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Analytical Modeling of Concrete Columns Reinforced with GFRP Bars under Seismic Loads

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الملخص العربى :

لطالما كان تآكل حديد التسليح مشكلة في الهياكل الخرسانية ، وقد اجتذبت البوليمرات المقواة بأسياخ من الألياف الزجاجيه الانتباه مؤخرا كبديل محتمل لحديد التسليح في مثل هذه المشاريع. حيث انها ، تمتلك العديد من المميزات المرغوبة فيها منها المقاومة العالية مقارنة مع الوزن ،عدم التوصيل ، والشفافية الكهرومغناطيسية ، ومقاومة احمال الكلال. ومع ذلك ، فإن علاقة الإجهاد والانفعال لأسياخ الألياف الزجاجيه علاقة مرنة خطية حتى الانهيار دون منطقة الخضوع كما يحدث في حالة حديد التسليح. هذا يثير مخاوف حول إمكانية استخدام أسياخ من الألياف الزجاجيه في تسليح الأعضاء الإنشائية الخرسانية المعرضة لأنشطة زلزالية الهدف من من هذه النقطة ، ركز هذا البحث على معرفة مدى مرونة أعمدة الخرسانة المسلحة بأسياخ من الألياف الزجاجيه باستخدام الموجات الزلزالية المحاكية والضغوط المحورية المستمرة ، تم عمل تحليل للأعمدة باستخدام برنامج ال ANSYS15 . كان طول العمود 1650 مم ، وكان مساحة مقطع العمود 350*350 مم مربع.. أخذت الدراسة في الاعتبار مستوى الحمل المحوري. أظهرت النتائج أن أداء ليونة الأعمدة المقواة بأسياخ من الألياف قد تضرر من خلال زيادة القوة المحورية ، مما أدى إلى زيادة هامشية في القوة.

Abstract:

Steel reinforcement corrosion has long been a problem in concrete structures, and fiber reinforced polymers (FRP) have recently attracted attention as a potential replacement for steel reinforcement in such projects. FRP reinforcement has a number of advantageous properties, including a high strength-to-weight ratio, nonconductivity, electro-magnetic transparency, high fatigue strength, and low relaxation characteristics. However, the stress-strain relationship for FRP bars is linear elastic up to failure, rather than a yielding plateau as with steel bars. From this point on, this research focused on knowing how seismically resilient GFRP-reinforced concrete columns are. Using simulated seismic waves and continuous axial

stresses column prototypes were analyzed by using Ansys15 program. Its span was 1650 millimeters, and its cross-section was 350 millimeters square. The study took into account the axial load level. The results show that, the ductility performance of the GFRP reinforced columns was harmed by increasing the axial force, leading to a marginal increase in strength.

Key Words — GFRP, Columns, Hybrid, Seismic, Reinforced Concrete

1. INTRODUCTION

Due to steel's natural corrosion tendency, reinforced concrete buildings with standard steel reinforcement degrade rapidly in harsh settings, such as bridges exposed to de-icing salts and the sea environment. Corrosion of the lateral steel in columns not only leads in spalling of the concrete cover, reducing the column's load-bearing capacity, but also exposes the steel longitudinal bars to corrosion, which may finally result in structural collapse. A potential solution to this issue is to replace steel with a non-corroding material such as glass fibre reinforced polymer (GFRP) bars. Using glass fiber reinforced polymer bars, Tobbi [1] conducted an experiment on concrete columns that was longitudinally and transversally strengthened. GFRP and steel concrete longitudinal columns exposed to axial compression stresses were studied by Pantelides [2]. In comparison to the reinforced of steel control column, Both the GFRP reinforced hybrid and the completely GFRP columns met or exceeded 87% of their axial load capacity. Using cyclic stress, Sharbatdar [3]constructed and tested three large-scale FRP reinforced concrete joints. According to the findings, New concrete structures may benefit from FRP reinforcing, which reduces joint drift by a third. Outside T-shaped beam column junctions with full-scale prototypes exposed to simulated seismic stresses were used in Mady [4]experimental study. According to the researchers, GFRP-reinforced concrete joints can withstand a 4 percent drift value without significant damage. According to this study, GFRP reinforced joints can withstand an earthquake and need little, if any, ongoing maintenance. The seismic behavior of external beam–column connections reinforced with glass fiber reinforced polymer bars and stirrups was studied by Hasaballa[5] . For seismically loaded beam column junctions, the researchers discovered it's possible to utilize GFRP bars and stirrups as longitudinal and transverse reinforcements. Researchers Zafra [6] examined CFRP sheet-retrofitted RC bridge columns under lateral cyclic loads have been studied experimentally and analytically, and the results are in. As-built columns' hysteretic response may be improved by using CFRP sheet jacketing, which increases lateral confinement and, as a result, flexural strength and ductility. According to the results of an earthquake simulation, adding CFRP sheets to the 7.5_meter_tall pier boosts the structure's flexural strength while minimizing its displacement. A study by Ozbakkaloglu and Saatcioglu [7] studied the seismic performance of square reinforced concrete columns installed in FRP stay in place form work . Further investigation reveals a strong correlation between column confinement efficiency and casing corner radius. The confinement efficiency may also be improved by using FRP crossties. It was shown that FRP stay in place formwork may help improve HSC columns' deformability by as much as 11%, proving its usefulness. Eight reinforced concrete columns were examined by Ali and El_Salakawy [8] under simulated earthquake stresses in the lab. In terms of drift capacity, tightening the confinement around the column has a considerable impact. Axial loading reduces both strength and drift performance quickly. According to Mohamed [9], They built four massive shear walls as a result., three of which used GFRP bars while the fourth used steel bars as reinforcement. There is evidence to suggest that properly planned and specified GFRP reinforced walls have the flexural capabilities they need without degrading in strength. Attained an acceptable energy dissipation and drift value using GFRP and steel walls, with dissipation rates of over 3% and drift rates of over 2.6%, respectively. The aim of this research to investigate analytically the effect of changing of axial load.

2. TEST DATA

For comparison purposes, references is made to the specimens tested by Mahmoud Ali [10] in the McQuade Heavy Structures Laboratory at the University of Manitoba on five full-scale GFRP-reinforced concrete (RC) columns.

TABLE 1. PROPERTIES OF REINFORCING BARS (MAHMOUD ALI [10]).

Bar Type	Bar diameter (mm)	Bar area (mm^2)	Modulus of elasticity (GPa)	Tensile strength (MPa)	Ultimate strain (%)
No.16	15.9	198	62	1184	1.89
No.10 a	9.5	71	52	1022	1.97

[a] Properties of the straight portion of the bent GFRP bar.

TABLE 2. CHARACTERISTICS OF TEST SPECIMENS (MAHMOUD ALI [10]).

Specimen	Reinforcement ratio, ρ (%)	Longitudinal Bars	Stirrups
G-C-1.3	1.3%	8 No.16	No.10@75 mm

Figure 2 shows the loading scheme that used in analysis and to compare between experimental and Ansys, the numbers on top are the drift ratios (y-axis values), while the numbers on the X-axis are the cycle numbers.

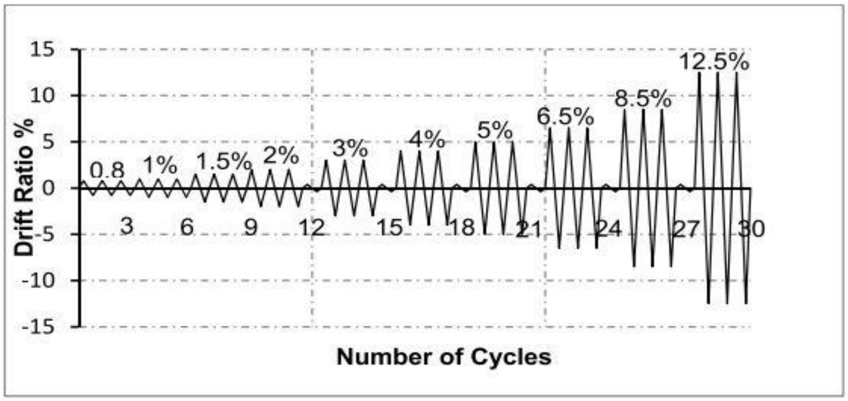

Figure 2- Seismic loading scheme

3. ANSYS ANALYTICAL PROCEDURE

ANSYS 15 APDL program has been used by many researchers for FE modeling of reinforced concrete structures. In his numerical modeling, SOLID65, LINK180 and SOLID185 elements were used to model concrete, GFRP bars and Steel Plates, respectively.

3.1 CONCRETE

In ANSYS, the only element that is suitable for modeling concrete is SOLID65. This element is used for 3D modeling of solids with or without rebar. The solid is capable of cracking in tension and crushing in compression. The elements are defined by eight nodes having three degrees of freedom at each node: translations in x, y and z directions. Figure 3 shows the geometry of element SOLID65.

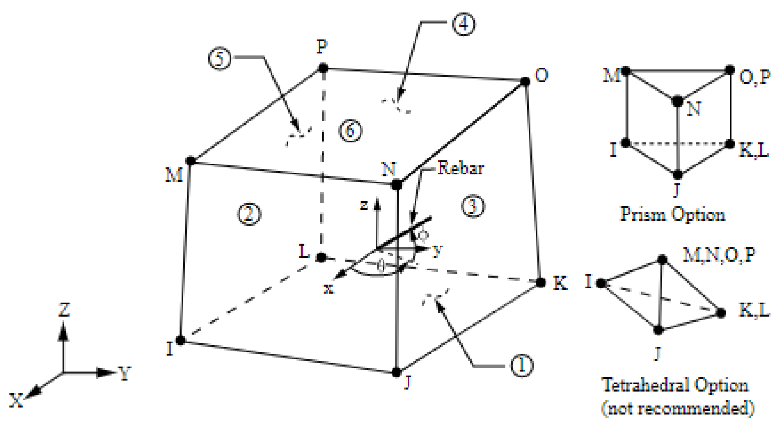

Figure 3. SOLID65 Homogeneous Structural Solid

3.2 GFRP Bars

A 3-D element (LINK180) will be used to model reinforcement, see Figure 4. The element can be used to model trusses, sagging cables, links, springs, and so on. The element is a uniaxial tension-compression element with three degrees of freedom at each node: translations in the nodal x, y, and z directions. Tension-only (cable) and compression-only (gap) options are supported. As in a pin-jointed structure, no bending of the element is considered. Plasticity, creep, rotation, large deflection, and large strain capabilities are included.

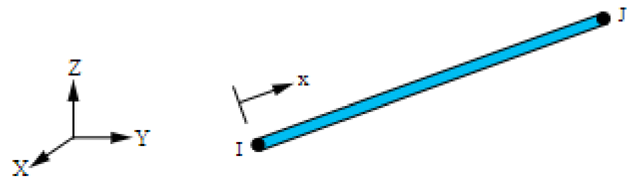

Figure 4. Link180

3.3 Steel Plates

A three-dimensional solid element (SOLID185) models made from steel plates are utilized in this project used for loading and supporting with the Homogeneous Structural Solid for SOLID185. Three dimensional solid structures may be accurately modelled with SOLID185 Homogeneous Structural Solid. Nodes in this graph have nodal x, y, and z degrees of freedom translations may all occur simultaneously. Plasticity, hyper elasticity, stress stiffening, creep, enormous deflection, and high strain are all possible with this element. see Figure 5.

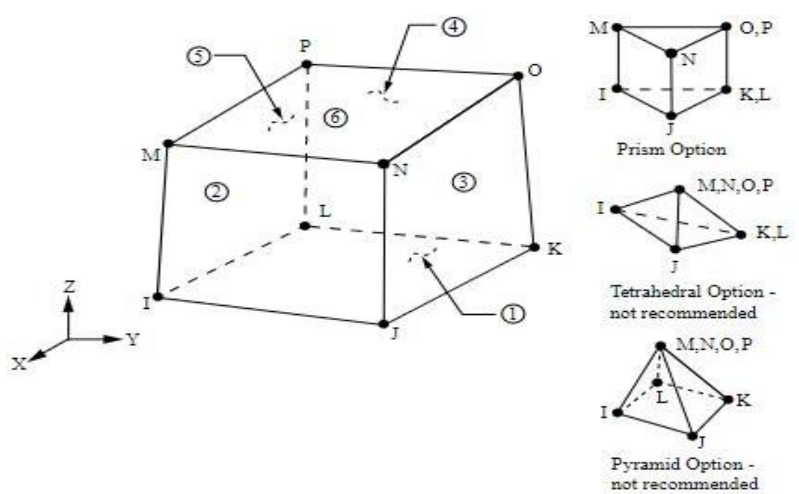

Figure 5. SOLID185 Homogeneous Structural Solid Geometry

In figures 6,7&8 showing the shape of column, meshing and loads on Ansys.

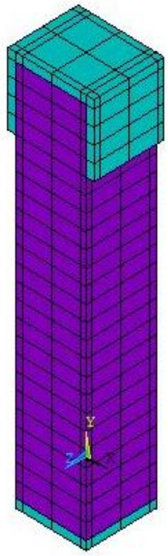

Figure 6.
Shape of Column in Ansys

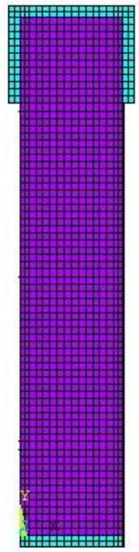

Figure 7.
Meshing in Ansys

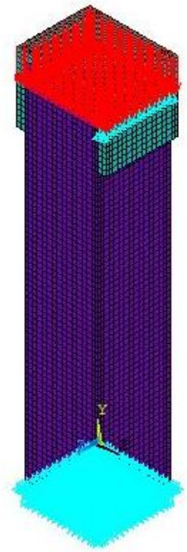

Figure 8.
Loads in Ansys

In figures 9,10&11 showing the Displacement and Stress of column with 15,20&30% of axial load.

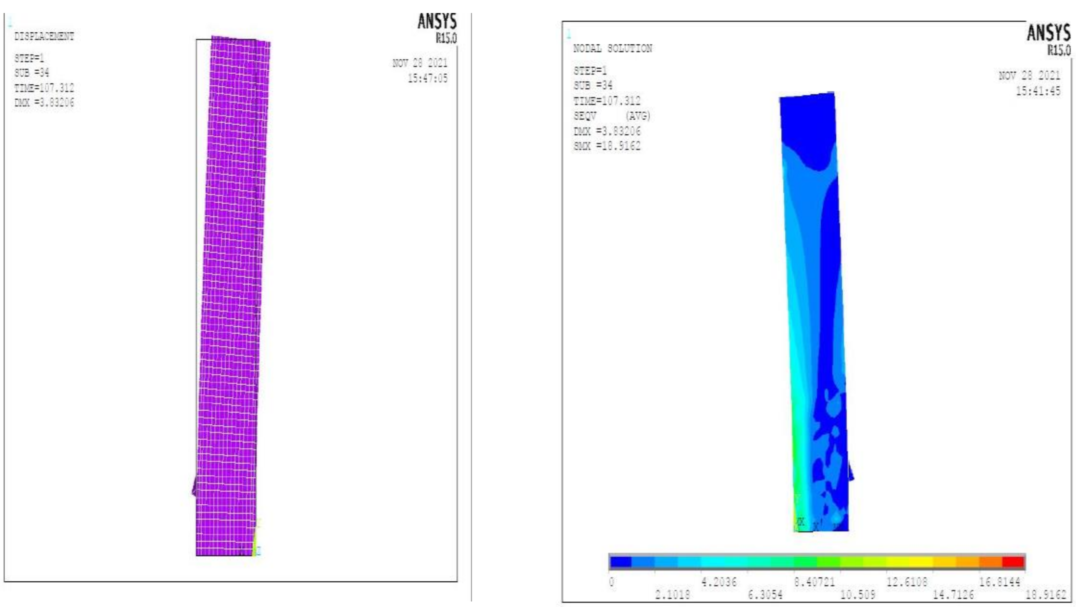

Figure 9. Displacement and Stress of column with 15% of axial load

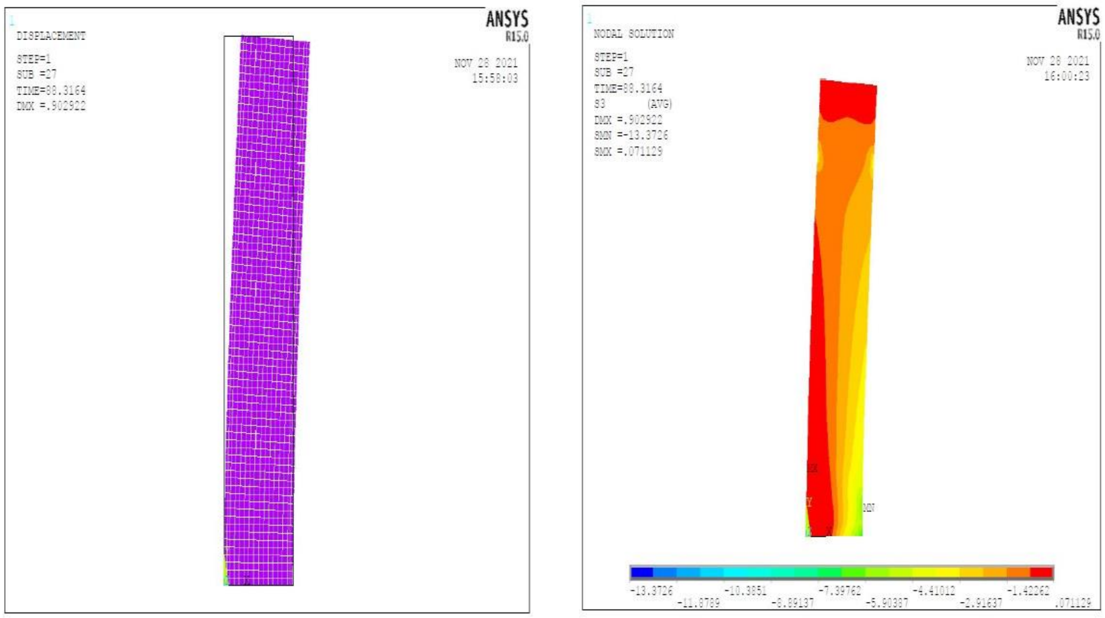

Figure 10. Displacement and Stress of column with 20% of axial load

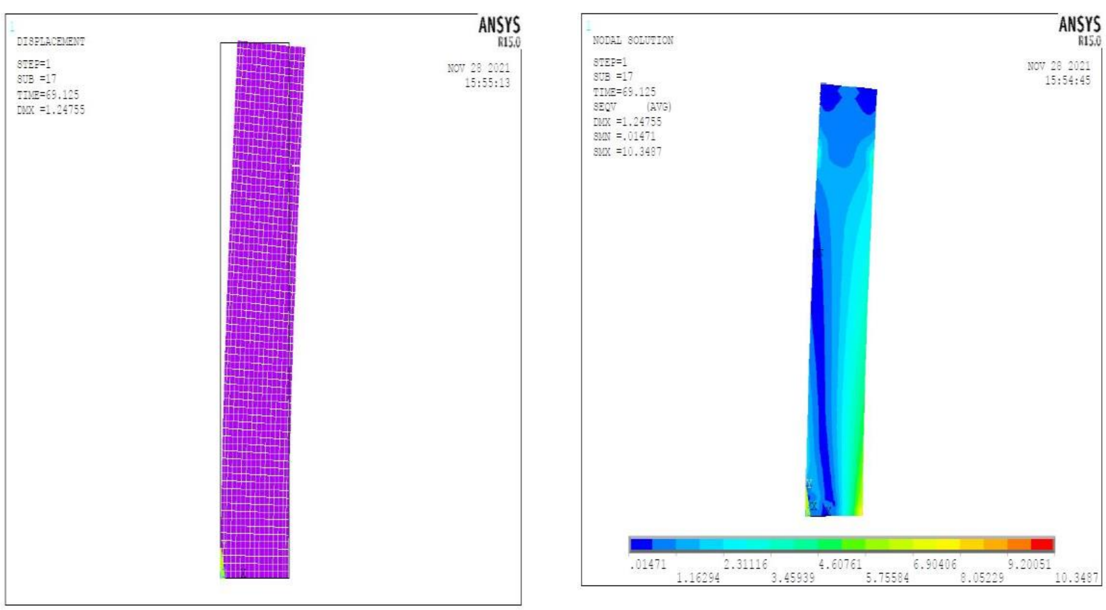

Figure 11. Displacement and Stress of column with 30% of axial load

4. RESULT OF COMPARISON BETWEEN EXPERIMENTAL AND NUMERICAL ANALYSIS

The comparison shows that the ANSYS 15 energy dissipated are about 90% to 102% of the Experimental results, which shows that there is good agreement between the experimental results and the ANSYS results as shown in figure 12.

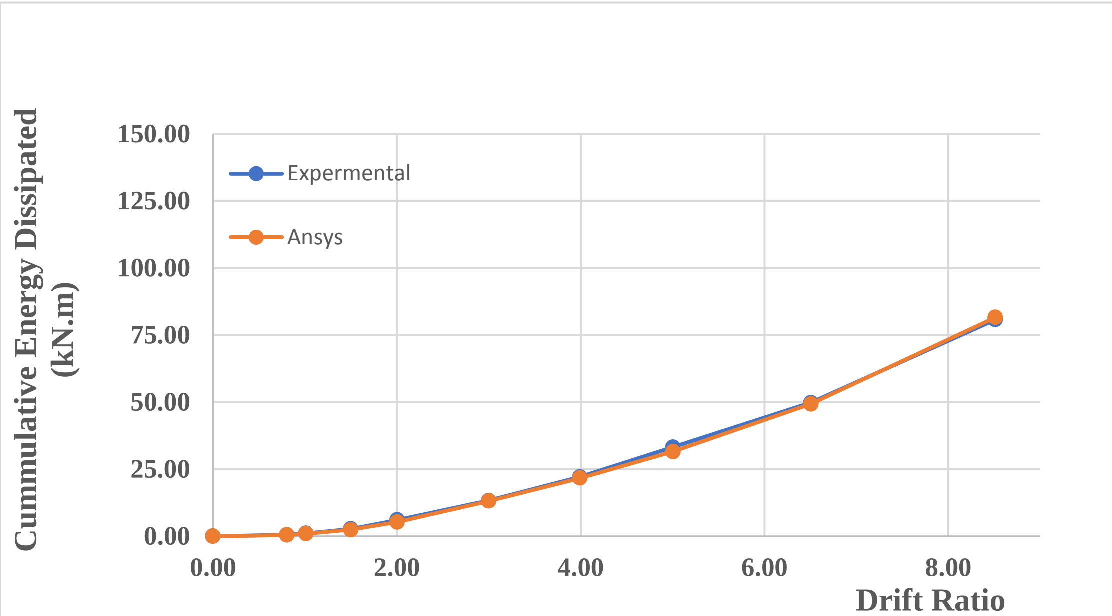

Figure 12. Comparison graph

5. THE EFFECT OF CHANGING OF AXIAL LOAD

In the table 2 illustrate the percentage of axil load that used in this study.

TABLE 2. CHARACTERISTICS OF TEST SPECIMENS (MAHMOUD ALI [10]).

Specimen	Axial load	Reinforcement ratio, ρ (%)	Longitudinal Bars	Stirrups
G-15%	$0.15 f'cAc$	1.3%	8 No.16	No.10@75 mm
G-20%	$0.20 f'cAc$	1.3%	8 No.16	No.10@75 mm
G-30%	$0.30 f'cAc$	1.3%	8 No.16	No.10@75 mm

6. Results and Discussion

6.1 Energy Dissipation

The capacity of buildings to resist severe earthquakes is represented by the energy dissipation of reinforced concrete structures. The cumulative energy dissipation of the test sample s is shown in Figure 13 as a function of the drift values. The cumulative energy dissipation was estimated by adding up the energy lost during each load displacement cycle. Using the associated column tip load displacement, each cycle's energy dissipation may be calculated. Due to their elastic properties up to failure, all of our GFRP RC sample s absorbed the same amount of energy.

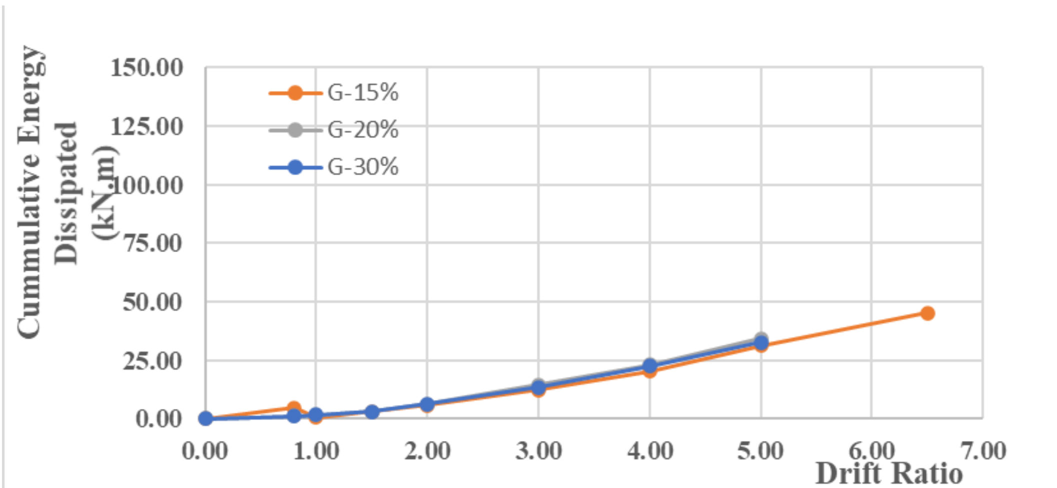

Figure 13. Cumulative energy dissipated

6.2 Longitudinal Column Reinforcement Strains Develop

The maximum reinforcement strain–drift value was the same for all GFRP RC samples. The strain remained linear all the way to failure in Sample G -15%. G 20% and G 30% exhibited lower levels of stress than G 15 % before the 3% drift value was implemented (Fig. 14). Samples G 20% and G 30%, in contrast, showed higher stresses as loading progressed. Samples G 20% and G 30% had maximum strain values of 11,650 and 12,750 at 6.5 percent drift, respectively. After a 3 percent drift value, the strength of the sample s with the highest axial loads decreased.

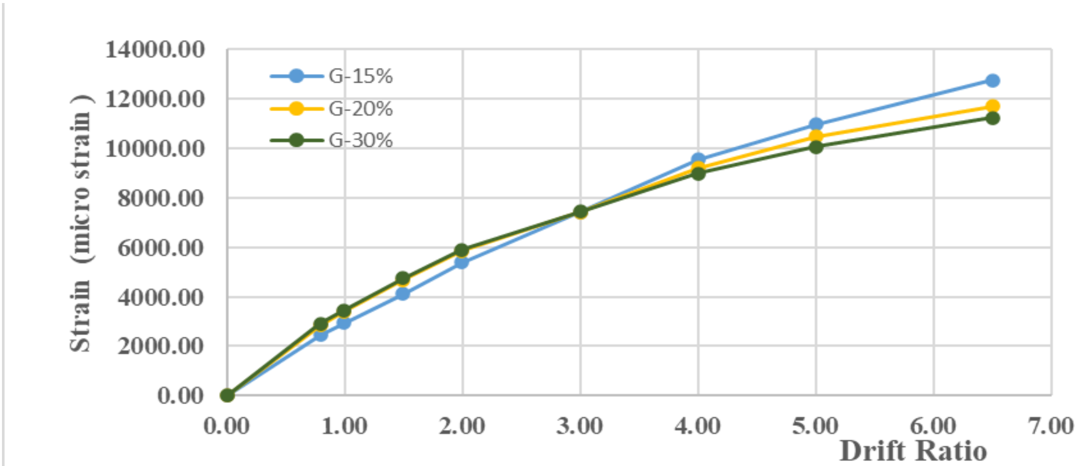

Figure 14. Maximum strain–drift ratio relationship for the longitudinal bars in Specimens.

6.3 DEVELOPED STRAINS IN COLUMN TRANSVERSE REINFORCEMENT.

the GFRP stirrups had a greater amount of strain When the drift value was increased, the strain differential increased as well Strength-drift relationships for stirrups are shown graphically in figures 15.

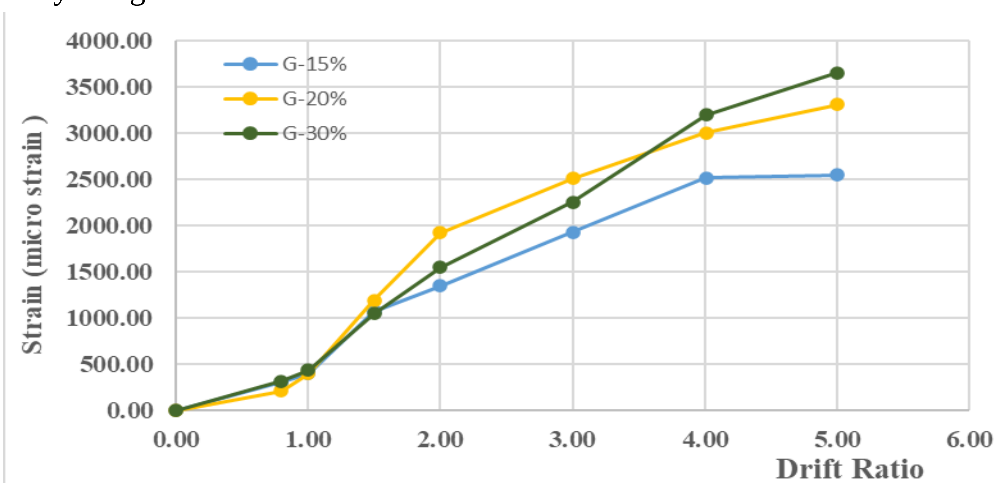

Figure 15. Maximum strain–drift ratio relationship for stirrups in Specimen.

7. CONCLUSION

From the results you can conclusion that

- Columns with higher axial loads showed rapid deterioration with lower level of strength gain and deformability at failure
- Increasing the axial load from 15% to 30% of the column axial capacity resulted in approximately 15% decrease in strength
- Increasing the axial load from 15% to 30% of the column axial capacity resulted in

approximately 50% decrease in the drift capacity at failure.

- All the GFRP-RC specimens failed in flexure, failure occurred by crushing of concrete, followed by compression failure of the longitudinal bars.

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