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Flexure Behaviour of Using Glass Fiber Reinforced Polymer Bars on Lightweight Aggregate Concrete Beams

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Abstract

This paper pointed to examine the glass fiber reinforced polymer bars effect on behaviour of flexural of lightweight aggregate concrete. Tests of flexure behaviour on beams were under four points in bending with total number of samples eight beams. The impact of type of reinforcement “glass fiber reinforced polymer reinforcement” that used in top and bottom reinforcing of beams, concrete strength, and concrete type were studied. The parameters that used in this study are maximum load, failure mode, flexural capacity, deflection, and stiffness of the tested beams were investigated. Using glass fiber reinforced polymer bars has more advantages like high longitudinal tensile strength, non-toxic, non-conductivity, lightweight, and doesn’t have any corrosion. Using lightweight aggregate concrete by replacement coarse aggregate with pumice because this aggregate has low density so the concrete weight decreased for the same strength and that lead to decreasing own weight so decreasing concrete sections and total cost of building. Experimental results showed that any concrete beams reinforced with glass fiber have greater deflection and strain than reinforced with steel and at any reinforcement type normal beams have deflection and strain mor than lightweight aggregate concrete.

Keywords: Lightweight concrete; Lightweight aggregate; glass fiber bars; GFRP

1. Introduction

This days all attention going to the new development of lightweight concrete (LWC) but all focusing on structural concrete that have strength more than 175 kg/cm^2 to reduce the dead load of a structure and consequently saving its construction cost by reducing the dimensions of structural members and foundations. In addition, further benefits such as superior heat and sound insulation could be gained by using lightweight concrete instead of normal weight concrete [1] Steel-bar reinforced concrete is the most often utilised structural material in building. Due to the corrosion of steel bars, other types of disintegration, or even the collapse of structure elements, the service life of the concrete of a structure may be shortened. In spite of fact that regular maintenance required to counteract durability decline. Repairing, restoring, or strengthening and fortifying steel reinforced concrete (RC) structures can be expensive [2, 3]. In particular in harsh natural conditions, new materials like fiber reinforced polymer (FRP) is non-corrodible by nature, can be used to dispense with erosion issues [4]. Many attempts have been made in later along time to unravel the corrosion issue, comparing using FRP bars as a substitute for steel bars [5, 6]. Lightweight concrete applications priorities density over element strength due to the material's low specific gravity. Density reduction at a given degree of strength reduces self-weight, foundation size, and building expenses [7]. Anisotropic, or directionally dependent FRP materials factor that affects shear strength, dowel action and bonding performance of FRP reinforcement bars. Only within the confines of the fibers that reinforced is tensile strength strong, whereas in the transverse direction, tensile strength is low. Tensile strength is highly according to the layer of epoxy. ACI 440-1R states because FRP materials do not yield until failure, design techniques must account for the absence of ductility in structural concrete members reinforced with FRP reinforcing bars [8, 9]. Tensile strength, young modulus (E_C), development length (L_d), mechanical properties such as in-plane and transverse shear strength are essential

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for the widespread application of fibre reinforced plastics. [10]. In recent years, numerous studies on glass fiber reinforced plastic (GFRP) bars as an alternative to steel reinforcement have been conducted. The GFRP bars have already demonstrated a bright future for overcoming the corrosion problem in numerous projects, particularly bridge decks and parking garages [11]. This is due to the benefits of GFRP, including its Low thermal and electrical conductivities, high longitudinal strength, corrosion resistance, and fatigue resistance [12]. It is necessary to investigate all aspects of their structural behavior [13] to ensure their safe application. It was discovered that the GFRP bars exhibited strong adhesion to reinforced concrete (RC). The bond was stronger for GFRP bars with a 12mm diameter [14]. It was studied the Flexural performance and reliability quality of RC beam reinforced with a variety of GFRP bars with sand-coated, helical, and grooved surface profiles. The cracking propagation behaviour of the examined beams indicates that sand-coating GFRP bars enhances bond performance in concrete [15]. Awad-Allah et al. developed reinforcing bars made of glass fibre that are resistant to fire and high temperatures. Numerous attempts were made locally to develop resins that could withstand high temperature fluctuations for extended periods. It was discovered that tire carbon (C330-l0%) has a high resistance to high temperatures and a prolonged melting time [16]. It was studied that the influence of the setup of Fiber - reinforced polymer tensile reinforcement on the flexural stiffness and cracking of RC beam. When the reinforcement layout was examined, there was no correlation between crack width and crack spacing was altered. It was discovered that the maximum crack width was not necessarily adjacent to the maximum crack spacing. Results demonstrated that the number of reinforcement layers increases flexural stiffness [17]. It was examined 17 concrete rectangular columns reinforced with steel or GFRP. 13 samples were evaluated as columns and 5 samples were evaluated as beams. It was observed that Interaction diagrams for both steel- and GFRP-reinforced concrete columns were also provided [18]. Due to the low young modulus of GFRP, it is particularly prone to buckling, the application of pure fiber reinforced for the manufacturing of lightweight and cost-effective sustainable composites is increasing in popularity [19]. Glass fibre is currently the preferred inorganic material due to its tensile strength, strain to failure, ease of processing, and non-toxicity.

2. Experimental Program

2.1. Materials

Natural sand, crushed stone (dolomite), coarse lightweight aggregate, cement, silica fume, super-plasticizers, and tap water were used as the construction materials. Properties of the used materials are shown and discussed in the following sections.

2.1.1. Cement

Type of cement that used "CEM I 42.5 N" from Tourah cement company. It was tested according to ESS 4756-1/2013 [20]. The physical properties and mechanical also of cement as its chemical composition was determined in the chemistry laboratory of (Housing and Building National Research Center) shown in tables (1, 2) and figure (1).

Figure 1: Determination the main composition of Cement

Table (1)
Cement properties

Property		Result	Limits*
Compressive strength (Kg/cm^2)	2 days	218.8	Not less than 10
	28 days	433.3	Not less than 42.5
Soundness (Le Chatelier) (mm)		1	Not more than 10
Specific surface area (cm2/gm.)		3120	>2250
Setting time (min.)	Initial	135	Not less than 60
	Final	180	———

*ESS 4756-1/2013 [20]

Table (2)
Chemical composition of cement

Component	%
Al_2O_3	5.8
MgO	3.5
K2O	0.3
Fe2O3	3.1
S_iO_2	20.1
Loss on ignition	1.8
CaO	62.4
Na2O	0.4
SO_3	2.8
Insoluble residue	0.9

2.1.2. Normal Aggregate

2.1.2.1. Fine Aggregate

Local natural sand was used as the fine aggregate. composed mainly of siliceous materials. The used sand was tested according to the Egyptian Guide for Laboratory Tests for concrete materials issued 2007 [21]. The characteristics of sand: Bulk density 1720 kg/m^3, specific gravity 2.63, clay and fine materials 0.58% < 4%, chlorides 0.037% < 0.06% and Sulphates 0.061% < 0.4%. The grading is given in table (3) and figure (2).

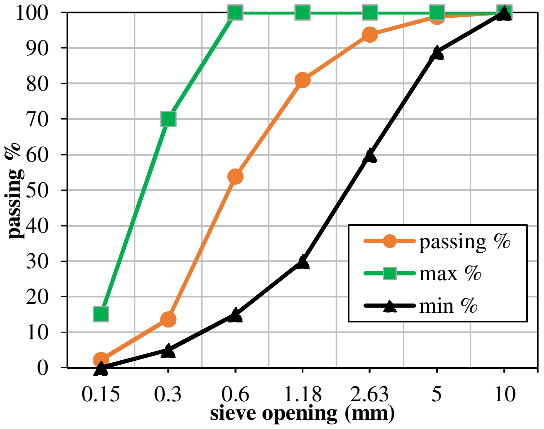


Figure 2: Grading curve for sand

Table (3): Sieve analysis for sand

Sieve opening (mm)		10	5	2.63	1.18	0.6	0.3	0.15
Passing (%)		100	98.8	93.8	81	53.8	13.6	2.2
Limits *	Max.	100	100	100	100	100	70	15
	Min.	100	89	60	30	15	5	0

* ECP 203/2007 [21]

2.1.2.2. Coarse Aggregate

The coarse aggregate used was crushed dolomite with a nominal maximum particle size of 14 millimeters. It was free from impurities and organic matters. The used crushed dolomite was tested according to the Egyptian Guide for Laboratory Tests for concrete materials issued 2007 [21]. The grading is given in table (4) and the characteristics of crushed dolomite is given in table (5) and figure (3).

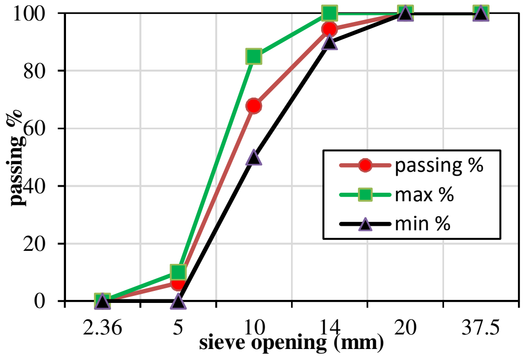


Figure 3: Grading curve for crushed dolomite

Table (4)
Sieve analysis for crushed dolomite

Sieve opening (mm)		37.5	20	14	10	5	2.36
Passing (%)		100	100	95.4	67.8	6.26	0
Limits *	Max.	100	100	100	85	10	0
	Min.	100	100	90	50	0	0

* ECP 203/2007 [21]

Table (5)
Characteristics of the used crushed dolomite

Property	Result	Limits*
density (kg/m^3)	1520	———
Flakiness index (%)	15.8	Not more than 25
Specific gravity	2.54	———
Elongation index (%)	17.6	Not more than 25
Impact value (%)	11.1	Not more than 45
Crushing value (%)	20.5	Not more than 30
Water absorption (%)	2.11	Not more than 2.5
Clay and fine materials (% by weight)	0.43	Not more than 4
Los angles abrasion loss (%)	22.3	Not more than 30
Chlorides (%)	0.015	Not more than 0.04
Sulphates (%)	0.032	Not more than 0.4

* ECP 203/2007 [21]

2.1.2.3. Lightweight Aggregate (Pumice)

The coarse lightweight aggregate (LWA) that was used was natural pumice aggregate shown in figure (4). Pumice passing through 14 mm sieve and remaining on 4.75 mm sieve. Testing of coarse lightweight aggregate was carried out according to the Egyptian Guide for Laboratory Tests for Concrete Materials issued 2007 [22] and ASTM [23]. Table (6) shows the chlorides and sulphates content before and after soaking. Characteristics of LWA: Bulk density 500 kg/m^3, specific gravity 0.835, water absorption 14%, flakiness index 21.8%, elongation index 11.7%, impact value 30% and los angles abrasion loss 50.8%.

Table (6)
Chlorides and sulphates content in LWA

Property	Result		Limits*
	Before-soaking	After-soaking	
Chlorides (%)	0.674	0.005	Not more than 0.04
Sulphates (%)	0.189	0.014	Not more than 0.4

* ECP 203/2007 [21]

Figure 4: Natural Pumice

Figure 5: Soaking process (pumice)

Lightweight aggregate grading curve is given in figure (6) and table (7) comparing it to maximum and minimum limits according to ASTM C330-4 [23].

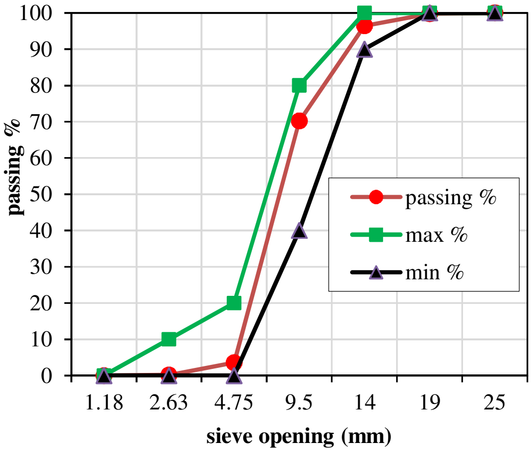


Figure 6: Grading curve of lightweight aggregate

Table (7)
Sieve analysis for LWA

Sieve opening (mm)		25	19	14	9.5	4.75	2.63	1.18
Passing (%)		100	99.8	96.4	70.2	3.55	0.15	0
Limits*	Max.	100	100	100	80	20	10	0
	Min.	100	100	90	40	0	0	0

*ASTM C330-4 [23]

2.1.3. Silica Fume (SF)

A commercial silica fume was purchased locally from Metallurgical & Construction Chemicals in Egypt to be used as a mineral admixture. The manufacturing of silicon or ferrosilicon alloys produces silica fume as a byproduct. The physical properties and the chemical composition of silica fume: specific gravity 2.15, color light grey, and bulk density 260 to 320 kg/m^3.

2.1.4. Water

Clean tap drinking water from holding company for water & waste water was used for fresh concrete mixing and concrete curing after casting. It was free from impurities and organic matters.

2.1.5. Chemical Admixture

Sikament-NN from Sika Egypt Company was used as a super-plasticizer to improve the workability of concrete.

Table (8)
Technical data of Sikament-NN

Property	Description
Base	Naphthalene formaldehyde sulphonate
Form	Liquid
Color	Brown
Odor	None
Density (at 20 °C)	1200 kg/m^3
pH Value	Not more than 8
Dosage	0.6 – 3 % by weight of cement

2.1.6. Reinforcement Bars

Two types of reinforcing bars: Steel bars from EZZ Steel Company, high tensile steel of 12 mm and10 mm Glass fiber reinforced polymer bars manufactured manually consisted of 70% E-glass diameter was used as longitudinal reinforcement while mild steel 8 mm diameter was used as stirrups. fiber and 30% polyester resin to achieve ductility and also increase the efficiency of the bars in changes in temperature. Glass fiber roving formed from continuous, untwisted strands that are bonded together with a polyester. The resin mainly consisted of polyester and peroxide and carbon tire 330 with 10% to improve some properties like elasticity and temperature. GFRP bars were used as longitudinal reinforcement with diameters 12 mm bottom and 10 mm top as shown in figure (7).

Figure 7: Glass fiber reinforced polymer bars

Tensile tests were carried out on GFRP bars as shown in table (9). Both ends of the tensile GFRP bars were secured with bond-type anchor points (steel tube sleeve with a length of 250 mm not welded). Both ends were filled and sealed with the epoxy anchorage adhesive depicted in the figure (8).

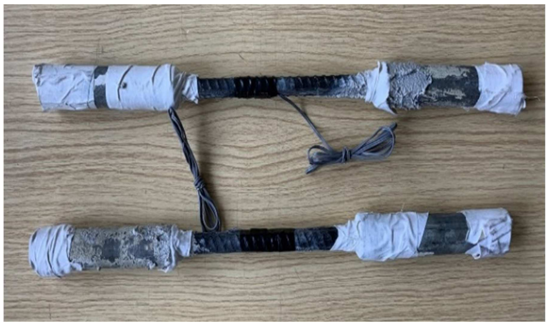


Figure 8: Glass fiber reinforced polymer bars with steel tube

Table (9)
Properties of GFRP bars

Diameter mm	Area mm^2	Ultimate Load KN	Ultimate Tensile Strength N/mm^2	Strain	Elasticity N/mm^2	Elasticity fiber / Elasticity steel
12	113.14	49.5	437.51	0.003	146002.49	0.73

2.2. Concrete Mix Proportions

Concrete mix consist of two types of concrete lightweight aggregate concrete LWAC and normal concrete every type is four beams and have two type of reinforcement (steel and glass fiber reinforced polymer).

A total number of samples of reinforced concrete beams 8 beams were cast, For LWAC beams the density needed was 1800 kg/m^3 the low density depend on the low weight of lightweight coarse aggregate (pumice) and aggregate pumice is local aggregate from Egypt, the ingredients of LWC consisted of ordinary portland cement, basalt, sand, silica fume, pumice, and super-plasticizers (Sikament-NN).

For NWC consist of ordinary portland cement, basalt, sand, silica fume, water, and super-plasticizers (Sikament-NN) which its weight is around 2400 to 2500 kg/m^3.

Table (10)
Concrete mix proportion

Concrete Type	Cement Kg/m^3	NWA Coarse Kg/m^3	NWA Fine Kg/m^3	LWA (pumice) Kg/m^3	Water Kg/m^3	Silica Fume Kg/m^3	Super-Plasticizer Kg/m^3
NWC	350	960	680	-	181	-	-
	375	960	680	-	175	35	7
LWC	400	258	843	254	140	-	8
	450	244	799	241	140	45	10

2.3. Fabrication of Test Specimens.

The specimens were fabricated at the Concrete Laboratory of the Civil Engineering Department, Al-Azhar University. Firstly the reinforcement and then it was installed in formwork. After casting, the concrete was compacted using an electrical vibrator.

Water curing was started 24 hours after casting for 28 days as shown in figure (6a to 6d). Then, was cast with a target cube compressive strength of 250 and 350 Kg/cm^2.

Eight reinforced beams of 12 x 25 x 210 cm dimensions and 2 cm clear cover over reinforcement. The longitudinal bars were 2T12 as a bottom reinforcement and 2T10 as a top reinforcement connected with 10R8/m stirrups.

One strain gauge were fixed on the longitudinal bottom bar at the mid-point and another strain gauge were fixed at the mid-point on top of concrete beam. Beam setup and specimen details shown in table (11) and figure (9).

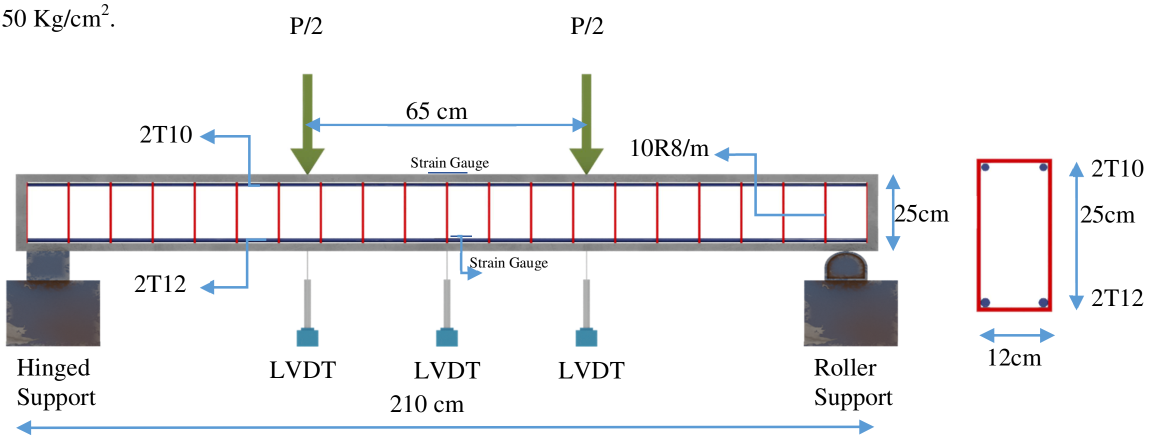


Figure 9: Beam setup details

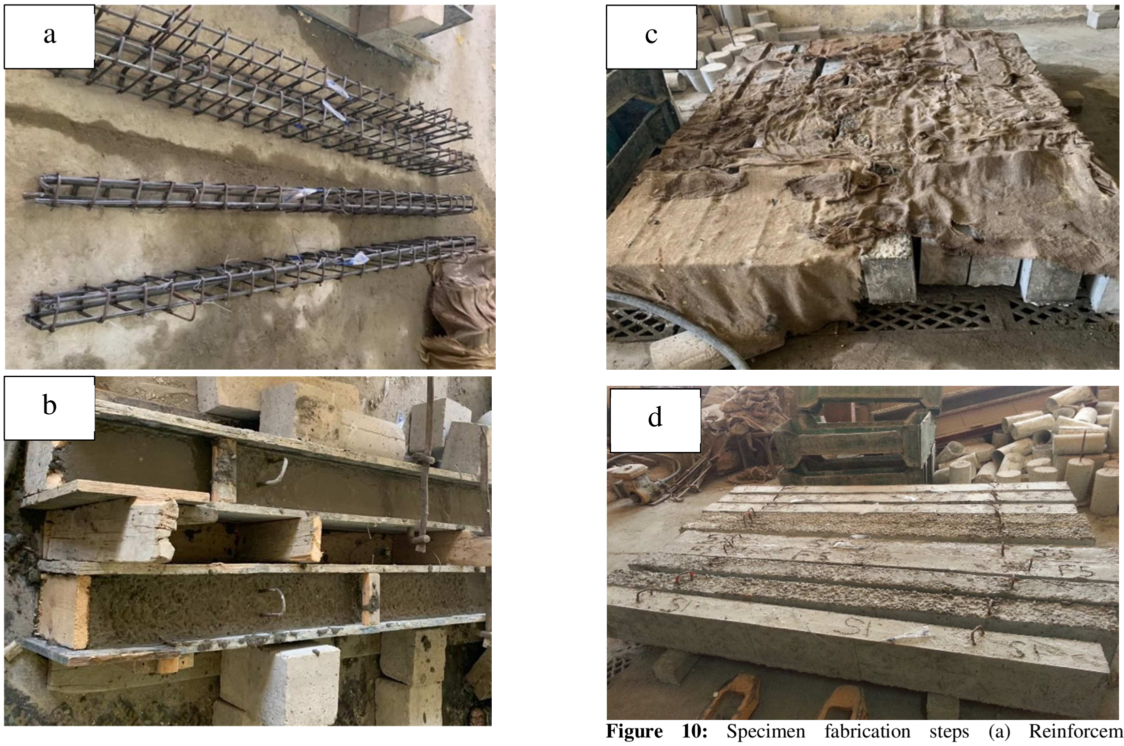


Figure 10: Specimen fabrication steps (a) Reinforcement preparation (b) Casting of beams (c) Curing of beams (d) Beams before testing

Table (11)
Specimens details

Group	Beam code	Concrete		Reinforcement			
		Type	F_{cu} (Kg/cm^2)	Type	Bottom	Top	Stirrups
N	NS	Normal Concrete	250	Steel bars	2T12	2T10	R8@100
			350	Steel bars			
	NF		250	GFRP bars			
			350	GFRP bars			
L	LS	Lightweight Concrete	250	Steel bars	2T12	2T10	R8@100
			350	Steel bars			
	LF		250	GFRP bars			
			350	GFRP bars			

2.4. Testing Procedures

Tests were conducted on fresh concrete. In addition, hardened concrete it was determined the unit weight and compressive strength on cubes and reinforced concrete beams were tested to determine their flexure behavior and calculate deflection in concrete beams and strain in reinforcement bars steel or GFRP, also strain in the compression zone.

2.4.1. Slump Test

Slump test was carried out on fresh concrete just after mixing to check the workability of concrete. The test was done according to the Egyptian Guide for Laboratory Tests for concrete materials issued 2007 [21]. Concrete mix of normal concrete or lightweight concrete was designed to have slump from 10 to 15 cm to be in good workability.

Figure 11: Slump test

2.4.2. Unit Weight Test

After 28 days of manufacturing, a unit weight test was performed on concrete cubes. The specimens were oven-dried for 24 hours at 105 °C until their weight remained constant. They were allowed to cool to room temperature before being weighed to determine their dry mass. The unit weight is the ratio of the specimen's dry weight to its volume.

2.4.3. Compression Test

Compressive strength is the maximum measured resistance to axial loading of a concrete specimen. The experiment was conducted after 7 and 28 days. During testing, a 15 x 15 x 15 cm specimen was positioned centrally in the machine after that load continuously applied and perpendicular uniformly to the tamping direction. The maximum load was recorded after the load was increased until failure. Figure 11 illustrates the test. The calculation for compressive strength was as follows: Compressive strength (F_{cu}) =Load (P) / Area of cube face (A).

Figure12: Compression test

2.4.4. Test Setup.

All samples of beams with a length equal of 210 cm and a clear length of 190 cm were analyzed under four-point flexural. The beam's cross section measured 12 cm in width and 25 cm in height.

Beams deflection were measured by three LVDTs one under every point and another in the bottom center. Cracks were aligned on the specimens, and experiment analyses during static load and at the failure time were noted. The tension strain at bottom reinforcement and compression strain on the top of concrete at the middle point was recorded by strain gauges.

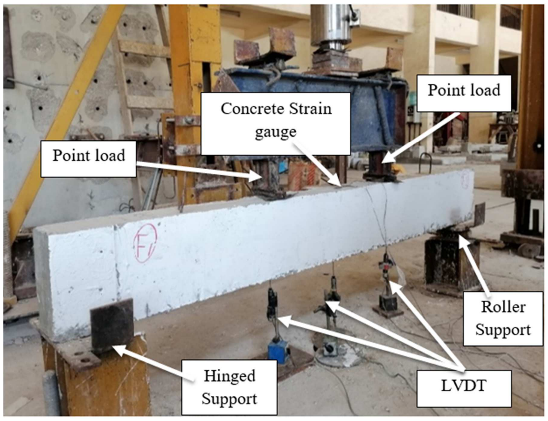


Figure 13: Testing of flexure in lab

3. Results and Discussions

3.1. Load – Midspan Deflection Behavior

Table (12) displays the testing load to beam deflection curves and failure loads for the concrete beams and figures (14, 15, 16, and 17).

Behavior of GFRP bars is linear and reinforced concrete beams not have yield zone so the curve almost linear to the failure and crushing of concrete. It was found that before the first visible crack, the concrete member in this time have high stiffness so the deflection very small ($k = \frac{p}{\Delta}$) in the un-cracked part of the curve.
After analysis of date it was noted that deflection in when using steel as a beam reinforcement is greater than GFRP at the first crack, but after cracks appears gradually the deflection curve begins to increase when using GFRP bigger than steel.

Meandering in the load-deflection curve because of loss of stiffness of concrete member in the stage of crack load when concrete fractured in the tension zone.

Table (12)
Test results

Beams	Ultimate load KN	Maximum deflection Δu mm	Reinforcement strain εs	Reinforcement strain εc
NS250	83.36	2.01	0.003	-0.00181
NS350	88.369	17.79	0.0199	-0.00177
NF250	64.35	26.061	0.0151	-0.0022
NF350	59.3	22.528	0.0138	-0.00127
LS250	91.95	19.11	0.0197	-0.00235
LS350	93.3	13.209	0.0158	-0.00110
LF250	52.74	24.495	0.011	-0.0022
LF350	72.7	25.56	0.0120	-0.003

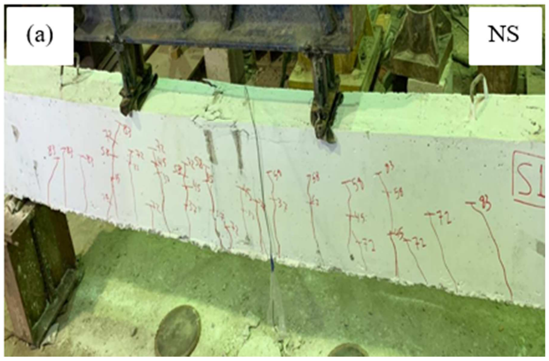


Figure 14: Crack patterns and failure shapes of normal concrete with steel reinforcement

Figure 15: Crack patterns and failure shapes of lightweight concrete with steel reinforcement

Based on the load-midspan curves for LF and LS lightweight concrete beams, the deflection of the GFRP-reinforced beam is greater than the deflection of the steel-reinforced beam.

Figure 16: Crack patterns and failure shapes of normal concrete with GFRP

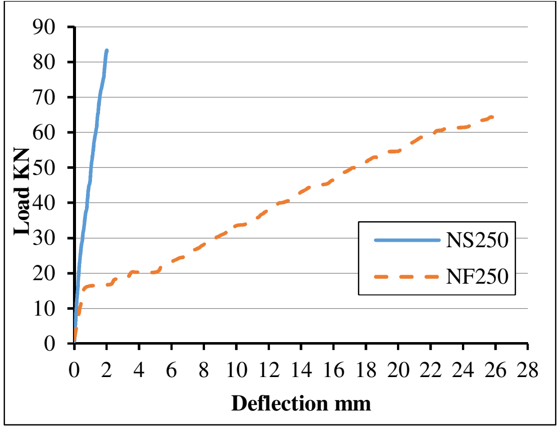
Figure 17: Crack patterns and failure shapes of lightweight concrete with GFRP

In addition, based on the beam reinforced with GFRP bars deflected more than the beam reinforced with steel bars in accordance with the load-midspan deflection curves for normal concrete beams NF and NS.

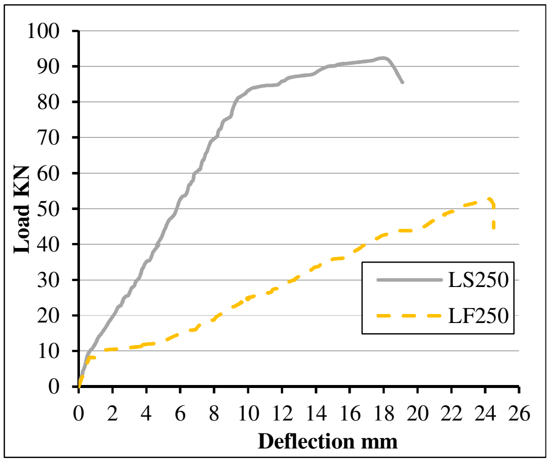
This is because GFRP bars have a smaller young modulus than steel bars and the direct relationship between elasticity and stiffness (k= 6EI/L2), which leads to a reduction in stiffness. This reduction in stiffness causes greater deflection of GFRP beams than steel beams.

Figures 18a and 18d demonstrate that the stiffness of beams reinforced with GFRP bars is lower than that of beams reinforced with steel bars. This is because the lower young modulus of GFRP than steel bars.

For Fcu=250 Kg/cm^2

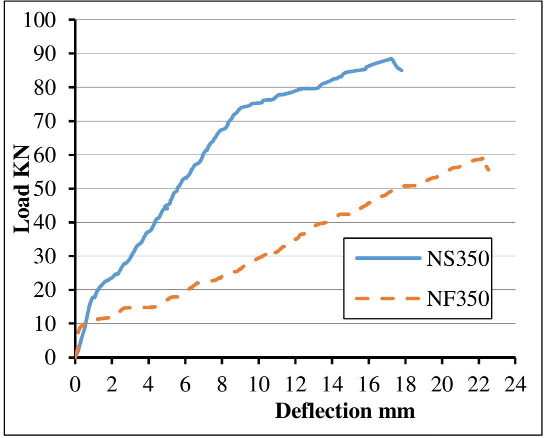


a) Beams NS and NF at Fcu=250 Kg/cm^2

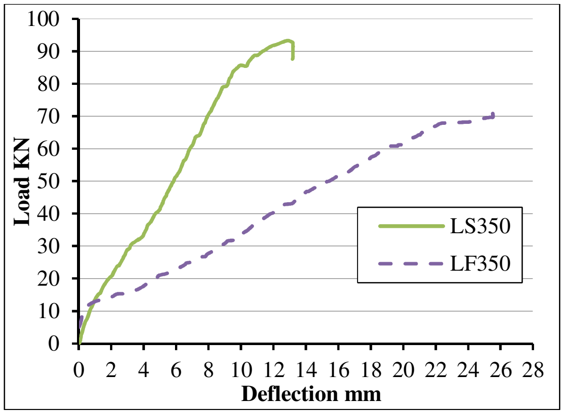


b) Beams LS and LF at Fcu=250 Kg/cm^2

For Fcu=350 Kg/cm^2



c) Beams NS and NF at Fcu=350 Kg/cm^2



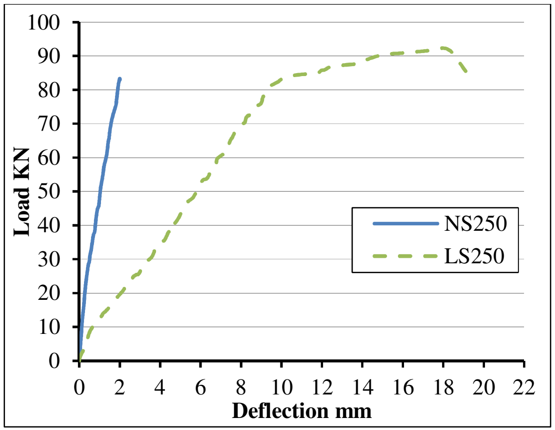
d) Beams LS and LF at Fcu=350 Kg/cm^2

Figure 18: Load-Midspan Deflection of All Beams

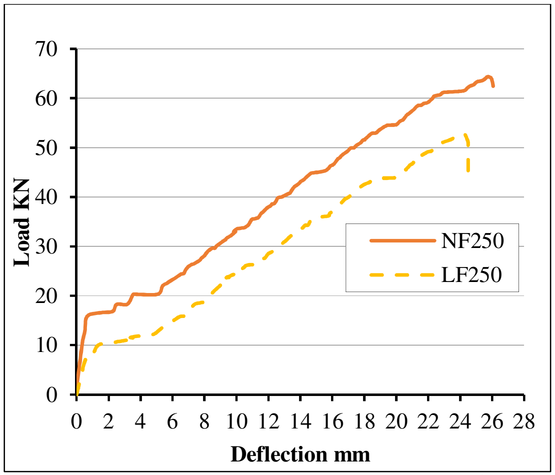
On the basic principle of the load-midspan curves for GFRP beams LF and NF, the normal concrete beam deflects more than the lightweight concrete beam. Moreover, according to the load-midspan deflection curve for beams reinforced with steel bars, the deflection of the normal concrete beam NS is greater than that of the lightweight concrete beam LS. Under flexural loading, the beam's stiffness is the slope of the load-deflection curve.

From figure 19a and 19d the deflection of lightweight concrete beams is less than that for normal concrete beams. This is due to the low weight of lightweight concrete which its weight 1800 kg/m^3 compared to normal concrete and this will make loss in self-weight of the beam w and that lead to low in deflection as per relation $\Delta = \frac{5\,w\,L^4}{384\,EI}$.

For Fcu=250 Kg/cm^2

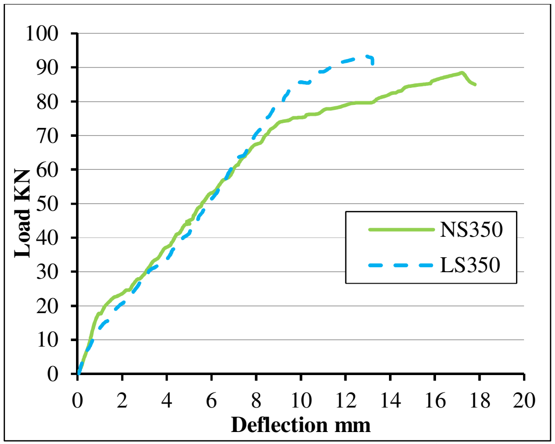


a) Beams NS and LS at Fcu=250 Kg/cm^2

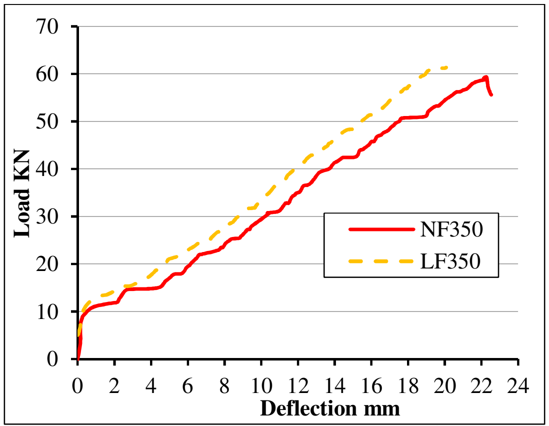


b) Beams NF and LF at Fcu=250 Kg/cm^2

For Fcu=350 Kg/cm^2



c) Beams NS and LS at Fcu=350 Kg/cm^2



d) Beams NF and LF at Fcu=350 Kg/cm^2

Figure 19: Load-Midspan Deflection of all beams

3.2. Strain of Main Reinforcement at Intermediate Section in Span of Beams.

As shown in figures (20 and 21), the GFRP strain curve was linear up to failure without any yielding behaviour, whereas the steel strain curve exhibits yielding behaviour prior to failure.

Because GFRP bars have a lower modulus of elasticity than steel bars, their strain was greater than that of steel bars.

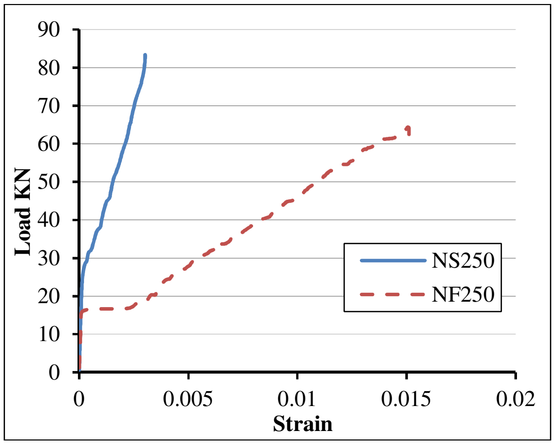
$$E\ (Modulus\ of\ Elasticity) = \frac{f\ (Stress)}{\epsilon\ (Strain)}$$

In conventional concrete beams, the GFRP bar strain is greater than in lightweight concrete beams. The strains increase significantly when the first crack forms, whereas the strains in the reinforcement are compatible with the strains in the surrounding concrete and are, therefore, of negligible magnitude prior to cracking.

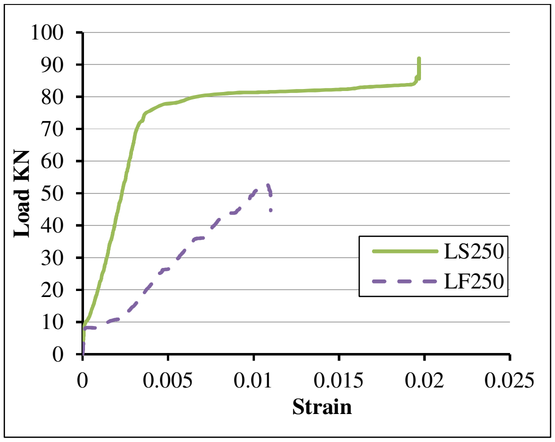
As the tension carried by the uncracked concrete increases, the magnitude of the strain increase is greatest at the crack and gradually decreases away from it.

The strains between the cracks then follow a nearly linear relationship with load until failure occurs, either by rebar rupture or concrete crushing somewhere within the constant flexure zone.

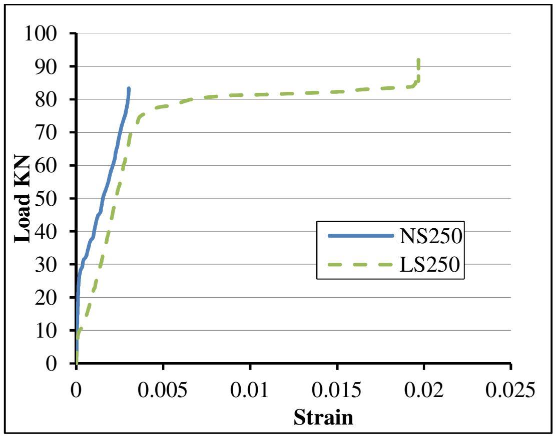
In addition, as shown in figures, the behaviour of both types of concrete (normal and lightweight concrete) is nearly identical until the formation of the first crack (20 and 21).



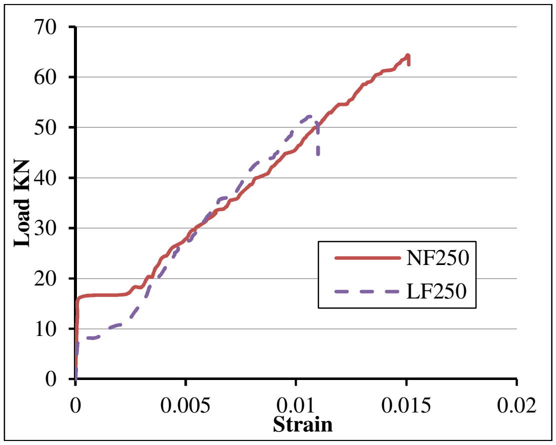
a) Load–Strain for NS and NF beams



b) Load–Strain for LS and LF beams

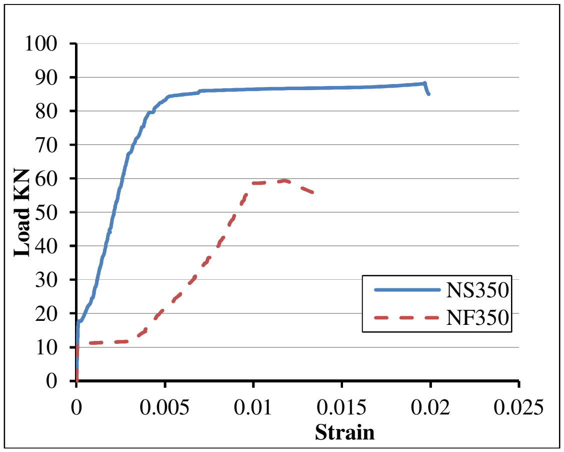


c) Load–Strain for NS and LS beams

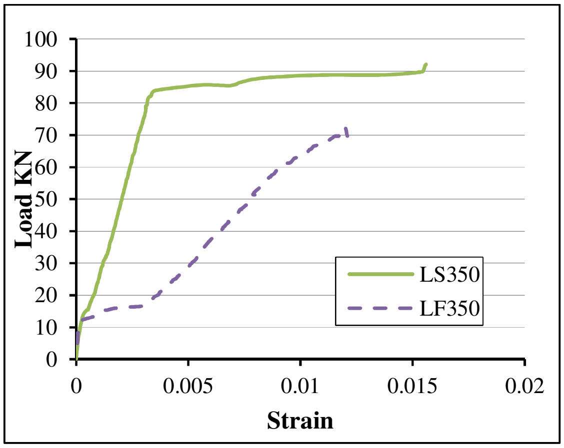


d) Load–Strain for NF and LF beams

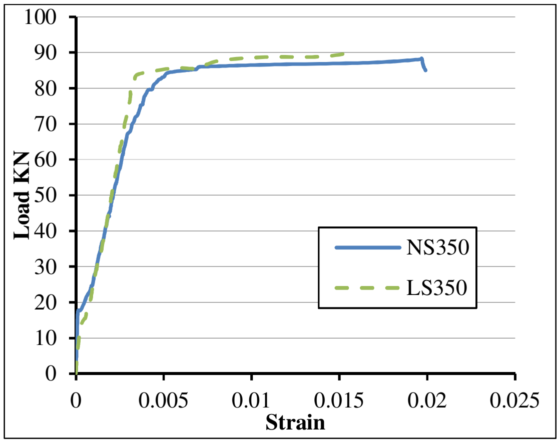
Figure 20: Load–Strain of main reinforcement bars of all beams at Fcu=250 Kg/cm^2



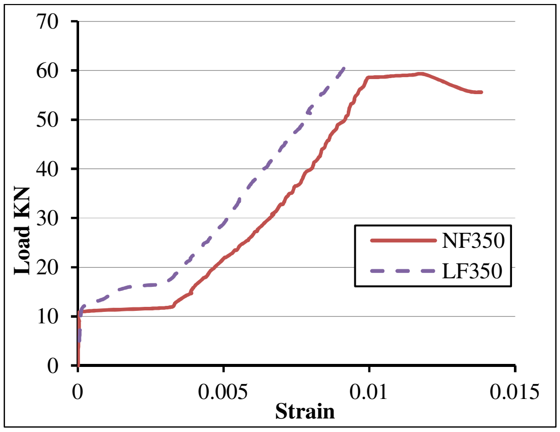
a) Load–Strain for NS and NF beams



b) Load–Strain for LS and LF beams



c) Load–Strain for NS and LS beams

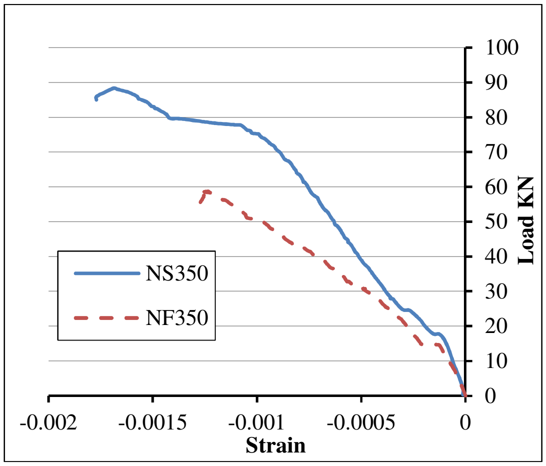


c) Load–Strain for NS and LS beams

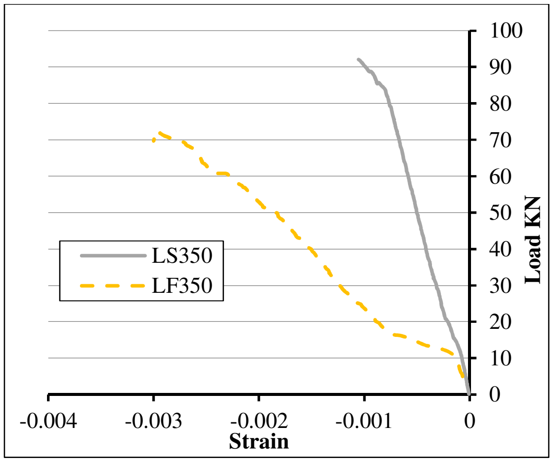
Figure 21: Load–Strain of main reinforcement bars of all beams at Fcu=350 Kg/cm^2

3.3. Concrete Strain at Top of Midspan Section of Beams

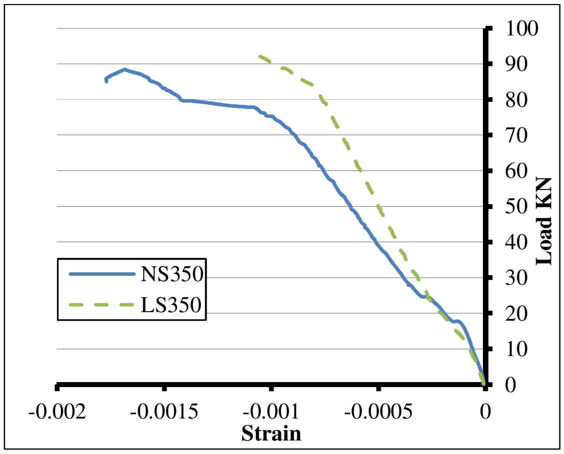
The lightweight concrete strain for beams reinforced with GFRP bars was linear and greater than the normal concrete strain. This is due to the low modulus of elasticity of lightweight concrete, which led to a high deformability, and fibre, which evenly distributes stress in lightweight concrete, resulting in linear concrete strain. As shown in figure (21) below, for beams reinforced with steel bars, the lightweight concrete strain closely resembled the normal concrete strain. As shown in figure, the concrete strain in beams reinforced with GFRP bars is greater than that in beams reinforced with steel bars at lightweight concrete (22). Prior to cracking, the concrete strain is minimal. With the appearance of the first crack at the midspan, the concrete strain increases significantly.



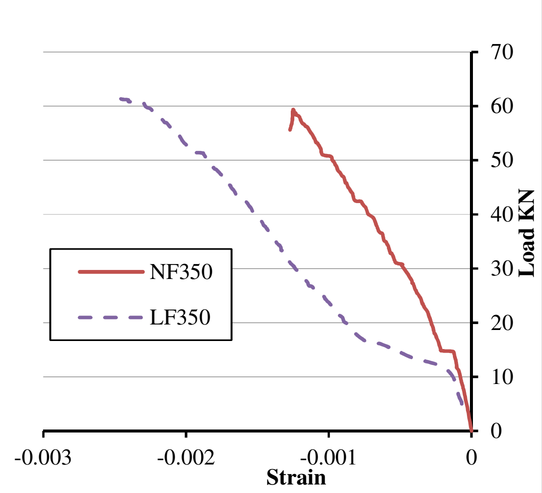
a) Load –Concrete strain curve for NS and NF beams



b) Load –Concrete strain curve for LS and LF beams



c) Load –Concrete strain curve for NS and LS beams



d) Load –Concrete strain curve for NF and LF beams

Figure 22: Load-Concrete strain curves of all beams

4. Conclusion

(1) Load capacity for beams reinforced with GFRP bars, it was found that load capacity for lightweight concrete is increase with 22.59% than load capacity for normal concrete beams.
(2) Load capacity for beams reinforced with steel bars, it was found that the load capacity for lightweight concrete is increase with 5.58% than load capacity for normal concrete beams.
(3) Load capacity for lightweight concrete beams, it was found that load capacity for beam reinforced with GFRP is decrease with 22% than the load capacity for beams reinforced with steel bars.
(4) Load capacity for normal concrete beams, it was found that load capacity for beam reinforced with GFRP is decrease with 32.88% than the load capacity for beams reinforced with steel bars.
(5) The deflection in beams reinforced with GFRP bars is greater than in the beams reinforced with steel bars.
(6) The deflection of normal concrete beam is greater than the deflection of lightweight concrete beam.
(7) The strain of GFRP bars was higher than the strain in the steel bars.
(8) The GFRP bars strain in normal concrete beams is greater than that in lightweight concrete beams.
(9) The concrete strain in lightweight cancrete was linear and higher than the normal concrete strain.
(10) The concrete strain for GFRP bars is greater than steel bars.

5. References

[1] R. B.Karthika, V. Vidyapriya, et al, 2021, “Experimental study on lightweight concrete using pumice aggregate”,Materials Today: Proceedings 43 (2021) 1606-1613.
[2] Nkurunziza G, Debaiky A, Cousin P, Benmokrane B. Durability of GFRP bars: A critical review of the literature. In: Proc., Structural Engineering and Materials 2005; 7(4): 194–209.
[3] Banibayat P, Patnaik A. Creep rupture performance of basalt fiber reinforced polymer (BFRP) bars. ASCE J Aerospace Engineering 2015; 28(3). p. 9.
[4] Elgabbas F, Vincent P, Ahmed EA, et al. Experimental testing of basalt-fiber reinforced polymer bars in concrete beams. Compos Part B 2016; 91:205–18.
[5] Sim K, Park C, Moon DY. Characteristics of basalt fiber as a strengthening material for concrete structures. Compos Part B 2005; 36(6–7):504–12.
[6] Herwig A, Motavalli M. Axial behavior of square reinforced concrete columns strengthened with lightweight concrete elements and unbonded GFRP wrapping. J Compos Constr 2012; 16(6):747–52.
[7] I. Semambya and M. Kyakula. Recycling of Burnt Clay Rubble as Structural Concrete, Kyambogo University, Kyambogo, Uganda.
[8] ACI 440.1R-06. Guide for the design and construction of concrete reinforced with FRP bars. ACI committee 440. Farmington Hills: American Concrete Institute; 2006.
[9] Zhang H, Yao Y, Zhu D, et al. Tensile mechanical properties of basalt fiber reinforced polymer composite under varying strain rates and temperatures. Polymer Testing 51 (2016) 29-39.
[10] Dal lago B, Taylor S, Deegan P, et al. Full-scale testing and numerical analysis of a precast fiber reinforced self-compacting concrete slab pre-stressed with basalt fiber reinforced polymer bars. Department of Civil and Environmental Engineering, Politecnico di Milano, p.za Leonardo da Vinci 32, 2013 Milano, Italy.
[11] ACI Committee 440.3R-04, Guide Test Methods for Fiber-Reinforced Polymers (FRPs) for Reinforcing or Strengthening Concrete Structures Reported by ACI Committee 440 ..
[12] S. B. Patil and G. S. Manjunatha, “Experimental study on bond strength of GFRP bars” Mater. Today Proc., vol. 21, pp. 1044–1049, 2020.
[13] Y. Chen, J. F. Davalos, I. Ray, and H. Y. Kim, “Accelerated aging tests for evaluations of durability performance of FRP reinforcing bars for concrete structures,” Compos. Struct, vol. 78, no. 1, pp. 101–111, 2007,

[14] D. Szczech and R. Kotynia, “Beam bond tests of GFRP and steel reinforcement to concrete,” Arch. Civ. Eng., vol. 64, no. 4, pp. 243–256, 2018.

[15] H. Huang, Y. Yuan, W. Zhang, R. Hao, and J. Zeng, “Bond properties between GFRP bars and hybrid fiber-reinforced concrete containing three types of artificial fibers,” Constr. Build. Mater, vol. 250, p. 118857, 2020.

[16] S. Awad-Allah, “Feasibility of Using GFRP Bars as Reinforcement for Reinforced concrete elements,” Al-Azhar University, 2018.

[17] V. Gribniak, A. Pérez Caldentey, G. Kaklauskas, A. Rimkus, and A. Sokolov, “Effect of arrangement of tensile reinforcement on flexural stiffness and cracking,” Eng. Struct., vol. 124, pp. 418–428, 2016.

[18] M. Elchalakani, G. Ma, F. Aslani, and W. Duan, “Design of GFRP-reinforced rectangular concrete columns under eccentric axial loading,” Mag. Concr. Res., vol. 69, no. 17, 2017.

[19] V. Dhand, G. Mittal, K.Y. Rhee, S.J. Park, D. Hui, A short review on basalt fiber reinforced polymer composites, Compos. Part B Eng. 73 (2015) 166e180.

[20] ESS 4756-1/2013, Egyptian standard specification, “Cement-physical and chemical tests”.

[21] Egyptian Guide for Laboratory Tests for concrete materials issued 2007.

[22] Egyptian Code for Design and Construction of Concrete Structures “ECCS 203/2007”.

[23] ASTM C330-4, “Standard specification for lightweight aggregates for structural concrete”.