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Enhancement of Glass Fiber Bars by Steel Rods (Hybrid-rod bars)

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ABSTRACT:This research presents an initial evaluation of hybrid-rods reinforcement for concrete members. A hybrid rod consists of an FRP (Fiber-Reinforced-Plastic) skin with a steel core with diameter (3,4,5, and 6) mm. The FRP skin is made of braided glass fiber. Besides protecting the steel core from corrosion, the FRP skin provides a ductile behavior. Hybrid – rods reinforcement behavior effected by changing the inner steel rods ratio. Tensile tests have shown that changing the FRP skin thickness, steel core diameter, and steel core yield strength resulted in various stress-strain behaviors. The stress-strain curves of the hybrid rods were semi- bilinear behavior.

KEY WORDS: Fiber-Reinforced Polymers (FRP) bars; Hybrid FRP (HFRP) bars, Hybrid rod bars, Tensile strength, elastic modulus.

I.INTRODUCTION

Structures reinforced with steel often caused durability problems as steel bars are susceptible to corrosion. The corrosion problems shortened the life span of concrete members. FRP bar reinforced structures are highly durable as the FRP bars, being non-metallic in nature, are corrosion resistant. They offer better resistance to chemical attack and fare better in accelerated environments [1] and [2].The fire resistance of FRP bars is low as the polymer matrix melts soon to lose physical shape and integration [3]. FRP bars have very good tensile strength in the longitudinal direction (direction of orientation of fibers) but are poor in compression and shear. Their tensile behavior is linear till failure without any yielding. Hence beams reinforced with them are not ductile enough.

Certain structures require a certain amount of ductility so that they do not collapse when unexpected magnitudes of forces act on them. This varies from structure to structure and also from place to place. [4]

The idea of combining two different materials to make a single superior composite is not new. Some of the first building materials were composite materials. The ancient Egyptian reinforced their mud bricks with straw to make them stronger. Fiber Reinforced Polymers (FRP) is just the latest version of this very old idea.

Hybridization is a solution to the mentioned problems. Most of the previous researches studied the effect of combining two different materials to enhance the mechanical properties and to reduce the cost. This has been reported in many studies such as Fukuda andChou [5], Chou and Kelly [6],Manders and Bader [7], Bunsell and Harris [8], and Phillips [9]. Minkwan [10] we developed the GFRP hybrid bar with a core of deformed steel bar to enhance the modulus of elasticity and corrosion resistance. It was found that the modulus of elasticity improved by approximaly 54.9% as compared to that of the normal GFRP bar.

II.EXPERIMENTAL TENSILE TESTENGOF FRP

The tensile test of GFRP and hybrid (rod)rebars was done to determine their mechanical properties. The mechanical property is tensile strength, modulus of elasticity and maximum strain. It is not possible to use the traditional tensile test methods for FRP and hybrid-wire materials due to its lower strength and stiffness in transverse direction. A total of 25 samples of reinforcement with 55 cm length were prepared and tested in tension according to ECP 208 as listed Table (1). All specimens were fixed both at the top and the bottomwith steel grip of 500 mm long steel tubes because FRP bars are considerably weakerin compression than tension, and must be gripped in an unconventional manner toperform tensile testing so that the jaws of the testing machine do not crush the specimen(unlike steel which can be

gripped directly. Samples were centered inside the steel tubewith epoxy resin (Kemaboxy 165)already injected inside the steel tubes
and cured for four weeks to obtain a perfect bond between the samples and to preventany slippage during testing. The ends of each sample bar was enclosed with plasticTeflon rings. One strain gauge of 10mm length was attached at the center of thespecimens, all details shown in Fig (1)

Table (1): Required dimensions of the tensile strength test specimens (FRP).

Outer diameter of steel tube (cm)	Minimum length of free length	Free length between the tubes	Total length
2.54	10cm or 40D	15cm	50cm

Fig (1): Tensile test setup.

A) Tension Test Method

The tensile test on the specimens were carried out in accordance with ECP208[11]. The specimen was put into the testing machine.Loading began until the bar was loaded to 20 and 50% of the predicted ultimate load.The testing continued until failure of the bar. The applied load in (KN), elongation in(mm) and the induced strain were recorded by a computer to be used in the evaluationof results. All details are shown in Fig (2).

Fig(2): Tensile test setup.

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B)Tension Stress And Modules Calculation

The tensile strength of the specimen was calculated by dividing the measured maximum applied load by the cross-sectional area of the bar. As well as the elastic modulus of the FRP and hybrid bars was calculated using the following equation as recommended in the ECP 208[16].

$$E_{rode}=\frac{(p_1-p_2)}{(\varepsilon_1-\varepsilon_2)A_{rode}} \qquad (1)$$

where, P_1 and P_2 are the applied loads corresponding to 50% and 25% of the ultimate load, respectively, and $\varepsilon_1$andε_2 are the corresponding strains.

It is obvious that using hybrid reinforcement gives a reasonable value compared with reference (GFRP and Steel) bars. The improvements of tensile strength and elastic modulus for different specimens are shown in Table (2).

III. EXPERIMENTAL RESULTS

During the test the behavior of GFRP and hybrid bars were observed. In GFRP the tensile test specimens failed suddenly due to splitting and rupturing. There was collapse failure (no warning before the failure). The glass Fibers were completely separated from each other within the free length. Stress-strain behavior was linear elastic up to failure. To overcome the problem of sudden failure for GFRP, the hybrid-wire bars were used. It was observed that the yielding of steel reduced the sudden failure and better in the tensile test.

The average values of the ultimate tensile strength, ultimate deformation, the modulus of elasticity of GFRP specimens and FRP hybrid bars specimens are presented in the Table (2) and Figs from (3) to (4). the modulus of elasticity calculated according to Eqs (1).

Table (2): Properties of tested bars.

Specimen type	Specimen Shape	Actualbar diameter (mm)	Ultimate tensile stress (MPa)	Elastic modulus (GPa)	Improvement
Glass	○	10	1048	44	1
3mm rod	◉	10	630	45.8	1.04
4mm rod	◉	10	730	51.4	1.17
5mm rod	◉	10	780	55.7	1.27
6mm rod	◉	10	530	66.2	1.5

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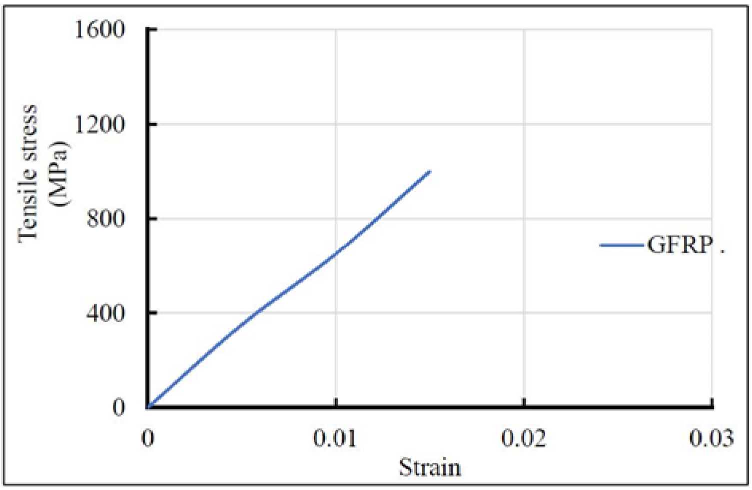

Fig (3): Stress – strain curve for tensile test of 10mm GFRP bars.

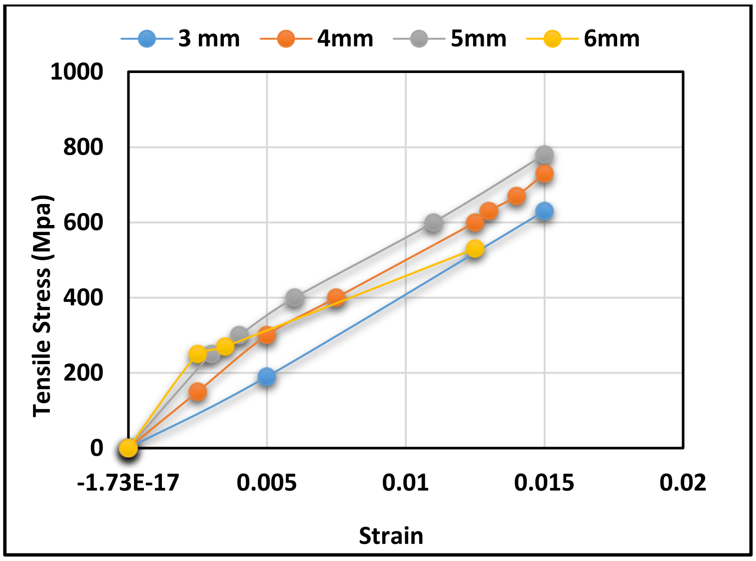

Fig (4): Stress-strain curve for 10 mm hybrid rod bar (3mm,4mm,5mm, and 6mm).

IV.CONCLUSION AND FUTURE WORK

- As a result of tensile tests, the elastic modulus of FRP Hybrid Bars with inserted rods were improved approximately50% compared to the fully GFRP Bars.
- Hybrid -rod bars have a more ductile behavior than GFRP bars which have a brittle characteristic.
- The maximum tensile strength decreases after a certain limit around 50% of the volume fraction.
- Hybrid- rod bars are all effective in increasing the elastic modulus. Most effective case in increasing the module's is rod 6mm.

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