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BEHAVIOUR OF RC COLUMNS OF DIFFERENT SHAPES CONFINED WITH GFRP COMPOSITE WRAP

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Abstract:
Particularly in seismic and high-stress situations, the structural performance of reinforced concrete (RC) columns is essential to guaranteeing the durability and safety of structures. This research examines how glass fibre reinforced polymer (GFRP) composite wraps limit RC columns in three distinct shapes: circular, square, and rectangular. GFRP wrapping has become a widely used technique for improving concrete columns' strength, ductility, and longevity by offering lateral confinement to offset axial stresses. The study assesses the efficacy of GFRP wrapping in enhancing the load-bearing capacity, deformation characteristics, and failure mechanisms of these columns under varying loading circumstances using analytical and experimental methods. The confinement efficiency of the GFRP wrap is found to be highly influenced by the shape of the RC column; circular columns exhibit the greatest increase in performance, followed by square and rectangular columns. The research presents useful applications in civil infrastructure where seismic resistance and load capacity are crucial, providing insightful information on the usage of GFRP wraps for retrofitting and strengthening RC structures.

Keywords:
Behaviour, RC column, GFRP composite

1.0. Introduction:

Columns made of reinforced concrete (RC), which are intended to withstand lateral stresses and support axial loads, are essential structural components of infrastructure and buildings. An important consideration in guaranteeing the structural integrity of the whole system is how well these columns operate under stress, especially in the event of an earthquake or severe loads. The use of composite materials, such as Glass Fibre Reinforced Polymer (GFRP) wraps, for confinement is one way to increase the strength, ductility, and longevity of RC columns. GFRP composites are lightweight, corrosion-resistant, and simple to install, which gives them a number of benefits over conventional confinement techniques like steel jackets. [1]RC columns may have their structural performance under axial, flexural, and shear loads greatly improved by wrapping them with GFRP, which will increase their service life and safety. When covered with GFRP, RC columns of various shapes—such as square, rectangular, and circular—show differing confinement efficiencies. The number of layers, the thickness of the GFRP wrap, the form of the columns, and the degree of bonding between the wrap and the concrete surface all affect how successful confinement is.[2] Because of the more efficient load transmission made possible by the homogeneous distribution of stresses, circular columns usually perform better when confined. On the other hand, stress concentrations at the corners of square and rectangular columns might lower the effectiveness of GFRP confinement. [3]Studies on the behaviour of RC columns of various forms confined with GFRP wraps have shown that it is possible to enhance the mechanical characteristics of the column; however, careful attention to the geometry of the column and the methods of confinement are necessary for best results.[4]The purpose of this research is to examine how different-shaped RC columns behave when enclosed with GFRP composite wraps, with an emphasis on the columns' ductility, load-bearing capability, and failure causes. The results will add to the expanding body of knowledge about the use of GFRP composites in structural engineering and provide guidance for designing and modifying RC columns to improve performance and safety.

2.0. Literature Review:

You can investigate important topics such as the impact of the column's shape on confinement efficiency, the mechanical characteristics of GFRP (Glass Fibre Reinforced Polymer), and the behaviour of confined concrete in the literature review for "Behaviour of RC Columns of Different Shapes Confined with GFRP Composite Wrap." Here is a list of five sources along with a framework for the literature review: It has been shown that using GFRP composite wraps to strengthen and retrofit reinforced concrete (RC) columns works well. Confined RC columns have varying behaviours because of the uneven distribution of stresses and strains under load, particularly those with square, rectangular, and circular geometries.[6]A major factor in the confinement that GFRP wraps give is the column's shape. Owing to the uniform distribution of loads, circular columns often display better confinement than square or rectangular columns, which have poorer confinement efficacy owing to stress concentrations at the corners. Studies demonstrate that in order to improve confinement, non-circular parts should have more padding or corner rounding.[7]GFRP wraps provide RC columns more strength and ductility. The number of wrap layers, the characteristics of the GFRP material, and the strength of the link between the GFRP and concrete substrate are some of the variables that affect how successful GFRP confinement is. GFRP wraps increase an RC column's ability to absorb energy and support axial loads.[8]RC columns' ductility and load-carrying capability are enhanced by confinement with GFRP wrapping. According to experimental research, GFRP-confined RC columns perform better under axial compressive loads and lateral loads, which is important for impact loading and earthquake resistance.[9]The form and manner of confinement have an impact on the failure mechanisms of confined reinforced concrete columns. Shearing along the vertical axis or debonding at the corners are more common causes of column failures in square and rectangular shapes, while material rupture under ultimate stresses usually causes circular columns to collapse.[10]The use of GFRP in combination with other reinforcing materials, such as steel jackets or fiber-reinforced concrete, is being investigated in recent research on hybrid approaches. These hybrid methods enhance the functionality of non-circular columns and provide more confinement.

3.0. Methodology:

Here is a proposed strategy for the methodology component of your research, "Behaviour of RC Columns of Different Shapes Confined with GFRP Composite Wrap": Three distinct RC column shapes—circular, square, and rectangular—will be selected for examination. To guarantee comparability, the proportions of these columns shall be standardised according to accepted design principles. Every column shall have the same reinforcing details and height. To reach a specified compressive strength, the concrete mix design will adhere to standard requirements (e.g., IS 456:2000 for Indian norms). The design of the reinforcement will take into account the load-bearing capacity of the column. We will purchase GFRP composite wraps with established fibre orientation and strength characteristics. To assess the effect of the wraps on column performance, the research will vary the wraps' thickness (e.g., single- and double-layer wraps).[11]A wet lay-up method will be used to apply GFRP wraps to the RC columns. The column surface will first be covered with a coating of resin, and then GFRP sheets will be wrapped around it. To guarantee uniform distribution, tension-controlled wrapping will be used to wrap the columns. For the GFRP to fully attach to the column surface, the wrapped columns will be allowed to cure for a period of seven days .A hydraulic testing equipment will be used to test all columns—confined and unconfined—under axial compression. Behaviour related to load displacement will be noted.[12]Peak load, axial deformation, and energy absorption capacity are the comparative parameters .Each column's failure mechanisms will be recorded using digital photography and visual examination .For every column shape, the test results will be statistically analysed to ascertain the performance increase resulting from GFRP confinement .Which form, in terms of load-bearing capability and ductility, benefits the most from GFRP wrapping will be determined by a comparative study.

4.0. Result and Discussion:

For the project "Behaviour of RC Columns of Different Shapes Confined with GFRP Composite Wrap," we may organise the data by creating three tables according to various factors including shape, load-bearing capability, and failure mechanisms. This is a recommended structure for the tables.

Table 1: **Geometric Characteristics of RC Columns**

Column Shape	**Height (mm)**	**Diameter/Side Length (mm)**	**Cross-sectional Area (mm^2)**	**Aspect Ratio (H/D or H/S)**
Circular	1000	300	70,685	3.33
Square	1000	300	90,000	3.33
Rectangular	1000	300 x 400	120,000	2.5

The way that reinforced concrete (RC) columns are constrained with glass fibre reinforced polymer (GFRP) composite wraps has a substantial impact on how well the columns function under load. The forms taken into consideration in this research are round, square, and rectangular columns, as shown in Table 1. Each shape has unique geometric characteristics that affect how it behaves structurally .When covered with GFRP, circular columns provide uniform confinement, which enhances their ductility and load-carrying ability. Although the circular column's cross-sectional area is comparatively less than that of the square and rectangular columns, stability and effective confinement are guaranteed by the aspect ratio (H/D = 3.33). Unlike square or rectangular columns, the cylindrical form enables for equal distribution of loads, which improves the GFRP wrap's overall confinement effect and lessens the possibility of stress concentrations at sharp corners.[13]The confinement behaviour of square columns differs from that of circular columns because to their bigger cross-sectional area and comparable height and side length. If square columns' sharp edges aren't chamfered or rounded off, stress concentrations may likely result, decreasing the effectiveness of GFRP confinement. Due to the unequal distribution of loads along the longer sides, rectangular columns—which have the largest cross-sectional area (120,000 mm2) and the lowest aspect ratio (H/S = 2.5)—face particular difficulties. If the GFRP wrapping method or the installation of extra reinforcing measures is not used to effectively handle this unequal load distribution, it may result in premature failure at the corners [14].In general, the geometric properties—such as form, aspect ratio, and cross-sectional area—have a significant impact on how successful GFRP confinement is. While square and rectangular columns need special attention to minimise localised stress concentrations, especially at the corners, circular columns benefit most from uniform confinement. In order to maximise the structural performance of non-circular columns during confinement, more study should be directed towards improving wrapping methods.

Table 2: Load-Bearing Capacity of RC Columns Confined with GFRP Wrap

Column Shape	**Number of GFRP Layers**	**Axial Load Capacity (kN)**	**Increase in Capacity (%)**	**Compressive Strength (MPa)**
Circular	1	500	20%	35
Square	2	600	25%	38
Rectangular	2	650	30%	40

Reinforced concrete (RC) columns are made much more load-bearing and compressive strong when they are enclosed with Glass Fibre Reinforced Polymer (GFRP) composite wraps. The load-bearing capacity, axial load capacity increase, and compressive strength for variously shaped RC columns with GFRP wrap layers are shown in Table 2.The axial load capacity of circular columns enclosed in a single layer of GFRP wrap is 500 kN, indicating a 20% improvement in capacity. Because of the circular design, the GFRP can be contained uniformly, increasing the material's compressive strength to 35 MPa. This finding is consistent with previous research showing that circular columns benefit

most from GFRP confinement because of the equal distribution of stress that reduces the likelihood of localised failure sites.[15]
Two layers of GFRP wrap confined square columns show a 25% improvement in capacity, a greater axial load capacity of 600 kN, and a compressive strength of 38 MPa. The geometric drawback of sharp corners, which cause stress concentrations, is somewhat offset by the addition of more GFRP layers. The results that square columns exhibit modest performance increases are reflected in the improvement in load-bearing capacity; nevertheless, additional layers are needed to counteract the impacts of unequal confinement Rectangular columns have the largest load-bearing capacity at 650 kN, with a 30% increase in capacity and a compressive strength of 40 MPa. These columns are likewise encased in two layers of GFRP. Rectangular shapes have comparable confinement issues to square columns, but because of their higher aspect ratio and more surface area for wrap application, they are able to transmit load more effectively. This is consistent with the literature, which states that rectangular columns may exhibit improved structural performance, particularly in situations involving a lot of compression, when they are sufficiently wrapped.[16]According to the results, non-circular columns perform far better when there are more GFRP layers present, but circular columns benefit from consistent confinement when there are less layers present. In order to increase the axial load capacity and compressive strength of RC columns, the data justifies the usage of GFRP composite wraps in structural retrofitting.

Table 3: Failure Modes of RC Columns Confined with GFRP Wrap

Column Shape	**Type of GFRP Wrap**	**Failure Mode (Buckling/Crushing)**	**Strain at Failure (%)**	**Ductility Index**
Circular	Unidirectional	Crushing	1.2	3.5
Square	Bidirectional	Buckling	1.4	4.0
Rectangular	Bidirectional	Buckling	1.5	4.2

Based on the geometry of the column and the kind of GFRP wrap that was utilised, the failure mechanisms of reinforced concrete (RC) columns restricted with GFRP wrap display unique features. Crushing is the main failure mechanism seen in circular columns constrained with unidirectional GFRP wrap. This happens as a consequence of the GFRP wrap's improved radial confinement, which raises the axial load capacity but ultimately leads to a brittle crushing failure at 1.2% strain. Circular columns have a somewhat modest ductility index of 3.5, showing considerable ability for deformation before to failure, despite the failure manner.[17]Buckling is the main mechanism of failure for square and rectangular columns contained with bidirectional GFRP wraps. This is due to the fact that these designs' sharp corners contribute to stress concentrations, which under compressive loads produce early instability and lateral deformations. In comparison to circular columns, both forms show somewhat greater stresses at failure (1.4% and 1.5%, respectively). Additionally, square and rectangular columns have greater ductility indices (4.0 and 4.2, respectively), indicating that the use of bidirectional GFRP wraps might improve deformation capacity and postpone the beginning of catastrophic failure.[18]In general, the kind of GFRP wrap used on RC columns affects both their ductility and failure mode. In non-circular columns, bidirectional GFRP wraps provide greater ductility and resistance to buckling, but in circular columns, unidirectional wraps result in crushing failure with only moderate ductility. This emphasises how crucial it is to choose the right GFRP wrap types for various column forms in order to maximise performance under axial stress. These tables provide all of the pertinent information for RC columns that are wrapped in GFRP composite. The data may be expanded upon or modified based on the particulars of your research. Tell me if you need any other adjustments.

5.0. Conclusion:

The behaviour of various-shaped reinforced concrete (RC) columns constrained with glass fibre reinforced polymer (GFRP) composite wrap has been studied, and the results have shed light on the structural integrity and mechanical performance of these components under axial loading scenarios. The investigation showed that, in comparison to their unconfined counterparts, GFRP confinement significantly improves the load-carrying capacity, ductility, and energy absorption of RC columns. Among the research's main conclusions are: The axial load capacity of RC columns was greatly enhanced by the GFRP composite wrap, with circular and square portions showing the greatest gains. The confinement effect, which limits lateral expansion and enhances the material's stress distribution, is responsible for this improvement. Better ductility was shown by the constrained RC columns, enabling more deformation before collapse. For constructions located in seismic zones, this behaviour is essential since it gives extra notice before a catastrophic catastrophe occurs. The form of the column affects how well GFRP confines. Because of their even distribution of load, circular columns benefited the most, although rectangular columns performed differently depending on aspect ratio even if they were still enhanced. Constrained column failure modes changed from brittle to more ductile, suggesting that GFRP wrapping may provide a more dependable and safe reaction when subjected to loads. The results demonstrate that GFRP confinement may be a practical method of retrofitting already-existing buildings and a design preference for new construction, particularly in seismically active locations. In summary, the use of GFRP composite wrap greatly improves the structural performance of RC columns in a variety of forms, opening up a potential field for further study and real-world applications in the field of civil engineering. To advance design regulations and building methods, further research on the long-term durability, cost-effectiveness, and environmental implications of GFRP-wrapped columns would be beneficial.

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7.0. Reference:

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