International Journal of Innovative Research in Advanced Engineering (IJIRAE) ISSN: 2349-2163
Volume 1 Issue 5 (June 2014) http://ijirae.com

Experimental Study of Behavior of RCC Beam by Replacing Steel Bars with Glass Fibre Reinforced Polymer and Carbon Reinforced Fibre Polymer (GFRP)

Venu R. Patil
Department of Civil Engineering
Visvesvaraya Technological University

ABSTRACT—Reinforced Cement Concrete (RCC) structures are usually reinforced with steel bars which are subjected to corrosion at critical temperatures and atmospheric conditions. Also the cost of steel reinforcement plays a significant role in any RCC construction. The rising prices of steel and their unavailability throughout the year have brought the contractors and engineers into a great trouble. The RCC structures can also be reinforced with other materials such as fibres specifically Glass Fibre Reinforced Polymer and Carbon Reinforced Fibre Polymer (GFRP). This paper deals with the study of RCC beams when reinforced with the Glass Fibre Reinforced Polymer (GFRP) as a replacement of steel reinforcement and studying the behavior of beam under flexure. The GFRP as an internal reinforcement has proved to be of great interest not only in India but worldwide.

Keywords- Reinforced Cement Concrete (RCC), steel bars, corrosion, steel reinforcement, Glass Fibre Reinforced Polymer and Carbon Reinforced Fibre Polymer (GFRP).

I. INTRODUCTION

Reinforced concrete is a common building material for construction of facilities and structures. While concrete has high compressive strength, it has limited tensile strength. To overcome these tensile limitations, reinforcing bars (rebar) are used in the tension side of concrete structures. Steel rebar has historically been used as an effective and cost efficient concrete reinforcement. When not subjected to chloride ion attack, steel reinforcement can last for decades without exhibiting any visible signs of deterioration. However, steel rebar is very susceptible to oxidation (rust) when exposed to chlorides. Examples of such exposure include coastal areas, salt contaminated aggregates used in the concrete mixture and sites where aggressive chemicals and ground conditions exist. In cold climates, treating snow with salt is another cause of accelerated deterioration of concrete bridge decks. When corrosion of steel rebar occurs, the resulting corrosion products have a volume 2 to 5 times larger than the original steel reinforcement. As the concrete cannot physically sustain the high internal tensile stresses developed from this volume increase, it eventually may crack and spall causing further deterioration of the steel. The combination of ongoing deterioration and loss of reinforcement properties ultimately requires potentially significant and high cost repairs and possibly the endangerment of the structure itself. The advantageous properties of fiber reinforced polymer (FRP) such as high strength-to-weight ratio, and corrosion and fatigue resistance create an interest in engineers.

The behavior of beams reinforced with GFRP bars has been shown to be predictable by section analysis techniques normally used in design. The behavior of the beams is reliable and repeatable. The deformability of beams at failure is similar to that of steel reinforced beams. Different approaches for design are discussed and illustrated with examples. The choice of design approach depends largely on the design constraints. Shear capacity is predictable by using modifications to equations proposed by Clarke. However, the strength of GFRP links appears to be limited due to a number of factors.[9]

The beams reinforced with plain GFRP bars as shear reinforcement, have taken more shear than the control specimen, with no shear reinforcement, which indicates that the GFRP bars are able to take shear and are comparable to mild steel (Fe 250) reinforcement. It was observed that the failure of beams was not sudden, though the failure of GFRP bars was sudden and associated with splintering of fibers in direct tension. [8]

A research by Robert Mathieu and Benmokrane Brahim: Corrosion of steel reinforced concrete members has stimulated the research on fiber reinforced polymers (FRP) to be used as an internal reinforcement for concrete structures. The behavior of glass fiber-reinforced polymer (GFRP) reinforcing bars subjected to extreme temperatures is very critical for applications in North America, especially in Canada. There is a high demand for experimental studies to investigate the thermal stability of strength, along with the ultimate elongation, and modulus of GFRP bars. [7]

A research by Kemp Michael: The corrosion of steel reinforcement in concrete reduces the life of steel structures, causes high repair costs and can endanger the structural integrity of the structure itself. Glass fibre reinforced polymer (GFRP) offers a number of advantages over steel especially when used in marine and other salt laden environments.

GFRP reinforcing bars are gradually finding wider acceptance as a replacement for conventional steel reinforcement as it offers a number of advantages. Technical studies on a number of concrete structures, from five to eight years old and constructed with GFRP reinforcement, have shown that there is no degradation of the GFRP from the alkaline environment. GFRP has a very important role to play as reinforcement in concrete structures that will be exposed to harsh environmental conditions where traditional steel reinforcement could corrode. It is the unique physical properties of GFRP that makes it suitable for applications where conventional steel would be unsuitable. Detailed laboratory studies of samples taken from reinforced concrete structures, aged from five to eight years old, have confirmed that GFRP has performed extremely well when exposed to harsh field conditions.[5]

II. METHODOLOGY FOR EXPERIMENTATION

A. Materials and its testing

The various materials used are cement, fine aggregates, coarse aggregates, steel and glass fibres. The experimental results of specific gravity of cement, fine aggregates and coarse aggregates are shown in table below:

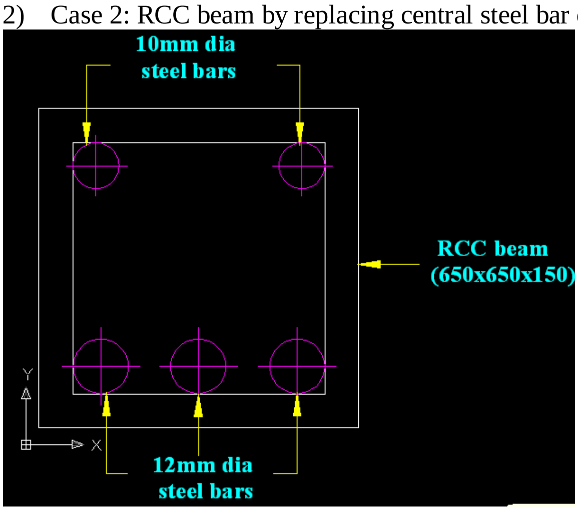
TABLE I
TEST RESULTS OF MATERIALS

Sl.No	*Title Of The Experiment*	*Result*
1	Specific gravity of cement	2.2
2	Specific gravity of fine aggregate	2.7
3	Specific gravity of coarse aggregate	2.6

B. Casting of beams

Beams are casted using metal moulds of sizes 700mmx700mmx150mm. Standard mix design for M20 grade concrete obtained is 1:2:4 as per IS:10262:2009. The concrete after proper mixing either in the mixer drum or manually is placed on the bottom of the mould to a height of 25 mm approximately which forms the cover of specimen. The concrete mix is then poured on the reinforcement specimen and to its sides by tamping the concrete simultaneously using a tamping rod. The concrete is thus poured to the top of mould and the uppermost surface is made plain and slightly marked with a knife to keep a track of the compression side of the specimen. The mould is kept for a day and then the specimen is removed from the mould and kept in a curing tank for 28 days to cure. After 28 days of proper curing, the specimen is then taken for flexural testing under Universal Testing Machine (UTM). On similar basis seven different cases were experimented and studied by replacing steel bars with GFRP bars. The different cases are as follows:

1) Case 1: RCC beam with steel reinforcement on compression and tension sides
2) Case 2: RCC beam by replacing central steel bar on tension side of beam with a hollow GFRP bar



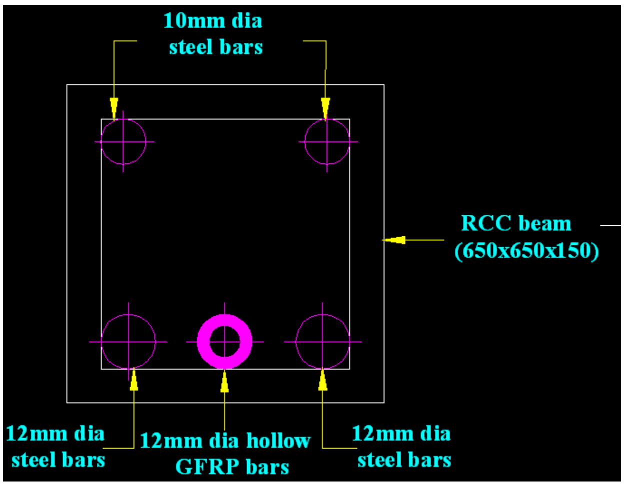
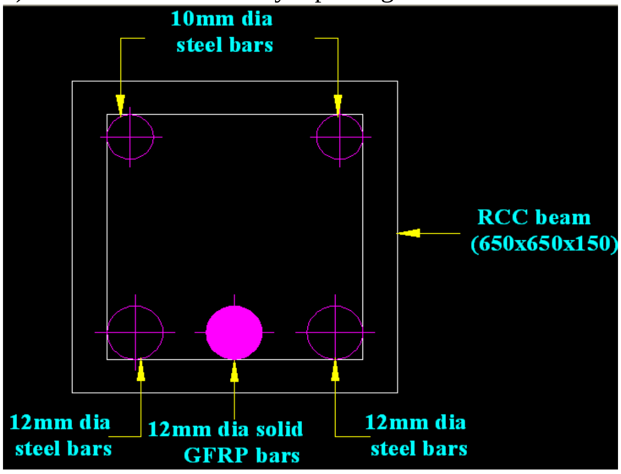


Fig.1 Case 1 Fig.2 Case 2

3) Case 3: RCC beam by replacing central steel bar on tension side of beam with a solid GFRP bar
4) Case 4: RCC beam by replacing two steel bars on tension side of beam with a hollow GFRP bar



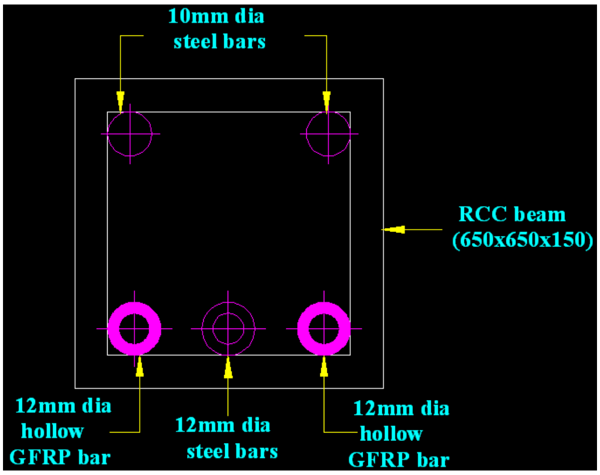
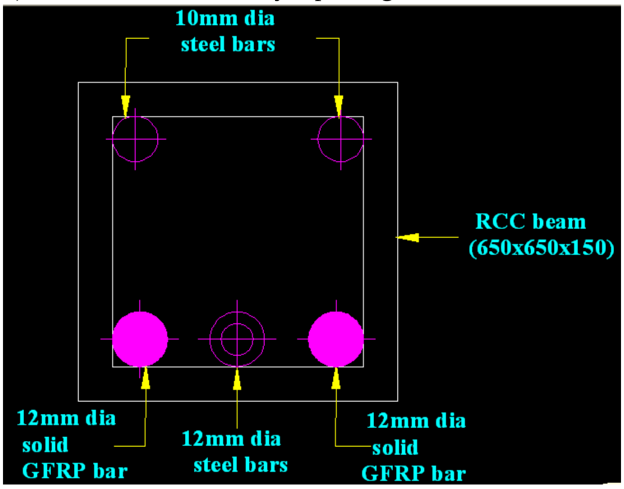


Fig.3 Case 3 Fig.4 Case 4

5) Case 5: RCC beam by replacing two steel bars on tension side of beam with a solid GFRP bar
6) Case 6: RCC beam by replacing all steel bars on tension side of beam with a hollow GFRP bars



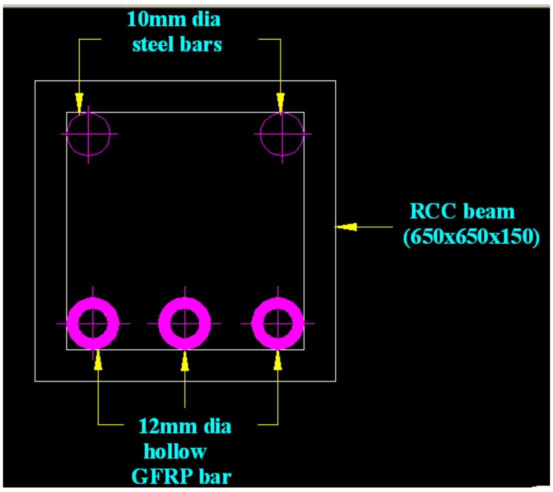
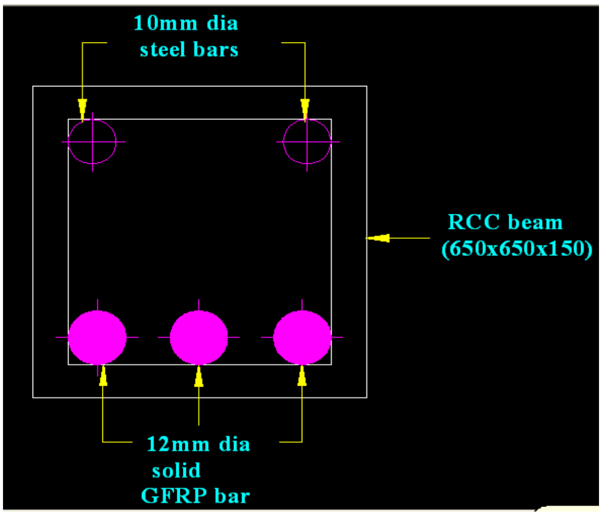


Fig.5 Case 5 Fig.6 Case 6

7) Case 7: RCC beam by replacing all steel bars on tension side of beam with a hollow GFRP bars



International Journal of Innovative Research in Advanced Engineering (IJIRAE) ISSN: 2349-2163
Volume 1 Issue 5 (June 2014) http://ijirae.com

Fig.7 Case 7

III . RESULTS

TABLE II
TEST RESULTS FOR VARIOUS CASES

Case No.	Maximum Flexure Load (kN)	Maximum Deflection (mm)	Shear Stress (kN/mm^2)	Bending Stress (kN/mm^2)
1: RCC beam with steel reinforcement on compression and tension sides	131.40	4.80	$1.34x10^{-3}$	$23.57x10^{-3}$
2: RCC beam by replacing central steel bar on tension side of beam with a hollow GFRP bar	126.30	4.90	$1.29x10^{-3}$	$22.45x10^{-3}$
3: RCC beam by replacing central steel bar on tension side of beam with a solid GFRP bar	132.60	5.00	$1.36x10^{-3}$	$23.66x10^{-3}$
4: RCC beam by replacing two steel bars on tension side of beam with a hollow GFRP bar	122.60	4.60	$1.25x10^{-3}$	$21.79x10^{-3}$
5: RCC beam by replacing two steel bars on tension side of beam with a solid GFRP bar	134.48	5.20	$1.38x10^{-3}$	$23.96x10^{-3}$
6: RCC beam by replacing all steel bars on tension side of beam with a hollow GFRP bars	119.66	4.40	$1.22x10^{-3}$	$21.27x10^{-3}$
7: RCC beam by replacing all steel bars on tension side of beam with a hollow GFRP bars	135.18	5.30	$1.40x10^{-3}$	$24.08x10^{-3}$

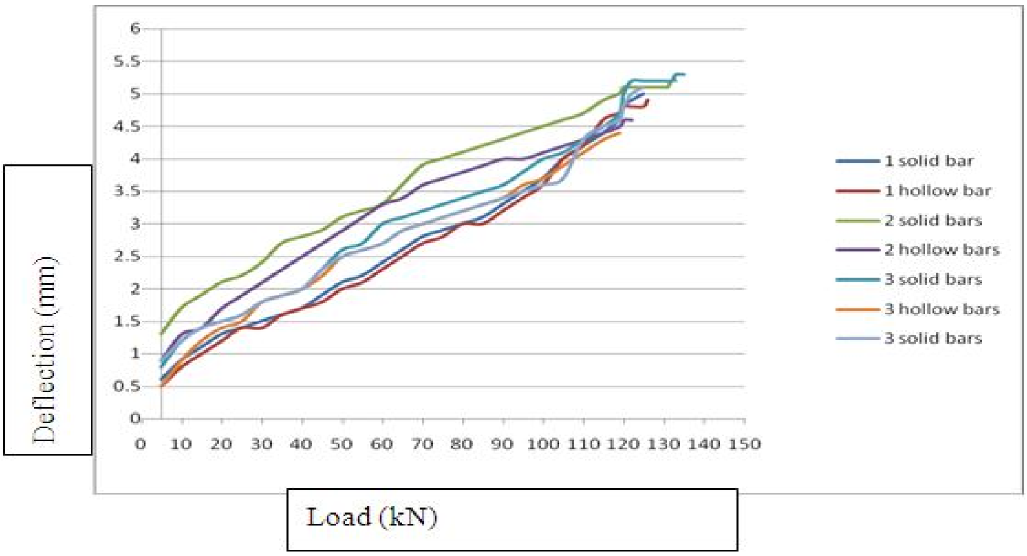


Fig.7 Graph of load versus deflection for all cases above

IV . CONCLUSION

1.Replacement of steel bars with GFRP bars on tension side of beam have shown better results in flexural load carrying capacities.
2.The solid GFRP bars allow the beam to deflect more and carry higher loads compared to the normal RCC beam with only steel reinforcement.
3.The hollow GFRP bars allow the beam to deflect less and carry lesser loads compared to the normal RCC beam with only steel reinforcement.
4.The use of GFRP bars in RCC structures has yielded not only greater flexural strength to the beam but also good shear capacities and bending moment.
5.Use of GFRP as hollow bars in concrete structures as a replacement of steel reinforcement proves to be cheaper. Huge cost difference may be found in large constructions.

ACKNOWLEDGEMENT

I'am grateful to the Almighty who is the "source of knowledge" and one who guides us in all aspects to bring out this paper work a successful one. I express my deep respect and profound gratitude to our college management committee for providing us an opportunity and infrastructure to undertake this paper work. I express my sincere gratitude to Dr. K.G.Vishwanath, Principal and director, Jain College Of Engineering Belgaum and Prof. Sachin M.Kulkarni, Head Of Civil Department for providing an opportunity to undertaken this work. I express sincere gratitude to my parents and friends for encouraging in the completion of this work.

REFERENCES

[1] David Tse Chuen Johnson, *"Investigation of glass fibre reinforced polymer reinforcing bars as internal reinforcement for concrete structures"* (2009).
[2] Glass Fiber Reinforced Polymer (GFRP) Rebar - Aslan™ 100 series FIBER GLASS REBAR (2011).
[3] Iman Chitsazan, Mohsen Kobraei, Mohd Zamin Jumaat and Payam Shafigh(2010) *"An experimental study on the flexural behavior of FRP RC beams and a comparison of the ultimate moment capacity with ACI"*
[4] IS Code books IS:10262-2009 and IS:456-2007.
[5] Michael Kemp and David Blowes "*Concrete Reinforcement and Glass Fibre Reinforced Polymer*"(2011).
[6] Masmoudi,R., Masmoudi, A., Ouezdou, MB., and Daoud, (2011) A ,"*Long-term bond performance of GFRP bars in concrete under temperature ranging from 20 °C to 80 °C "*
[7] Mathieu Robert and Brahim Benmokrane "*Behavior of GFRP Reinforcing Bars Subjected to Extreme Temperature*" (2009).
[8] Mettu Bhaskara Rao, P.J. Rao, M.V.S. Rao, K.J. Rao, (2013) *" Study of the behavior of GFRP – RC beams under shear"*.
[9] Nebojsa Duranovi, Kypros Pilakoutas and Peter Waldron *" Tests on concrete beams reinforced with glass fibre reinforced plastic bars"*.
[10] Park Yeonho(2012) *"Long-term performance of gfrp reinforced concrete beams and bars"*.
[11] S.H. Alsayed, Y.A. Al-Salloum, T.H. Almusallam *"Performance of glass fiber reinforced plastic bars as a reinforcing material for concrete structures"*.

