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A STUDY ON REPLACEMENT OF STEEL REBARS BY GFRP REBARS IN THE CONCRETE STRUCTURES

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ABSTRACT

Glass fiber reinforced polymer (GFRP) has been confirmed to be the solution as a major development in strengthened concrete technology. Synthesis of GFRP rebars by using the longitudinal glass fibers (reinforcement material) and unsaturated polyester resin with 1% MEKP (matrix material) via manual process. GFRP rebars have diameter 12.5 mm (this value is equivalent to 0.5 inch; it's most common in foundations application). GFRP surfaces are modified by the inclusion of coarse sand to increase the bond strength of rebars with concrete. Then, the mechanical characterizations of rein- forced concrete with GFRP rebars are performed and compared with that of steel rebars. Preparation of concrete samples (unreinforced concrete, smooth GFRP reinforced concrete, sand coated GFRP rein- forced concrete and steel reinforced concrete) with fixed ratio of ingredients (1:1.5:3) and 0.5 W/C ratio were performed at two curing ages (7 and 28) days in ambient temperature. The value of volume fraction of GFRP and steel rebars in the reinforced concrete was (5 vol. %) equally distributed with specified distances in the mold. The results show the tensile strength of GFRP rebar is 593 MPa and bend strength is 760 MPa. The compressive strength was within reasonable range of concrete is 25.67 MPa. The flexural strength of unreinforced concrete is 3 MPa and reinforced concrete with GFRP rebar, especially sand coated GFRP RC exhibit flexural strength is 13.5 MPa as a result to increase bonding with concrete and higher strain is 10.5 MPa at 28 days than that of steel reinforced concrete at the expense of flexural modulus.

I INTRODUCTION

The traditional strengthened concrete members such as beams are composed of concrete included Portland cement and steel rebars reinforcement. The function of concrete in these beams is the resistance to compressive loads. The tensile and shear loads will be resisted by steel rebars embedded in the concrete. Such structure is efficient where the concrete inseparable resistance to compressive loads, while the steel en- hances tensile and partially shear strengths. However, the problem of corrosion associated with the steel re- bars reduced its live time and the solutions such as the coating of the steel rebars are costly. Recent technologies have resulted in alternative reinforcing materials such as GFRP materials commercially available in the form of bars or sheets that can be bonded in concrete members to fulfill several desired properties. The most important is that the corrosion resistance feature of the polymer and the elongated strain to failure that give enough time to alert before failure takes place. Experimental researches on some of concrete structures reinforced with GFRP bars were done (5e8) years ago. The results have shown that GFRP rebars weren't subject to any degradation process in existence of the alkaline and corrosive environment. The tensile and shear strengths of GFRP bars by using four various diameters (20, 22, 25, 28 mm) have been discussed by authors. The young's modulus of GFRP bars was equal (1e5) of young's modulus of steel. The GFRP bars exhibited brittle behavior and the relationship between stress and strain was linearly elastic up to failure. The GFRP bars were anisotropic and they were characterized by high tensile strength only in the direction of the reinforcing fibers. The cross section dimensions didn't affect the GFRP bar modulus. Variation of the shear strength of all GFRP bars diameters was little, but the higher load caused failure. The ranges of GFRP bars shear strength were 16%e20% lower than the longitudinal tensile strength Reinforced concrete beams with the Glass Fiber Reinforced Polymer (GFRP) as an alternative of traditional rebar and behavior of beam under bending were also studied. The results concluded that use of GFRP rebar in tensile loads direction of beam have displayed flexural properties similar to the steel rebar and GFRP reinforced concrete has offered high bending properties, besides acceptable shear properties

Other authors presented a properties of reinforcing bars (steel and GFRP) in the concrete beams were used. The GFRP surface finish was different (sand coating and helically grooved surface). The concrete beams were normal and high strength reinforced with steel and GFRP rebars. Steel reinforced concrete beam represents the reference sample. Bending test variables were type and reinforcement ratio, surface finish and rebar diameter. The results of the test showed that the cracks width in concrete was affected by the diameter of the reinforcement and the surface finish while the deflection was not affected by these parameters. All GFRP reinforced beams showed linear relation be-tween stress and strain until failure. Normal strength concrete beams reinforced with GFRP have low strains compared with high strength concrete at the same level

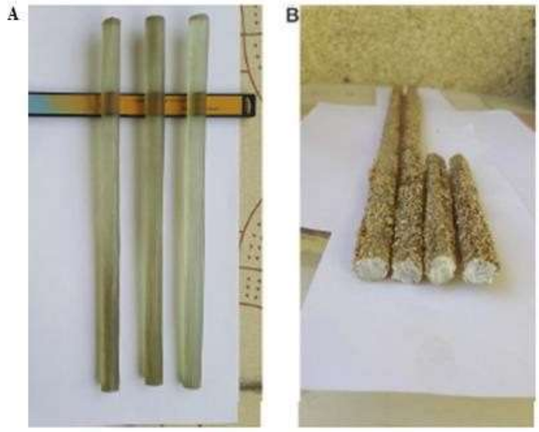

Fig. 2. GFRP specimens. (A) GFRP only, (B) Sand coated GFRP.

The hybrid reinforcement (steel and GFRP) was discussed by authors for ultra-high performance fiber-reinforced concrete to improve the ductility and elas-ticity of FRP reinforced concrete. Bending test for high strength fiber-reinforced concrete reinforced with GFRP rebars (3 beams) and ultra- high performance fiber-reinforced concrete reinforced with steel (4 beams) at different reinforcement ratios was per-formed. Due to the strain hardening, all samples showed high stiffness after initial cracking. Increased GFRP ratio improved performance under bending test (ductility and stiffness). The hybrid reinforcement was by replacing part of the GFRP with steel rebars to improve stiffness before steel yielding which leads to less deformability

OBJECTIVE OF THE STUDY

Glass fiber reinforced polymer (GFRP) was used as an alternative material to the steel rebar. It is light- weight, no-corrosion, superior tensile strength, and high mechanical performance. Installation of the GFRP rebar is similar to steel rebar, but with less handling, transporting and storage problems. In this work, the unsaturated polyester resin and E-glassfibers are used to synthesis GFRP rebars of
1.25 cm diameter to simulate the dimensions of steel rebars. Their sur-faces are modified by the inclusion of coarse sand to avoid slipping in stress conditions. Then, the mechanical characterizations of reinforced concrete with GFRP rebars are applied and compared with that of steel rebars.

II. LITERATURE REVIEW

Georgiannou, V.N., made an examination on the direct of clayey sands under monotonic and cyclic stacking. He contemplated that the fines substance impacts the weight strain response of the soil mass. As the fines substance constructs, the dilatant lead of the soils is smothered, and the response a little bit at a time ends up obliged by the fine structure at about
% 40 fines substance.

Georgiannou, Burland& Hight played out an exploratory examination about stressstrain direct of anisotropically consolidated clayey sands using PC controlled triaxial cells. The models were set up by sedimenting Ham River sand into a kaolin suspension. They watched the effects of assortments in earth substance and basic granular void extent. They assumed that this technique makes a material which is exceptionally less relentless, which has a higher granular void extent and showcases a higher undrained shortcoming conduct, which is the structure trademark like bendable lead and it is constrained by weight history, formative history, microstructure, rate of shearing and structure and surface of muds, at whatever point differentiated and a comparative sand that is sedimented through clean water (for instance contains no soil). Moreover they exhibited that a sand that has 30 % earth parcel the usually joined material is no longer dilatant and demonstrates the response that would be ordinary in a sedimented mud. They similarly communicated that for mud divisions up to 20 %, the mud does notby and large lessening the purpose of shearing resistance of the granular fragment.

Georgiannou, Burland& Hight have depicted the undrained direct of ordinary clayey sand from the site of the Gulfoks C oil age organize in the North Sea. The lead of a model soil surrounded from Ham River sand and kaolin was viewed. This model soil was picked to demonstrate for the most part closer response of the earth at the field. These reconstituted models have been presented to Ko cementing and undrained shear in the triaxial weight test under movement control. They assumed that undrained delicacy in weight increases as the soil substance increases from 4.5 % to 11.5 %, anyway reduces as the overconsolidation extent, OCR, increases. They furthermore shown that the clayey sand accomplishes its apex check at minimal crucial strains: a ε in weight increases from 0.1 % to 0.3 % as OCR increases from 1 to 2.

Pitman, Robertson and Sego, have finished an examination to look into the effect of fines and degree on the lead of around orchestrated sand tests. Free sand tests, formed by wet pressing and hardened to the identical convincing sentiment of nervousness, were set up with fluctuating rates of both plastic and nonplastic fines. Tests were isotropically consolidated and presented to monotonic undrained triaxial weight. They communicated that undrained shortcoming decreased as the fines content, for both plastic and nonplastic type, extended. They furthermore construed that the undrained delicacy may not be compelled by the adaptability of the fines anyway more by the proportion of fines (< 0.074 mm.) on the shear quality and compressibility properties of the soil mixes were investigated.

III MATERIALS

The Materials used in this research and their characteristics are: Glass fibers in the form of a mat “JIASHAN FIBERGLASS WEAVING FACTORY
ZHEJIANG, China” Weighing 600 gym2 and a length of 1250 mm.
The fibers are pulled from the mat and utilized to synthesis rebars. It is found that 86 fibers and the added resin are required to produce a rebar of 1.25 cm diameter. Unsaturated polyester resin “FAR- APOL Company, Iran” and Hardener (Methyl ethyl ketone peroxide) “akpakimya company, Turkey”. Or-dinary Portland cement manufactured by (Mass- Bazian) was used, conformed to the Iraqi standard . Al-Ukhaydir natural sand as fine aggregate and the gradation and selected chemical and physical properties were within limits of the Iraqi standard. Gravel of (5e19 mm) gradation was utilized as a coarse aggregate from north of Baghdad (Al- Nabaai) and the sieve analysis, specific gravity, density and sulfate contents are within Iraqi standard No.45/1984. Tap water was used.

GFRP rebar

Synthesis of GFRP rebar from glass fibers and un- saturated polyester resin was produced by immersing
the fibers longitudinally in the unsaturated polyester resin with (1%) of its hardener and then the excess polymer is removed. That was without the utilization of a mold, because in case of using a mold, the matrix will fail before fibers resistance when subjected to the forces of tension. Several efforts were made to fulfill the required diameter of bar byusing different number of fibers and measuring diameter every time

Mixing method

The used mixing proportion was (1:1.5:3). The dry materials (cement and sand) were thoroughly mixed per ASTMC-192 in a pan and then the gravel was combined and mixed with the entire batch by shovel until the gravel is uniformly distributed throughout the batch. Then the water was poured and blended with the dry materials for specific duration until the concrete is homogenous in appearance and has the desired consistency. The mixing process was paused and then returned for a few minutes and the open end or top of the pan was covered to prevent evaporation during the rest period. This step was repeated in two cycles to insure the homogeneity for mixture. The total mixing time was about 15 min

Molds used

Wooden mold for compressive strength and flexural strength was used throughout this investigation. Cubic shapes (edge length of 100 mm) of molds were used to prepare specimens for compressive strength and prismatic specimens of 100 100 400 mm for flexural strength. The molds were softly coated with Vaseline oil before use, per ASTMC- 192 concrete casting was per-formed in different layers, each layer of 50 mm.

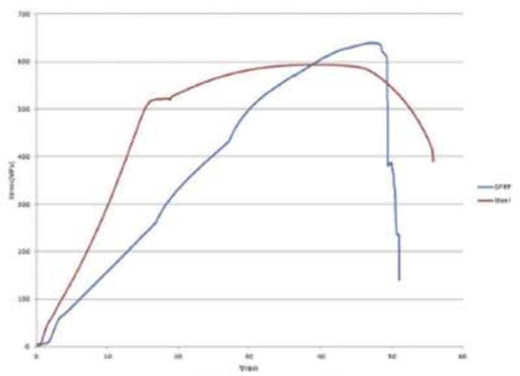

Fig. 4. Tensile curves of rebars.

The effective curing in first ages is essential for thegain of durability, strength and stability of volume The basic conditions that must be supplied tocontinue a reaction is the appropriate temperature,and adequate moisture. The green concrete containsenough water to complete the hydration process ofcement, but in most conditions a large quantity ofwater is evaporated by heat. Moisture curing methodwas utilized to compensate for the

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water thatevaporates during the casting process

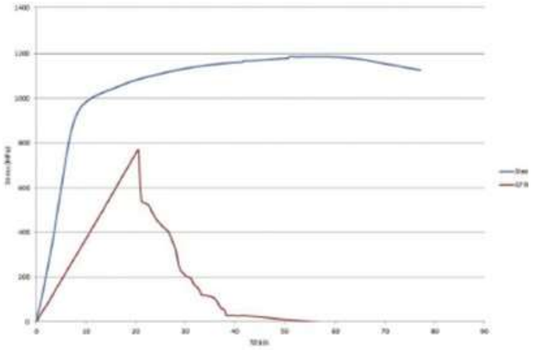

Fig. 5. Bending curves of GFRP and steel.

IV RESULTS AND DISCUSSION

Characterization of rebarTensile strength

The tensile strength was measured according to ASTM D7205-06 for GFRP rebar and ASTMA496- 02 for steel rebars using specimen of 25 ± 5 cm length, 1.25 cm diameter The concrete will be

bonded with reinforcing bars, so that the extra tensile stresses, which can’t be resisted by concrete, will be transported to the reinforcing bars therefore, the rebars must have a relatively high tensile strength. Tensile measurement results are offered

The curves have shown that GFRP has higher yield strength than traditional steel rebar due to unique anisotropic property of composites makes them strong in tension. The yield strain of GFRP is higher than steel rebar; this will give the engineer premature warning of the failure Table.

Bending strength

Bending strength is measured per ASTM D790 for GFRP and steel rebar using specimen of 25± 5 cm length, 1.25 cm diameter. This measurement is performed to determine an approximate values of the bending (strength and strain) of a bare GFRP rein-forcing bar and it’s compared with bare steel rein-forcing bar.

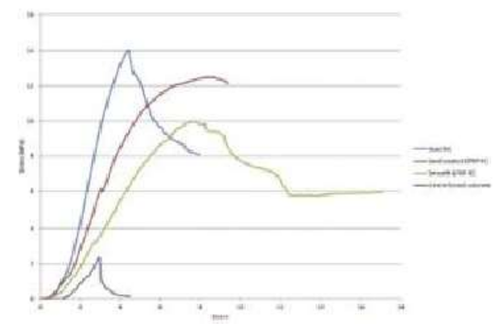

Fig. 6. Flexural curves of unreinforced and reinforced concrete at 7 curing age.

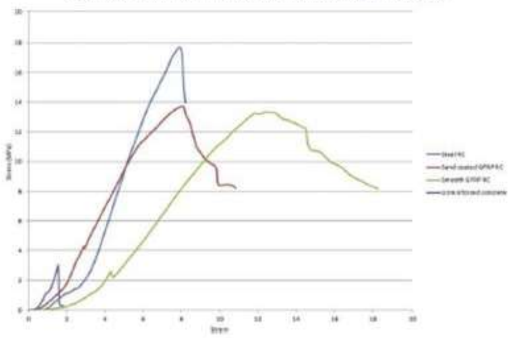

Fig. 7. Flexural curves of unreinforced and reinforced concrete at 28 curing age.

higher than that the steel rebar, while yield strain ofGFRP is higher than steel about58%.
Bend strength of bare GFRP bar is good; where yield strength of GFRP rebar achieved 72% of steel rebar strength while yield strain of GFRP is higher than steel about 20%.
Compressive strength of unreinforced concrete is
25.67 MPa; this value is acceptable according to British Standard specification.
Flexural strength is good of sand coated GFRP RC at all curing ages. Increase of smooth GFRP RC flexural strength was about 76e81% and sand coated GFRP RC about 78e83% as compared with unreinforced concrete strength. However, strength of smooth GFRP achieved 71e75%, while sand coated strength achieved 77e82% of steel RC flexural strength. Decrease of flexural modulus of smooth GFRP RC around 66% and sand coated GFRP RC around 33% compared with steel RC. The flexural strain of Smooth GFRP RC is increased around 44% and sand coated GFRP around 14% as compared with steel RC at 28 day curing age.

V. CONCLUSIONS

From this work, the following conclusions are withdrawn:
In general: GFRP reinforcing bar has higher tensile strength and higher corrosion resistance than steel rebar in addition, moderate flexural strength, these properties make GFRP is good alternative of steel in foundations application
According to the results, the mechanicalcharacteristics can be concluded as the following: Tensile strength of bare GFRP bar is high, becausethey are anisotropic composite mate-rials, GFRPrebar achieved yield tensile strength about 13%

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GFRP rebars shows more deflection before starting to fail. This can give more chance to be alerted before failure takes place

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