IJITKM 0973-4414
International Journal of IT & Knowledge Management (ISSN: 0973-4414)
Volume 12 • Issue 2 pp. 195-198 Jan 2019 - June 2019 www.csjournals.com

Concrete Structures Reinforced with Fiber Reinforcement Polymer Bar

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Abstract: Fiber Reinforcement Polymer (FRP) bars are wide utilized in engineering science used as a substitute for steel reinforcement as a result of its several benefits like high strength-to-weight quantitative relation, magnetic attraction neutrality, lightweight weight, simple handling and no corrosion. Moreover, the productive technology becomes a lot of and a lot of mature and industrial so FRP has become one economic and competitive structure material. Supported the recent researches, this paper principally introduces progress within the studies on concrete structures strengthened with FRP bars. These contents during this paper include the bond performance of FRP bars in concrete, Compression Behavior, flexural behavior, and plasticity of concrete structure strengthened with FRP bars within the past few years within the world.
Key words: FRP Bars; Concrete Structure; Bond Performance; Pullout Behavior; Compression Behavior and Flexural Behavior.

1. INTRODUCTION

Infrastructure decay thanks to corrosion of embedded reinforcing steel stands out as a big challenge worldwide [1]. the employment of FRP bars as reinforcement for concrete components looks to be a good resolution for overcoming sturdiness issues of ancient steel concrete structures thanks to the corrosion of gold-bearing bars. For this reason, the replacement of steel with FRP bars is gaining quality worldwide [2]. it's several blessings like high strength-to-eight magnitude relation, magnetic force neutrality, light weight, simple handling, no corrosion, low weight to strength magnitude relation (1/5 to 1/4 times of the density of steel), high longitudinal enduringness, and non-magnetic characteristics. though the initial value of FRP reinforcement is on top of steel reinforcement, the overall life cycle value of the structure or structural elements bolstered with FRP is lower, as considerably less maintenance prices area unit needed for structures or structural elements bolstered with FRP [3]. the applying of FRP bars in engineering is divided into 2 categories. One is to substitute steel bars in concrete structures, and also the alternative one is to keep up and strengthen previous structures. within the past few years, with the event of FRP material technique, a lot of and a lot of scholar began to specialize in the applying analysis work on FRP. This paper chiefly introduces progress within the studies on concrete structures bolstered with FRP bars. These contents during this paper embrace the bond performance of FRP bars in concrete, shear resistance, flexural behavior, compressive behaviour and plasticity of concrete structure bolstered with FRP bars within the past few years within the world.

Bond strength and its factors: The mechanics of bond stress transfer between FRP reinforcement and concrete has been investigated extensively. Bond stress is that the cut stress whose direction is parallel to the interface plane of FRP bars and concrete. The bond of associate degree embedded bar, despite material, resists pull-out via 3 main mechanisms. the primary is chemical adhesion between the 2 materials at their interface. The second is that the friction bond that is because of coarseness within the surface of the bar. The first is chemical adhesion between the 2 materials at their interface. The second is that the friction bond that is thanks to coarseness within the surface of the bar. The third mechanism conducive towards the bond is mechanical bearing, like that generated from the lugs on reinforcing bars upon the encompassing concrete [4]. Based on the studies on concrete bolstered with FRP bars, the factors that influence the bond strength is divided to many categories below:

The bond performance of FRP bars in concrete that is that the basic mechanical behavior, is that the main issue of the mechanical performance, failure mode, serviceableness, crack breadth, deformation and structure analyses and style.

2. PULLOUT BEHAVIOR OF FRP BAR WITH DIFFERENT STRENGTH OF CONCRETE

The bond performance of eighty eight concrete pull-out specimens ready per ACI 440.3R-04 and CSA S806-02 standards with FRP bars were investigated by Baena et. al. [5]. Rebars (reinforcing bars) manufactured from carbon-fibre and glass-fibre bolstered chemical compound (CFRP and GFRP), additionally as steel rebars, with a continuing embedment length of 5 times the rebar diameter were used. The influence of the rebar surface, rebar diameter and concrete strength on the bond–slip curves obtained is analyzed. Hence, a mean bond stress is outlined? = P/ ? sound unit pound wherever P is that the tensile load, sound unit is that the rebar diameter, and pound is that the embedment length. In his experiment, totally different strength of concrete was adopted. The experimental results ensure the tendency of rebars with larger diameters to possess lower bond strength, particularly within the case of upper strength concrete (M60). Pull-out take a look at of normal-strength concrete and high-strength concrete were performed by Chaallal and Benmokrane [6]. The experimental bond strength results from retreat tests performed on GFRP rods embedded in NSC (Normal strength concrete) varied from eleven.1 to 15.1 MPa with associate overall average of one2.9 MPa. For the sake of comparison, retreat tests were performed on typical distorted steel rebars victimization identical NSC overall average of eighteen MPa. GFP rod bond strengths related to HSC (high strength concrete)varied from 8.4 to 15.8 MPa, with an overall average of 12.1 MPa. For the sake of comparison, pullout tests were performed on conventional deformed steel rebars using the same HSC overall average of 30 MPa (which is 62% to 84% of that of steel deformed bars). Veljkovic et. al. [7] found in his experiment that the Ribbed GFRP bars develop bond strength differently according to concrete mechanical properties. Concretes with average compressive strength in range 25-40 MPa do not influence strongly the bond strength, while within range of 40-65 MPa, bond strength is enhancing significantly.

Highest concrete strength delays onset of cracking in low covers, but allows smoother and faster crack advancement. Veljkovic et. al. [7] also uses DIC (Digital Image Correlation) technique for recording and evaluating of strain field of the specimens. Results shows that the both types of GFRP bars presented comparable, but still, in average, lower bond strength compared to steel ones under the same experimental conditions however the employment of skinny concrete cowl (10 millimeter during this case) together with ribbed GFRP bars earned similar bond strength as steel bars and showed the important advantage of use of this GFRP bars rather than commonplace steel ones. Golafshani et al. [8] did in depth analysis on bond behavior of steel and GFRP bars in traditional concrete (NC) and self-compacting concrete (SCC) of 104 fallback specimens. The results unconcealed that the bond behavior of GFRP bars in SCC shows higher results as compared to the GFRP bars utilized in North Carolina. this can be thanks to the superior filling capability of SCC compared to North Carolina. However, the bond strength variations of steel bars square measure but that of GFRP bars.

3. FLEXURAL BEHAVIOR OF REINFORCED CONCRETE BEAMS WITH FRP BARS

Several experimental studies were conducted to analyze the flexural behavior of FRP concrete beams and comparison therewith of steel concrete beams. Rafi et. al. [9] investigated flexural behavior of CFRP (Carbon fiber strengthened polymer) reinforcement RC beams and traditional RC beams and compared the results of each. take a look at results show that the structural behaviors of CFRP concrete square measure the same as traditional RC in several aspects. The CFRP RC beams displayed sensible bond between the reinforcement bars and concrete, with no signs of bond failure or slip. Beams failing thanks to concrete crushing at virtually double the hundreds on the opposite hand steel RC beams failing thanks to steel yielding. The semi permanent flexural behaviors of a hybrid system consisted of continuous fiber-reinforced-polymer (FRP) rebar and fiber- reinforced-concrete (FRC) were investigated by the Wang and Belarbi [10], and also the results shows that the final word flexural strength toughened minor reduction once exposed to combined environmental learning, together with freeze–thaw cycles, warmth (60°C), and de-icing salt resolution. The degradation of concrete is also the most reason for the flexural strength degradation. The behaviour of GFRP (Glass fiber strengthened polymer) RC beams with completely different percentages of reinforcement magnitude relation and concrete strengths below static and impact loading were investigated by the Goldstones et. al. [3], the results reveals al. [3], the results reveals that the six GFRP RC beams were tested below static loading and therefore the remaining six GFRP RC beams were tested below impact loading (using a drop hammer). to look at the failure modes and associated energy absorption capacities. Author reportable that the 15- 2 hundredth higher dynamic moment capacities compared to static moment capacities and Reinforcement quantitative relation and therefore the strength of concrete influenced the behaviour of GFRP RC beams. Escorcio and Franca [18] given a rehabilitation resolution to exchange the stress steel reinforcement of a RC beam with GFRP bars that could be a material resistant to corrosion. As per the author observation that the restored beams with GFRP bars exhibited a linear behaviour till failure in terms of load-deflection evidently since the ductile performance of the reference beam with steel reinforcement isn't potential to duplicate thanks to the GFRP material linear elastic property till failure.

An experimental study was conducted by Hosen et. al. [11] to investigate the performance of RC beams strengthened with SNSM (side near-surface mounted)-GFRP (Glass fiber reinforced polymer) bars. The results of this study showed that the Strengthening using SNSM (side near-surface mounted) -GFRP bars enhanced the first crack and ultimate loads up to 4.38 and 1.55 times compared with the control specimen. The use of GFRP an SNSM reinforcement has exhibited a tri-linear response in load-deflection behavior and reduced the deflection at any load level of the specimens, which would address the serviceability concerns.

4. COMPRESSIVE BEHAVIOR OF REINFORCED CONCRETE COLUMNS WITH FRP BARS

Few experimental studies were conducted to analyze the influence of commutation steel bars with GFRP bars on the behaviour of sq. and circular concrete columns. H. Karim et. al. [12] investigated the behaviour of concrete columns bolstered with FRP bars. a complete of 5 circular concrete columns of 205 metric linear unit in diameter and 800 metric linear unit tall were solid and tested below axial compression. The specimens were bolstered either with GFRP bars and GFRP helices or solely with GFRP helices. The experimental results showed that the GFRP-RC columns old 2 peak axial hundreds. the primary peak load represents the most load carrying capability of the gross concrete cross-sectional (concrete core and cover). The second peak load represents the most load carrying capability of the concrete core confined by the FRP helices. M.Z. Afifi et.[13] conjointly given tests that were performed to analyze the axial compression behavior of circular concrete columns bolstered lengthways with GFRP bars and transversally with freshly developed GFRP spirals. a complete of twelve all-out RC columns were ready to check 5 check variables: reinforcement sort (GFRP versus steel); longitudinal FRP reinforcement ratio; and completely different volumetrically ratios, diameters, and spacing of spiral reinforcement. The check results indicated that the GFRP and steel RC columns behaved in an exceedingly similar manner. the common load carried by the longitudinal GFRP bars ranged between five-hitter and 100 percent of the most load. The check observations conjointly indicated that failure of the GFRP RC columns with massive spiral spacing or with little volumetrically quantitative relation (0.7%) was controlled by longitudinal bar buckling. Conversely, failure of the well- confined GFRP RC columns was attributed to the crushing of the concrete core and rupture of the GFRP spirals. The experiments were conducted to researchalyze the behavior of fiber strong compound concrete columns (GFRP-RCCs) below associate eccentric axial load by L. Sun et. al. [14]. nine short columns (L/h = 4) were cast: three each with initial eccentricities of 1 hundred seventy 5 metric long measure, 125 mm, and 75 mm. The check results showed that the steel concrete columns fails in terms of steel yielding behavior on the alternative hand GFRP RCCs older pressure-side concrete crushing failures. However, the fiber strong compound (GFRP) bars inside the concrete columns primarily remained intact once the concrete was crushed. so the load-deformation curves of eccentrically loaded GFRPRCCs unit of measurement on associate overall basis entirely completely different from regular steel concrete columns in terms of yielding behavior, so damage is foreseen instantly once final load is reached, which they exhibit brittle characteristics. fiber strong plastic (GFRP) was used to reinforce concrete columns that were experimentally investigated below compression loading to assess structural behavior and performance by W. Prachasaree et. al. [15] specimens were prepared with varied longitudinal reinforcement, concrete cowl, and lateral reinforcement. Supported this study, the amount of GFRP longitudinal and lateral reinforcement slightly affected the column strengths. Whereas differing kinds of lateral group action had little distinction in strength, the spiral lateral reinforcement was the foremost effective in terms of the confining pressure and thus the dead deformation.

5. DURABILITY OF FRP BARS UNDER DIFFERENT TEMPERATURE IN CONCRETE

Galati et al. [2] perform AN experimental investigation was disbursed on concrete specimens strengthened with a FRP bar and subjected to thermal cycles with a most temperature price of 70°C and Galati et. al. [2] additionally determined that the foremost of the specimens the thermal treatment elicited a small degradation within the bond performance in terms of final load and a lot of extended small cracking of the concrete (due to the various CTE (coefficient thermal expansion)) of GFRP bars and concrete once the bars square measure placed at a lower cowl. Henry M. Robert and Benmokrane [11] additionally accomplish an experimental investigation of the sturdiness of the bond between GFRP bars and concrete. The GFRP bars were embedded in concrete and exposed to water at (23°C, 40°C and 50°C) to accelerate potential degradation. Henry M. Robert and Benmokrane [11] were additionally use Fourier remodel infrared spectrum analysis (FTIR), differential scanning menstruation (DSC), and scanning microscopy (SEM) to characterize however bar aging affected the bond between the GFRP bars and therefore the concrete. Results demonstrations that aging failed to considerably have an effect on the sturdiness of the bar–concrete interface below the conditions employed in this study.

6. ROLE OF DUCTILITY IN FRP REINFORCED CONCRETE STRUCTURES

The plasticity and confinement potency will be higher improved by exploitation little GFRP spirals with nearer spacing instead of larger diameters with bigger spacing. Ignoring the contribution of GFRP bars within the style equation underestimated the most capability of the tested specimens. Sun et al. [3] determined that the GFRP bars can play a specific role in improving ductility for large-eccentricity specimens while this effect is weak or insignificant with respect to small- eccentricity specimens. In the descending section of the load-deformation curve, the ductility of the GFRP reinforced concrete columns increased with increases in eccentricity. Therefore, it is recommended by the author that the configuration of stirrups in GFRP-RCCs should be strengthened when they are used in a small eccentric compression environment to improve ductility. Wang and Belarbi [10] investigate that the concrete properties was improved by adding fibers with a volume fraction of 0.5% has been proved to be an effective way to enhance the ductility of FRP reinforced system. When compared to the companion plain concrete beams, the FRC beams showed more than 30% increase in the ductility index for both unweathered and weathered.

7. ROLE OF STIFFNESS IN FRP REINFORCED CONCRETE STRUCTURES

Stiffness is outlined because the capability to forestall bending or deflection of the specimens underneath loading. it's one in every of the foremost necessary characteristics of the RC structures underneath utility behavior. The SNSM-GFRP-strengthened specimens resulted in higher stiffness compared with the management specimen ascertained by Hosen et.al [11]. take a look at results disclosed that the increasing the scale of GFRP bars from eight to ten metric linear unit Ø exaggerated the stiffness from 100 percent to 114% compared with the management specimen. Moreover, the increase within the bond length from 1600 metric linear unit to 1900 metric linear unit improved the stiffness by thirty fifth and V-day, severally, for 8-mm Ø to 10-mm Ø GFRP bars. during this study, the stiffness of the strong specimens principally relied on the scale of the SNSM bars. Baena et. al. [5] additionally ascertained that there's a high level of stiffness with no stick in the steel rebars, whereas the FRP rebars develop slip from the start (The slip values obtained for GFRP are bigger than those for CFRP bars). The experimental results additionally ensure the tendency of rebars with larger diameters to own lower bond strength, particularly within the case of upper grade of concrete.

8. ROLE OF ECONOMY WHILE USING FRP REINFORCED CONCRETE STRUCTURES

Researchers all over the world are focusing on the use of GFRP bars in concrete structures owing to their advantages in comparison to normal reinforcing steel. Berg et. al. [16] presented a study of the bridge is almost entirely reinforced with GFRP, with a small amount of steel used also. Although the initial material cost for the GFRP reinforced deck was 60% higher than the steel reinforced deck the construction time for the GFRP deck was considerably faster than the steel deck. The rate of concrete placement on the GFRP reinforced bridge deck was 51.15m3 per hour compared to 29.05 m3 per hour for the steel reinforced deck. This shows that the GFRP deck was able to reduce construction costs by 57% compared to steel. Additionally to that long term cost savings due to decreased need for maintenance works or increased service life of the bridge deck. Long term monitoring of this bridge and its twin will be conducted to determine comparisons between the long term behavior of both GFRP and steel reinforced bridge decks.

El Salakawy et. al. [17] presented a study of Wotton Bridge, in Quebec, Canada, is essentially a full-scale long term test comparing the performance of GFRP reinforcing bars to conventional steel reinforcing bars. Test results showed that the FRP portion of the bridge behaved fine. Author ascertained that the deflections were well at intervals the boundaries set by the Canadian code and most recorded strains for the static truck loading were solely zero.13% of the last word for FRP and simply four-dimensional for the service load over one year. Strain values within the concrete because of truck masses were considerably not up to the anticipated cracking strain. current check information are going to be valuable to permit direct comparison between steel and FRP bolstered bridge decks.

9. CONCLUSION

With twenty years' studies on the mechanical behaviors of FRP bars RC structure, nice progress has been created, and plenty of style codes are printed worldwide. The corrosion of steel reinforcement in concrete and therefore the ensuing deterioration of structures prompted analysis on FRPs as potential reinforcement for concrete. State of art in analysis indicate that FRP reinforcement are often effectively utilized in beams and column in new concrete structural components. There has been a big progress in understanding the behaviour of FRP (GFRP mostly) bars in concrete however, the main focus of most of those studies has Been the modification in the flexural and shear strength capacities of concrete beams reinforced with FRP bars. The effectiveness of FRP reinforcement as main reinforcement and hoops steel in columns has also been reported. The level of understanding of structural behavior has reached a stage where several codes and design guidelines have been issued and developed around the world. FRP bars as reinforcement improve the flexure and shear behaviour but the analysis of onset and progression of cracking in FRP reinforced concrete beams by the complementary use of NDT techniques for the characterization of mechanical performance is still untouched. Therefore, studies are still needed to be investigated on the FRP bars RC structures, especially bond behaviors, flexural behaviour and compressive behaviour.

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