Flexural and Bond Response of RCC Beam and Cube by Using Glass Fiber Reinforced Polymer Bar

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"FLEXURAL AND BOND RESPONSE OF RCC BEAM AND CUBE BY USING GLASS FIBER REINFORCED POLYMER BAR"

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Abstract— This article deals with the results of an experimental investigation on the flexural and bond characteristics response of Glass fiber reinforced polymer material in structural concrete. Glass fiber reinforced polymer bars of various diameters are used in this investigation. the performance of these bars with the full and partial replacement with steel bars is studied. M25 grade of concrete is used for making concrete beams and blocks as the main purpose of this investigation is to use Glass fiber reinforced polymer bars in water retaining structures. The reason behind this is glass fiber reinforced polymer material is corrosion resistant which can be the solution over the corrosion problem of steel reinforcement getting used in water retaining structures, and it could increase its lifespan. The various strengths considered for investigation are flexural strength and bond strength. Beams of 100 × 100 × 700 mm for flexural strength and cubes of 150mm for bond strength with glass fiber reinforced polymer bars penetrated in it are casted. All the specimens are water cured and tested after 28 days. Flexural strength tests gives satisfactory results with 50% replacement of glass fiber reinforcement. A significant improvement in bond strength is observed in pullout test.

Keywords— : glass fiber reinforced polymer, partial replacement of glass fiber reinforced polymer bars, Thermo mechanically treated (TMT) bars, workability, strength of concrete, flexural response, bond strength.

INTRODUCTION

Fiber-reinforced plastic rebar are currently entering the market as a replacement for steel reinforcement in concrete structures. There are many existing methods available for preventing, delaying or repairing the deterioration of concrete structures due to corrosion of reinforcing steel. However, these methods are costly and their long time effectiveness is not assured. A better and a more innovative solution to the corrosion problem in structures is to eliminate one of the contributing ingredients (i.e.) steel. This can be achieved by replacing the steel bars with fiber reinforced polymer bars. The civil engineering community's progress towards comfort with Glass Fiber Reinforced polymer rebar is very slow, but it has not discouraged the pursuit of new approaches to its manufacture that could make the composite rebar a much more attractive alternative to steel. Although the initial cost of composite rebar is generally higher than standard steel rebar, however when considered on a Life Cycle Cost (LCC) basis, it can be quite economical for structures that typically require frequent repair and maintenance provided serviceability criteria is satisfied. For all these reasons and more, composite rebar has slowly begun to gain share in the civil engineering market. If the composite rebar can add a price advantage and serviceability requirements to its other benefits, then it will stand a much better chance of being specified in higher volume. It is a challenge and an opportunity for the whole composites industry to develop GFRP as replacement to steel.

LITERATURE SURVEY

The research undertaken during the last two decades has shown that one of the potential solutions to the steel-corrosion-related problems in concrete is the use of fiber-reinforced composite (FRP) reinforcement as a replacement for traditional steel bars. Glass FRP (GLASS FIBER REINFORCED POLYMER) reinforcement is gaining more popularity in construction of bridges and in other concrete structures because of its low cost compared to Carbon FRP reinforcement.

One of the major challenges for researchers that also represent an obstacle to an increased use of these materials in the civil engineering infrastructures relates to durability. During the last two decades, several studies were carried out on the parameters affecting durability and the long-term behavior of FRP materials used in civil engineering applications. However, the data available on the durability of the FRP bars are dispersed, sometimes contradictory and often improperly documented. Accelerated tests were carried out at the University of Iowa by Porter and Barnes to determine the long-term tensile strength of GLASS FIBER REINFORCED POLYMER bars. The FRP bar samples were exposed to an alkaline solution at a high temperature (608C) for periods of 2–3 months, which represents 50 years of exposure in a Northern climate. The tensile tests carried out on three types of GLASS FIBER REINFORCED POLYMER bars resulted in residual strengths of 34, 52, and 71% compared to the original tensile strength.

In 2017, tests carried out by shamim A. Shaikh, Et. al.[1] that Corrosion of steel in reinforced concrete structures has cost a significant amount of resources globally over the past few decades. Glass fiber reinforcement polymer bars present a feasible and cost effective solution to the problem of steel corrosion. The aim of this paper is to let engineers gain a better understanding of the overall behavior of GLASS FIBER REINFORCED POLYMER as internal reinforcement so that they have more confidence using it as a sustainable material. This paper provides a few significant outcomes from an extensive experimental program underway at the University of Toronto. The work discussed here provides a summary of the tests on 24 GLASS FIBER REINFORCED POLYMER reinforced beams, 60 GLASS FIBER REINFORCED POLYMER direct tension specimens and 20 GLASS FIBER REINFORCED POLYMER confined columns, and evaluates the behavior of GLASS FIBER REINFORCED POLYMER-RC in flexure, shear, tension and compression. A recently proposed tension-stiffening model has been incorporated in analytical modeling of GLASS FIBER REINFORCED POLYMER-RC beams and the results show significant improvement in the prediction of deflection and stiffness of the beams. Results from column tests show that GLASS FIBER REINFORCED POLYMER bars used as longitudinal reinforcement can resist compressive stresses in excess of 700 MPa and GLASS FIBER REINFORCED POLYMER lateral reinforcement can confine concrete core more effectively than steel. The research undertaken during 2005,by Gilbert nkurunziza, et.al.[2] Canada has shown that one of the potential solutions to the steel-corrosion-related problems in concrete is the use of fiber-reinforced composite (GFRP) reinforcement as a replacement for traditional steel bars. GFRP reinforcement is gaining more popularity in construction of bridges and in other concrete structures because of its low cost compared to Carbon FRP reinforcement. The durability of these materials, especially under severe environmental conditions, is now recognized as the most critical topic of research. The lack of data on durability of the GLASS FIBER REINFORCED POLYMER reinforcements is a major obstacle to their acceptance on a broader scale in civil engineering. This paper summarizes the most significant research work published on the durability of FRP bars in the past two decades. A comprehensive review of the literature on the durability of FRP bars indicates a significant increase in the number of studies in this area in the last decade. The durability tests conducted by the authors and others on the latest generation of GLASS FIBER REINFORCED POLYMER bars subjected to stresses higher than the design limits, combined with aggressive mediums at elevated temperatures, have concluded that the strength reduction factors adopted by current codes and guidelines are conservative. These factors were based on limited test results that were carried out on the early generations of the GLASS FIBER REINFORCED POLYMER products, which have now substantially changed. The paper P. Gandhi et.al [3] presents the details of experimental investigations and the results of The use of Glass Fiber Reinforced Plastic (GLASS FIBER REINFORCED POLYMER) rebars as a potential replacement for steel reinforcement has raised quite a bit of controversy among the professionals and engineers engaged in the construction industry. Divergent views have been opined by the professionals for its usage in civil engineering structures. Even though, the GLASS FIBER REINFORCED POLYMER rebar has some advantages with regard to corrosion, its usage in the construction industry is still a big question mark due to its low modulus of elasticity and serviceability aspects towards construction of structural elements. In this background, experimental investigations have been taken up at the CSIR— Structural Engineering

Research Centre, Chennai to study the static and fatigue behavior of concrete beams reinforced with GLASS FIBER REINFORCED POLYMER and Thermo Mechanically Treated (TMT) bars. Concrete beams with GLASS FIBER REINFORCED POLYMER bars of dimensions 100 mm × 200 mm × 1500 mm have been subjected to static monotonic loading to study the flexural behaviour and companion concrete beams of same dimensions with TMT bars have also been investigated. The investigations have revealed that the concrete beams with GLASS FIBER REINFORCED POLYMER bars resulted in unacceptable deflections and crack widths, with regard to serviceability, compared to the companion beams with TMT bars of same amount of area of reinforcement. The fatigue studies conducted on concrete beams, at four different load ranges, with GLASS FIBER REINFORCED POLYMER bars were also not encouraging. S.F. Hussain et.al.[4] has studied GLASS FIBER REINFORCED POLYMER bars for RC structures. In that study he said that the ever changing dynamics of construction industry has brought about new materials every once in a while. The conventional steel bars used in RCC work is slowly being replaced by glass fiber reinforced polymer (GLASS FIBER REINFORCED POLYMER) bar. This major shift in construction practice can be attributed to GRRP's versatility of having high strength to weight ratio, corrosion resistance, durability and better stiffness than conventional steel bars. However, due to linear stress strain behaviour of GLASS FIBER REINFORCED POLYMER, these are prone to sudden and brittle failure and hence, reinforcing fiber are used in combination to provide structural safety. In the present study, a review has been made to discuss the critical aspects on the effect of GLASS FIBER REINFORCED POLYMER bars and AR-glass fibers on the flexural behavior of RC members and compared with the flexural behavior of RC members reinforced with HYSD bars. Shahad Abdul adheem jabbar et.al.[5] has introduced Replacement of steel rebars by GLASS FIBER REINFORCED POLYMER rebars in the concrete structures. As per his point of view Glass fiber reinforced polymer (GLASS FIBER REINFORCED POLYMER) has been confirmed to be the solution as a major development in strengthened concrete technology. Synthesis of GLASS FIBER REINFORCED POLYMER rebars by using the longitudinal glass fibers (reinforcement material) and unsaturated polyester resin with 1% MEKP (matrix material) via manual process. GLASS FIBER REINFORCED POLYMER rebars have diameter 12.5 mm (this value is equivalent to 0.5 inch; it's most common in foundations application). GLASS FIBER REINFORCED POLYMER surfaces are modified by the inclusion of coarse sand to increase the bond strength of rebars with concrete. Then, the mechanical characterizations of reinforced concrete with GLASS FIBER REINFORCED POLYMER rebars are performed and compared with that of steel rebars. Preparation of concrete samples (unreinforced concrete, smooth GLASS FIBER REINFORCED POLYMER reinforced concrete, sand coated GLASS FIBER REINFORCED POLYMER reinforced 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 GLASS FIBER REINFORCED POLYMER 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 GLASS FIBER REINFORCED POLYMER 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 GLASS FIBER REINFORCED POLYMER rebar, especially sand coated GLASS FIBER REINFORCED POLYMER 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. B Ramesh et.al.[6] in his article Flexural behaviour of glass fiber reinforced polymer (GLASS FIBER REINFORCED POLYMER) laminated hybrid-fiber reinforced concrete beams . in this study The flexural behaviour of externally bonded glass fiber reinforced polymer (GLASS FIBER REINFORCED POLYMER) reinforced concrete (RC) beams incorporating both 'basalt' and 'polyolefin' fibers at a constant ratio of 70:30 and in several combinations of fiber volume fractions (Vf) ranging from 0–2% (at a constant increment of 0.5%) were investigated, to highlight to role of strengthening and the hybrid fibers in beams. Three different types of beams, namely: a control beam (1 No.); GLASS FIBER REINFORCED POLYMER laminated RC beam (1 No.) and laminated and hybrid fiber reinforced (HFRC) beams (4 Nos.) were cast, and tested under a four-point bending. The load-deflection response at: first crack, yield point, at initiation of de bonding lamination and at ultimate stages were recorded by appropriate instrumentation. The results indicate that there is a 'combined effect' of lamination and incorporation of the above hybrid fibers in contributing to the very high load-carrying capacity and enhanced ductility of laminated HFRC beam, especially at a fiber volume content of 1.5%. Further, the maximum yield and ultimate load carrying capacity of laminated HFRC beam is found to be 59% and 49% higher than the laminated RC beam and 125% and 98% higher than the control beam. However, the deflections are higher, and their permissibility have to be ascertained with respect to relevant codal provisions. All the laminated HFRC beams exhibited 'gradual debonding' and 'ductile' failure, whereas, the control beam exhibited 'flexural mode' of failure. The 'combined effect' can be used advantageously in structural applications, where both 'strength' and 'ductility' are important.

METHODOLOGY

To check the flexural response and bond characteristics of GLASS FIBER REINFORCED POLYMER bars we have carried out flexural tests and pull out tests with different combinations with steel. M25 grade of concrete is used as it is mostly used in water retaining structures. The manner in which beams are casted with variation in reinforcement is also given.

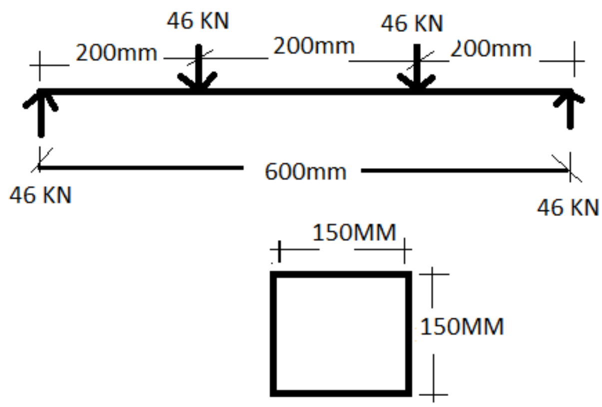
Flexural test:

- To check flexural response of GLASS FIBER REINFORCED POLYMER reinforced concrete , flexural test is being performed on three number of beams in which one with fully reinforced with GLASS FIBER REINFORCED POLYMER ,one with partial replacement of steel by GLASS FIBER REINFORCED POLYMER, last one is fully steel reinforced concrete beam.

- Beam size used is 150*150*700 mm
- 4 number of 10mm dia main bars used at bottom 20mm c/c dis.

- In partially reinforced beam, bottom corner bars used are of GLASS FIBER REINFORCED POLYMER and remaining two are steel bars.
- Top bars used in every beam is of 2 number of 8mm dia ., steel bars used in partially reinforced beams as top bars as shown in fig. 5.1
- 7 number of stirrups used in each beam of 6mm dia. At 100mm c/c spacing.
- GLASS FIBER REINFORCED POLYMER stirrups used in pure GLASS FIBER REINFORCED POLYMER beam and partially reinforced beam. Steel stirrups used in pure steel beam.
- Due to unavailability of stirrup making machine , instead of using stirrups, 6mm dia GLASS FIBER REINFORCED POLYMER bars are used in pieces of 17cm length , and jointed by binding wire which worked as GLASS FIBER REINFORCED POLYMER stirrups in 100% GLASS FIBER REINFORCED POLYMER beam and partially GLASS FIBER REINFORCED POLYMER replaced beam.
- A cover of 25mm is used at bottom and side from reinforcement.
- M25 grade of concrete is used for casting.
- Shuttering is removed after two days of casting.
- Beams kept for curing under water tank for 28 days.

Flexural strength test on 100% Steel Beam :



L = 600 mm

B = 150 mm

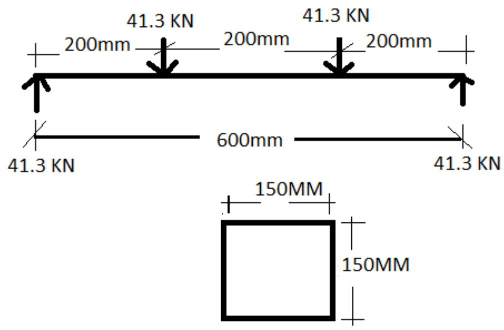
D= 150 mm

$\sigma = FL / BD^2$

$\sigma = [(92 \times 10^3 \times 600) / (150 \times (150^2))]$

$= 16.35 \ N/mm^2$

Flexural strength test on 50% Steel And 50%FRP Beam :



L = 600 mm

B = 150 mm

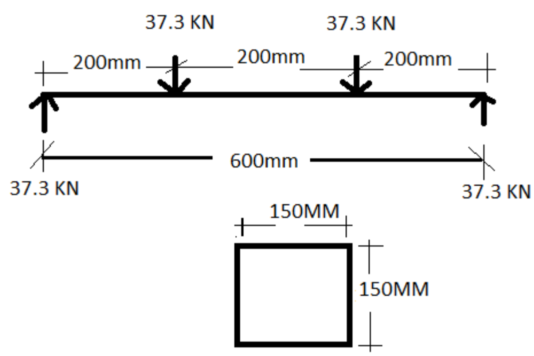
D= 150 mm

$\sigma = FL / BD^2$

$\sigma = [(82.6 \times 10^3 \times 600) / (150 \times (150^2))]$

$= 14.68 \ N/mm^2$

Flexural strength test on 100% FRP Beam :



L = 600 mm

B = 150 mm

$D = 150$ mm

$\sigma = FL / BD^2$

$\sigma = [(74.6 \times 10^3 \times 600) / (150 \times (150^2))]$

$= 13.6$ N/mm^2

Pull out test:

- To Calculate Bond strength of GLASS FIBER REINFORCED POLYMER bar , Pull out test is to be performed on UTM machine.
- 3 number of 15cm^3 concrete cubes casted with 10mm dia. GLASS FIBER REINFORCED POLYMER bars penetrated 13cm deep at centre.
- M25 grade of concrete is used in casting.

$$(\pi/4) \times d^2 \times \sigma = \tau \times \pi \times d \times l$$

$$P = \tau \times \pi \times d \times l$$

$$\tau = P / (\pi \times d \times l)$$

First bar : P = 33 KN

$\tau = 33 \times 10^3 / (\pi \times 10 \times 130)$

$= 8$ N / mm^2

Second bar : P = 40.3 KN

$\tau = 40.3 \times 10^3 / (\pi \times 10 \times 130)$

$= 9.86$ N / mm^2

Third bar : P = 41.5 KN

$\tau = 41.5 \times 10^3 / (\pi \times 10 \times 130)$

$= 10.16$ N / mm^2

Averge $= (8 + 9.86 + 10.16) / 3$

$= 9.34$ N / mm^2

For deformed bars conforming to IS 1786 ,

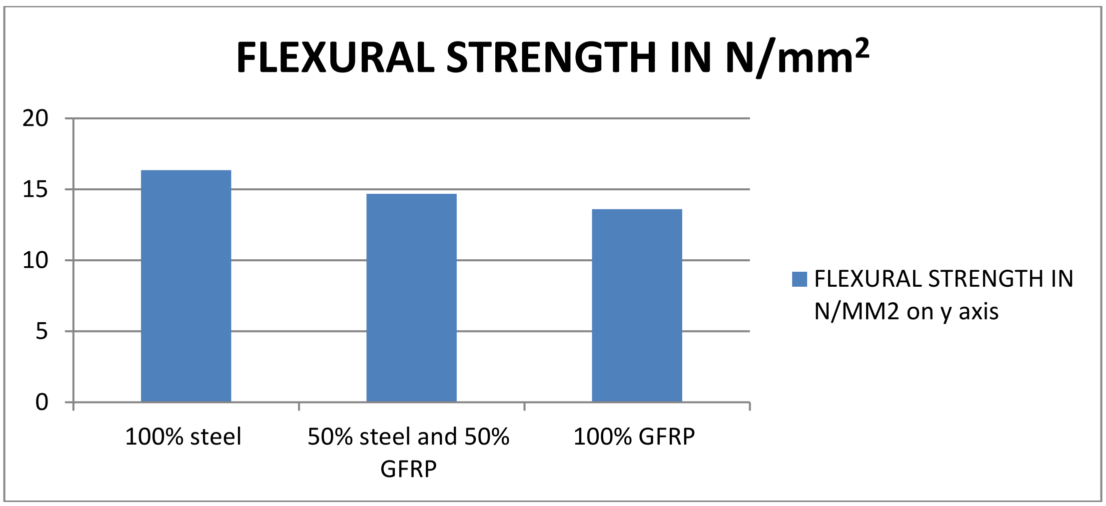
For M25 Grade of concrete , design bond stress τ in N/mm^2

- For plain bars = 1.4 N / mm^2
- For Deformed Bars = 60 % more than plain bar

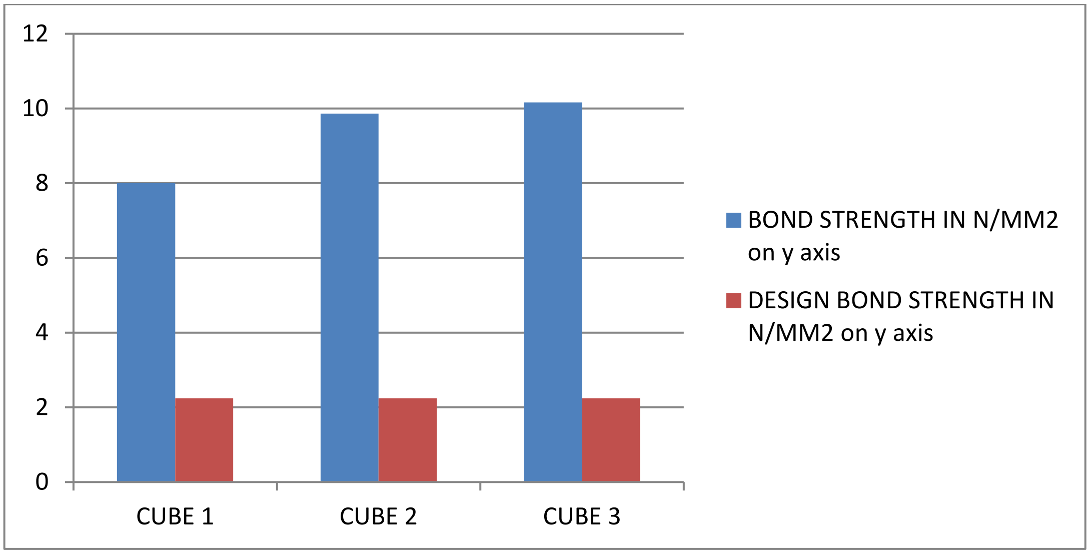
$= 1.4 \times (1 + 60/100)$
$= 1.4 \times 1.6$
$= 2.24 \text{ N / mm}^2$

Conclusion and discussion:

- In flexural strength test, second beam containing 50% FRP and 50% steel is giving satisfactory results, which are close enough to the 100% steel reinforced beam. It will be considered as best best material to replace steel as an reinforcement as economical point of view.



- It will give more satisfactory results if some improvements will be there in manufacturing of FRP such as stirrup making, fire resistance etc.



- In bond strength test , GLASS FIBER REINFORCED POLYMER is giving very good results , the average bond strength of 3 GLASS FIBER REINFORCED POLYMER bars is 9.34 N/mm^2 which is much more than design bond strength of steel bars which is 2.24N/mm^2 .
- Under bond strength test , after failure of concrete as shown in fig, Glass fiber reinforced polymer bar is remains as it is , as there is no any failure of this bar under pull out test.

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