

Replacement of Steel Reinforcement by Glass Fiber Reinforcement in RCC Structure-A Review

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Abstract

Experimental study of physical and mechanical properties of concrete specimens under the performance of elevated temperature. Studied the tensile behavior of FRP bars using ASTM and suggested that tensile properties depended on the surface deformation of the FRP bars. Investigated the performance of FRP bars when immersed in salt solutions. Various tests conducted on FRP reinforcement in specimen which is tension tests, direct pullout test. Investigated the effect of distilled water and alkaline condition on the durability of glass fiber bars. Reduced weight eases the handling of FRP bars. Observed FRP reinforced section show large deformations before failure. Compression behaviour of column specimen studied. Seismic performance of various specimens studied. The influence type of reinforcement, spacing of stirrups and loading condition (concentric, eccentric) on the performance of specimens were investigated. The increase in tensile strength, post cracking strength and toughness was reported. Focused on the structural behaviour and the performance of concrete column internally reinforced with glass fiber reinforced plastic bars. The mechanism of failure was explained. The gain in strength and ductility were recorded for well-confined columns. A comparative study between steel and fiber reinforced concrete column was reported. Studied the relation between axial load capacity of square concrete column and glass fiber reinforcement ratio. Three modes of failure were recorded such as crushing of concrete, compressive as well as tensile rupture of fiber reinforcing bars. The study involves work can be done in the field, it will give good strength. It will be good replacement to eliminate the corrosion problem.

Keywords: Axial loading, Column, Concentric load test, Elevated temperature, FRP.

INTRODUCTION

The use of fiber-reinforced polymer (FRP) bars as an alternative to steel reinforcement in concrete structures to resolve corrosion-related issues has become increasingly popular, particularly due to the high cost of maintenance generally associated with critical infrastructure. The several very good physical and mechanical characteristics cause increasingly widespread use of fiber-reinforced polymer (FRP) bars as the main reinforcement of concrete members. The FRP bars having properties, such as low self-weight and very good fatigue properties Brózda [1]. Utilizing FRP bars as a supplement or replacement to the conventional steel rebar in concrete members has many advantages such as increased fatigue resistance, magnetic neutrality, and zero conductivity. Furthermore, FRP bars are easy to handle and install, which reduces construction time and costs making them very attractive to industries and end-users Fergani [2] Corrosion of steel reinforcing bars in reinforced concrete (RC) structures is a major problem when they are in exposure to various environments. In particular, sodium chloride and calcium chloride-based deicers, traditionally used in cold regions for snow and

ice removal operations, primarily responsible for the initiation of steel corrosion ACI Committee[3] Due to their high strength to weight and stiffness-to-weight ratios, corrosion resistance, lightweight and potentially high durability of Fiber-reinforced polymer (FRP) composites or advanced composite materials are very attractive for use in civil engineering applications E inde[4].

Literature review

Guo[5] investigated the effect of the specimen size on the axial compressive behavior of circular concrete columns wrapped with spaced FRP rings. For the checking behavior of section, specimen size had been taken 100 mm ϕ , 150 x 300 mm, 200 x 400 mm and 300 x 600 mm and 200 mm height. For checking the behavior of specimens, tensile tests were carried out to measure the mechanical properties of CFRP composites. In tensile tests, one-layer flat CFRP bars tested optical strain gauges. Depending on test failure mode of specimen observed. It was concluded that it increases the strength and the axial deformation capacity achieved for the FRP-confined concrete in circular columns partially wrapped with FRP rings. Similar to the fully wrapped columns and the partially wrapped columns failed due to the tensile rupture of FRP strips.

Najafabadi[6] investigated mechanical properties of glass and carbon fiber-reinforced polymer (FRP) bars with epoxy resin matrices embedded in concrete under an extensive range of elevated temperatures (25 – 800°C). For the checking behavior of section, specimen size had been taken different diameters of FRP bars with 400 mm length. For checking performance of FRP specimen, tensile test had conducted by SANTAM STM-150 universal test device. Depending on test, section presented results of mechanical tests at elevated temperatures. The results included ultimate tensile strength of FRP bars, different failure modes of FRP bars, changes in the appearance of bars inside the concrete sleeve, and the changes in the appearance of concrete sleeve under elevated temperatures. It was concluded that the concrete sleeve prevents direct heat and oxygen from reaching FRP bars and increases their tensile performance at elevated temperatures by decreasing fiber and resin oxidation.

AlAjarmeh [7] presented the use of glass-fiber-reinforced-polymer (GFRP) composite bars as reinforcement for HCCs and effect of the reinforcement ratio on HCC structural behavior. For the checking behavior of section, specimen size had been taken 250 mm ϕ and 1000 mm height also 1 % - 4 % different reinforcement ratio considered for bars. In the paper FRP bars of 12.7 mm, 15.9 mm, 19.1 mm ϕ used in the same section for checking the behavior of specimen, compressive load test for Monotonic concentric loading had conducted by testing machine. It was concluded that the reinforcement ratio affected the axial load-deformation behavior of the hollow concrete columns reinforced with GFRP bars and spirals.

AlAjarmeh[8] presented glass-fiber-reinforced-polymer (GFRP) bars and spirals as reinforcing materials in hollow concrete columns in order to eliminate steel-related corrosion problems and understand the fundamental behavior of such specimen under the applied loads. For the checking behavior of section, specimen size had been taken 250 mm ϕ and 1000 mm height. FRP bars of 15.9 mm ϕ used for longitudinal reinforcement and 9.5 mm ϕ used for transverse reinforcement in the section for checking behavior of specimen, compressive load test Monotonic concentric loading had conducted by testing machine. Depending on test vertical and inclined cracks observed. It was concluded that the hollow columns failed at a lower load than the solid column due to the reduced effective area. the hollow columns yielded higher concrete compressive strength at peak load than the solid column.

Smarzewski[9] established the fracture properties of high-performance concrete (HPC) containing hybrid basalt and polypropylene fibers. 100 × 100 × 500 mm, 80 × 150 × 700 mm beams. For the checking behavior of specimen, tensile test had conducted by testing machine. The depending result, the basalt and polypropylene fiber reinforced HPC specimens exhibited a reduction in the compressive strength compared to the plain HPC. It was concluded that the flexural strength slightly depended on the addition of basalt and polypropylene fibers in HPC. The FRC exhibited the ability to increase energy dissipation and post-cracking ductility. The presence of basalt and polypropylene fibers reduced the compressive strength of plain HPC. Therefore, polypropylene and basalt fibers cannot be used to enhance compressive strength of HPC.

Hajiloo[10] conducted tensile strength tests on glass fiber reinforced polymer (GFRP) bars at high temperatures. For the checking behavior of section, specimen size had been taken 350 x 350 mm and 1400 mm height. For checking behavior of specimen at elevated temperature, steady-state and transient temperature tests had conducted by Intron 600LX testing machine. Depending on test average surface temperature, failure load, retained ratio, tensile strength found out for steady-state temperature test and for transient state temperature test load, stress, stress ratio, furnace temperature, and average surface temperature found out. It was concluded that steady-state tests, bars showed a linear degradation in tensile strength, but kept 40% of their room temperature strength after exposure to 375 °C transient temperature tests, bars failed at 518 °C under a sustained load of 75 KN (22% of room temperature strength) Subjected to 25% (64 KN) of the original strength, bars did not fail at 420°C bars under 70 KN (25% of ultimate strength) failed at 508°C.

Sheikh [11] conducted test on GFRP direct tension specimens and GFRP confined columns and evaluates the behavior of GFRP-RC in flexure, shear, tension, and compression. For the checking behavior of section, beam specimen size had been taken 400 x 650 mm and 3640 mm height also 100 x 100 x 600 mm, 200 x 200 x 600 mm for column specimen taken. For checking behavior of specimen, shear, tension, compressive load test had conducted by testing machines. Depending on test, the failure in most of the columns was due to the crushing of concrete core and or yielding of the longitudinal steel bars. It was concluded that GFRP bars in monotonic compression were able to resist stress levels in excess of 700 Mpa, about 60% of the tensile strength of the bar.

Ashrafi[12] studied the effect of physical and thermal properties of various FRP bars on their performance under elevated temperatures are investigated and GFRP bar of nominal diameters of 4 mm ϕ , 6 mm ϕ , and 8 mm ϕ , 10 mm ϕ and CFRP bar of diameter 5mm ϕ used for 800 mm length. For the checking behavior of the specimen, the tensile test had conducted by testing machine. It was concluded that the critical temperatures of GFRP bars were obtained about 300° C, 375° C, 377° C, and 450° C for 4, 6, 8, and 10 mm ϕ bars, respectively.

Hasan[13] explained the experimental investigation on high strength concrete (HSC) and steel fiber high strength concrete (SFHSC) circular column specimens reinforced longitudinally and transversely with Glass Fiber-Reinforced Polymer (GFRP) bars and helices, respectively. For the checking behavior of section, specimen size had been taken 210 mm ϕ and 800 mm height. For checking behavior of specimen, tension and compressive load test had conducted for eccentric and concentric loading by testing machine. Depending on test the axial load-axial deformation and the axial load lateral deformation behavior of all specimens tested. It was concluded that GFRP bar reinforced high strength concrete specimens experienced about 10% and 12% lower axial load-carrying capacity than the steel bar reinforced HSC specimens as a result of changing the loading condition from concentric axial load to 25 and 50 mm eccentric axial load respectively.

Hales [14] represented analytical buckling model based on numerical integration was presented to predict the load versus deflection performance of slender concrete columns reinforced with FRP spirals and longitudinal bars subjected to eccentric loads. For the checking behavior of section, specimen size had been taken 305 mm ϕ and 3730 mm height. For checking analytical buckling of the specimen, compressive load test had conducted for eccentric and concentric loading by testing machine. Depending on test analytical model was made for eccentricity 25 mm and 102 mm. load versus deflection curves plotted. After testing it was clear that these columns experienced a buckling failure mode. It was concluded that the load-deflection behavior of slender FRP circular columns can be predicted through the use of the analytical model developed which was verified through large-scale experiments of slender columns for two levels of eccentricity reinforced with GFRP spiral longitudinal reinforcement.

Ali [15] presented assessment of the seismic performance of concrete columns internally reinforced with glass-fiber reinforced polymers (GFRP) bars. For the checking behavior of section, specimen size had been taken 350 x 350 mm and 2450 mm height. For checking behavior of specimen, stiffness degradation test had conducted by testing machine. Depending on test flexural cracks were observed on the column faces perpendicular to the direction of the load application at approximately a load of 50 KN during load-controlled phase. It was concluded that Columns with higher axial loads defined rapid deterioration with low level of strength gain and deformability at failure increasing the axial load from 10 to 20% of the column axial capacity resulted in approximately 15% decrease in strength and 50% decrease in the drift capacity at failure.

Fahmy[16] presented the load-carrying capacity of reinforced concrete rectangular columns confined with fiber-reinforced polymer and subjected to small eccentric loading. For the checking behavior of the section, specimen size had been taken 160 x 250 mm and 960 mm height. For checking behavior of specimen, compressive load test had conducted by testing machine. Depending on test cracks were observed on the column faces. It was concluded that eccentricity-based modification on the behavior of an FRP non-circular concrete column was proposed. Modification indicated clear effect on the constructed P–M diagrams of the FRP-confined RC non-circular columns which appropriately evaluated their load-carrying capacities.

Maranan[17] investigated the effect of the anchor head on the pullout behavior of the and coated glass-fiber-reinforced polymer (GFRP) bars embedded in the geopolymer using a direct pullout test. For checking behavior of section, specimen size had been taken 100 x 200 mm and 700 mm height and three types of bars having nominal diameters of 12.7 mm ϕ , 15.9 mm ϕ , and 19.0 mm ϕ used. For checking behavior of specimen, direct pullout test had conducted by 500 KN testing machines. Depending on test the tensile stress developed in the bar at failure (f_s). It was concluded that the tensile stress developed in the headed GFRP bars with only the anchor head embedded in geopolymer concrete can reach up to approximately 597 MPa, which is 45% of the nominal tensile strength of the GFRP bars.

Prachasaree[18] tested structural performance and behavior of the concrete column specimens under axial load. For the checking behavior of section, specimen size had been taken 150 x 150 mm and 125 x 125 mm section respectively and 150 mm ϕ and 125 mm ϕ respectively and 500 mm length. For checking the behavior of the specimen, conduct the monotonically compressive load test on concrete column specimen was placed on a steel roller support and located on the steel base of a universal testing machine. Depending on test the contribution to the confined compressive strength of specimens increases with an increase of GFRP reinforcement ratio. It was concluded that the amount of GFRP longitudinal and lateral reinforcement slightly affected the column strengths. While different types of lateral reinforcement had little difference in strength and the spiral lateral reinforcement was the most effective in case of confining pressure and the inelastic deformation.

Tobbi [19] studied the behavior of the concrete column section reinforced with GFRP bars under concentric loading for checking the behavior of section, specimen size had been taken 350 x 350 mm and 1400 mm height. For checking behavior of specimen, tension and compressive load test had conducted by testing machines. Depending on test cracking of test specimens at different loading stages and after failure observed. It was concluded that the GFRP bars used contributed 10% of column capacity, which is close enough to contribution of steel (12%). proved that GFRP bars could be used in compression members provided there was adequate confinement to eliminate bar buckling.

De Luca[20] investigated the compressive behavior of longitudinal GFRP bars impacted the column performance, understood the contribution of GFRP ties, to prevent instability of the longitudinal reinforcement. For the checking behavior of section, specimen size had been taken 610 x 610 mm and the height 3000 mm. For checking behavior of specimen, compressive load test had conducted by using (22,241 KN) testing machine. Depending on compressive test, Cracking of the concrete was observed before the concrete cover split and the longitudinal bars buckled. The maximum (post-peak) axial deformation recorded, maximum deflection was approximately 135% of the peak load, whereas the load decreased by 70% of the peak load. The failure was brittle and occurred at the center of the upper half of the column specimen. It was concluded that the contribution of the GFRP bars to the column capacity was less than 5% of the peak load, which was lower than that of approximately 12% of the steel bars in the steel RC section. The contribution of the GFRP bars may be ignored when evaluating the nominal capacity of an axially loaded RC column.

Table No. 01 Literature in tabular format

Sr. No.	Name of Author	Title	Publication Year	Remarks (Specimen, test, result, Conclusion)
1	Y.C. Guo	“Compressive behavior of FRP ring-confined concrete in circular columns: Effects of specimen size and a new design-oriented stress-strain model”	2019	Specimen-100mm ϕ ,150x300, 200x400, 300x600mm, 200mm ht., tensile test, failure mode, strength raised axial deformation achieved.
2	E. P. Najafabadi	“The tensile performance of FRP bars embedded in concrete under elevated temperatures”	2019	Different bars,400mm length, tensile test, ultimate tensile strength, failure mode ,tensile performance increases by decrease fiber&resin oxidation
3	A. C. Manalo	“Axial performance of hollow concrete columns reinforced with GFRP composite bars with different reinforcement ratios”	2019	250 mm ϕ ,1000 mm,1%-4% ratio of reinforcement,12.7mm,15.9 mm,19.1 mm ϕ , hydraulic machine testing under 2000 KN
4	O. S. AlAjarmeh	“Compressive behavior of axially loaded circular hollow concrete columns reinforced with GFRP bars and spirals”	2019	250mm ϕ ,1000 mm,15.9 mm bar used for longitudinal reinforcement,9.5 mm bar used for transverse reinforcement.
5	P. Smarzewski	“Influence of basalt-polypropylene fibers on fracture properties of high-performance concrete”	2019	100x100x500mm, beam 80x150x700mm notched beam Tensile test, reduction in compressive strength
6	H. Hajiloo	“Mechanical properties of GFRP reinforcing bars at high temperatures”	2018	350x350x1400mm, steady and transient state temp. test, average surface temp., failure load, retained ratio, steady-state linear degradation, transient bar failed at 518 ⁰ C.
7	S. A. Sheikh	“Replacement of steel with GFRP for sustainable reinforced concrete”	2018	200 x200 x600 mm column, Compression test, monotonic stress level up to 60% of tensile strength.
8	H. Ashrafi	“The effect of mechanical and thermal properties of FRP bars on their tensile performance under elevated temperatures”	2017	GFRP-4,6,8,10 mm ϕ ,CFRP-5mm ϕ , 800mm length, Tensile test, at very high temperatures the ultimate tensile strengths decreased considerably.
9	H. A. Hasan	“Performance evaluation of high strength concrete and steel fiber high strength concrete columns reinforced with GFRP bars and helices”	2017	210mm ϕ x800mm, tensile and compression test, axial load, and axial deformation, axial load lateral deformation behavior, GFRP in HSC 10%-12% axial load capacity < steel.
10	T. A. Hales	“Analytical buckling model for slender FRP-reinforced concrete	2017	305mm ϕ x 3750mm, compressive load test for

		columns”		eccentric,concentric loading, buckling mode failure, load-deflection predicted
11	M. A. Ali	“Seismic Performance of GFRP-Reinforced Concrete rectangular Columns”	2016	350x350x2450mm,stiffness degradation test, flexural cracks perpendicular to load direction, increasing axial load from10 % to 20 % of column axial capacity decreases 15% strength
12	M. F. M. Fahmy	“Eccentricity-based design-oriented model of fiber-reinforced polymer-confined concrete for evaluation of the load-carrying capacity of reinforced concrete rectangular columns”	2016	160 x 250 x 960 mm, Compressive load test, P-M diagram, Eccentricity, Model error 1.9 %, Decrease in ultimate strain then increase in the eccentricity of applied load,
13	G. B. Maranan	“Pullout behavior of GFRP bars with anchor head in geopolymer concrete”	2015	100x200x700mm,direct pullout test under 500KN, the tensile stress in the bar at failure, GFRP bars with anchor head reach 45% of nominal tensile strength of GFRP bars.
14	W. Prachasaree	“Behavior and Performance of GFRP Reinforced Concrete Columns with Various Types of Stirrups”	2016	150x150x500, 125x125x500, 150mmφx500, 125mmφx500, monotonically compressive load, when GFRP reinforcement ratio then compressive strength increases, GFRP longitudinal &lateral reinforcement affected column strength.
15	H. Tobbi	“Concrete columns reinforced longitudinally and transversally with glass fiber-reinforced polymer bars”	2012	350x350x1400mm,tensile and compressive load test, cracking at different stages, cracking after failure, GFRP 10% of load capacity closely to steel 12% load capacity, GFRP used in the column to eliminate bar buckling
16	Antonio De Luca	“Behavior of full-scale glass fiber-reinforced polymer reinforced concrete columns under axial load”	2010	610x610x3000mm, Compressive load test, Longitudinal bars buckled, max. Deflection 135% of peak load, the contribution of GFRP Bars to the column capacity 12% lower than steel bar of the RC section.

CONCLUSIONS

From the above all literature study, these researchers had discussed the replacement of steel reinforcement by different fiber reinforced bars, different loading on different shapes of materials like square, rectangle circular shape. Various tests adopted on RC column section. In this work, some FRP reinforced sections can conduct under elevated temperature by

using High Strength Concrete. It can be suitable for sea-shore purposes also it can eliminate the corrosion effect on bars.

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