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PARAMETRIC STUDY OF GLASS FIBRE REINFORCED POLYMER (GFRP) STRENGTHENED CONCRETE COLUMN UNDER ECCENTRIC COMPRESSION LOAD

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ABSTRACT: The study investigated the performance of reinforced concrete columns that were strengthened using GFRP materials when subjected to eccentric loading. Eccentric loading refers to the application of a load that is not centrally located, causing an off-centre force on the column. This type of loading is known to introduce additional challenges and stress concentrations in the column.

The objective of the research was to evaluate the effectiveness of GFRP strengthening in improving the performance of reinforced concrete columns under eccentric loading. The researchers conducted FEA analysis on a series of reinforced concrete columns, with various parameters such as length, cross section, eccentricity, end condition and varied spacing of stirrups to compare their ultimate load carrying capacity and displacement.

Finite Element Analysis (FEA) is employed to simulate the behaviour of GFRP-strengthened concrete columns. The numerical models are validated against experimental results obtained from laboratory tests conducted on prototype specimens. The study investigates the influence of each parameter on the ultimate load carrying

capacity and displacement of the columns, aiming to identify the optimal configuration for GFRP strengthening.

Overall, the research demonstrated the potential of GFRP strengthening in enhancing the behaviour and performance of reinforced concrete columns subjected to eccentric loading. These findings can contribute to the development of improved design guidelines and strategies for strengthening existing structures or designing new ones with increased resistance to eccentric loading effect.

Key words: GFRP, Eccentric loading, Strengthening.

1. INTRODUCTION:

When exposed to a humid environment, the steel bars in reinforced concrete (RC) structures experience a decline in their mechanical properties, resulting in reduced load-carrying capacity and serviceability. To prevent corrosion and degradation, protective measures are necessary, but they can come with a significant upfront cost.

Glass fiber reinforced polymer (GFRP) bars are considered the optimal alternative to steel bars due to their high tensile strength, lightweight nature, low density, and excellent electromagnetic resistance. Most importantly, they possess superior corrosion resistance.

Fiber Reinforced Polymers (FRP) were originally created for the aerospace industry and later adopted by the automotive industry. However, their superior characteristics in comparison to other materials made them a preferred choice for civil engineering applications over time.

When it comes to research on FRP-confined concrete columns, the focus is typically on studying the stress-strain relationship of these columns, observing how they behave under eccentric load, and evaluating their seismic performance.

Since most columns in structures are subjected to eccentric loads, the study of the behaviour of FRP-confined reinforced concrete columns under such loads holds greater significance.

2. FINITE ELEMENT MODELLING:

Numerical simulations of GFRP reinforced concrete columns were done by using software ABAQUS. During the modelling of specimens, the concrete material models, boundary conditions, and different geometric and material parameters. The concrete material was modelled as a homogeneous 3D solid section. Diameter of main reinforcement is 25 mm and diameter of stirrups is 8 mm.

In total 48 number of models were prepared and the variable in models are length, end condition, cross sectional dimension, eccentricity and varied stirrup spacing.

For considering the variation in eccentricity 12 models were prepared in which three eccentricities of 0 mm, 100mm and 175mm are considered for two different length and for two different end conditions but having same cross-sectional dimension. For same eccentricities 12 models were also

prepared having different cross-sectional dimension (400 x 400mm).

As per the provision of IS 13920 for special confining reinforcement a stirrup spacing of 85mm in top and bottom 450 mm and a spacing of 100mm in middle portion of column is taken for that 24 models were prepared having variation in length, eccentricity, cross sectional dimension and end condition of column but having two layers of hoop GFRP.

To determine the axial load-deflection history of reinforced concrete columns up to failure, a static monotonic loading was applied on the top by the displacement control technique. An induced displacement of 20mm was applied on the top centre of concentric columns and at a distance equal to required eccentricity from the centre of specimens along the weaker axis of eccentric columns. The geometry and the modelling details of the finite element models of steel-reinforced columns are shown in Figure 1.

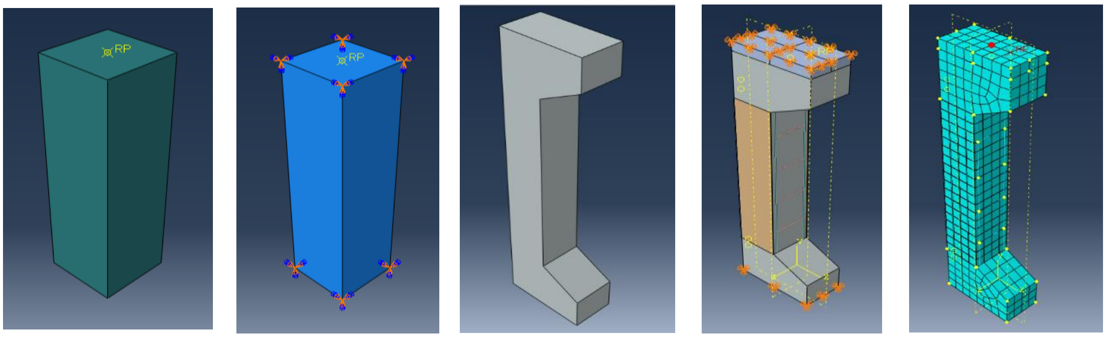


Figure 1 A typical steel reinforced concrete column strengthened with two layers of hoop wrapping

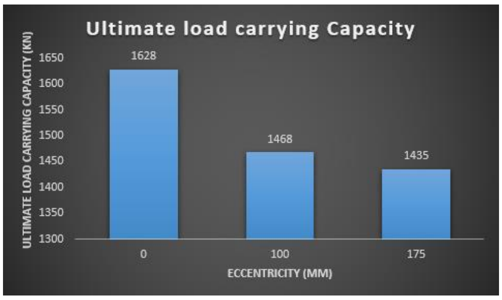
Length (mm)	End condition	Eccentricity (mm)	Cross section (mm)	Spacing of stirrups
3500	Both ends hinged	0	350 x 350	Constant spacing of 100mm
2500	Both ends fixed	100	400 x 400	Varied spacing of stirrups
		175		

Table 1 Variables in modelling of column

Parameter	Value
Density of concrete (ton/mm^3)	2.4 x 10^{-9}
Poisson's ratio	0.2
Youngs modulus (N/mm^2)	26587
Concrete cover (mm)	40
Initial and maximum increment size of the loading	0.01
Minimum increment size	10^{-10}

Table 2 Element intricacies

3. FEA Model Results:



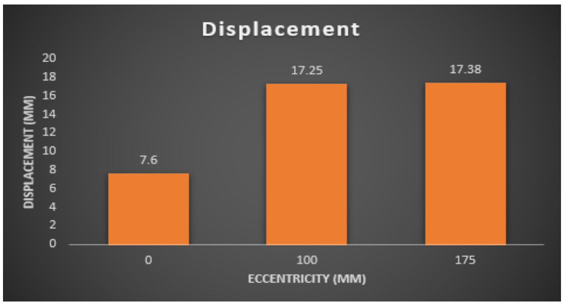
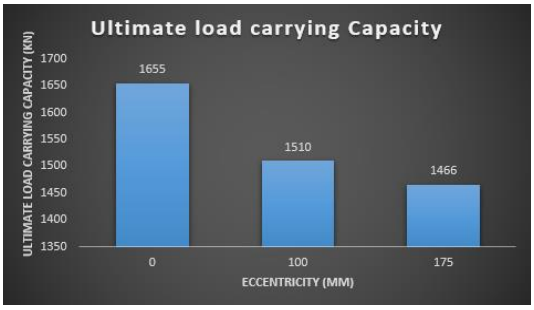


Figure 2 Ultimate load carrying capacity of 3.5 m column having both ends fixed and cross section of 350 x 350 mm with different eccentricity



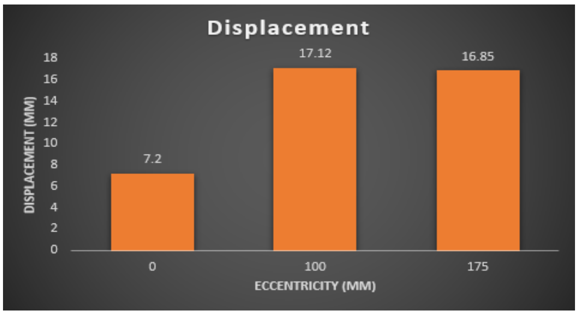
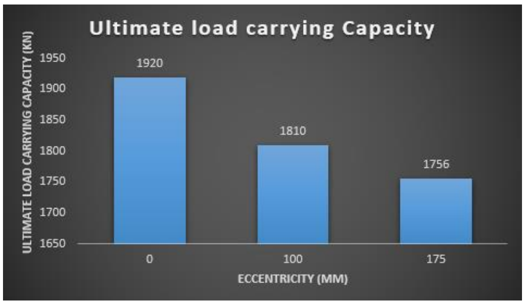


Figure 3 Ultimate load carrying capacity of 2.5 m column having both ends fixed and cross section of 350 x 350 mm with different eccentricity



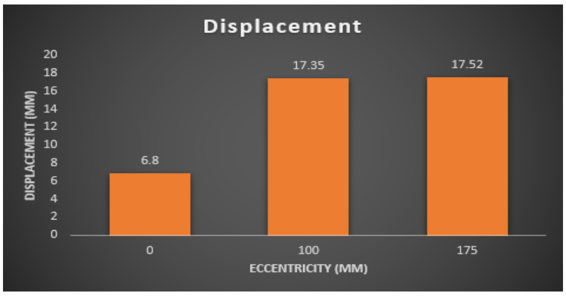
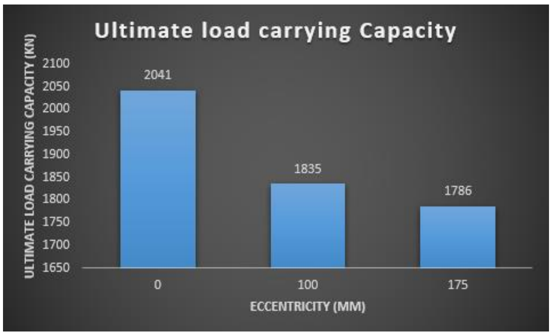


Figure 4 Ultimate load carrying capacity of 3.5 m column having both ends hinged and cross section of 400 x 400 mm with different eccentricity



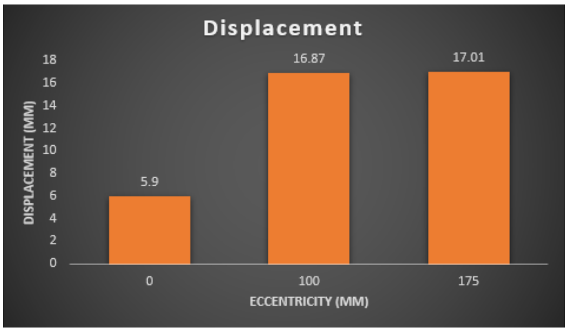
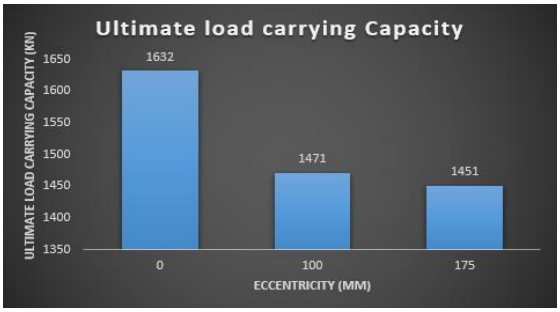


Figure 5 Ultimate load carrying capacity of 3.5 m column having both ends fixed and cross section of 400 x 400 mm with different eccentricity



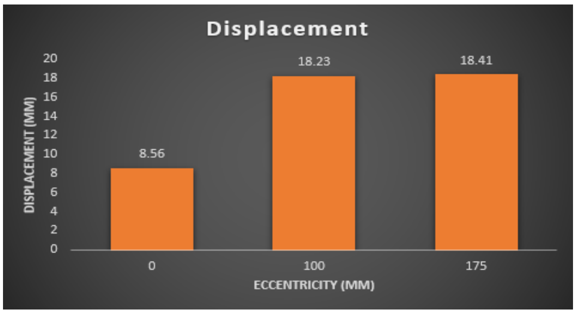
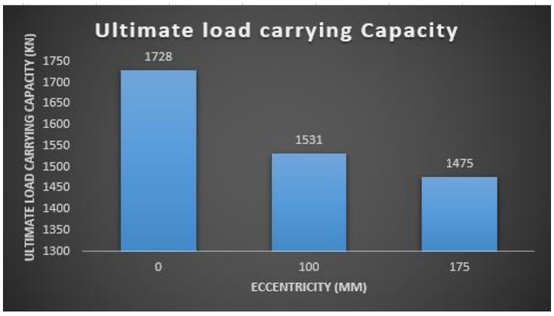


Figure 6 Ultimate load carrying capacity of 3.5 m column having both ends hinged and cross section of 350 x 350 mm having varied spacing of stirrups with different eccentricity



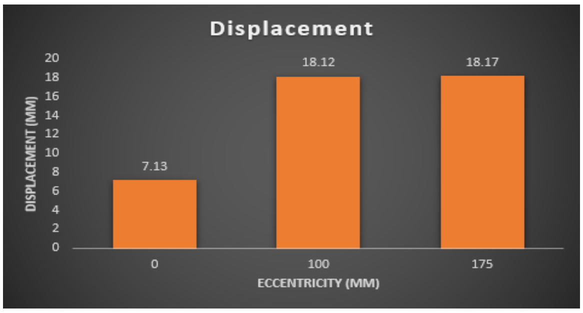
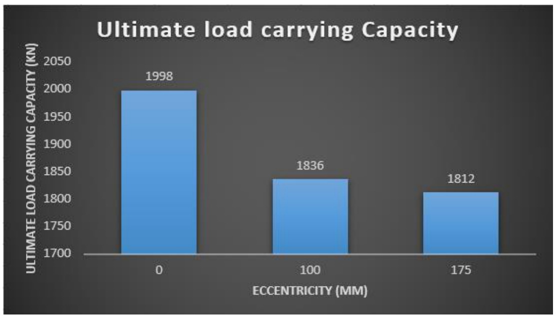


Figure 7 Ultimate load carrying capacity of 2.5 m column having both ends hinged and cross section of 350 x 350 mm having varied spacing of stirrups with different eccentricity



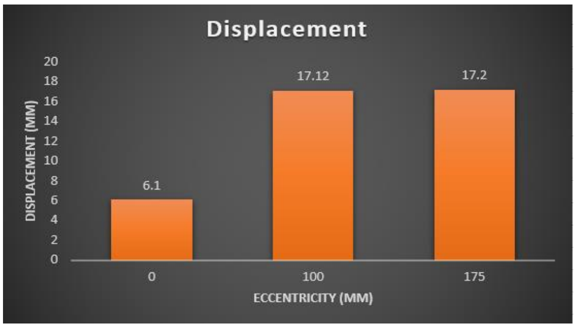
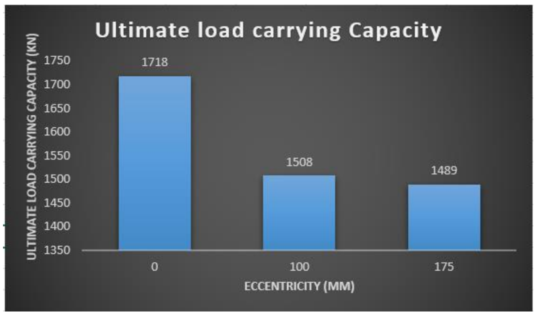


Figure 8 Ultimate load carrying capacity of 2.5 m column having both ends hinged and cross section of 400 x 400 mm having varied spacing of stirrups with different eccentricity



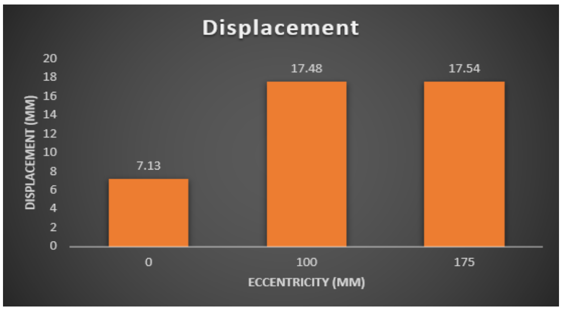


Figure 9 Ultimate load carrying capacity of 2.5 m column having both ends fixed and cross section of 350 x 350 mm having varied spacing of stirrups with different eccentricity

4. Conclusion:

It can be concluded that by using GFRP under eccentric loading for different length of column and same cross section does not increase the load carrying capacity as much but it significantly reduces the displacement by 13.5 % for concentric loaded column.

By changing the end condition from hinged to fixed, the load carrying capacity of the GFRP strengthened RC column is increased by 2.78 % for 100 mm eccentricity and displacement is reduced by 3.14 % for 175 mm eccentricity with respect to column having both ends hinged.

The load carrying capacity of GFRP strengthened RC column under eccentric loading is increased by 3.46 % for column having larger cross section as compared to smaller cross section.

By reducing the length of column by taking same cross section and end condition the load carrying capacity is increased by 4.77 % for 100 mm eccentricity significantly but very less for 175 mm eccentricity and displacement is also reduced by 7.46 % for 100 mm eccentric loading.

GFRP strengthened RC column under eccentric loading having varied spacing of stirrups along the length of column significantly reduces the displacement by 20 % under 100 mm eccentric loading for smaller length of column.

The ultimate load carrying capacity is increased by 3.15 % and displacement is reduced by 10.16 % for concentric loading by changing the spacing of stirrups for smaller length of column under both ends hinged condition.

For column having cross section 350 x 350 mm having both ends fixed does not enhance load carrying capacity significantly but it reduces the displacement by 1.54 % under 175 mm eccentric loading by reducing the length of column.

For column having cross section 400 x 400 mm and both ends fixed reduces the displacement by 2.87 % and there is negligible change in ultimate load carrying capacity under concentric loading by reducing the length of column.

So, it is better to use GFRP for smaller length of column under small eccentric loading and larger cross section. GFRP also enhances the load carrying capacity when the spacing of stirrups is varied along the length of column.

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