*International Journal of Research in Engineering and Science (IJRES)*
*ISSN (Online): 2320-9364, ISSN (Print): 2320-9356*
*www.ijres.org Volume 10 Issue 4 ǁ 2022 ǁ PP. 23-27*

# A Review on Performance of RC Column Reinforced With Steel and GFRP Bars Subjected to Axial Compression

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***ABSTRACT:***
*The main function of a reinforced concrete column is to sustain axial loads with or without bending moments. The axial load carrying capacity of steel bar reinforced concrete columns decreases over the design (service) life of the concrete structures due to the corrosion of steel bars, especially in coastal regions or in harsh environments. The cost of rehabilitation and repair of deteriorated concrete structures is significantly high. The Fibre Reinforced Polymer (FRP) composites including FRP bars possess many advantageous characteristics such as the resistance to the harsh environmental conditions, light weight and high tensile strength. Hence, FRP bars have the potential to replace steel bars and overcome deterioration of concrete structures associated with the corrosion of steel reinforcement. This paper investigates the Performance of RC column reinforced with steel and Glass Fibre Reinforced Bars (GFRP) subjected to axial compression. In this phase, the preliminary tests on steel and GFRP bars and test on conventional concrete such as Youngs modulus, compressive strength, split tensile strength were carried out. The test result indicates that (GFRP) rebars gives better performance than steel bars in terms of tensile strength.*
***Keywords:*** *GFRP bars, Axial compression, Reinforced concrete, corrosion resistance.*

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Date of Submission: 13-04-2022 Date of acceptance: 29-04-2022

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## I. INTRODUCTION

Fibre-reinforced polymer (FRP), also Fibre-reinforced plastic, is a composite material made of a polymer matrix reinforced with fibre. The Fibre are usually glass, carbon, or aramid. The applicability of Fiber Reinforced Polymer (FRP) reinforcements to concrete structures as a substitute for steel bars or Prestressing tendons. FRP is actually a stronger material than steel. It has many advantages such as high strength-to-weight ratio, electromagnetic neutrality, light weight, ease of handling, no corrosion, high longitudinal tensile strength, and non-magnetic characteristics. Although the initial cost of FRP reinforcement is higher than steel reinforcement, the total life cycle cost of the structure or structural components reinforced with FRP is lower, as significantly less maintenance costs are required for structures or structural components reinforced with FRP.

## II. LITERATURE REVIEW

The principal interest is to focus on the strengthening of the reinforced concrete column using GFRB. In order to completely utilize the effectiveness and properties of GFRB in strengthening process, behavior of GFRB strengthened reinforced concrete elements, ductility, shear capacity, and other parameters were studied through various data collected from various journal paper in different approaches and aspects.

The literature review on the GFRB strengthened reinforced concrete columns with regard to Axial, shear, buckling and other aspects are discussed based on the data collected for literature studies in the project.

### 2.1 EXPERIMENTAL INVESTIGATION

**Hadi (2005)** investigated the behaviour of FRP strengthened concrete columns under eccentric compression loading. This paper presents results of testing eccentrically loaded columns externally wrapped with two types of materials. All columns were tested by applying an axial load at 50 mm eccentricity. Based on testing the columns it can be concluded that considerable gain in strength and ductility are obtained when reinforcing the columns with CFRP (vertical straps and horizontally wrapped). The better performance applies both for strength and ductility. The concrete used in the current study had a compressive strength of 65 MPa.

**Mendis et al (2016)** investigated the behavior of concentrically loaded geopolymer-concrete circular columns reinforced longitudinally and transversely with GFRP bars. Fiber-reinforced-polymer (FRP) bars and geopolymer concrete have been increasingly used in the construction industry because of their many advantageous properties. Further studies dealing with the behavior and slenderness limit in GFRP-reinforced geopolymer concrete slender columns are recommended to increase its uptake in the construction industry.

**Benmokrane et al (2018)** investigated the strength of compression lap-spliced GFRP bars in concrete columns with different splice lengths. Recent years have seen valuable research work on using glass-fiber-reinforced-polymer (GFRP) bars in reinforced-concrete (RC) members under compression. The results were compared in terms of the stress–strain curves, ultimate loading, displacement capacity, and splice strength. The test results indicate that the required compression splice length for GFRP bars is less than that required for steel.

**Hadi et al (2018)** made the analytical investigation on the load-moment characteristics of GFRP bar reinforced circular NSC and HSC columns. It was also observed that HSC columns reinforced longitudinally with GFRP bars with small longitudinal reinforcement ratio or low tensile modulus of elasticity might experience a tensile failure of the GFRP bars located on the tension side of the column cross-sections, especially if the columns are subjected to a high level of axial load eccentricity.

**Radhouane et al (2018)** investigated the axial behavior of circular CFFT long columns internally reinforced with steel or carbon and glass FRP longitudinal bars. As expected, an increase in the FRP tube thickness (or stiffness) resulted in an increase in the strength and strain enhancement ratios. The presented study showed the applicability of exclusively reinforcing the CFFT columns with FRP bars and subjected to axial compression load**.** This proves the applicability of exclusively reinforcing the CFFT columns with FRP bars and subjected to axial compression load.

**Farid et al (2019)** determined the possibility of Fiber-reinforced polymers bars for compression reinforcement: A promising alternative to steel bars**.** Fiber-reinforced polymers (FRP) have been introduced as alternative reinforcement for concrete members since decades. The results of compressive strength on FRP bars showed that the compression strength and modulus of FRP bars ranged from 10 to 86% and 65 to 97% of their tensile strength and modulus, respectively, depending on the type of fibers of the bar. Columns reinforced with FRP bars exhibit 1.5 to 20% lower capacities.

**Mendis et al (2020)** investigated the hollow concrete columns: Review of structural behavior and new designs using GFRP reinforcement. Hollow concrete columns (HCCs) reinforced with steel bars have been employed extensively for bridge piers, ground piles, and utility poles because they use fewer materials and offer higher structural efficiency compared to solid concrete columns with the same concrete area. In addition, the corrosion of steel bars has become an issue in reinforced-concrete structures.

**Afaq et al (2021)** made investigation of HFRC columns reinforced with GFRP bars and spirals under concentric and eccentric loadings. There is a lack of experiments and finite element analysis (FEA) on the structural behavior of glass fiber reinforced polymer (GFRP) reinforced concrete columns with hybrid fibers. Steel fibers (SF) and polypropylene fibers (PF) were used together to develop the hybrid fiber reinforced concrete (HFRC). The average axial strength of GHC columns was 91.32% of the axial strength of SHC columns.

### 2.2 CORROSION RESISTANCE

**Neaz Sheikh et al (2016)** investigated the axial behavior of unreinforced and FRP bar reinforced circular concrete filled FRP tube columns. Fiber Reinforced Polymer (FRP) composites have emerged as a viable alternative of steel reinforcement due to higher ultimate tensile strength to weight ratio and corrosion resistance of FRP composites. The strength and ductility of steel bar Reinforced Concrete (RC) members in harsh and corrosive environments may decrease due to the corrosion of steel reinforcement.

**Denvid et al (2017)** examined the structural behavior of GFRP reinforced concrete columns under the influence of chloride at casting and service stages. Corrosion attack due to chloride ions is a major problem found in steel reinforced concrete structures when subjected to marine environment. Glass fiber reinforced polymer (GFRP) has become an alternative reinforcement in marine concrete structures due to its excellent corrosion resistance, making it possible to combine with concrete composed of seawater and sea sand.

**Elchalakani and Guowei (2017)** investigated the tests of glass fibre reinforced polymer rectangular concrete columns subjected to concentric and eccentric axial loading. GFRP's excellent corrosion resistance, high tensile-strength-to-weight ratio, non-magnetic, nonconductive make it an excellent solution for projects requiring improved corrosion resistance or reduced maintenance costs. The columns were tested to failure under various loading conditions, in order to determine the effect of load eccentricity on axial capacity.

**Azam et al (2020)** experimentally the Behavior of circular concrete columns reinforced with hollow composite sections and GFRP bars. Hollow concrete columns (HCCs) constitute a structurally efficient construction system for marine and offshore structures, including bridge piers and piles. Conventionally, HCCs reinforced with steel bars are vulnerable to corrosion and can lose functionality as a result, especially in harsh environments. Moreover, HCCs are subjected to brittle failure behavior by concrete crushing due to the absence of the concrete core.

**Wright and Pantelides (2021)** investigated the axial compression capacity of concrete columns reinforced with corrosion-resistant hybrid reinforcement**.** this series reached a compression capacity 11.0% higher than the average; the axial compression capacity reduction of all-carbon steel columns ranged from 13.0% to 24.0% with a mass loss ranging from 16.0% to 18.0%; the axial compression capacity reduction of hybrid specimens with all-carbon steel vertical bars and GFRP spiral was 5.0% with a corresponding mass loss of 7.0%.

## 2.3 AXIAL COMPRESSION BEHAVIOR

**Zhenyu Wang et al (2016)** investigated the experimental investigation on the seismic performance of GFRP-wrapped thin-walled steel tube confined RC columns. By comparing the results of specimen GS-RC-1 to S-RC and G-RC, it was found that for the specimens designed and tested in this study, the thin-walled steel tube in the GST was more effective than the GFRP wraps in improving the ultimate drift ratio, even though its out diameter-to thickness ratio was as large as 135. With an increase in axial compression ratio from 0.2 to 0.45, the decrease in ductility of the GST confined RC column was negligible.

**Xiuli and Zongcai et al (2018)** made experimental study and theoretical analysis on axial compressive behavior of concrete columns reinforced with GFRP bars and PVA fibers. There have been some studies on the axial compressive behavior of concrete columns reinforced with fiber-reinforced polymer (FRP) bars. But most studies focused on normal concrete without fibers. When the volumetric ratio was constant, the confinement efficiency and ductility of the specimens using GFRP ties with smaller diameter and closer spacing were higher than that using GFRP ties with larger diameter and larger spacing.

**Xinping et al (2018)** conducted experimental study on the axial compression performance of GFRP-reinforced concrete square columns. These experiments investigated the effects of the longitudinal reinforcement ratio, stirrup configuration (spirals versus hoops) and spacing on the load-carrying capacity and failure modes of GFRP-RC rectangular columns. The test results indicate that the load-carrying capacity of longitudinal GFRP bars accounted for 3%-7% of the ultimate load-carrying capacity of the columns. The load-carrying capacity of GFRP bars accounts for 3%–7% of the ultimate load-carrying capacity of a GFRP-RC column.

**Kang He and Yu Chen (2019)** investigated the experimental evaluation of built-in channel steel concrete-filled GFRP tubular stub columns under axial compression. The displacement-load curve, strain-load curve, ultimate load, axial compressive stiffness and failure characteristics of the specimens were analyzed. The results of the test show that the specimens' ultimate bearing capacity increases as the concrete strength increases. The axial deformation behaviors of the channel steel reinforced concrete-filled GFRP tubular short columns do not change with varieties of the steel ratio regularly when the steel ratios range from 0.046 to 0.083.

**Mendis et al (2019)** experimented the axial performance of hollow concrete columns reinforced with GFRP composite bars with different reinforcement ratios. This study explored the use of glass-fiber-reinforced-polymer (GFRP) composite bars as reinforcement for HCCs and evaluated the effect of the reinforcement ratio on HCC structural behavior. For columns with equal reinforcement ratios, using more and smaller-diameter GFRP bars yielded 12% higher confinement efficiency than in the columns with fewer and larger-diameter bars.

**Ali et al (2020)** determined the Axial performance of hybrid fiber reinforced concrete columns having gfrp longitudinal bars and spirals. The experimental results revealed that the GHC columns have low axial strength (AS) than SHC columns by 8.68% but GHC columns presented higher ductility than SHC columns by 19.71%. The average AS of GHC compression members was 91.32% of the average AS of their SHC equivalents. compression members with hybrid fibers by 8.68%.

**Ali and Umer (2021)** identified the efficiency of GFRP bars and hoops in recycled aggregate concrete columns: Experimental and numerical study. The axial compressive strength of GRAC columns was less than that of SRAC columns by an average difference of 7.79%. The proposed FEM represented a mean percentage error of 3.94% and 6.83% for axial strength and the relative axial strain. The modes of failure and the crack patterns of samples were quite precisely imitated by ABAQUS.

**Anees et al (2021)** investigated the axial performance of GFRP composite bars and spirals in circular hollow concrete columns. The fiber reinforced polymer (FRP) bars are used in hollow concrete columns (HCCs) to alleviate the steel reinforcement corrosion problem and to make an efficient and lightweight structure. The second peak capacity of GFRP-reinforced HCCs can be reliably predicted by considering the axial strain of 0.011 in GFRP bars. For the second peak load, the average discrepancies of theoretical and FEM results from the test results were 6.54% and 6.46%, respectively.

## 2.4 ECCENTRICALLY LOADED COLUMN

**Hadi et al (2016)** investigated the performance evaluation of high strength concrete and steel fibre high strength concrete columns reinforced with GFRP bars and helices. the maximum load sustained by the GFRP-HSC specimens under eccentric axial load was 10 - 12% lower than the maximum load sustained by the steel-

HSC specimens. The axial carrying capacity and the bending moment resistances of the GFRP bar reinforced concrete specimens can be reasonably calculated.

**Zhang et al (2017)** investigated the experimental study on the behavior of GFRP reinforced concrete columns under eccentric axial load. The load eccentricity had a significant influence on the force-deformation curves with increased eccentricity leading to a better ductility performance. The results also indicate that GFRP bars work better with concrete as the compression reinforcement when compared to a tensile reinforcement

**Benmokrane et al (2019)** carried out on the Structural performance of high-strength-concrete columns reinforced with GFRP bars and ties subjected to eccentric loads. Most concrete codes do not explicitly cover concrete with strengths above 55 MPa. This paper investigates the structural behavior of HSC columns reinforced with GFRP bars and ties when subjected to eccentrically axial loads**.** At the high level of eccentricity (e/h = 0.6), the GFRP-reinforced column experienced deep and wide cracks as well as a 30% increase in lateral deformation compared to the steel-reinforced column at peak load.

## III. CONCLUSION

Following are the major conclusions derived from the literature study,

- The use of FRP tube confined concrete can be recommended in combination with FRP bars to enhance the peak axial load and ductility of columns under eccentric axial compression as an alternative of steel RC columns in areas where corrosion of steel bar is a major concern.
- The reinforcement ratio significantly affected the axial load–deformation behavior of the hollow concrete columns reinforced with GFRP bars and spirals. Increasing the reinforcement ratio enhanced the axial-load capacity, confined strength, and ductility of the hollow concrete columns.
- The early spalling of the concrete cover resulted in a loss of axial capacity before any lateral confinement came into effect. After the concrete cover had completely spalled off, important gains in strength, ductility, and toughness were recorded for the concrete cores of well-confined specimens.
- The composite columns load bearing capacity increases as the concrete compressive strength increases. Higher concrete compressive strength can also lead to higher initial stiffness in the elastic stage.
- The GFRP ties could provide good confinement for concrete core. The effect of tie spacing on the confinement efficiency was greater than that of tie diameter on confinement efficiency.

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