Using of Glass Fiber Reinforced Polymer Bars as Reinforcement for Reinforced Concrete Beams Exposed to Fire

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Abstract: In recent years, some attempts have been performed to extend general design rules reported in the codes for steel reinforced concrete to Fiber Reinforced Polymer (FRP) materials; this is the case of relationships adopted in the evaluation of the effect of high degrees of temperature on FRP bars comparison with steel bars. However, such relationships seem to be inappropriate for FRP reinforcing bars: in fact, experimental test results have shown high resistance to tire carbon (C330-10%) bars to change the high temperatures and high outweigh on GFRP compared to steel reinforcement and that bond behavior of C.GFRP (C330-10%) bars is different from that observed in case of deformed GFRP and deformed steel. As a consequence, a new procedure for the evaluation to change the high temperatures based on an analytical approach is needed in order to directly account for the actual values as obtained by experimental tests on mixing different resin types with GFRP reinforcing bars. During this research contribution, an experimental study of C.GFRP (C330-10%) bar as a resistance bar for high degrees of temperature and concrete bond test is carried out and presented to investigate the bond stress behavior for normal concrete, and study feasibility of using glass fiber reinforced polymer bars resistance high degrees of temperature as reinforcement for reinforced concrete beams. The tested specimens included eight concrete beams with 1800mm length, 100mm width and 200mm height.

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1. Introduction:

Considerable research efforts have been conducted on behavior of resistance for changing of temperature of glass fiber reinforced plastic (GFRP) bars in concrete. Generally different types of FRP bars have a bad behavior of high degrees of temperature.

In order for C.GFRP (C330-10%) bars to become widely accepted in the construction industry, all aspects of their structural behavior must be studied to guarantee their safe application. Resistance for changing of temperature is a very critical characteristic and bond behavior is a critical issue for their successful application as reinforcement in concrete structures. Bond characteristics affect the anchorage of bars, strength of lap splices, required concrete cover, and serviceability and ultimate states. The continued integrity of the bond is also a critical issue for the long lasting performance of concrete structures reinforced with C.GFRP bars.

This research found that tire carbon (C330-10%) not only improves the resistance change of temperatures but also improves the bond strength and corrosion resistance.

Experimental Work

Beam Test is the commonly used test procedure to evaluate the workability of C.GFRP bar and GFRP bar as a reinforcement in structure elements. Eight concrete beam specimens are 100 mm wide, 200 mm height and 1800 mm long, of normal concrete with reinforcement C.GFRP bars, GFRP bars and steel bars are constructed and carried out in laboratories of Higher Technological institute at 10th of Ramadan City. Four beam specimens were burned for 400 degree Celsius heat at varying times of 2 hours before beam test at laboratories of Building National Research Center, Cairo, Egypt. The used C.GFRP bars, GFRP bars and steel bars have a same surface texture of steel bar. To avoid shear failure, traditional (8 mm) steel stirrups with a spacing of 100mm were used as shear reinforcement for the beam specimens as shown in Fig. (1) and Fig. (2). A concrete clear cover of 25 mm was used for all beam specimens. [3].

Linear vertical displacement transducers (LVDT) were used to measure displacement increment, while strain gauges were mounting in mid span of the bottom bar to measure its strain as shown in Fig. (3). Piece of rubber with thickness 10mm was placed between concrete beam and supporting steel block to prevent bending or movement due to the irregularities at the contact surface of the beam. The beam specimens were tested under two point bending (4-PB) up to failure as shown in Fig. (4). Fig. (5) is shown schematic view of the 2-point beam test setup. Displacement control Load was applied. The maximum capacity of jack is 200 KN. Beams characterization of the tested four beams is essential, and the same description of the four beams were to be burnt to the extent that 400 degrees Celsius for two hours joined together to work compared to the same reinforcement before and after the burn. Descriptions of eight beam specimens are shown in Table (1).

2. Materials

The materials used in the reinforced specimens' construction and those for repairing the tested were:

Fine aggregate (Sand), Coarse aggregate (Crushed Dolomite), Cement (CEM {1} Ordinary Portland cement {N42.5}), Water, Steel Reinforcement, FRP Reinforcement (GFRP bars), (C.GFRP).

The concrete mix was designed with average compression strength (fcu) after the 28 days was 30Mpa. Concrete was poured in the mold cylinder after placing reinforcement bars. The normal concrete mix design are shown in Table (2). Table (3) is describe compression strength (fcu) values for cube 15 *15*15 cm side lengths were tested without heating and with heating for 400 degree Celsius time intervals 2, 4 and 6 hours as shown in Fig (9).

Fine aggregates

Natural siliceous sand was used as Fine aggregate, with properties and grading curve presented in Tables (4), (5) and Fig (6) respectively.

Coarse aggregates

Dolomite with nominal maximum size of 16 mm is used as coarse aggregate. Sieve analysis of dolomite is given in Table (6), Table (7) and Fig. (7). The dolomite is washed twice with clean drinking water, and immersed in water to be fully saturated and then left to dry in the room temperature before mixing.

Cement

CEM (1) Ordinary Portland cement (N42.5) is used in this work.

Water

Potabole water from the city network was used. The water-cement ratio is taken constant in all mixes and equals to {0.5}.

Steel Reinforcement

The steel in experimental work is the high tensile steel (st. 52) of Ø12 mm diameter. Yield stress, Tensile strength, and Elongation were obtained by performing different tests. Test results are given in Table (8).

Tension Tests on GFRP and C.GFRP Bars

The GFRP and C.GFRP Manufacturing process was carried out in laboratories of Higher Technological institute at 10th of Ramadan City. While the testing phase was carried out in laboratories of Structural Engineering Department, Zagazig University on the MTS machine, of 200 KN capacity. The failure shape of GFRP in Fig. (8) and C.GFRP bars are shown in Fig. (9).

The tensile test results are shown in Table (9). The results of GFRP and C.GFRP bars tensile test namely the load-displacement curve and stress-strain curve. The increasing of percentage of mixed resin with GFRP bar increases the tensile strength and thus improves the tensile properties compared to the GFRP matrix.

Tire carbon C330 was proven to be one of the successful materials in terms of tensile strength with different percentage from 2%, 6%, 8% and 10%. For Ø12mm with percentage 2%, 6%, 8% and 10%, the tensile failure load was 40, 43, 45 and 46 (KN) respectively. It was found that the (C330-10%) is the best added material to the resin in terms of tensile strength after exposing the bar directly to a temperature of 400 degrees Celsius for two hours compared to the GFRP bar. The ratio 10% of resin carbon (C330) was the suitable ratio in test of burning over than 400°C for two hours.

Ductility describes the ability of a structure member to sustain large inelastic deformations before collapse without significant loss in resistance. (C330-10%) increases the ductility of C.GFRP higher than GFRP bar and high grade steel as shown in table (9).

The ultimate strength, strain and the modulus of elasticity of each GFRP bar (Eg) and mixed resin with different ratios are also listed in Table (10). To evaluate the produced bars properties, the modulus of elasticity of C330-10% was 0.058 relative to the steel modules of elasticity (E g / E s), which is higher than those of GFRP and C330 with ratios of 2%, 6% and 8%.

Bond Pullout Test specimens

Twelve concrete cylinder specimens included of three types of bars, four with GFRP bars, four with C.GFRP bars and four with steel bars as a reference. Concrete strength of all specimens was 30 Mpa after 28 days. Developed length was used 150mm, (embedded length of bars into concrete). Concrete dimension of cylinders were 200mm height and 150 mm diameter, Fig. 13. Concrete was poured in the mold cylinder after placing reinforcement bars. The concrete cylinder specimens cured for 7 days after casting before they were subjected to the environment. After 28 days of casting, the specimens were subjected to 400°C temperature, as shown in figure 13. The pullout tests were carried out on the MTS machine at laboratories of Higher Technological institute at 10th of Ramadan City, Egypt. Displacement control Load was applied. Table (11) shows the details of concrete cylinders that have been tested.

Table (12) shows the details of bond strength values obtained from the pull-out tests for the different specimens. Fig.16 shows cylinder bond failure and bond splitting failure of concrete cylinder.

The bond stresses results of steel bars, GFRP bars and C.GFRP (C330-10%) bars are listed in table (12). All nine specimens were burned for 400 degree Celsius for times of 2, 4 and 6 hours before pull-out test. Tire carbon C330-10% has shown slightly higher bond strength compared to steel bar and GFRP bar. This indicate a very good performance of C.GFRP (C330-10%) bars in terms of bond strength under high temperature effect, 400 degree Celsius, for durations of 2, 4 and 6 hours.

Casting and Curing

The beam specimens were 100 mm width, 200 mm depth and 1800 mm long. The concrete was cast after reinforcement was installed inside the mold as shown in Fig. (17) [7].

Concrete Testing

Testing of Fresh Concrete

Slump test was carried out to control the plastic consistency of the fresh mix. The slump value was 164mm, this indicate to dry mixture. This test was carried out according to Egyptian Standard Specifications (E.S.S) [4, 5].

Compression Test

Concrete cubes with 15*15*15 cm side lengths were used to determine the characteristic compressive strength (fcu). The steel cube filled with concrete in three layers and each layer received 25 blows of the standard tamping to be compacted according to the E.S. specification [4, 5]. Three cubes were tested at ages 7 and 28 days by using 2000 KN compression test machine as Fig. (18).

Results of Beam Test

The Eight beam specimens were tested under two point bending (2-PB) up to failure. The deflection was measured at the bottom of middle span of the beam. Tested eight beam specimens and the failure shapes of beam specimens were plotted in Fig. (19), (20), (21), (22), (23) (24), (25), and (26), Also; Table (1) shows the ultimate load, the corresponding deflection, maximum stress and maximum strain at middle span values of tested specimens. Four beam specimens were exposed in the middle of beam a distance of meter to a temperature of 400 degrees Celsius for two hours as shown in Fig. (27). The Eight beam specimens were carried out in laboratories of The Building National Research Center for Housing and Construction, Cairo. Four beam specimens were burned in the fire laboratories for materials belonging to by The Building National Research Center for Housing and Construction, Cairo.

Load-Deflection for Beam (1)

Fig. (28) Shows the load-deflection curves of the specimen (B1) which reinforcement with upper 2Ø10 steel bar and lower 2Ø12 steel bar. The specimen (B1) before and after burn to 400 degree Celsius for two hours failed at 78.8 KN and 60.6 KN respectively by flexural cracks in middle span and ductile failure. The maximum deflection of specimen (B1) decreased from 26.4 mm to 19.7 mm with burning to 400 degree Celsius for two hours.

Fig. (29) Shows the stress-strain curves of the specimen (B1), the specimen (B1) before and after burn to 400 degree Celsius for two hours failed at 3.9 MPa and 3.03 MPa respectively with strain between 0.1319 and 0.0984 respectively.

Load-Deflection for Beam (2)

Fig. (30) Shows the load-deflection curves of the specimen (B2) with upper reinforcement 2Ø10 steel bar and lower 2Ø12 GFRP bar. The failure load of (B2) before and after burn to 400 degree Celsius for two hours was 63.3 KN and 45.1 KN respectively by flexural cracks in middle span and ductile failure. The maximum deflection of specimen (B2) decreased from 38.2 mm to 26.6 mm with burning to 400 degree Celsius for two hours.

Fig. (31) Shows the stress-strain curves of the specimen (B2), the specimen (B2) before and after burn to 400 degree Celsius for two hours failed at 3.2 MPa and 2.3 MPa respectively with strain between 0.1627 and 0.133 respectively.

Load-Deflection for Beam (3)

Fig. (32) Shows the load-deflection curves of the specimen (B3) with upper reinforcement 2Ø10 steel bar and lower 2Ø12 C.GFRP (C330-10%) bar. The failure load of (B3) before and after burn to 400 degree Celsius for two hours was70.3 KN and 45 KN respectively by flexural cracks in middle span and ductile failure. The maximum deflection of specimen (B3) decreased from 43.9 mm to 30.6 mm with burning to 400 degree Celsius for two hours.

Fig. (33) Shows the stress-strain curves of the specimen (B3), the specimen (B3) before and after burn to 400 degree Celsius for two hours failed at 3.51 MPa and 2.24 MPa respectively with strain between 0.2197 and 0.1531 respectively.

4.2.4.4. Load-Deflection for Beam (4)

Fig. (34) Shows the load-deflection curves of the specimen (B4) with upper reinforcement 2Ø10 C.GFRP (C330-10%) bar and lower 2Ø12 C.GFRP (C330-10%) bar. The failure load of (B4) before and after burn to 400 degree Celsius for two hours was 76.9 KN and 48.6 KN respectively by flexural cracks in middle span and ductile failure. The maximum deflection of specimen (B4) decreased from 25.3 mm to 18.4 mm with burning to 400 degree Celsius for two hours.

Fig. (35) Shows the stress-strain curves of the specimen (B4), the specimen (B4) before and after burn to 400 degree Celsius for two hours failed at 3.8 MPa and 2.4 MPa respectively with strain between 0.1265 and 0.0920 respectively.

Fig. (36) and Fig (37) shows the load-deflection and stress-strain curves of the all beam specimens before burning respectively, where (B4) is the closest to the (B1) in terms of carrying the ultimate failure load by about 98 %, while the ultimate failure of (B3) by about 89 % and (B2) by about 80 %. So upper and lower reinforcement with C.GFRP (C330-10%) is a good material compared to steel in terms of access to the nearest ultimate failure load of this addition to being against corrosion unlike steel reinforcement. Lower GFRP bar had a preference as a reinforcement of the beam specimen with steel bar as opposed to C.GFRP.

Fig. (38) and Fig (39) shows the load-deflection and stress-strain curves of the all beam specimens after burning respectively, where (B4) is the closest to the (B1) in terms of carrying the ultimate failure load by about 80 %, while the ultimate failure of (B2) by about 74% and (B3) by about 74 %. So reinforcement with C.GFRP (C330-10%) compared to GFRP in terms of resistance of burning is a greatest reinforcement.

Finally, we have reached a new material suitable substitute for reinforcing steel has the characteristics of resistance to the approach of reinforcing steel and also have preference in terms of corrosion and high resistance to high temperatures is the material of Tire carbon (C.GFRP) -(C330-10%).

Fig. (1). Reinforcement details of Beams tested

Fig. (2). Beam specimens casted before the beam test

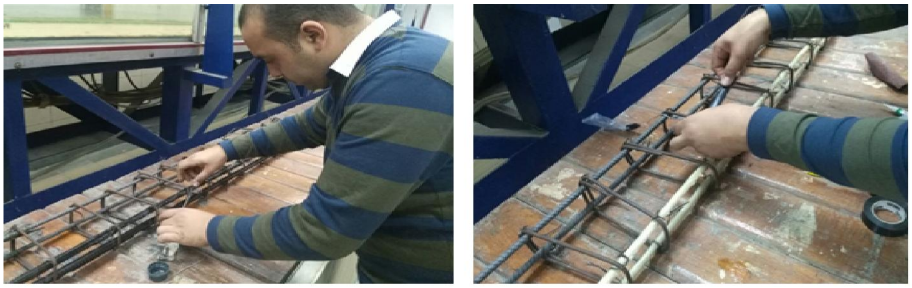


Fig. (3). strain gauge was mounting in mid span of the bottom bar to measure its strain

Fig. (4). 2-point beam tests of tested Beams by jack Capacity 200KN

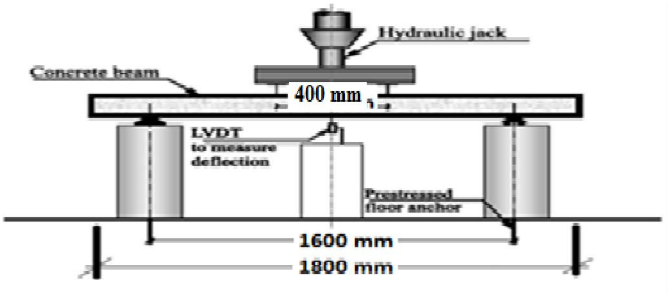
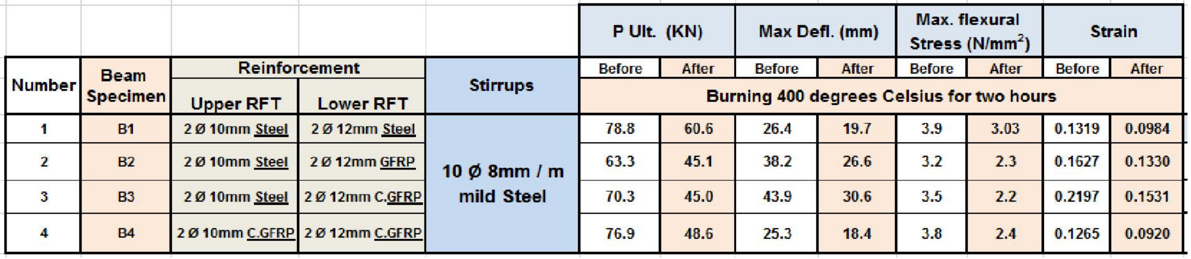


Fig. (5)Schematic view of the 2-point beam test setup

Table (1) Descriptions of eight beam specimens



Number	Beam Specimen	Reinforcement		Stirrups	P Ult. (KN)		Max Defl. (mm)		Max. flexural Stress (N/mm^2)		Strain	
		Upper RFT	Lower RFT		Before	After	Before	After	Before	After	Before	After
					Burning 400 degrees Celsius for two hours							
1	B1	2 Ø 10mm Steel	2 Ø 12mm Steel	10 ϕ 8mm / m mild Steel	78.8	60.6	26.4	19.7	3.9	3.03	0.1319	0.0984
2	B2	2 Ø 10mm Steel	2 Ø 12mm GFRP		63.3	45.1	38.2	26.6	3.2	2.3	0.1627	0.1330
3	B3	2 Ø 10mm Steel	2 Ø 12mm C.GFRP		70.3	45.0	43.9	30.6	3.5	2.2	0.2197	0.1531
4	B4	2 Ø 10mm C.GFRP	2 Ø 12mm C.GFRP		76.9	48.6	25.3	18.4	3.8	2.4	0.1265	0.0920

Table (2) The normal concrete mix design

Coarse agg.	Fine agg.	Cement	Water	W/C
Kg/m^3	Kg/m^3	Kg/m^3	Kg/m^3	Ratio
1250	750	350	175	0.5

Table (3) Proportion of Mix

Compressive Test (Mpa) - Av. Between 3 specimen								
	Without Heating	400^{O} C 2 Hr.	400^{O} C 4 Hr.	400^{O} C 6 Hr.	Without Heating	400^{O} C 2 Hr.	400^{O} C 4 Hr.	400^{O} C 6 Hr.
Compressive strength (Mpa)	31.7	28.3	24.4	13.5	30.5	27.3	24.7	13.7
					32.8	29.4	23.9	13.5
					31.9	28.3	24.7	13.4

Table (4) Physical properties of fine aggregates

Property	Measured Value	Egyptian Code Limits
Compacted density	1725 Kg/m^3	
Loose density	1600 Kg/m^3	
Specific gravity	2.65	2.5 – 2.75
Fine material< (75 µ)	1.0 %	up to 3%

* Egyptian Code No. 203 [4].

Table (5) Sieve analysis of sand

Sieve Opening, mm	4.76	2.36	1.18	0.60	0.30	0.15
Passing %	***99.2***	***94.7***	***84.9***	***53.7***	***13.9***	***1.6***
General Limits*	***89-100***	***60-100***	***30-100***	***15-100***	***5-70***	***0-15***

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فتحة المنخل	4.760	2.360	1.180	0.600	0.300	0.150
نسبة الوزن المار (%)	99.20	94.70	84.90	53.70	13.90	1.60

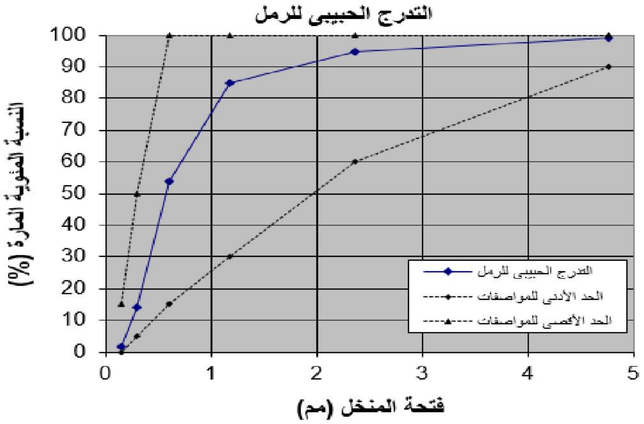

Fig (6) Grading curve of sand

Table (6) Physical properties of coarse aggregate (dolomite)

Property	Measured Value	Egyptian Code Limits
Specific gravity	2.65	2.6 – 2.7
Volume weight (t/m^3)	1.48	
Absorption %	0.8 %	< 2.5%
Crushing value %	25	<30%
Impact value %	12.5	<30%
Los Angeles value	19.7	< 30%
Organic materials	Non	

Table (7) Sieve analysis of dolomite

Sieve Opening, mm	37.5	20	16	9.5	4.75	2.36
Passing %	100	100	95.50	90.81	25.98	0.00
General Limits*	-	100	100	100-50	50-10	-

Egyptian Code No. 203[4]

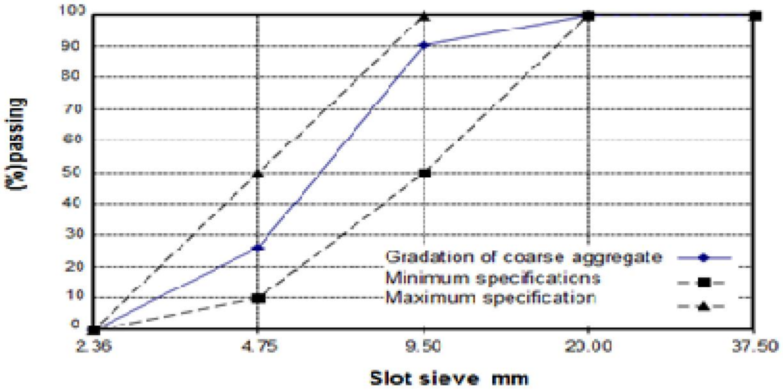

Fig. (7) Grading curve of dolomite

Table (8) properties of Steel Reinforcement

Steel Type	*Yield Stress (Mpa)*	*Tensile Strength (Mpa)*	*Elongation (%)*
High tensile steel	360	520	12

* Egyptian Code No. 203 [4]

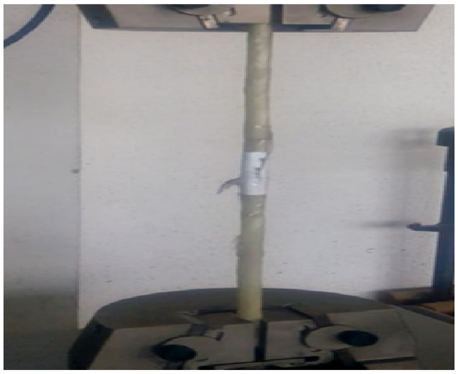

Fig. (8): failure shape of12mm GFRP bars

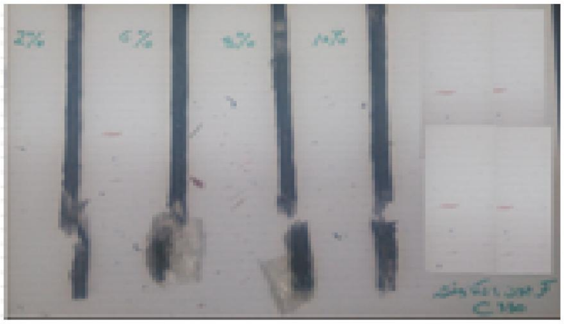

Fig. (9): failure shape of12mm C.GFRP bars

Table (9) The details of Steel, GFRP and C.GFRP bars tested with Tensile test

		Pu (KN)	**ȣ (ton/m^3)**	**Ductility (%)**
Steel		**59**	8.0000	**2.0**
GFRP		**42.6**	3.2000	**5.2**
C 330	**2%**	**40**	1.6208	**5.0**
C 330	**6%**	**43**	2.0633	**4.5**
C 330	**8%**	**45**	1.7902	**4.3**
C 330	**10%**	**46**	1.9452	**3.6**

Table (10) Ultimate strength, strain and elastic modulusof C.GFRP (C330) bars

Bar		***f_u (MPa)***	***ε_u***	***E_g (MPa)***	***E_g / E_s***
Steel				**200000**	
GFRP Bar		**377**	**0.0517**	**7292**	**0.036**
C 330	**2%**	**353.53**	**0.05**	**7071**	**0.035**
C 330	**6%**	**380.05**	**0.045**	**8446**	**0.042**
C 330	**8%**	**397.72**	**0.044**	**9039**	**0.045**
C 330	**10%**	**406.56**	**0.035**	**11616**	**0.058**

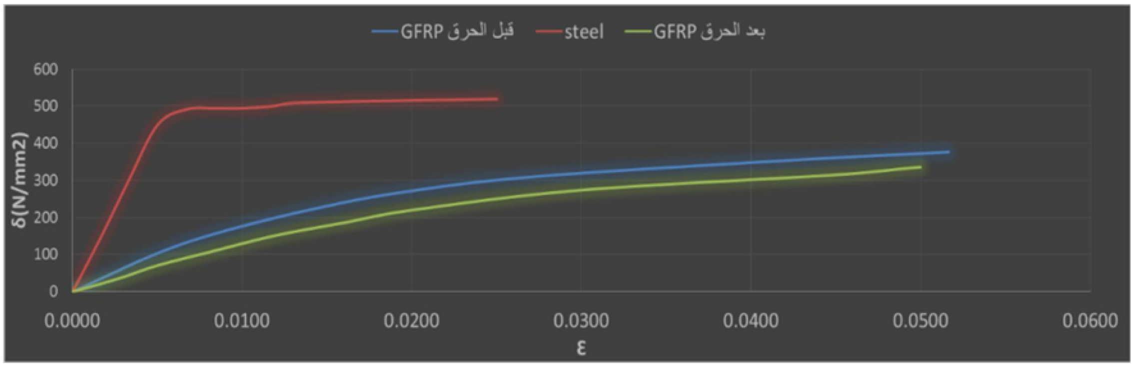

Fig. (10). Stress-Strain of GFRP bar before and after burning 400C and Steel bars

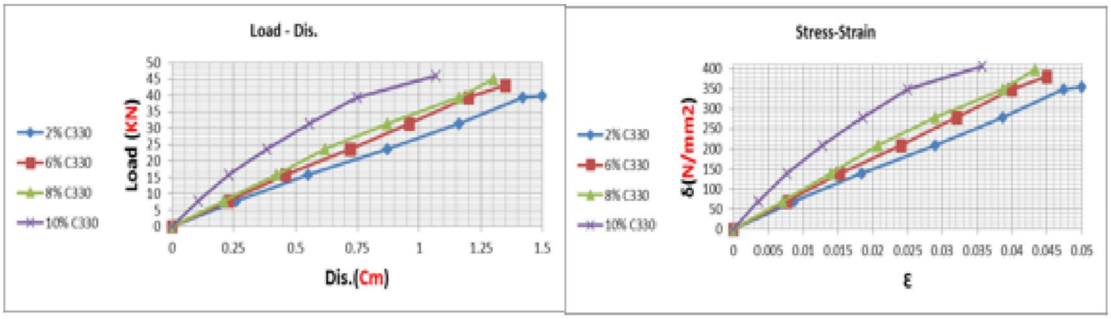

Fig. (11). Tension curve of C.GFRP (C330) bar with 2%, 6%, 8% and 10%, Stress-Strain of C.GFRP (C330)

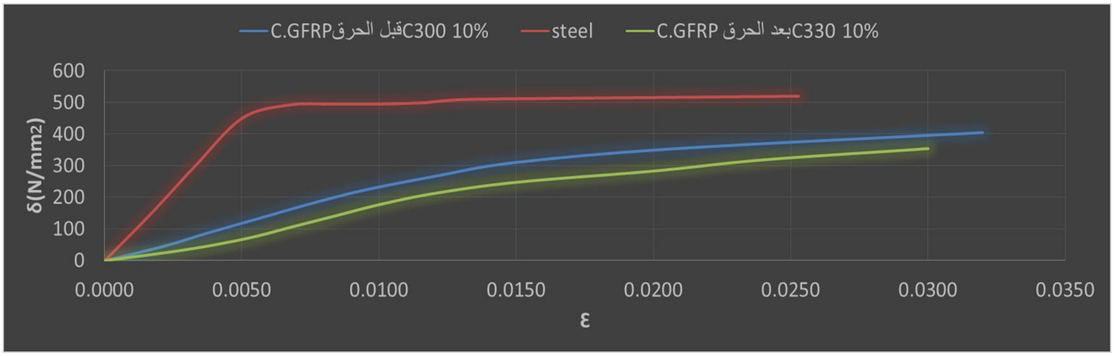

Fig. (12). Stress-Strain of C.GFRP (C330-10%) bar before and after burning 400C Steel bars

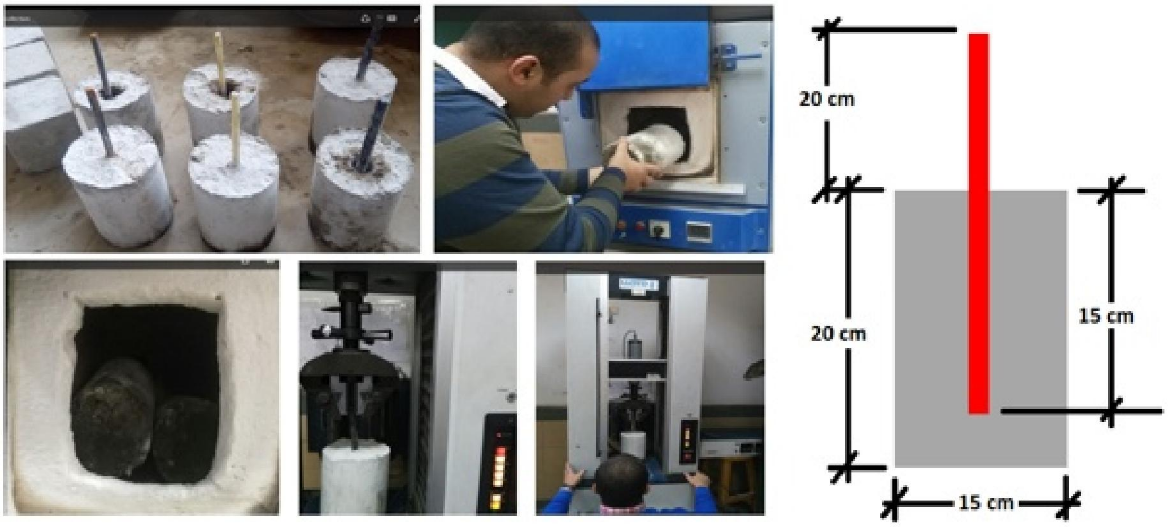

Fig. (13). Burning cylinders for 400°C andthe setup of pullout test

Table (11) Pull-out test results

Pull-Out Test ($P_{Max.}$ - KN) - Av. Between 3 specimen					
KN		Without Heating	400^{o} C 2 Hr.	400^{o} C 4 Hr.	400^{o} C 6 Hr.
with	steel bars	49.3	41.2	32.0	24.0
	GFRP	53.0	42.7	33.6	26.5
	C.GFRP	54.0	43.0	34.0	27.5

Fig. (14). Pull-out test for C.GFRP

Fig. (15). Pull-out test for C.GFRP

Fig. (16). failure of concrete cylinder

Fig. (17) Reinforcement was installed inside the beam mold

Fig. (18). Burning cube for 400°C and Compressive strength testing machine

Table (12) Bond strength values of pull-out specimens for each case of reinforcement

Bond Stress (N/mm^2) - Av. Between 3 specimen					
N/mm2		Without Heating	400º C	400º C	400º C
			2 Hr.	4 Hr.	6 Hr.
with	steel bars	8.73	7.29	5.66	4.25
	GFRP	9.38	7.56	5.95	4.69
	C.GFRP	9.55	7.61	6.02	4.86
	L=	150	mm		
	d=	12	mm		

Fig. (19). Shape and values of cracks of (B1)

Fig. (20). Crack pattern of (B1) after burning at 400°C for 2 hours

Fig. (21). Shape and values of cracks of (B2)

Fig. (22). Crack pattern of (B2) after burning at 400°C for 2 hours

Fig. (23). Shape and values of cracks of (B3)

Fig. (24). Crack pattern of (B3) after burning at 400°C for 2 hours

Fig. (25). Shape and values of cracks of (B4)

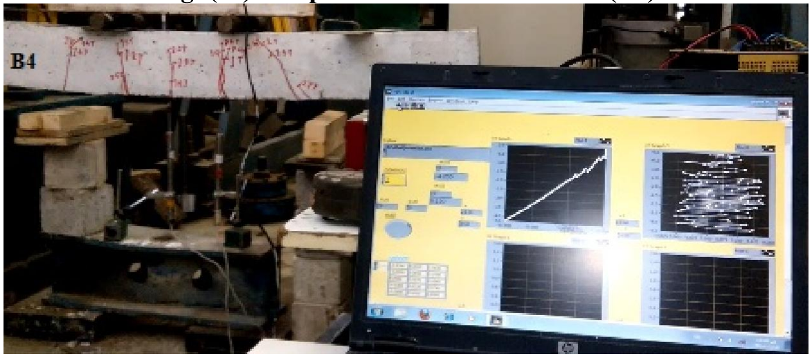

Fig. (26). Crack pattern of (B4) after burning at 400°C for 2 hours

Fig. (27). Four beam specimens were exposed in the middle of beam a distance of meter to a temperature of 400 degrees Celsius for two hours

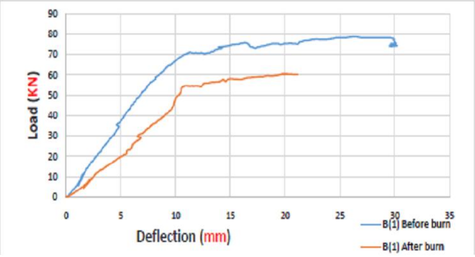

Fig. (28) Load-Deflection Curve of B (1)

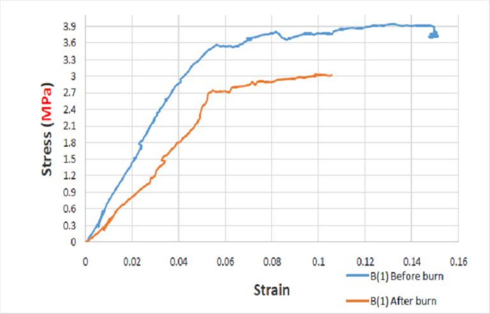

Fig. (29) Stress-Strain Curve of B (1)

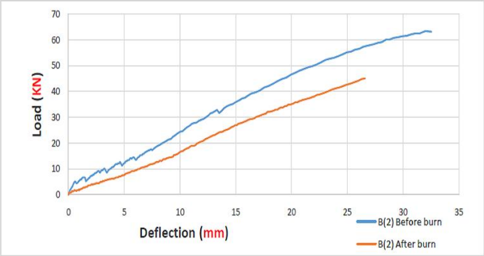

Fig. (30) Load-Deflection Curve of B (2)

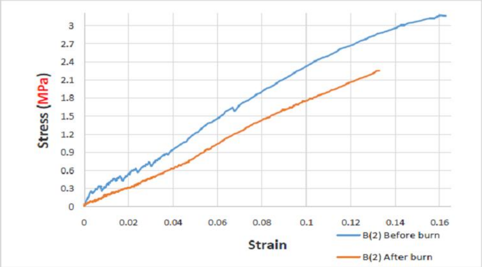

Fig. (31) Stress-Strain Curve of B (2)

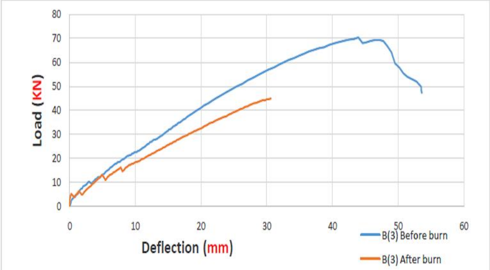

Fig. (32) Load-Deflection Curve of B (3)

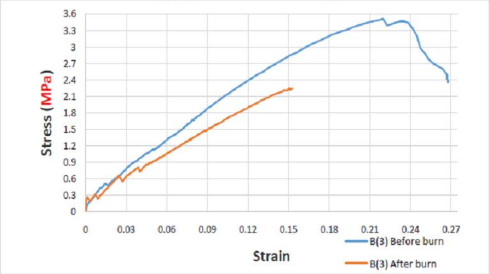

Fig. (33) Stress-Strain Curve of B (3)

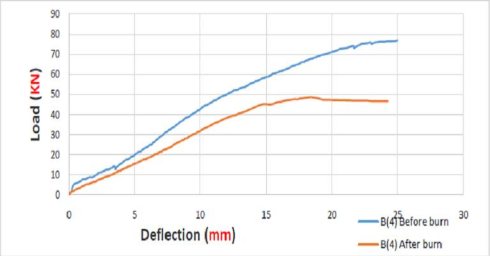

Fig. (34) Load-Deflection Curve of B (4)

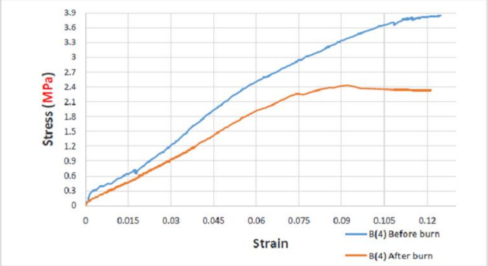

Fig. (35) Stress-Strain Curve of B (4)

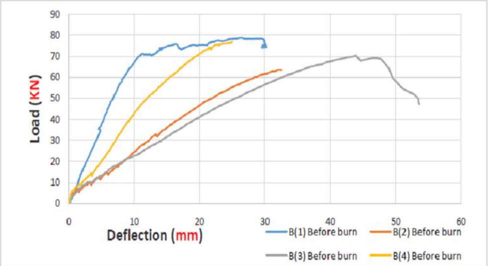

Fig. (36) Load-Deflection Curve of All Beam Specimens before Burn

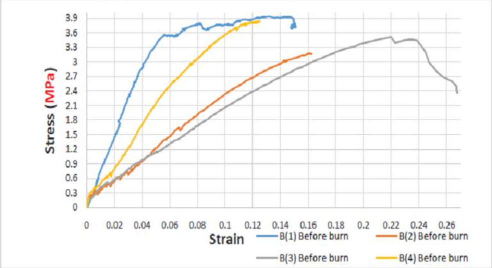

Fig. (37) Stress-Strain Curve of All Beam Specimens before Burn

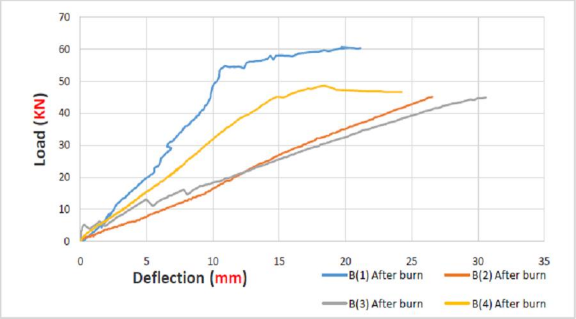

Fig. (38) Load-Deflection Curve of All Beam Specimens after Burn

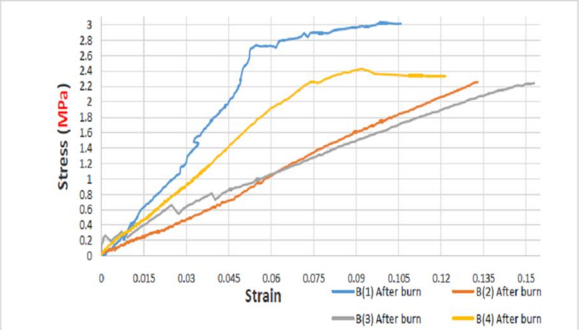

Fig. (39) Stress-Strain Curve of All Beam Specimens after Burn

Conclusion

1. The specimen (B1) with upper reinforcement 2Ø10 steel bar and lower 2Ø12 steel bar, before and after burn to 400 degree Celsius for two hours was 78.8 KN and 60.6 KN respectively by flexural cracks in middle span and ductile failure.
2. The maximum deflection of specimen (B1) decreased from 26.4 mm to 19.7 mm with burning to 400 degree Celsius for two hours.
3. The specimen (B2) with upper reinforcement 2Ø10 steel bar and lower 2Ø12 GFRP bar, before and after burn to 400 degree Celsius for two hours was 63.3 KN and 45.1 KN respectively by flexural cracks in middle span and ductile failure.
4. The maximum deflection of specimen (B2) decreased from 38.2 mm to 26.6 mm with burning to 400 degree Celsius for two hours.
5. Specimen (B2) before and after burn to 400 degree Celsius for two hours failed at 3.2 MPa and 2.3 MPa respectively with strain between 0.1627 and 0.133 respectively.
6. The specimen (B3) with upper reinforcement 2Ø10 steel bar and lower 2Ø12 C.GFRP (C330-10%) bar, before and after burn to 400 degree Celsius for two hours was70.3 KN and 45 KN respectively by flexural cracks in middle span and ductile failure.
7. The maximum deflection of specimen (B3) decreased from 43.9 mm to 30.6 mm with burning to 400 degree Celsius for two hours.
8. Specimen (B3) before and after burn to 400 degree Celsius for two hours failed at 3.51 MPa and 2.24 MPa respectively with strain between 0.2197 and 0.1531 respectively.
9. The specimen (B4) with upper reinforcement 2Ø10 C.GFRP (C330-10%) bar and lower 2Ø12 C.GFRP (C330-10%) bar, before and after burn to 400 degree Celsius for two hours was 76.9 KN and 48.6 KN respectively by flexural cracks in middle span and ductile failure.
10. The maximum deflection of specimen (B4) decreased from 25.3 mm to 18.4 mm with burning to 400 degree Celsius for two hours.
11. Specimen (B4) before and after burn to 400degree Celsius for two hours failed at 3.8 MPa and 2.4 MPa respectively with strain between 0.1265 and 0.0920 respectively.
12. Before burning (B4) is the closest to the (B1) in terms of carrying the ultimate failure load by about 98 %, while the ultimate failure of (B3) by about 89 % and (B2) by about 80 %. So upper and lower reinforcement with C.GFRP (C330-10%) is a good material compared to steel in terms of access to the nearest ultimate failure load of this addition to being against corrosion unlike steel reinforcement.
13. C.GFRP more effective than GFRP and steel from the point of view failure load before and after burnt by ratios 98% and 80% respectively.

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