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EXPERIMENTAL STUDY ON GFRP REINFORCED CONCRETE BEAMS

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Abstract:

Corrosion of steel in reinforced concrete structures is one of the biggest challenges faced by the civil construction industry todays. In reinforced concrete structures, corrosion of steel reinforcement due to adverse environment effect considerably reduces the durability and life span of these structures. To overcome this corrosion problems, many new techniques have been tried and found to be either expensive or ineffective. Fiber reinforced polymer (FRP) material in the form of solid bars has been successfully tried as a substitute for steel reinforced in concrete structures. FRP materials are anticorrosive, have low weight to strength ratio and are used for various modern engineering applications. Research has carried out to study the behavior of FRP reinforced concrete beams. However,very little effort has been taken to study the behavior of reinforced concrete [RC] beams reinforced with FRP rebars. This work is an attempt to study the behavior of RC beams with glass fiber reinforced polymer [GFRP] web reinforcement .A concrete beam reinforced with FRP is vulnerable to brittle failure under load condition as , individually, both concrete and FRP have the tendency for brittle failure under loading conditions.

Keywords **— GFRP rebars; steel rebars; reinforced concrete; flexural strength.**

I.INTRODUCTION

Corrosion of steel reinforcement in Reinforced Concrete (RC) structures considerably reduces the durability and life span of these structures. The problem of corrosion is also a matter of concern especially when the RC structures are exposed to severe adverse environmental conditions such as in an urban or in a coastal area. In cold region countries, corrosion is a menace at places where de-icing salts are used over RC structures in cold region countries. To overcome this corrosion problem, many new techniques have been tried and tested and these tests were found to be either expensive or ineffective. The use of protective coating by epoxy polymers, the use of stainless steel in the place of conventional steel, controlling corrosion by cathodic protection were some of the methods tried earlier to overcome corrosion. But none of them were fully effective from the functionality or economical point of view.

Fiber Reinforced Polymer (FRP) materials which are anticorrosive, were found to be a prospective substitute to conventional steel reinforcement used in RC structures. During the last two decades, FRP materials in the form of solid bars have been successfully tried as a substitute for steel reinforcement in concrete structures. The corrosion resistance of FRP (Fiber-Reinforced Polymers) bars added to their high strength advantage makes it a promising alternative reinforcement material in RC structures, which are prone to corrosion. FRP materials are anti-corrosive and have a low weight to strength ratio. All types of FRP materials are widely used for various modern engineering applications.

A.Glass fiber

The glass fiber used for fabricating the GFRP reinforcements is of E- Glass fiber type of Saint-Gobain vetrotex with identification number as RO 99 2400 P 566. The fiber which was available in roving of 2400 normal liner density (tex) was specifically selected for the purpose of manufacturing by 'Manual Fiber-Trusion. The proprietary sizing system of the selected P 566 type fiber was designed to give a high level of performance with greater compatibility with Polyester, epoxy, vinyl and phenolic resins. The test specifications supplied by the fiber manufacturer are as shown in Table.

PROPERTY	VALUE	TEST METHOD
Glass content (%)	60-65	BS 3691:1969
Tensile strength (Mpa)	1700-1800	BS 3691:1963
Tensile modulus (Gpa)	65-75	BS 3691:1963

Some of the other advantages of using this type of fiber include fast and complete wet-out of fibers with most resins, good resin wettability by fibers, excellent spreading on the mandrel which gives a smooth and regular surface, high mechanical properties, good composite translucency. These were found to be needed for this type of manufacturing process to be efficient and hence this type of fiber was adopted.

Fig-1Glass fiber

B. FRP Material

Fiber-reinforced polymers (FRP) are composite materials which are made of fibers embedded in polymeric resin. The most commonly used synthetic fibers are made of glass fiber (GFRP), carbon fiber (CFRP) and Aramid fiber (AFRP). Some of the commonly used resin matrices that bind the fibers together to form a FRP composite material are polyester, vinyl ester, and epoxy groups.

The excellent characteristics and advantageous properties of FRP materials are good corrosion resistance, high strength, low weight, nonmagnetic and non- conductivity, high fatigue resistance, ease of handle at construction site and ease to cut and color code. These outstanding characteristics of FRP materials make them an ideal material of choice to be used as a reinforcing material.

The fiber reinforced composite, which are used for many engineering applications, are made of high strength fibers embedded within a suitable matrix material which is in the form of a resin, which confines the fibers. The fibers are embedded and bonded in polymeric resin through which it is impregnated during its manufacturing process. The fibers after impregnating in resin are cured to obtain the end product called 'Fiber Reinforced Polymer' (FRP) material.

Fig-2 GFRP bars

C. Uses of GFRP

The GFRP reinforcement materials are being extensively used in many infrastructure projects such as, in highway bridges, box culverts, retaining walls, walkways, etc. in many developed countries. According to the 9 recent statistics, there are over a hundred bridges that have been constructed worldwide using GFRP bars as reinforcement in their superstructures. GFRP composite materials are widely and commonly used as gratings in off-shore platforms to overcome the problem of corrosion.

D. Advantages of GFRP bars

1. GFRP is a cost – effective construction material and it has full potential to extend the life of structures from corrosion.
2. GFRP rebars is non-conductive to electricity and heat , so that it is used in power generation plants and scientific installation.
3. It is invulnerable to chloride ions and other chemical elements.
4. A project reinforced with GFRP rebar is maintenance free, enabling builders to avoid a rehabilitation cost.
5. As compared with the traditional reinforcement material, GFRP rebar is ¼ the weight of steel with twise the tensile strength of steel.

II. REVIEW OF LITERATURE

Shahad Abdul AdheemJabbar, Saad B.H. Fari (2017) Carried out 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 reinforced 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 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 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.

M.Harisankar (2017) studied on High Tensile Strength Corrosion Free FRP Rebars using Chemical Application it is well known that steel rebars are used to improve tensile strength of the concrete for the all type of structural application. Steel reinforced concrete posses excellent mechanical properties but lacks in chemical composition due to corrosion resistance. When the steel rebars starts corroding, the shape of the steel rebars is destabilized and results in detrimental failure of the concrete. To overcome this draw backs several approaches have been done to prevent the corrosion of the steel rebars. One of the approach is to replace the steel with noncorrosive reinforce material, namely Fiber reinforced polymers. Therefore this work is to create a new innovative researching material about rebar's [Sisal Fiber] using chemical application. More recently these techniques have been refined by embedding the steel bars in the concrete, and by the introduction of deformed bars to improve bonding, thus producing modern reinforced concrete now a day's. Research has been proved, to replace the iron with other materials such as sisal. Fibre reinforced plastic and even galvanized iron because iron can rust easily and weaken the structure. But the sisal fiber is a natural fiber, so its free from corrosion and prevent the structure safely. In particular, the sisal fiber is one of the most investigated and being used in engineering systems.

Chidananda S. H (2017)studied on Flexural behaviour of Concrete Beams Reinforced With GFRP Rebar..This study reports test results of 12 concrete beams measuring 150mm wide × 180mm deep× 1200mm long reinforced with glass fiber-reinforced polymer (GFRP) bars subjected to a four-point loading system. The test specimens were classified into three groups according to the concrete compressive strength. The main variation done for each beam in all the three groups was a percentage of reinforcement (0.5%, 1%, 1.5% and 2%). Since all the beams were over reinforced failure occurred due to rupture of concrete at compression zone. The failure is initiated by a vertical crack at the mid span whichextended up to compression zone of the beam and propagated horizontally which leads to bond failure between top concrete and compression reinforcement. The test results revealed that the crack widths and mid-span deflection significantly reduced by increasing the reinforcement ratio. The ultimate load increased by 7.5%, 16.8%, 27.7% as the reinforcement. Percentage increased from 0.5% to 1%, 1.55 and 2% respectively. The flexural provisions of structural design guidelines namely ACI 440.1R-06, ECP 208-2005, and CSA S806-12 were evaluated against the test data. ACI 440.1R-06 overestimates the moment resistance of GFRP bars as compared to other codes and experimental results. Whereas all the design guidelines predict nearly the same values for deflection. And for crack width approximation Toutanji's equation is more accurate compared to ACI equation.

S. Maksimov(2017) Carried out Glass fiber reinforced plastic rebar (GFRP-rebar) is widely used in the modern construction industry. The analysis of the manufacturing methods showed that the epoxy adhesive impregnation unit is imperfect. The impregnation is carried out by immersion of filaments in a pastepot or bending them around a rotary spool. After that, the devices are used to remove excess adhesive and guide rollers and form the rebar roving. The parts contacting with adhesive must be regularly cleaned. It makes the process low-efficient and increases financial and time costs. An open pastepot with the epoxy adhesive pollutes the air of the working area. We propose to change the impregnation unit and combine it with the device twisting filaments into a roving. It is necessary to dispense adhesive exactly from the nozzle to the place of the filaments connection. This will prevent harmful fumes from penetrating into the work area, maintain accurate adhesive dispensing, increase the production purity, reduce the processing line and the cost. This construction doesn't require large financial costs but can significantly improve the production efficiency.

S. A. Bhalchandra (2007) studied in this paper presents results of an experimental program to determinemechanical properties of Glass fibre reinforced Geo polymer Concrete which contains fly ash, alkaline liquids, fine & course aggregates & glass fibres. The effects of inclusion of glass fibers on density, compressive strength & flexural strength of hardened geo polymer concrete composite (GPCC) was studied. Alkaline liquids to fly ash ratio were fixed as 0.35 with 100% replacement of ordinary Portland cement by fly ash. For alkaline liquid combination ratio of Sodium hydroxide solution to Sodium silicate solution was fixed as 1.00. Glass fibers were added to the mix in 0.01%, 0.02%, 0.03% & 0.04% by volume of concrete. Based on the test results it was observed that the glass fibers reinforced geopolymer concrete have relatively higher strength in short curing time (3 days) than geopolymer concrete & Ordinary Portland cement concrete.

G. Nandini Devi (2015) carried out Cracking is difficult to control in any structure. The risk of the measures used to protect black steel failing if cracks occur in the concrete is very high. As soon as these measures fail the steel corrosion cycle starts again. Glass fiber-reinforced polymer rebar's is one of the new products on the market that could offer a number of benefits to the construction industry. Durability testing of GFRP bars has been conducted by a number of universities and research centers throughout the world, covering a large variety of different environments and evaluation conditions.

ZARINA SAIDIVO(2017)carried out Thermal analysis of glass-fiber reinforced polymer rebars in This article contains a short overview of current research base state in the field of thermal analysis of glass-fiber reinforced polymer (GFRP). The relationship between temperature raise and specimens weight loss is presented. It is noted that results of experiments run by different scientists vary widely and cannot form a common GFRP behavior model under heating. To compare the effect of thermal exposure on GFRP of a number of Russian manufacturers, the thermal analysis of composite rebar was carried out. Weight fluctuation was recorded with temperature ranging from 22 to 500 °C. The results of visual estimation of the effect of heating GFRP specimen up to 200 °C is also presented. All experiments were conducted according to requirements of corresponding regulations.

III.MATERIALS AND METHODS

A. Materials used

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 g/m^2 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 "FARAPOL Company, Iran" and Hardener (Methyl ethyl ketone peroxide) "akpakimya company, Turkey". Ordinary Portland cement manufactured by (ultra tech) was used, conformed to the Indian standard. A natural river sand as fine aggregate and the gradation and selected chemical and physical properties were within limits of the Indian standard. Gravel of (5-19 mm) gradation was utilized as a coarse aggregate and the sieve analysis, specific gravity, density and sulfate contents are within Indian standard. Tap water was used.

B.GFRP rebars

Synthesis of GFRP rebar from glass fibers and unsaturated 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 by using different number of fibers and measuring diameter every time . Finally a bar of diameter 12.5 mm was obtained which is common in construction applications. The resulting bar has fibers volume fraction of 80% and polyester volume fraction of 20%. After obtaining GFRP, tensile and bend strengths were measured and compared with normal reinforcement bar. There are many ways to increase bonding between reinforcement and the concrete such as coating of GFRP bars with coarse sand of above 300 µm

Properties of GFRP used in the experiment

Tension tests on GFRP bars were conducted to know the ultimate tensile strength and modulus of elasticity for the bars used for this experiment. The bars were placed inside the specially made pipe fixtures fitted at its ends and filled with a mixture of epoxy and sand to avoid slippage. The results of which prove to be greater than values of the FRP bars manufactured by conventional pull trusion method. The calculated values of some of the physical properties from the test results are tabulated in Table

Material	Average tensile stress (GFRP)Mpa	Ultimate tensile strain (ε)	Modulus of elasticity (GFRP)Mpa
GFRP	780	0.017515	44,530

C. Mixing methods

The used mixing proportion was (1:1:2). The drymaterials (cement and sand) were thoroughly mixed 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 .

D.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 x100 x5000 mm for flexural strength. The molds were softly coated with Vaseline oil before use, per IS 516-1959 concrete casting was performed in different layers, each layer of 50 mm. Each layer was compacted by using Tamping Rods until no air bubbles emerged in the concrete, and the surface of concrete was leveled off fully to the upper of the molds by using steel trowel. Concrete is reinforced by 5 vol. % GFRP and steel bars evenly distributed with specific distance in the mold. Polyethylene sheets are utilized as covers for specimens after their casted for 24 h in roomtemperature (24 ± 2) C to inhibit moisture content fromevaporation.

IV.RESULTS AND DISCUSSION

A. Compressive strength test

Specimens of dimensions 150x150x150mm were prepared. They are tested on 2000KN capacity compression testing machine as per IS 516-1959.

Table-1 Concrete cube test results

BEAMS	Compressive Strength N/mm2 (7Days)	Compressive Strength N/mm2 (28 Days)
Sample-1	28.7	41.9
Sample-2	30.9	43.3
Sample-3	28.8	40.8
Sample-4	34.9	40.1

Fig-3 compression testing

B. Flexural strength

Measurement of flexural properties was done according to IS 516-1959. The test samples were 100 x100x500 mm prism and tested via three point loading. The specimens were measured after (7 & 28)daysof immersion in water.

Table-2 Average flexural values of samples(7days)

Property	Unreinforced concrete	GFRP reinforced concrete	Steel reinforce concrete
Flexural strength (Mpa)	2	10.5	14
Stain	4.5	17	8
Modulus of elasticity(Mpa)	500	500	2000

Table – 3 Average flexural values of samples(28days)

Property	Unreinforced concrete	GFRP reinforced concrete	Steel reinforced concrete
Flexural strength (Mpa)	3	12.5	17.5
Stain	2	16	9
Modulus of elasticity(Mpa)	1000	500	1500

Fig-4 ultimate load

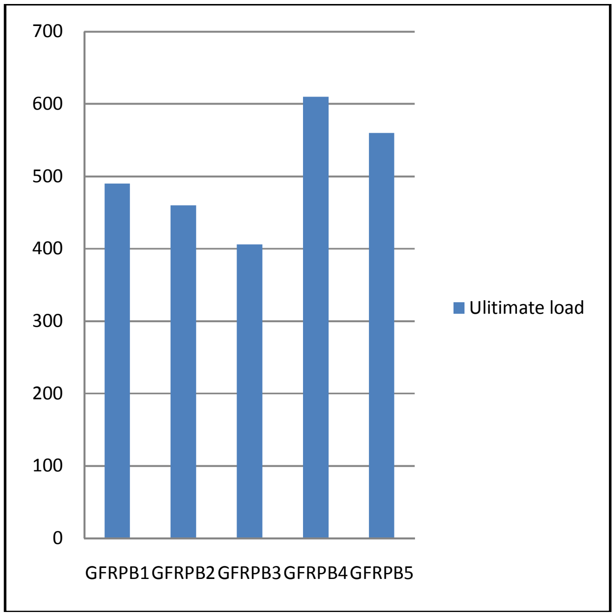


Fig-5 Maximum strain

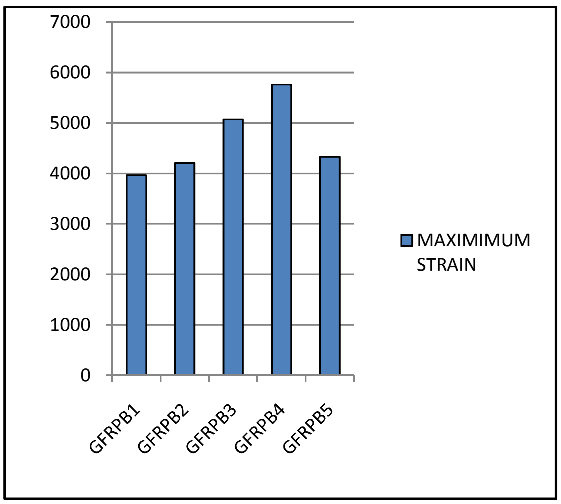


Fig-6 Applied load vs strain

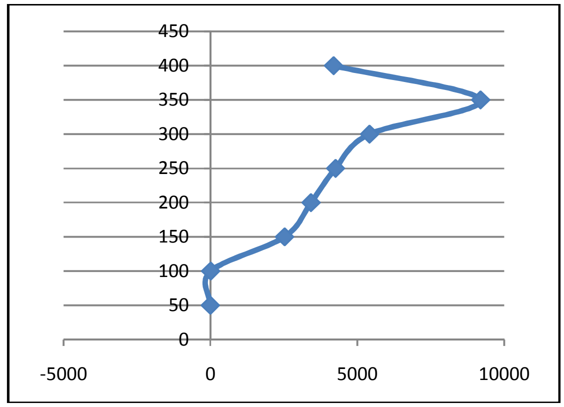


Fig-7 Beam testing process

Fig -8 Mid span deflection

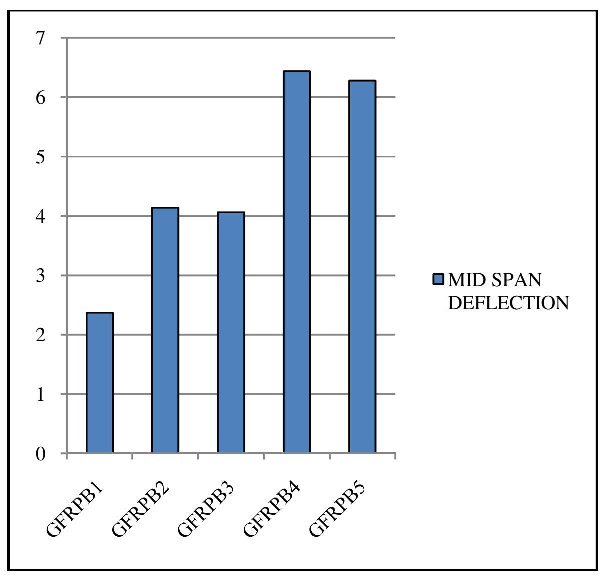
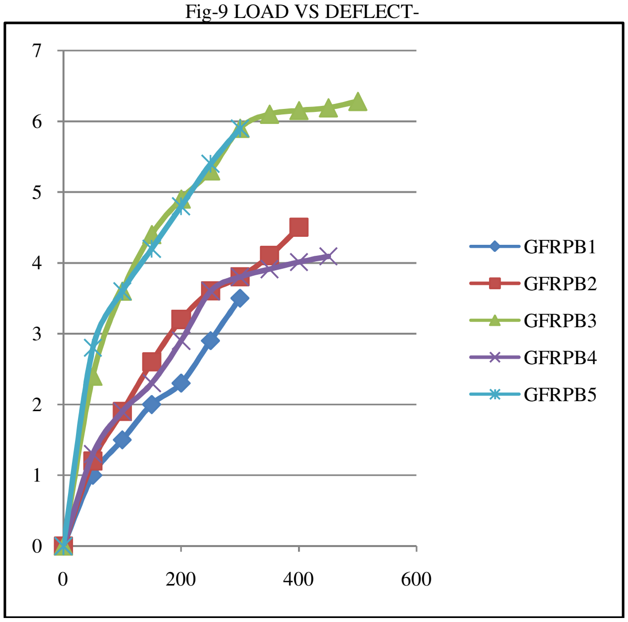


Fig-9 LOAD VS DEFLECT-



V.CONCLUSIONS

The conclusions arrived at during this study are summarised in this conclusions. From the discussions made in the previous and based on some vital observations, the following conclusions have been arrived at on the basis of the parameters involved.

a) The presence of a combination of both the vertical and horizontal GFRP web reinforcements plays a significant role in contributing to the shear carrying capacity of the beams. This is apparent by comparing the shear performance of beams GFRB-1 and GFRB-2. However the amount of the contribution made by the GFRP web reinforcement to carry shear varies depending upon its amount and its position.

b) Compared to the beams without any web reinforcement, there has been a three-fold increase in the ultimate load carrying capacity of beams provided with GFRP web reinforcement. This increase is considered to be substantial. In case of beams with combined web reinforcement, this increase was even more sizeable which may be attributed to the effect of cage reinforcement.

c) Based on the strain values observed, it is recommended that the allowable strain limit of FRP shear reinforcement which had been standardized to a value of 2000 microstrains in ISIS Canada Design Manual 3 may be increased to a higher value in case of beams provided with combined GFRP web reinforcement.

d) Other than any other type of crack, it was the diagonal shear cracks that were primarily responsible for the failure of GFRP reinforced beams in the range of a/d ratio < 1.0. The occurrence of 'tie-arch' action which is noticeable in steel reinforced beams was also present in GFRP reinforced beams.

e) Compared to GFRP reinforced slender beams, the cracks in GFRP reinforced beams were not as wide and deep. This shows that the formation and width of a crack is effectively controlled by the presence of web reinforcement in beams.

f) In the presence of combined GFRP web reinforcement in concrete beams, dowel action and dowel splitting were found to be absent.

g) The GFRP web reinforcement in concrete beams plays a significant role in controlling its deflection. This became evident as it was observed that the increase in deflection drastically declined after the formation of the first crack in concrete.

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