapped RC columns is compared to that of non-wrapped RC columns in an experimental setting. Under axial compression, 15 RC columns with cross-sectional dimensions of 125 mm x 125 mm and a length of 1200 mm were tested. The findings revealed that smoothing the margins of square cross-section RC columns has a significant impact in delaying FRP composite edge rupture. The radius of the corner is equal to the thickness of the concrete cap.

**Tamer El Maaddawy (2009)** studied the strengthening of eccentrically loaded reinforced concrete columns with fibre-reinforced polymer wrapping system experimental investigation and analytical modelling The findings of an experimental program and analytical modeling to evaluate the performance of a FRP wrapping system to upgrade eccentrically loaded RC columns are presented in this research. There were a total of 12 RC columns with end corbels that were put to the test. The entire length of the test specimen was 1200 mm. Each end corbel measured 350 mm in length and had a cross section of 250 x 250 mm. Concealment conditions comprised no wrapping, complete FRP wrapping, and partial FRP wrapping, as well as eccentricity-to-section height  $e/h$  ratios of 0.3, 0.43, 0.57, and 0.86, respectively. According to the data, when  $e/h$  rose, the strength gain produced by FRP wrapping reduced. At a minimal  $e/h$  of 0.3, full FRP wrapping resulted in a 37 percent increase in compression strength, whereas only 3% strength gain was achieved.

## 2.2 SUMMARY OF LITERATURES

Jacketing an RC column with GFRP increases column performance by bearing a portion of the axial load applied to it as well as providing external lateral restricting pressure. In compared to steel, GFRP Jacketing is effective in terms of strength, stiffness, and weight, as well as good ductility, corrosion resistance, and inexpensive installation and repair costs. Smoothing the margins of RC columns with square cross-sections plays an important role in delaying FRP composite rupture at the edges.

## III. MATERIALS USED

### 3.1 CEMENT

OPC is graded in three distinct ways by the Bureau of Indian Standards (BIS). The categorization is primarily based on the compressive strength of cement-sand mortar cubes with a face area of 50 cm<sup>2</sup> that are comprised of 1 part cement to 3 parts standard sand by weight, with a water-cement ratio determined according to a formula. I 33, (ii) 43, and (iii) 53 are the grades. The grade number refers to the minimum compressive strength of cement sand mortar in N/mm<sup>2</sup> after 28 days, as determined by the technique described above. Dalmia 53 Grade Ordinary Portland Cement (IS 12269-1987) was utilized for this project.

### 3.2 FINE AGGREGATE

Fine aggregate is defined as aggregate that passes through a 4.75mm IS Sieve and is kept on a 75micron (0.075mm) IS Sieve. Fine aggregate is added to concrete to improve workability and consistency in the mix. As a fine aggregate, natural river sand is commonly employed. In this project, ordinary river sand that complied with IS 383-1970 was employed.

### 3.3 COARSE AGGREGATE

River gravel or crushed stone should be used as the coarse material for the project. The aggregate was angular in form and 20mm in size. Coarse aggregate is defined as material that passes through a 75mm screen and retains a size of 4.75mm. It should be firm, robust, thick, and long-lasting, as well as devoid of clay or loamy admixtures, quarry debris, and vegetative matter. Aggregate particles should be cubical or spherical in form, with granular or crystalline surfaces, or smooth (but not shiny) non-powdery surfaces. Before usage, aggregates should be thoroughly screened and, if necessary, cleaned clean. Flat, elongated, or flaky particles or mica in coarse aggregates should be disregarded. The grading of coarse aggregates should follow IS 383-1970 requirements

### 3.4 WATER

Water that is suitable for mixing should be used. There is a risk of alkali-aggregate reaction if the water has high salt and potassium concentrations. Natural waters that are somewhat acidic are safe to drink, but water that contains humid or other organic acids can cause concrete to harden prematurely. Such water, as well as water that is very alkaline, should be examined. The water should meet IS 456-2000 requirements. In general, water that is appropriate for mixing is also good for curing. Curing water, on the other hand, must be devoid of chemicals that damage hardened concrete, such as free CO<sub>2</sub>. This technique makes advantage of locally accessible ground water.

### 3.5 E-GLASS FIBRE CHOPPED STRAND MAT (CSM)

Chopped strand mat (CSM) is a kind of glass-reinforced polymer reinforcement. A 450g/m<sup>2</sup> density E-glass fibre chopped strand mat (CSM) was employed.





| SI NO | PROPERTY                               | VALUE |
|-------|----------------------------------------|-------|
| 1     | Thickness (mm)                         | 0.3   |
| 2     | Density (GSM)                          | 450   |
| 3     | Young's Modulus (KN/mm <sup>2</sup> )  | 70-80 |
| 4     | Tensile Strength (KN/mm <sup>2</sup> ) | 2-4   |
| 5     | Elongation of break (%)                | 2-3.5 |

### 3.5. GENERAL POLYESTER RESIN

Resin is made from organic chemicals that have been etherified or soaped. Polyester resin is the most common kind, which is produced by polymerization-poly addition or poly condensation processes and is utilized as a thermoset polymer in adhesives and composites.



## IV. CONCLUSIONS

A thorough review of the literature provides us with theoretical understanding regarding the use of mixed fibers in conventional concrete to strengthen beam column joints. According to these studies, partial replacement of mixed fibers up to 20% results in improved physical and mechanical qualities in concrete, as well as greater concrete cohesiveness. The results of the material testing demonstrate that the materials to be used for the concrete are of the required quality and strength. Resin is made from organic chemicals that have been etherified or soaped. Polyester resin is the most common kind, which is produced by polymerization-poly addition or poly condensation processes and is utilized as a thermoset polymer in adhesives

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