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Analysis of Reinforced Concrete Column using FRP composites

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Abstract— **In this paper, technique for upgrading Reinforced concrete circular column have been studied with the application of composite material. The objective of the rehabilitation is to upgrade the stiffness and ductility of the reinforced concrete column using FRP composite material. The finite element method (ANSYS) is used to model and analyze the reinforced concrete column, first without FRP composite material and subsequently with different FRP composite materials. The Reinforced concrete columns are tested (with and without FRP) by applying static loads.**

Index Terms— **RC column, fiber reinforced polymer (FRP), Ductility, Stiffness.**

I. Introduction

The FRP products can be used for structural strengthening/ retrofitting of existing buildings and bridges and for construction. It is required when there are increases in the applied loads, human errors in initial construction, earthquakes and when a structural member losses its strength due to deterioration over time. The cost associated with replacing the structure back in service immediately is relatively high that strengthening/ retrofitting become the most efficient solution. There are different available materials like FRP, steel, concrete etc. for retrofitting of the structure, but use of FRP is increasing rapidly. This is due to the fact that FRP materials have several advantages over steel and other materials. They are light weight of the material, high-strength to weight ratio, corrosion resistance, high efficiency of construction and FRP material can be easily bonded to concrete surfaces. Typical uses of FRP in construction are as follows:

1. FRP wraps are used on columns to increase the column ductility
2. FRP plates are bonded to the surface of concrete members (beam , slab, walls) to improve the flexure and shear capacity of the concrete members,
3. FRP reinforcing bars and pre-stressing strands are used as an alternative to steel reinforcing,
4. Strengthening of Beam column joints

Experimental and theoretical studies on seismic retrofit of reinforced concrete circular columns using prefabricated composite jacketing (GFRP).

The civil engineering infrastructure has demonstrated that most of it will need major repairs in the near future. Rochette and Labossie [3]. This justifies the development of innovative rehabilitation and strengthening methods for reinforced concrete structures, especially with composite materials. This paper reports the results of a research program on this topic and concentrates on the behavior of square and rectangular columns confined with carbon fiber sheets. Results from a series of tests on small-scale specimens showed that confinement increased the strength and ductility of the concrete columns loaded axially. L.P.Ye and K. Zhang [1]. The ductility enhancement with the confinement of CFRP sheets was studied by the strain development and distribution in the CFRP sheets. The seismic design method of the current Chinese seismic design code for RC columns can be directly used in determining the amount of CFRP required for seismic strengthening. In this study, a finite element analysis using commercial software ANSYS was utilized to conduct a parametric analysis. Samuel and Su-Seng [5]. Experiments were also conducted to justify the finite element analysis results. A reasonable agreement was found between the finite element analysis and the test results. The effect of the thickness, stiffness, and fiber orientation of the CFRP layers as well as the interfacial bonding between the FRP wraps and the concrete on the strength and stiffness of the repaired columns was evaluated using the finite element modeling. The use of high-strength concrete HSC in seismically active regions poses a major concern because of the brittle nature of material. Togay and Murat [2]. An alternative to conventional confinement reinforcement is the use of fiber-reinforced polymer FRP tubes in the form of stay-in-place formwork which can fulfill multiple functions of formwork, confinement reinforcement and protective shell against corrosion, weathering and chemical attacks.

This paper presents the finite element analysis to study the behavior of retrofitted RC pile specimen strengthen with glass fiber reinforced polymer (GFRP) composites using ANSYS. Reddy and Sundaravadivelu [4]. Experiments were also conducted to justify the finite element analysis results. Eight RC piles specimens were cast with same reinforcement details to study the behavior under loading conditions. A parametric study is carried out to investigate the effect of various parameters on the strength of RC piles. The parameters include unconfined concrete strength, the steel ratio and the thickness of FRP.

II. MATERIAL PROPERTIES

2.1 Concrete

Grade of Concrete = M25

M25 concrete is used f_{ck} = 25 N/mm2

$$E_C = 5000\sqrt{f_{ck}}$$

Ec = 25000 N/mm2

Poisson's ratio (μ) value for concrete is taken as 0.2

2.2 Steel Reinforcement

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Grade of steel Fe 415
8 no 16mm diameter steel Fe 415 (HYSD) longitudinal bars are used
Poisson's ratio (μ) value of steel is 0.3
Permissible stress in compression in steel is 190 N/mm2

2.3 FRP Composite

For strengthening RC column Carbon fiber reinforced polymer(CFRP) and glass fiber reinforced polymer(GFRP) used with constant thickness of
0.5mm the material properties of FRP is shown in table 1 [6,4]

Table 1 Properties of CFRP and GFRP

Property	CFRP composite	GFRP composite
E_x(MPa)	50000	14708
E_y(MPa)	50000	14708
E_z(MPa)	7200	13886
υ_{xy}	0.3	0.16
υ_{yz}	0.25	0.14
υ_{zx}	0.25	0.14
G_{xy}(MPa)	5000	2632
G_{yz}(Mpa)	5000	2632
G_{zx}(Mpa)	3000	2300

III. RCC COLUMN MODEL

The RC column is circular in cross section having diameter of 300mm .length of column is 3m.The RC column specimen was modeled using a special concrete element-SOLID 65. SOLID 65 is an 8-node solid brick element having three translation degrees of freedom per node. This element has crushing (compressive) and cracking (tensile) capabilities. The cracking and crushing failure modes are respectively based on predefined tensile and compressive strength of the concrete. In the retrofitted pile specimen the layered SOLID-46 elements were used to represent the FRP composites. The element allows for up to 100 different material layers with different orientations and orthotropic material properties in each layer. The element has eight nodes with three degrees of freedom at each node, translations in the nodal x, y, and z directions. The layered elements were attached to the concrete elements of column specimen. To simulate the perfect bonding of the FRP sheets with concrete the nodes of SOLID-46 elements were connected to the nodes of SOLID-65 elements at the interface so that two materials shared the same nodes.

The elements have translations in the nodal x and y directions. The element has plasticity, creep, swelling, stress stiffening, and large deflection.

IV. ANALYSIS USING ANSYS

ANSYS is general-purpose finite element software for numerically solving a wide variety of structural engineering problems. The ANSYS [12] element library consists of more than 100 different types of elements. A 3-D model of the RC Column was built using ANSYS. The column specimen was built by first creating a circular area. The area was meshed using a 4-node PLANE42 element. The meshed circular plane was extruded using concrete element SOLID65. The retrofitted Column was also modeled in the same fashion except a layered element SOLID46 representing the FRP was used for extrusion. For the numerical simulation RC column three dimensional solid element SOLID65 has been used for modeling the nonlinear behavior of concrete, SOLID46 has been used for layered composites laminate.Plane42 is used for 2-D modeling of solid structures.

The element can be used either as a plane element (plane stress or plane strain) or as an axis symmetric element. The element is defined by four nodes having two degrees of freedom at each node: translations in the nodal x and y directions. The element has plasticity, creep, swelling, stress stiffening, large deflection, and large strain capabilities. The RC column specimen was modeled using a special concrete element-SOLID 65. SOLID 65 is an 8-node solid brick element having three translation degrees of freedom per node. This element has crushing (compressive) and cracking (tensile) capabilities. The cracking and crushing failure modes are respectively based on predefined tensile and compressive strength of the concrete. In the retrofitted pile specimen the layered SOLID-46 elements were used to represent the FRP composites. The element allows for up to 100 different material layers with different orientations and orthotropic material properties in each layer. The element has eight nodes with three degrees of freedom at each node, translations in the nodal x, y, and z directions. The layered elements were attached to the concrete elements of pile specimen. To simulate the perfect bonding of the GFRP sheets with concrete the nodes of SOLID-46 elements were connected to the nodes of SOLID-65 elements at the interface so that two materials shared the same nodes.

Parametric study is done by Using GFRP and CFRP Length of columns 3m.Varying the thickness of CFRP from 3mm to 6mm.

V. RESULTS AND DISCUSSIONS

The results are shown in the figures 1 to 3 for concrete column and column with FRP materials.

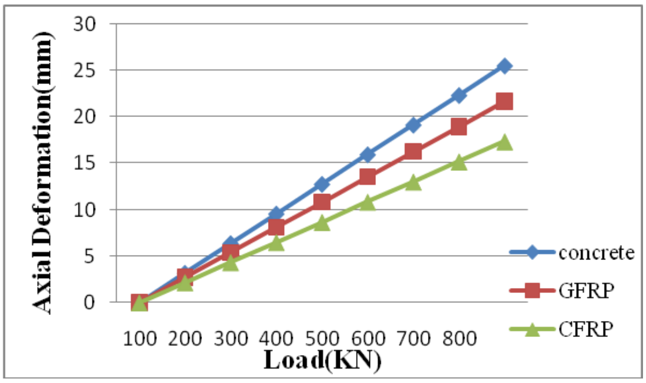

Fig.1Axial Deformation Vs Axial Load for CFRP and GFRP confined column.

This shows that CFRP is more effective for confinement in comparison to GFRP.

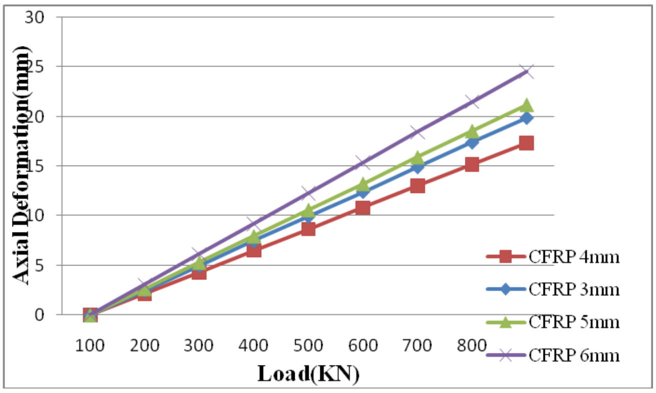

Fig.2 Axial Deformation Vs Axial Load for CFRP

This shows that CFRP with 4mm thickness is more effective, CFRP becomes less effective for higher thickness because of brittleness.

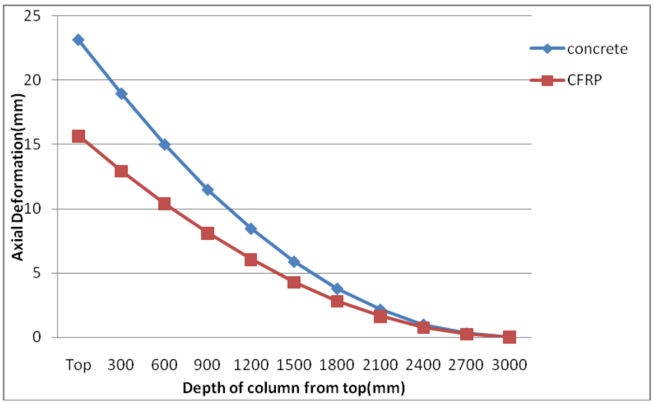

Fig 3.Axial Deformation Vs Axial Load for RC column and CFRP confined column at different sections of a column from top to bottom.

Column is divided in sections from top to bottom having interval of 300mm. This shows that axial deformation is maximum at top of the column section and decreases with the increase in the distance of the column section from top and becomes zero at the bottom of the column section where column is fixed.

VI. Conclusion

An extensive study was carried out regarding the CFRP and GFRP confinement effect RC columns. From the results of this study, following conclusions and recommendations for future research and implementation are made.

- Both CFRP and CFRP confinement are very effective for circular concrete columns by significantly increasing the axial strength, ultimate axial strain and ductility.
- GFRP should be used to provide higher ductility and moderate strength for circular columns due to the lower modulus of the GFRP material.
- On the other hand, because of the higher modulus of CFRP, this material can be used to provide circular concrete columns with higher strength increase and moderate ductility.
- GFRP jackets provided a slightly higher confinement than CFRP jackets. This is mainly because the GFRP composite jacket is softer than the CFRP jacket from the point of view of material properties, i.e., it has a lower modulus of elasticity.
- Although FRP composites could significantly improve column axial behavior, caution is required in the application of this material because of its brittle characteristics at failure.

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