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STRENGTHENING OF SHORT COLUMN APPLYING CARBON FIBRE REINFORCED POLYMER METHOD

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Abstract - Abstract - *In recent years using polymer materials in strengthening and retrofitting the concrete Elements is on the process. Fibre reinforced polymers (FRP), have emerged as an alternative solution to traditional materials for strengthening and retrofitting structures, especially in existing structures which need to up build or to change the usage. In attempt to increase strength and ductility of concrete column load bearing elements through confining systems the FRP membranes have become a familiar solution. The studies of Theoretical, Experimental And Finite Element Analysis are carried out. In these project column size of 150mm and 600mm height. The columns are retrofitted by carbon fibre reinforced polymer sheets. The theoretical calculation are performed based on the codal provision and literature available. In the Experimental studies of short column models are cast and tested under compressive test up to failure. In FE analysis the concrete columns with and without CFRP model are analyzed. The result of Theoretical, Experimental and FE analysis are tabulated discussed and conclusions are shown*

Key Words: **Theoretical calculation, Experiment work, FE Analysis, Compressive strength, CFRP**.

1.INTRODUCTION

Retrofitting is the process of upgrading or modifying existing systems, structures, or equipment to improve their performance, efficiency, safety or functionality. It involves integrating new technology, components, or features into an older system or structure, often to meet changing needs or standards. While retrofitting offers numerous benefits, it also presents challenges such as compatibility issues, cost considerations, and potential disruptions to operations during implementation. However, when done effectively, retrofitting can significantly improve the performance, sustainability, and value of existing systems and structures. Overall, retrofitting is essential for modernizing and improving existing systems and structures to meet contemporary standards, address emerging challenges, and promote sustainability and resilience.

FRP(fiber reinforced polymer) composites have been widely used in civil construction and infrastructure engineering because of their low density, high strength, high temperature resistance and corrosion resistance. The application of CFRP in infrastructure and civil buildings is analyzed in this paper. CFRP-wrapped column strengthens concrete structures by encasing them in carbon fiber reinforced polymer. This technique enhances load-bearing capacity, durability, and resistance to seismic events, offering a cost-effective solution for retrofitting aging infrastructure and improving structural performance. The seismic performance and safety performance is better. Compared with the original building materials, CFRP materials have higher natural frequencies, no resonance, and basically no rapid fracture due to resonance under the loading frequency and speed. It has a strong aesthetic appreciation plasticity.

2. Types of wrapping

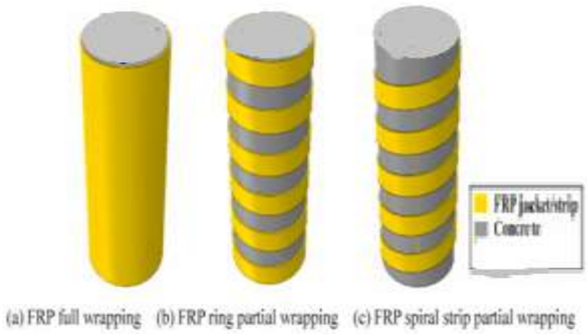

Fig 1 Types of wrapping

As the fig 1 shown the types of wrapping in the column

FRP Full Wrapping Of Column : A FRP fully wrapped column is a concrete column entirely encased FRP for enhanced strength and durability.

FRP Partially Wrapping :FRP partially wrapping involves encasing only specific areas of concrete column with FRP for targeted reinforcement.

FRP Strip Partial Wrapping : FRP strip partially wrapping involves applying FRP strips to specific sections of a concrete column for localized reinforcement.
In these project the fully wrapping method is used for the column for retrofitting

3. LITERATURE REVIEW

Ahmed.I.Ramadan (2007) : In these experimental work is carried out on FRP and FE analysis of columns by body axial and lateral loads. This work results is compared with rectangular and square columns and the columns are well modeled in FE Analysis.

K .OLIVOVA and J.BILCIK (2008) : The experimental work is carried in laboratory of the Department of concrete Structures and bridges at the Slovak University of Technology in Bratislava. Series of column are composed of strengthened with CFRP laminate strips before testing and last series composed with CFRP sheets and results in premature debonding which occurs in externally banded reinforcement is avoided.

Azadeh Pravin and David Bringthon (2014) : Existing studies have shown that the use of FRP materials restored or improve the column original design strength for possible axial, shear or flexural and in some cases allow the structure to carry out more load than it was designed. The evaluation of FRP strengthening of columns are deficient in design are serious for repair due to additional load.

Niloufar Moshiri , et, al (2015) : The 10numbers of column are tested under compressive load the columns were divided into 2 series depend upon their cross section. They use wet lay up method each group of specimens one control specimen and 4 strengthened with CFRP sheets and they are tested.

BHAGYA LAKSHMI,et,al (2019) : The strengthening and effectiveness of CFRP sheets on PCC and admixtures . The specimens are wrapped around the result is wrapped cylinders are superior than the unwrapped column.

4. OBJECTIVES
The objectives of this research is to quantify the load improvement using CFRP configuration.

- To study the effectiveness of column wrapped with CFRP in resisting axial force
- Calculating the axial capacity of columns using theoretical approach
- Carrying experimental work to determine the axial capacity of column with and without CFRP
- Developing FE model to determine the axial capacity of concrete column and retrofitted column using CFRP.

5. METHODOLOGY
- Literature review
- Theoretical calculation of ultimate load carrying capacity of concrete column
- Experimental program of concrete column with and without CFRP
- FE Analysis of concrete column with and without CFRP .
- Comparison of the axial strength of columns under Theoretical, Experimental and FE Analysis results.

6. MATERIAL PROPERTIES
The R&M fibres material properties shown below
Physical properties
- Density: 1.8 g/cm3
- Glass transition temperature: >100°C
- Sheet Width: 500mm
- Dry fibre thickness: 0.250mm
- Elongation at rupture: 1.8%
- Coefficient of thermal expansion:-1to0x10-6/°C

Mechanical Properties
- Elasticity modulus: Average value 240 GPa
- Range 235-245 GPa
- Tensile Strength: Average value 4000 MPa
- Range 3800-4200 MPa

Consumption of R&M-SATURANT (kg/sqm) 0.8-1.0 kg

7. THEORETICAL CALCULATION
The Theoretical calculation of a column involves analyzing its behavior under load, typically using Euler's column formula for long columns or more complex equations for short columns.

Design of column
Column size Diameter : 150mm Height : 600mm
Grade of concrete : M25

$P_u = 0.4 \times f_{ck} \times A_c$

$= 0.4 \times 25 \times \frac{\pi * d2}{4} \quad = 0.4 \times 25 \times \frac{\pi * 1502}{4}$

$P_u = 177$ kN

Design of CFRP wrapping column

P_u = 0.4 x fck x A_c + 0.67 x fy x A_{st}

= 0.4 x 25 x $\frac{\pi*150^2}{4}$ + 0

P_u = 177 kN

Providing 1 layer of 400 GSM

Thickness t = 0.9mm

E = 70 Gpa

n = 1

Volumetric ratio of FRD confinement

$\rho_f = \frac{4ntf}{d} \times \frac{wf}{sf} = \frac{4*1*0.9}{150} \times 1$

ρ_f = 0.24

Reinforcement ratio of longitudinal stress of gross cross sectional area

$\rho_{sg} = \frac{Ast}{B+D} = 0$ (∵ No steel used)

Effectiveness co- efficient

$k_e = \frac{d2 + h2}{3+\left(\pi*\frac{d2}{4}\right)+(1+\rho sg)} = \frac{150^2}{3+\left(\pi*\frac{150^2}{4}\right)+(1-0)}$

k_e = 0.115

Ultimate strain fibre = 1.8%

Effective strain $\mathcal{E}_p$ = 60% of 1.8%

By taking the strain as 0.004

Effective stress fs = Ef * $\mathcal{E}_p$

= 70 x 0.004

= 280 Mpa

Confining pressure

f_x = k_e x ρ_j x f_s /2 = 0.11 x 0.0240 x 280/2

= 0.37 Mpa

Effective cylindrical confined concrete strength

f_c = 0.8 x f_{ck} = 0.8 x 25 = 20

Effective confined compressive strength

$f^1_{cc} = f^1_c$ [2.254 $\sqrt{1+7.94*(fx/f_c)}$ - 2 fx/fc - 1.254]

20*[2.254$\sqrt{1+7.94*(0.37/20)}$ – 2 x 0.37/20-1.254]

= 46.98 Mpa

Effective cube compressive strength of strengthening

F^1_{ck} = 1.25 x f_c

= 1.25 x 46.98

= 58.75 ≅ 59 *Mpa*

Increase in axial capacity

= 339-177

= 162 kN

P_u = 0.4 x f_{cc} x A_c

= 0.4x 48 x π x150²/4

=339.29 ≅ 339 *Mpa*

8. EXPERIMENTAL METHOD

This chapter deals with the details of the specimen used, procedure adopted for strengthening of specimens, test for the experimental study and result obtained.in these 3 specimens of concrete column and 3 sets of strengthen column are prepared.

8.1 SPECIMEN DETAILS

The strengthening effectiveness of CFRP sheets on concrete column cylinders were studied by testing 6 cylinders.3 of them are concrete columns and 3 of them are strengthened

8.2 SPECIMEN PREPARATION AND PROCEDURE

The cylinder of 600mm height and 150mm diameter. The dimension were properly checked.

- The mould should set up properly grease the mould ,pour the concrete on it tamping should properly done and demould specimen after 24 hours and cured for 28 days.
- Strengthened cylinder preparation : the surface of the specimen was cleaned thoroughly to remove loosely held powders and is then cleaned with water and left to dry before wrapping.
- Before wrapping the concrete surface is coated with a mixture of epoxy primer and epoxy resin
- CFRP sheets wrapped around the specimen

The fig 2 and fig 3 shown the column specimens

Fig 2 Concrete column

Fig 3 Stregthened column

8.3 TEST SETUP

In a test setup for axial loading, a concrete column undergoes compression to measure its strength. For a strengthened column, additional materials like fiber-reinforced polymers are added to enhance load-bearing capacity. Both aim to evaluate structural integrity and performance under pressure. Here the fig 4 and fig 5 shown the testing setup of column

Fig 4 Testing setup for concrete column

Fig 5 Testing setup of Strengthend column

8.4 FAILURE MODES

The column as analyzed under incrementally vertical centric load with corresponding incremental load to top of the column up to failure.
Mode of failure of column for compressive stress failure at the top of the column by crushes the normal concrete column and the CFRP column was failure by its crushes inside wrapped sheet but it did not failure completely for some circumstance. The fig 6 and 7 shown the failure of column.

Fig 6 Failure of concrete column

Fig 7 Failure of Strengthend column (debonding stress)

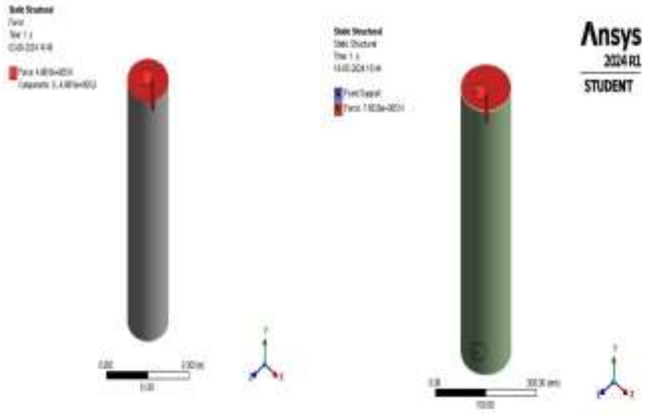

Fig 8 Loading condition of concrete column and strengthened column

8.5 TEST RESULTS

Table -1 Test Results

Concrete column		Strengthened column	
Samples	Load (kN)	Samples	Load (kN)
C1	450	CF1	560
C2	470	CF2	590
C3	490	CF3	620

Here the results of Strengthened column is recorded only for debonding stress not he failure load.

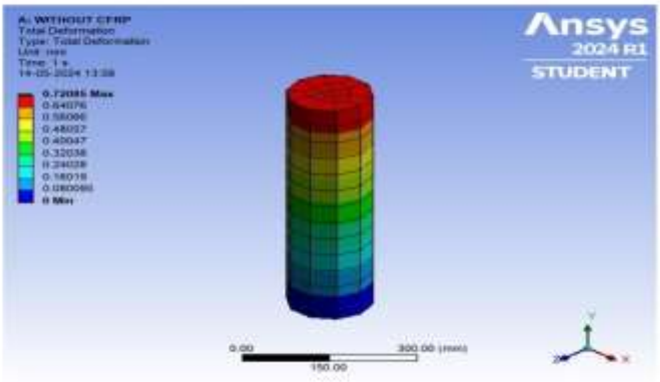

Fig 9 Total Deformation of Concrete Column

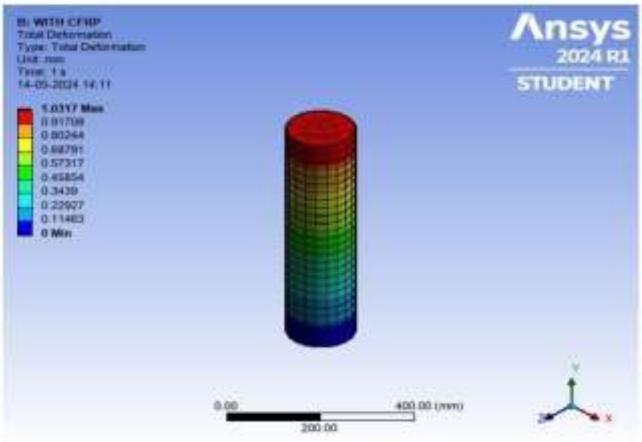

Fig 10 Total Deformation of Strengthened Column

9. FE ANALYSIS

This study develops a non-linear finite element model for FRP confined circular concrete column under vertical load. A series of 150mm diameter 600mm height circular columns were wrapped with one layer of CFRP sheets . All the concrete columns have a uniform grade of concrete M25.the column specimen were simulated in ANSYS workbench. ANSYS were well established FE engineering simulation programme that can execute simple static analysis as well as sophisticated non linear dynamic analysis. However , like all other finite element packages, the ANSYS programme has its own nomenclature and analysis procedures that need to be specified before executing the analysis.

The fig 9 and fig 10 shown the total deformation of the column models.

10. RESULT AND DISSCUSSION

10.1 Theoretical calculation

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Table-2: Load Carrying Capacity of Column by Theoretical Calculation

Type of column	**Load (kN)**
Concrete column	177 kN
Strengthened column	339 kN

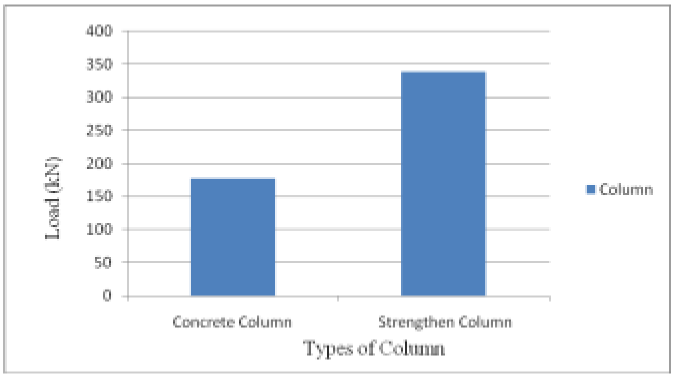

Fig 11 Graphical representation of Therotical result

- In reference to ACI 440 2r externally bonded FRP can be used to enhance axial capacity of the column.The table 2 and fig 11 graphical representation shown the result of therotical calculation as per the codal provision and literature review. In the analysis of the columns, therotical calculations provided the load bearing capacities for both a normal column and a strengthen column
- The normal column exhibited a therotical load-bearing capacity of 177kN, where as the strengthen column enhanced with additional materials or confinement, showed a significantly higher capacity of 339kN .
- The therotical calculation serves as a baseline for understanding the fundamental differences between the two types of columns. .For the normal column, the load capacity of 177kN is calculated on the material properties and geomertric dimensions, considering standard structural engineering principles.
- The wrapped column's capacity of 339kN,however, incoprates additional confinement provide by the wrapping materials which enhances the column's strength and ductility.
- . The design procedure in reference to the same has shown column retrofitted using CFRP Carbon fibre reinforced polymer has inherent capacity to bear a load of 339 KN when strengthening is done using 1 layer of unidirectional CFRP wrap (fibres oriented along the span length)

10.2 Experimental Method

Table -3: Load Carrying Capacity of Column by Experimental Method

Concrete column		Strengthened column	
Samples	Load (kN)	Samples	Load (kN)
C1	450	CF1	560
C2	470	CF2	590
C3	490	CF3	620

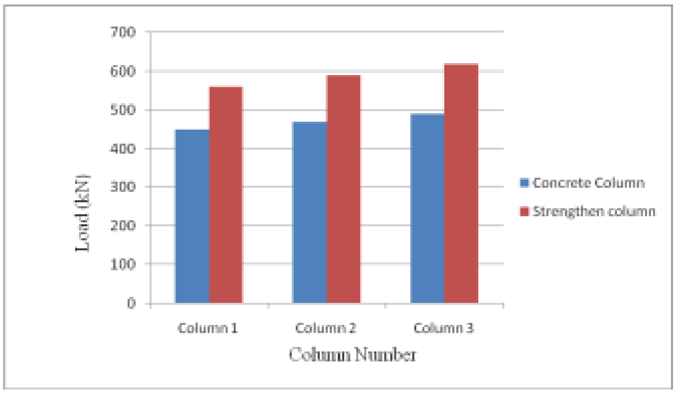

Fig 12 Graphical representation of Experimental results

- The table 3 and fig 12 graphical representation shown the Experimental results of the concrete columns and retrofitted columns .
- Experimental test showed that the normal column's strength increased from 450kN to 490kN, exceeding the therotical predictions of 177kN due to the material and construction quality
- The wrapped column, initially taking loads upto 620kN for debonding, surpassed its therotical capacity of 339 kN, hightlighting the significant strength provide by the wrapping. This enhancement attributed to the to the increased confinement and improved stress distribution, which delay failure.
- These results affirm the effectiveness of retrofitting substantially boosting load capacity and structural resilience in practical applications.The results indicates that the actual load capacities, for both normal and

wrapped columns exceed therotical expectation, giving the importance of experimental validations.

- The occurance of debonding at higher loads suggests that while wrapping enhances capacity, attention must be paid to the quality of the bond between the wrapping materials and the column to ensure maximum effectiveness.
- The wrapped column did not fail just it cracked inside wrap sheet and load did not increases till it fail it will takes more load as per tabulated in the result
- The comparision of the concrete column and CFRP column can increases the axial load of the column significantly the ductility of the columns improves because of the application of Retrofitting.
- Comparing the set of readings as shown in the graph. When compared the concrete column to CFRP column the strength increases and the strengthen column is just noted the cracking load not the failure load and it taken as the debonding stress of the column.

10.3 FE ANALYSIS

Table -4: Load Carrying Capacity by Column in FE Analysis

Type of column	Load (kN)
Concrete column	498.16 kN
Strengthened column	756.26 kN

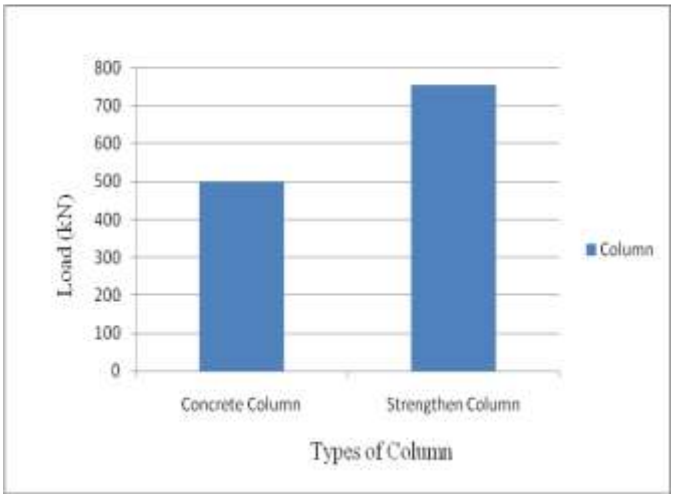

Fig 13 Graphical representation of FE analysis result

- The table 4 and fig 13 graphical representation gives the result of FE analysis of the concrete and Strengthen column.
- The FE analysis results indicate that the normal column has a load-bearing capacity of 498.16kN, while the strengthen column exhibits a significantly higher capacity of 756.26kN. These findings align with the expectation that wrapping enhances the structural performance the column.
- The FE analysis reveals that the wrapped column's load capacity is 756.26kN is significantly higher than that of the normal column 498.61kN. This substantial difference highlights the effectiveness of wrapping in enhancing structural performance.
- The FE results closely align with experimental findings, validating the accurancy of the FE model and its ability to predict real- world behaviour.
- The comparision between therotical,experimental, and FE results suggests that while therotical calulation provides a baseline, they often underestimated the actual capacity of columns due to simplifications and conservstive assumptions.

10.4 COMPARISION OF THEROTICAL, EXPERIMENTAL AND FE ANALYSIS RESULTS

Table -5: Load carrying capacity Concrete column

Theoretical	Experimental			FE Analysis	Percentage variation (Experimental to Analytical)
Load (kN)	Samples	Load (kN)	Average (kN)	Load (kN)	
177	C1	450	470	498.16	5.65 %
	C2	470			
	C3	490			

Table -6: Load carrying capacity Strengthened column

Theoretical	Experimental			FE Analysis
Load (kN)	Samples	Load (kN)	Average (kN)	Load (kN)

339	CF1	560	590	756.26
	CF2	590		
	CF3	620		

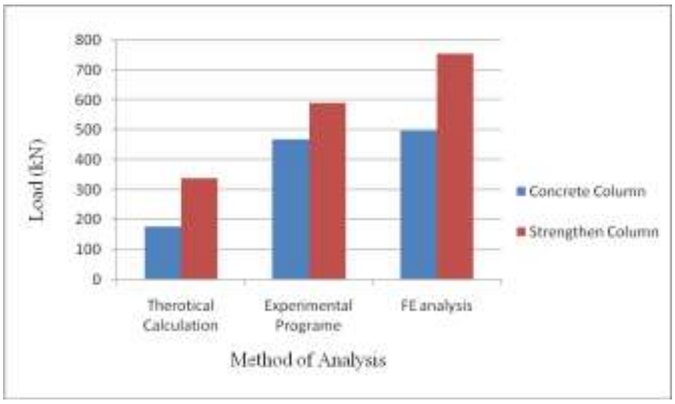

Fig 14 Graphical representation of comparision of therotical Experimental and FE analysis result

- The Theoretical analysis tends to provide conservative estimates, which are often lower than the actual capacities observed in Experimental testing. This is because Theoretical calculations may not fully account for all factors affecting the behavior of the column, such as material imperfections, construction tolerances, and environmental conditions.
- Both Experimental and FE analysis results for the strengthened column demonstrate higher load capacities compared to the concrete column. This suggests that the strengthening method applied to the column effectively enhances its load-bearing capacity, as supported by both Experimental validation and numerical simulations.
- The FE analysis results generally agree well with the Experimental findings, indicating that the FE model used is capable of accurately capturing the behavior of the columns under loading conditions. Any differences between the two may be attributed to simplifications or assumptions made in the FE model or variations in material properties.
- The higher load capacities observed in both Experimental and FE analysis for the strengthened column highlight the effectiveness of the strengthening technique employed. This information is valuable for engineers and designers, as it demonstrates the potential for improving the load-bearing capacity of existing concrete structures through reinforcement or strengthening methods.
- It would be beneficial to conduct additional Experimental tests and refine the FE model to better understand the behavior of the strengthened column under various loading conditions and to validate the effectiveness of the strengthening method further.
- The comparison of Theoretical, Experimental, and FE analysis results provides valuable insights into the behavior and performance of concrete and strengthened columns, highlighting the effectiveness of the strengthening method in enhancing load-bearing capacity. Further research and validation efforts are warranted to refine the analysis and ensure the reliability of the findings.

11. CONCLUSION

- FRP method of strengthening has been advanced method of strengthening in civil engineering sector however many researches have been done to prove its effectiveness in the strength enhancement of the structural element.
- In reference to ACI 440 2r externally bonded FRP can be used to enhance axial capacity of the column. The design procedure in reference to the same has shown column retrofitted using CFRP Carbon fibre reinforced polymer has inherent capacity to bear a load of 339 KN when strengthening is done using 1 layer of unidirectional CFRP wrap (fibres oriented along the span length), However the bear Column has the capacity of 177 KN.
- The experimental procedure has shown that the concrete column can bear a axial load of 470 KN and the column strengthened using FRP can bear a load of 590 KN. Hence there is an improvement in its axial capacity.
- The analytical model created using ANSYS software imparting same property of the material and experimentally taken ultimate load has shown load results without FRP as 498.16 kN and with FRP as 756.26 kN. Thus the percentage reduction in load
- In comparison of the load capacity arrived from Theoretical, Experimental and Analytical procedure it is found that the Theoretic procedure gives lower value of capacity as it

contains various safety factors given under design guidelines

- It is found that the Analytical model has shown slight increase value when compared with actual Experimental result. Hence Analytic method under estimates the Experimentally measured value.

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