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Behavior of Beams Reinforced by Steel and GFRP Bars

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ملخص البحث:

تستخدم ألياف الزجاج بشكل متزايد في صناعة المنشأت, نتيجة مزاياها مثل مقاومة التأكل والمقاومة العالية ومقاومة الأجهاد وخفيفة الوزن, الخ. هذا البحث يقدم دراسة معمعلية تهدف الى دراسة مقاومة الأحمال المؤثرة باستخدام أنواع مختلفة من التسليح كأسياخ الزجاج و أسياخ الحديد.عدد العينات ثلاث كمرات خرسانية مسلحة بأبعاد 150 مم عرض و 300 مم عمق و 1800 مم طول. البرنامج العملي يتكون من ثلاث عينات, أول عينة مسلحة بثلاث أسياخ حديد, وثاني عينة مسلحة بسيخ حديد و سيخين زجاج, و ثالث عينة مسلحة بثلالث أسياخ زجاج. يتم تقيم أداء الكمرات المختبرة على أساس نمط الأنيهار, الشرخ الأول, حمل الأنهيار, الممطولية, الصلابة, معامل التمزق. أظهرت النتائج أن زيادة أسياخ الجلاس تؤدي الى ضعف مقاومة الاحمال المؤثرة, وهذا نتيجة استخدام أسياخ الجلاس مع مقاومة شد قليله و ضعف مقاومة التماسك بين أسياخ الجلاس و الخرسانة.

Abstract:

Glass fiber reinforced polymers (GFRP) are increasingly used in the construction industry, due to its advantages as corrosion resistance, high strength, fatigue resistance, lightweight, etc. This paper presents an experimental study aimed to acts loads resistance by different types of reinforcement as GFRP bars and steel bars. A total of three reinforced concrete beams with 150 mm width, 300 mm depth, and 1800 mm span length. Experimental program Consists of three specimens, the first specimen reinforced by three bars of steel, the second specimen reinforced by one steel bar and two GFRP bars, the third specimen reinforced by three GFRP bars. The performance of the tested beam specimens is evaluated based on the crack pattern, first crack, failure load, ductility, modulus of rupture, and toughness. The results show that increasing for GFRP bars reinforcement leads to reduced of the load's resistance, this due to using GFRP bars with reduced tensile strength and weak for bond strength between GFRP bars and concrete.

Keywords: Beams, GFRP, First Crack, Failure Load, Ductility, Modulus of Rupture, and Toughness.

1. Introduction:

Glass fibers are commonly used because there is more experience with them and because they are relatively less expensive than the other fibers. Glass fibers are characterized by their resistance to wear and corrosion, a good conductor of electricity, low tensile modulus, high strength and high insulting properties, however they are defective by their high creep as well as its higher density compared to other types of fibers and they are affected by alkaline solutions: HE Xiongjun1 and YANG Jingnan1 **[1]**. For **Amr El-Nemr [2]** studied evaluation of the flexural strength and serviceability of concrete beams reinforced with different types of GFRP bars, The difference in surface profile of the GFRP bars in beams with the same EfAf does not significantly affect load-carrying capacity and deflection, but affects the crack widths and strains. The better bond performance for the tested beams which sand-coated GFRP bars, in contrast, the helically-grooved GFRP bars because of the uniform surface. For **G.B. Maranan [3]** studied evaluation of the flexural strength and serviceability of geo polymer concrete beams reinforced with glass-fiber-reinforced polymer (GFRP) bars under a four-point static bending test, improvement the serviceability performance for beams when increasing the reinforcement ratio, contrast to bar diameter no had the effect on the flexural performance of the beams. For **M. Reza Esfahani [4]** investigated that the Bond Strength of Lap-Spliced GFRP Bars in Concrete Beams, The experimental results show that concrete compressive strength does not significantly influence the bond strength of GFRP bars in spliced beams. The bond strength of GFRP bars decreases with increase in the bar diameter. For **Maher A. Adam [5]** studied analytical and experimental flexural behavior of concrete beams reinforced with glass fiber reinforced polymers bars. The load-deflection curves for all GFRP reinforced beams have two parts, crack behavior of the first part was un-cracked beams and crack behavior of the second part was crack beams with reduced stiffness. The ultimate capacity increased from 84.6 KN to 132.7 KN, at increasing the reinforcement ratio from 0.33 % to 0.54 %, and the ultimate capacity increased from 132.7 KN to 145.1 KN, at increasing the reinforcement ratio from 0.54 % to 0.92 %.

2. Experimental Program

A mix was designed to get a target cubic compressive strength of 45 MPa. Therefore, tests to determine the properties of these materials and the results of materials were carried out according to the Egyptian standard specifications ECP 201-2012 **[6].** The Details of beams for beams are demonstrated in the table (1). The dimensions and details of tested specimens are as shown in the figure (1). The used dolomite had a nominal maximum size of 10 mm. Ordinary Portland cement (OPC) was used for all beam specimens. The beams are loaded using two-point loads at the mid-span shown in figure (2). Properties for reinforcement bars shown in the table (2).

Table (1): Tested Specimens Details

Specimen Name	Type of Main Rein. Bars	Dimension (mm)	Comp. Steel	Vertical Stirrups
Steel	3Ø10 S	150×300	2 Ø 10	9 Ø 6/m
1S-2G	1Ø10S+2Ø10G	150 × 300	2 Ø 10	9 Ø 6/m
GFRP	3Ø10 G	150 × 300	2 Ø 10	9 Ø 6/m

Table (2): Reinforcement bars Properties

Bars	Area (mm^2)	Elastic Tensile Modulus (GPa)	Ultimate Strength (MPa)	Tensile Strain (%)
Steel	**78**	**216**	**655**	**0.29**
GFRP	**78**	**41**	**570**	**1.23**

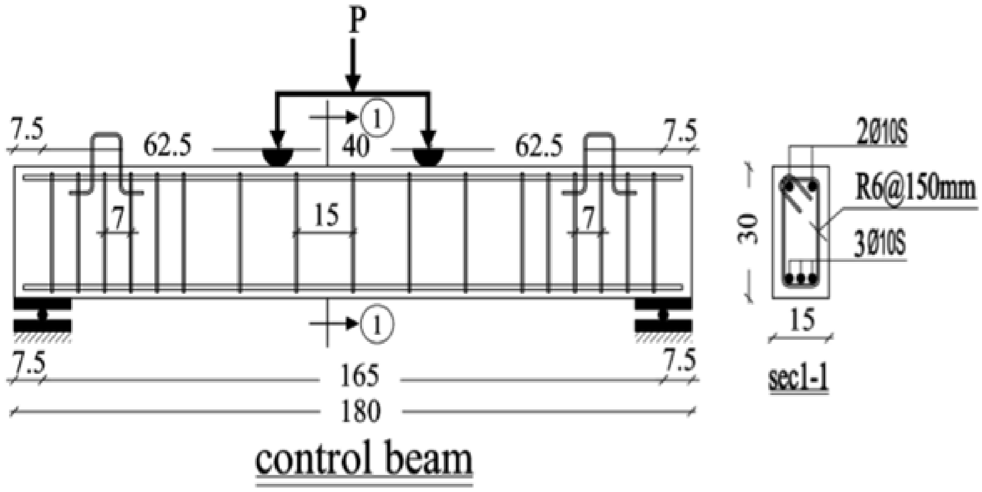

Figure (1): Concrete Dimension and RFT Details of Specimens.

Figure (2): Beam under Two Point Concentreted Load.

3. Experimental Results:

3.1 Crack Pattern:

Reinforcement beams with GFRP bars have a smaller number of tension cracks that extended from the centerline of the beam compare with the beam reinforced by steel bars (control) and cracks appeared with wider width, this is maybe due to using GFRP bars with reduced tensile strength and weak for bond strength between GFRP bars and concrete. The failure of GFRP beam was in flexure by increasing the cracks width under area of the applied concentrated load. Crack pattern shown in figure (3).

Figure (3): Crack Pattern for Tested Beams

3.2 Cracking load and Failure Load:

From figure (4), it should be observed that a decrease in the cracking load for all reinforcement beams with GFRP bars ratio compared with the steel beam. That means the crack faster in appearance with GFRP bars at the bottom of the beam because the steel bars carry higher tension stresses than the GFRP bars in the flexural zone. The failure of GFRP beam was in flexure by increasing the cracks width under area of the applied concentrated load was found that the steel beam has the ultimate load higher by 46.5 % and 33.8 than the ultimate load for the GFRP beam and (1S-2F) beam, respectively.

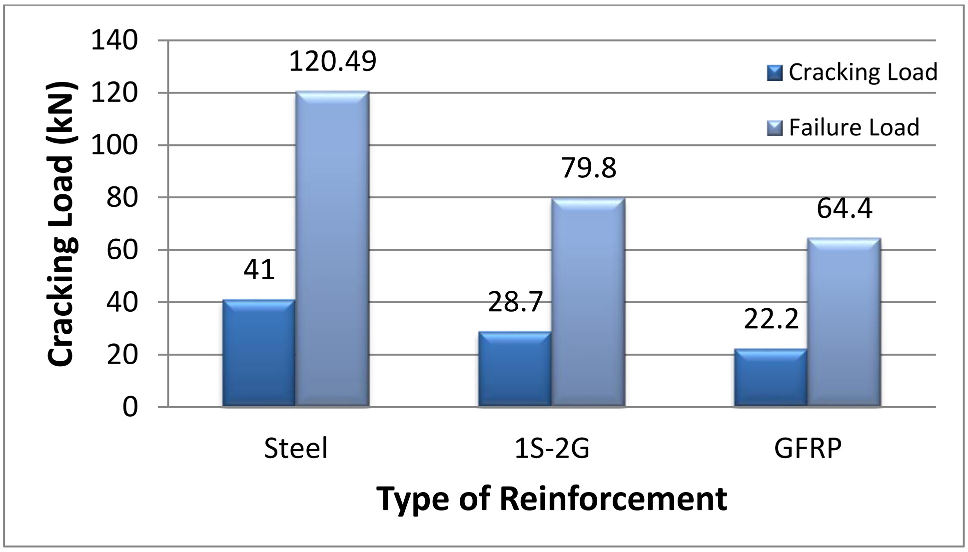

Figure (4): Effect of GFRP bars on the Cracking load and Failure Load.

3.3 Ductility, Modulus of Rupture, and Toughness

Ductility is evaluated as the ratio of maximum displacement to yield displacement (Δ_{max} / Δ_y), M. Reza Esfahani [7]. Toughness is defined as the slope of the load-deflection curve at the beginning of the test at values before the cracks initiation. Modulus of rupture is evaluated as the ratio of ($3Pl / 2bd^2$). From figure (5), figure (6), and figure (7) show effect increasing the ratio of GFRP bars on ductility index, toughness, and modulus of rupture.

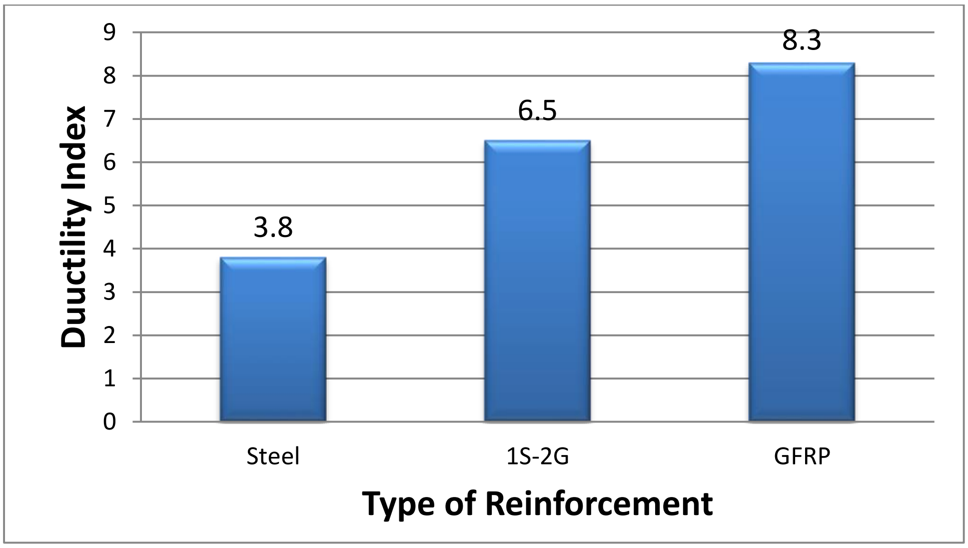

Figure (5): Ductility Index for Tested Specimens

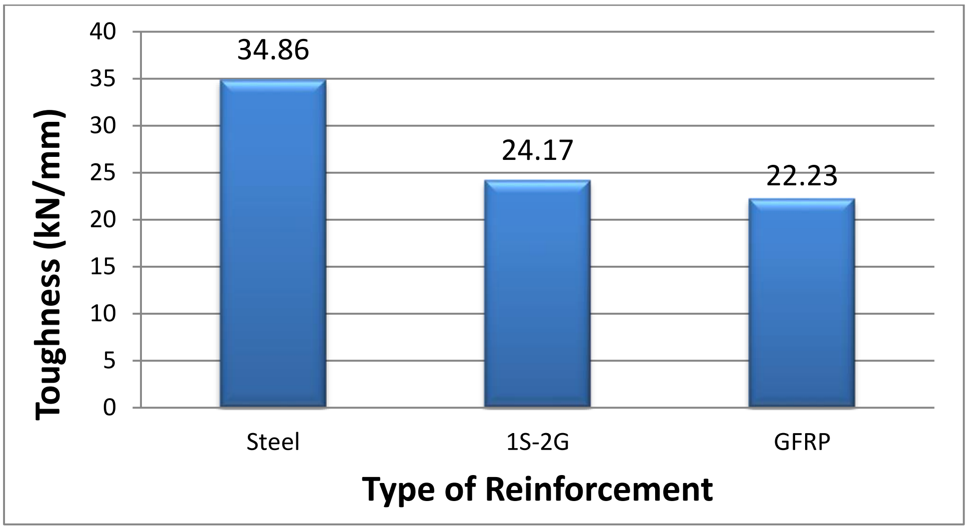

Figure (6): Toughness for Tested Specimens

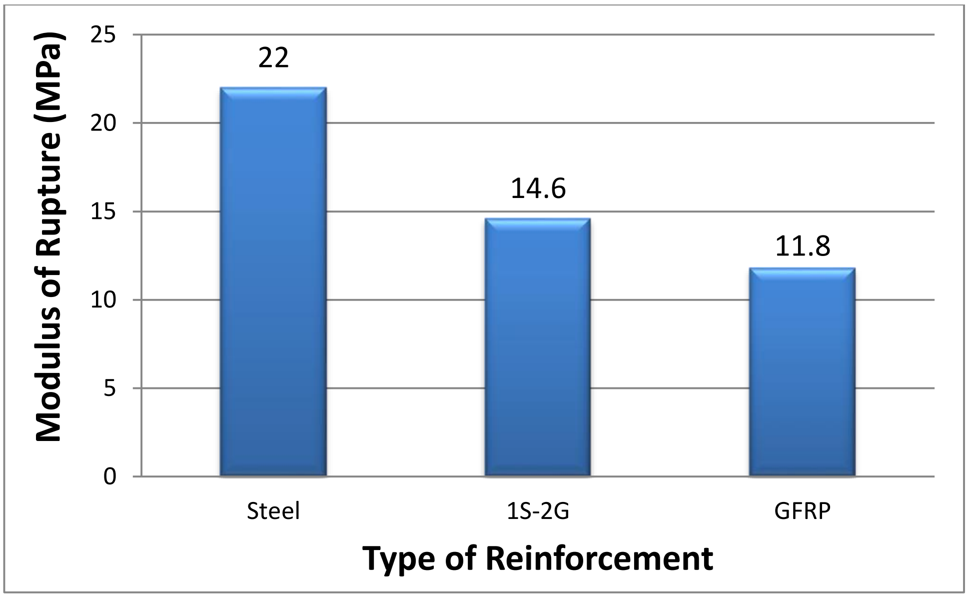

Figure (7): Modulus of Rupture for Tested Specimens

4. Conclusions:

1. The failure load for the tested beams reinforced by GFRP bars was much lower than the load carrying capacity of beams reinforced by steel bars, this is due to the tensile strength of steel bars which was higher than GFRP bars.
2. The beams reinforced by GFRP bars, it reaches in the case of GFRP, (1S-2F) beams to 53.45%, 66.23% of the steel beam failure load, respectively.
3. The highest ductility index occurred for the beam reinforced by GFRP bars, which represents 275% of the ductility index of the beam reinforced by steel bars.
4. Deformation of the reinforcement of concrete beams with GFRP bars reinforcement was considerably higher than the beam with steel reinforcement.
5. Due to the relatively lower elasticity modulus of GFRP bars compared to steel bars, both: the deflection and width of cracks can be a major factor in the designing the GFRP reinforced concrete beams.

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