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Tensile Behavior of Hybrid-wires Rebars in Uniaxial Tension

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ABSTRACT : This research studies the tensile test of Hybrid wires bars which are manufactured by using glass fibers and unsaturated polyester resins incorporated with steel wires with different ratios to increase modulus of elasticity and ensure the long-term durability of these bars with low cost and lightweight. The experimental study shows that using the Hybrid rebars with different ratios of smeared steel wires by 25%,50% and 75% leads to obtain a high elasticity coefficient at a low price. where the coefficient of elasticity increases by 190% and avoid the brittle behavior of FRP where The stress- strain behavior of this bar is Simi-ductile as close as to steel bars.

KEY WORDS: Hybrid-wires bars, modulus of elasticity, tensile strength, smeared steel wires and Simi-bilinear.

I.INTRODUCTION.

There are many advantages of using FRP bars as internal reinforcement for engineering structures. The main benefit compared to that of steel reinforcement is its non-corrosive behavior. It is most suitable for highly corrosive environments where structures such as bridge decks or piers are subjected to de-icing salts. In the case when steel reinforcement is used in this type of environment, the material is susceptible to corrosion, causing financial and structural issues relating to maintenance and safety. Other advantages include its low weight to strength ratio, high longitudinal tensile strength (in the direction of the fibers), nonmagnetic properties, making the reinforcement beneficial in the medical field, where magnetic resonance imaging (MRI) equipment is used. The main disadvantage associated with all types of FRP products including reinforcement bars is the brittle behavior up to failure. FRP reinforcement is well known as a non-ductile material and unlike conventional steel reinforced does not yield. As a result of the lack of plastic behavior, it is difficult to bend FRP reinforcement onsite. The bending must be done using professional machinery by the manufacturer. Other disadvantages include the strength of the reinforcement is dominated by the direction of the fibers. The strength is less in the direction perpendicular to the fibers compared to the fiber direction. Also FRP bars have low elastic modulus, causing serviceability problems including larger deflections and excessive cracking in flexural members. Finally, although the initial cost of FRP reinforcement is higher than steel reinforcement, the total life cycle cost of the structure or structural components reinforced with FRP bar is lower, as significantly less maintenance costs are required for structures or structural components reinforced with FRP bars. [1].

II.LITERATURE REVIEW.

As a solution to the mentioned problems FRP bars can be improved by combining with materials that have higher elastic modulus. Many researches published over the past 25 years [2-13] have reflected the possibility of using hybridization in reinforced concrete. Phillips et al [14]. Have performed experiments on the combined composites of carbon/ carbon, glass/glass, aramid/carbon, glass/carbon fibers, and then obtained pseudo-ductile behaviors when small amounts of fibers with low stretch were well-distributed. Bakis et al. [15] also noted that a good pseudo-ductile behavior was obtained for the specimen with well-dispersed carbon fiber. Yujin et al. [16] performed tensile tests on hybrid rods with carbon and glass fibers. Test results revealed that hybrid rods with carbon fiber showed a distinct pseudo-ductile behavior where a number of subsequent stress peak are repeated. Yujin et al [16]. also observed that, for specimens with carbon fiber concentrated in the core, a secondary failure occurred at stress larger than the maximum stress developed at the initial failure. In these cases, there was a problem of increasing the unit price of products [17].

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Korea Institute of Construction Technology (KICT [18]) in Korea is conducting studies on development of Glass-Fiber-Reinforced Polymer (GFRP) Bars that compensates for these shortcomings and the low economic benefits. Material properties with brittleness fracture and low elastic modulus can be improved by combining with cheaper material of steel than carbon or aramid fibers. Increasing elastic modulus by inserting steel as core material into GFRP, hybridized bars can be developed as a substitute of reinforced bars with merits that can strengthen durability in the condition of chloride corrosion such as the environment exposed to the ocean. Three kinds of reinforced bars have currently developed at KICT as follows: 1) those with inserted D9 reinforced bars as core material and externally braided with GFRP; 2) those with inserted D4 steel wires as core material and externally braided with GFRPs; 3) those with uniformly distributed D2 steel wires and FRPs. All three kinds of reinforced bars showed higher elastic modulus than the existing FRP Bars did and also plastic behaviors different from the existing GFRP bars.
Ju M, Lee S, Park C.[19] investigated the tensile properties of the GFRP hybrid bars experimentally. A total of 48 tensile specimens were tested by the uniaxial tensile test in accordance with the ASTM test method (ASTM D 3916 2002). The test specimens had geometrical variables in a cross section consisting of an outer GFRP surface and a deformed steel bar (steel core) In order to compare the enhanced tensile strength of the GFRP hybrid bars with the steel core. It was found that The hybridization of the GFRP and steel core could devote to the higher tensile strength than the steel core and the higher modulus of elasticity than the normal GFRP bar. And the higher modulus of elasticity than GFRP. Young-Jun You and et al. [20] investigated the effect of the hybridization bars on a total of 81 specimens and 13 cases of FRP Hybrid Bars were tested. The study, prototypes of FRP hybrid bars with inserted steel wires were developed and their tensile performance was verified through tensile tests depending on various variables, such as the proportion and diameter of steel. These FRP hybrid bars were designed by dividing into D13 and D16, as an outer diameter, according to the diameter and proportion of inserted wires: GFRPs were combined with steel wires with diameters of 0.5 mm, 1.0 mm, and 2.0 mm and the proportion of 10%, 30%, 50%, and 70%, respectively. As a result of tensile tests, the elastic modulus of FRP hybrid bars with inserted wires were improved comparing to the fully GFRP bars. In addition, the increment in elastic modulus decreased as the diameter of wires increased.
In this paper, useful insights on the tensile behavior of hybrid wires rebars will be discussed to achieve improvement in elastic modulusof fiber reinforced polymer.

III.EXPERIMENTAL WORK

In the following section Detailed description of the specimens, the material properties, test set-up, instrumentation, test steps, and measurements are presented.

A) Samples Preparation for Tension Test:

A total of 20 samples of hybrid wires bars were prepared and tested in tension according to ECP 208[21]. All specimens were fixed both at the top and the bottom with steel grip of 200 mm long steel tubes because FRP bars are considerably weaker in compression than tension, and must be gripped in an unconventional manner to perform 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 tube with epoxy resin (Kemapoxy 165) already injected inside the steel tubes and cured for four weeks to obtain 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 the specimens, all details shown in Fig.1.

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Figure.1 Preparation of test specimens.

B) TENSION TEST METHOD:

The tensile test on the specimens were carried out in accordance with ECP 208[21]. The specimen was put into 100KN capacity testing machine and gripped by the jaws. 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 evaluation of results. The load was measured by the load cell of the test machine, while the slip of bars from tube and elongation for bars were measured using differential transformers LVDTs and strain gauge respectively. A Data Loggers system was used to collect the test data automatically. All details are shown in Fig.2 The tensile test specimens were developed by trial batching in C.R.L. (Concrete Research Laboratory) at Assiut University.


Fig .2 Test setup and fracture for some test specimens.

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IV. TENSION TEST RESULTS

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[21].

$$E_{hybird} = \frac{p_1 - p_2}{(\varepsilon_1 - \varepsilon_2)\, A_{hybird}}$$

where, $\boldsymbol{p_1}$ and $\boldsymbol{p_2}$ are the applied loads corresponding to 25% and 50% of the expectedultimate load respectively, and $\boldsymbol{\varepsilon_1}$ and $\boldsymbol{\varepsilon_2}$are the corresponding measured strains. Table.1 summarizes the results of tensile tests for the tested bars. The stress strain results are tabulated and the curves are drawn, see Table.1 and Fig .3-6. In this table, three average values of ultimate tensile test and strains were calculated and presented. It is obvious that using hybrid reinforcement gives a reasonable value compared with reference (GFRP) bars. The improvements of tensile strength and elastic modulus for different specimens are shown in Table.2.

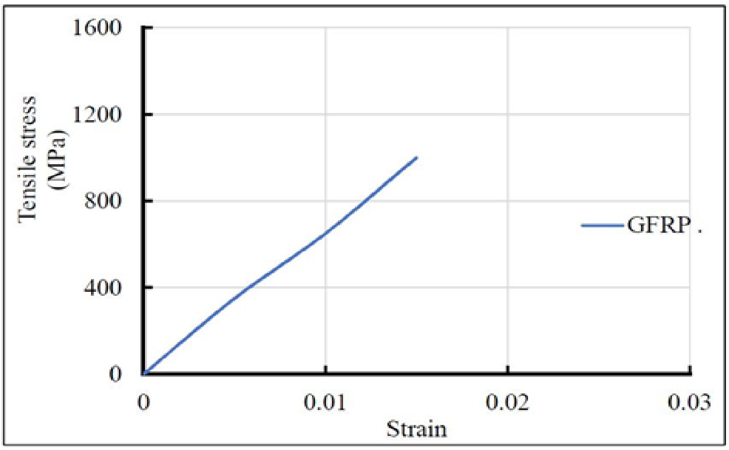

Fig .3 Stress – strain curve of 10mm GFRP bars.

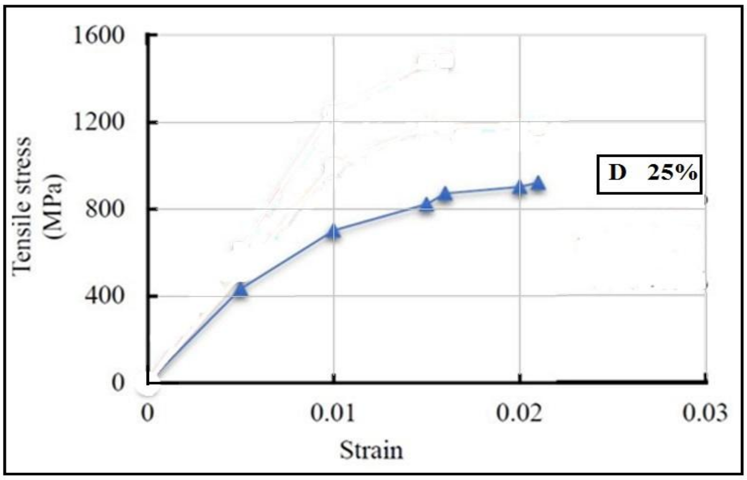

Fig .4Stress-strain curve of 10 mm hybrid wires bars (25 % wires).

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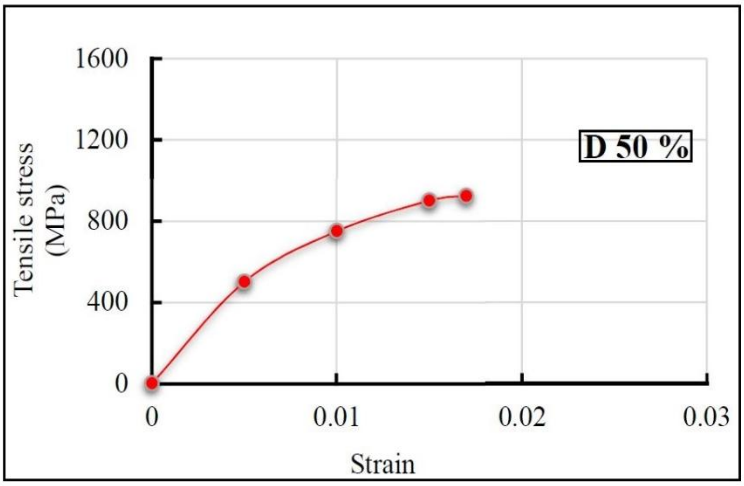

Fig .5Stress-strain curve of 10 mm hybrid wires bars (50 % wires).

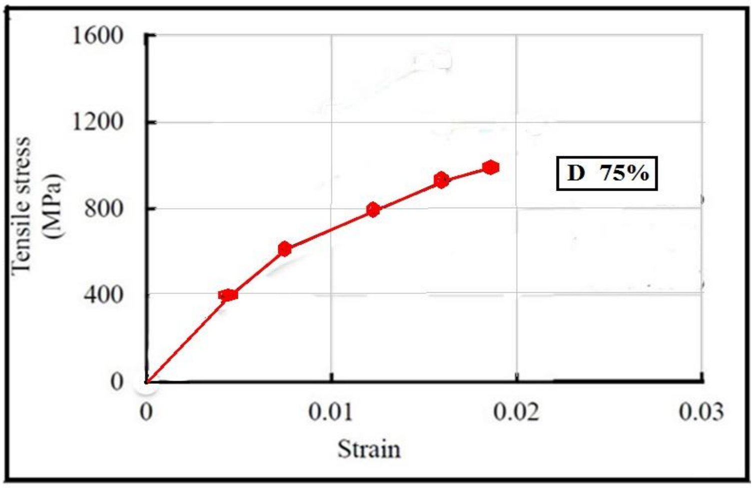

Fig .6 Stress-strain curve of 10 mm hybrid wires bars (75 % wires).

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Table .1 Results of tensile tests for three average values of specimens

Specimen type	Nominal Diameter, (mm)	Nominal Area, (mm²)	Average Tensile Strength, (Mpa)	Tensile modulus of elasticity, (Gpa)
GFRP	10	78.5	1048	44
Hybrid (25%S75%G)	10	78.5	920	65.7
Hybrid (50%S50%G)	10	78.5	923	72
Hybrid (75%S25%G)	10	78.5	1030	128

Table .2 Mechanical properties of the GFRP/Hybrid bars.

Reinforcement Type	Average (ultimate Tensile strength) (Mpa)	Improvements of strength (%)With respect to GFRP	Elastic modulus (Gpa)	Improvements Of Elastic modulus (%)With respect to GFRP
GFRP	1048	1	44	1
Hybrid (S25%, G75%)	920	0.87	65.7	1.49
Hybrid (S50%, G50%)	923	0.88	72	1.64
Hybrid (S75%, G25%)	1030	0.98	128	2.9

VI. CONCLUSION

- Tensile strength of the hybrid-wire bar used in the present study is slightly lower than GFRP bars.
- The hybrid bars consisting of the GFRP and steel wires,were found to improve the elastic modulus compared to GFRP bars without hybridization by approximately 190%.
- The relationship of load and strain Simi-bilinear due to the effect of the ratio of steel in hybrid hybrid-wire.
- The hybrid wires bars can be used instead of FRP bars or steel bars to overcome the low modulus of elasticity of FRP bars and avoid the corrosion problems of steel and increase the service life of buildings.
- The use of kemaboxy 165 and treatment for one month gave clear results and alsoreduced of probability of slipping during the test.

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