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COMPARISON BETWEEN BOND STRENGH OF C.GFRP BARS, GFRP BARS AND STEEL BARS UNDER TEMPERATURE EFFECT

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الملخص

فى هذا البحث تم تصنيع اسياخ تسليح للعناصر الخرسانية من المواد البوليمريه المسلحه بالالياف الزجاجيه والمعالجة بخليط كربون الكاوتش لمقاومه الحريق ودرجات الحراره العاليه. وقد تم اختبار مدى جدوى استخدام هذه الاسياخ لمقاومه الحريق ودرجات الحراره العاليه عند استخدامها كتسليح للخرسانة بالاضافه الى دراسه خواصها الاساسيه. وتم ايضا دراسه تاثير معالجة الاسياخ بخليط كربون الكاوتش علي مقاومتها للشد و قوى التماسك بينها وبين الخرسانه و مقارنتها باسياخ صلب التسليح لتكون نموذج عملى للمنشات الخرسانيه فى الطبيعة. و تم اجراء اختبار الشد علي عدد خمس عينات من هذه الأسياخ بطول 300مم و قطر 12مم و منها تم حساب ممطولية الاسياخ المختبرة (Ductility).كما تم تحديد كثافه الاسياخ مختلفه الخليط و مقارنتها بالوزن مع اسياخ حديد التسليح . و تم اختبار الاقتلاع على عدد اثنا عشر عينه لتحديد خصائص التماسك بين الاسياخ المصنعه و الخرسانه ذات مقاومه ضغط 300 كجم/سم2 .

ABSTRACT

The use of glass fiber reinforced polymer (GFRP) as reinforcements in the concrete structures had increased rapidly in the last decades due to their excellent performance and high tensile strength. Bond between GFRP reinforcing bars and concrete is one of some obstacles toward the widely usage of GFRP-reinforced concrete. More understanding and clarifications are needed. Moreover, GFRP bars have experienced weak resistance to high temperatures such as fire conditions. So, thinking in approaches of producing glass fiber reinforced polymer that has the advantages of the high resistance to fire was attracted the attention of a lot of researchers in the last few decades. In the present research, Tire carbon (C330-10%) was used to produce C.GFRP bars that have considerable efficiency to resist the fire and high temperature. The objectives of this research are to experimentally check the tensile strength, ductility and the bond between Tire carbon C.GFRP (C330-10%) bars and concrete under high temperature effect.

Pullout tests were carried out to investigate the bond stress-slip of C.GFRP bars. The used C.GFRP bars were manufactured during the course of this study. A brief description of the process is presented.

Five bar specimens of 300 mm height and 12 mm diameter, of glass fiber polymer with Tire carbon C330 resin and base resin (polyester and peroxide) were manufactured. Bars were produced with different percentages (2%, 6%, 8% and 10%) of the total volume of the base resin. Tension tests were carried out to determine the mechanical properties of different types of bars.

Pullout tests were carried out to investigate the bond strength of C.GFRP bars with normal concrete. Twelve concrete cylinder specimens of 200 mm height and 150 mm diameter, of normal concrete with centrally embedded C.GFRP bars, GFRP bars and

steel bars were casted. Nine cylinder specimens were burned up to 400 degree Celsius for different durations 2, 4 and 6 hours before pull-out test. The burned specimens were tested together with three reference specimens under tensile static load. The reinforcing bars have embedment length namely 150 mm. The used C.GFRP bars and GFRP bars have a same surface treatment of steel bar. The experimental results of tensile stress, ductility, and bond stress values were presented and discussed.
Keywords: C.GFRP bars, Pullout, bond, embedded length, mechanical bond, Tension test.

1- Introduction

The last decades have been marked by degradation of numerous concrete structures due to the corrosion of steel reinforcements that required costly repairs or replacements. To mitigate the corrosion problem, several methods, such as epoxy coated rebars, synthetic membranes, or cathodic protection, have been developed. However, many of these efforts have showed limited success [7, and 8].In recent years, research has been carried out on fiber reinforced plastic (FRP) bars as an alternative to steel reinforcement. These FRP rebars have already shown excellent corrosion resistance in many projects, especially in bridge decks, offshore reinforced concrete structures and Parking garages [2, 3].

Among the advantages of FRP reinforcement are its high tensile strength, corrosion resistance, magnetic transparency. Light weight, lower thermal and electric conductivity. However, FRP has weak fire resistance and high price due to its limited use.

Considerable research efforts have been conducted on the fire resistance behavior of glass fiber reinforced polymer mixing with Tire carbon C330 with percentage 2%, 6%, 8% and 10%. [1]

In this research, the used C.GFRP bars were manufactured as part of the current investigation. Specimens of the produced C.GFRP bars were tested to determine their ultimate tensile strength (fu), ductility and elastic modulus (Eg). Concrete cylinders with centrally embedded C.GFRP bars were casted and tested in tension up to failure. The obtained results were compared to those of similar cylinders but with GFRP and steel bars. The parameters of the current study were the type of bar embedded (bond).The used C.GFRP bars and GFRP bars have a same surface treatment of steel bar. The detailed account of C.GFRP and GFRP bars manufacturing process and the experimental part of the bond-slip behavior of the study was introduced. The ACI-440 committee has highlighted the research need for experimental evaluation of bond characteristics under general loads.

The current study is an effort aimed at better understanding of the C.GFRP bars and concrete bond-slip behavior.

2- Manufacturing of GFRP and C.GFRP bars

The manufacturing process GFRP and C.GFRP bars are illustrated in Figures 1 to 6. The glass fibers were stretched between two clamping devices, and then submerged with base resin (polyester and peroxide) for GFRP, and tire carbon resin (polyester, peroxide and tire carbon C330) for C.GFRP. The extra resin after the saturation of the fibers was removed. Then, saturated fibers were twisted several times from one end till the bars were formed. Then, the formed bar left for curing. Bar is placed within two parts of a tube has a corrugated inside surface to shape the outside surface of the bars to looks like the same surface of the standard of the steel bars. The used tube has an inside diameter

equals the required diameter of the manufactured bars. After about 2 hours the bar was cut at the ends using a saw. The manufactured 12 mm bars are shown in Figures 7 and 8. Bars of 2.0 m length and 12 mm nominal diameter were produced with final cross-section of 70% E-glass fiber and 30% polyester resin. The manufacturing process of GFRP bars was conducted according to Safaan [13].
The GFRP and C.GFRP Manufacturing process was carried out in laboratories of tenth of Ramadan Higher Technological institute.

Fig. (1) Two clamps

Fig. (2) Individual fiber process between two clamps

Fig. (3) Putting Resin in the Fibers

Fig. (4) Rolling the Fiber in the Resin

Fig. (5) Rolling to Squeeze out Extra resin

Fig. (6) C.GFRP with the notched surface

Fig. (7) 12 mm of GFRP bars

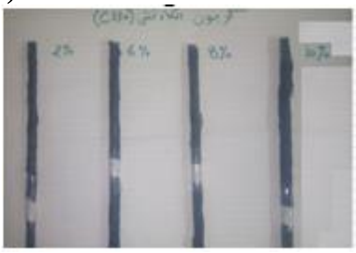

Fig. (8) 12 mm of C.GFRP (C330-10%) bars

3- 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. (9) and C.GFRP bars are shown in Fig. (10).

Fig. (9): failure shape of 12mm GFRP bars

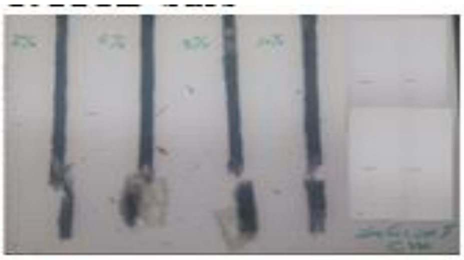

Fig. (10): failure shape of 12mm C.GFRP bars

The tensile test results are shown in Table (1). 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 (1).

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 (2). 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%.

Table (1) The details of Steel, GFRP and C.GFRP bars tested with Tensile test

		Pu (KN)	ɤ (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 (2) Ultimate strength, strain and elastic modulus of 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.(11). Stress-Strain of GFRP bar before and after burning 400C and Steel bars

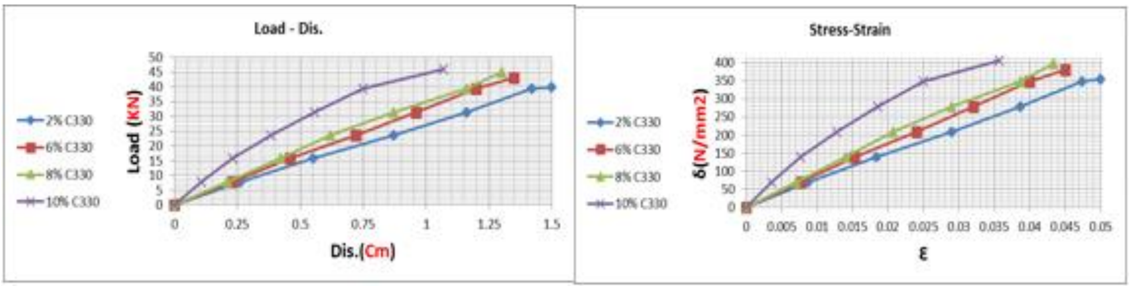

Fig.(12). Tension curve of C.GFRP (C330) bar with 2%, 6%, 8% and 10%, Stress-Strain of C.GFRP (C330)

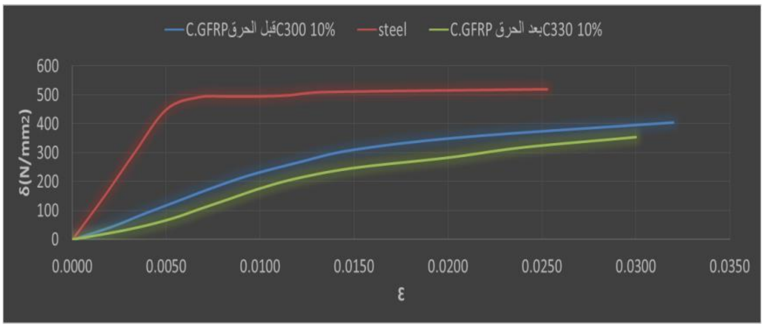

Fig.(13). Stress-Strain of C.GFRP (C330-10%) bar before and after burning 400C Steel bars

4- 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. 14. 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 14. 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 (3) shows the details of concrete cylinders that have been tested.

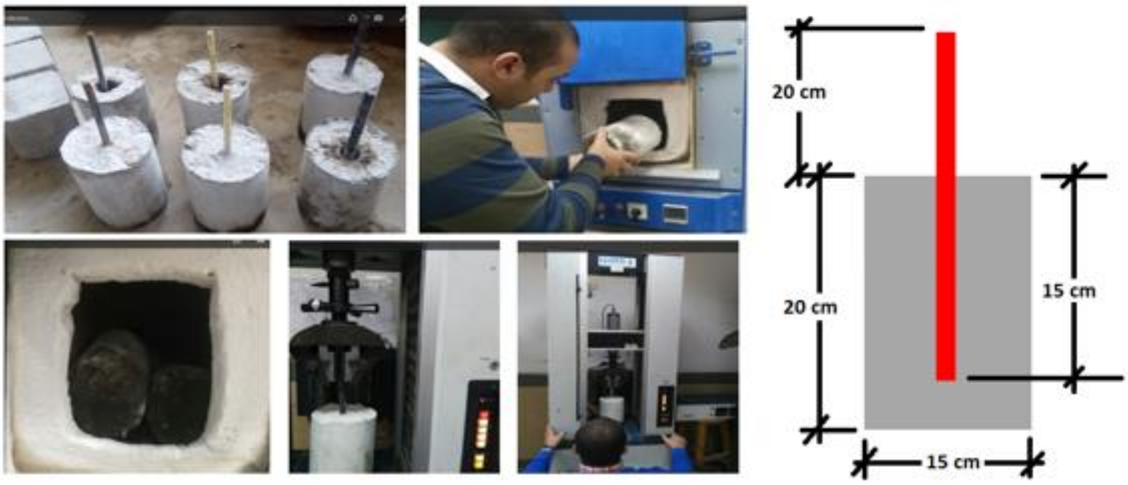

Fig.(14). Burning cylinders for 400°C and the setup of pullout test

Table (3) Pull-out test results

Pull-Out Test ($P_{Max.}$ - KN) - Av. Between 3 specimen					
KN		Without Heating	400° C 2 Hr.	400° C 4 Hr.	400° 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

4-1 Bond Test Results

Bond stress is calculated as average stress between the reinforcing bar and the surrounding concrete along the embedded length of the bar as shown in Fig. (15) and Fig. (16). In general, the bond stress corresponding to the maximum pull out load can be regarded as the bond strength or the ultimate bond. The criterion of ultimate bond strength is characterized by its clear definition and simplicity in bond strength interpretation. For uniform bond, the bond stress S can be expressed as:

$$S = P_{max} / (\pi \times L \times d) \qquad (1)$$

Where:-

Pmax= maximum pull out load

d=diameter of the bar

L =Embedded bar length

Equation 1 was employed in present calculation of bonding stress between the embedded bar and the surrounding concrete for the specimen.

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

Fig. (16). Pull-out test for C.GFRP

Table (4) shows the details of bond strength values obtained from the pull-out tests for the different specimens. Fig.17 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 (4). 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.

Table (4) Bond strength values of pull-out specimens for each case of reinforcement

Bond Stress (N/mm^2) - Av. Between 3 specimen					
N/mm^2		Without Heating	400º C 2 Hr.	400º C 4 Hr.	400º C 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
	Where:				
	L=	150	mm		
	d=	12	mm		

(a)Steel bar **(b) GFRP bar** **(C) C.GFRP bars**

Fig. (17). failure of concrete cylinder

5- Conclusion

From the analysis and discussion of the test results the following conclusions can be obtained:

1. Comparing to steel and GFRP bars, in terms of specific weight, tensile strength and ductility, the C.GFRP (C330-10%) bars has shown a very good computation.
2. Bond strength of pullout test of C.GFRP (C330-10%) specimens is comparable to bond strength of notched steel specimens and GFRP specimen.
3. The bond strength of C.GFRP (C330-10%) specimens is higher than steel specimens and GFRP specimen.
4. With the impact of the fire to the extent degrees 400 degrees Celsius for two hours C.GFRP is more successful than steel and GFRP in terms of the tensile strength and bond strength before and after the fire.

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