International Journal For Technological Research In Engineering
Volume 2, Issue 7, March-2015 *ISSN (Online): 2347 - 4718*

EXPERIMENTAL ANALYSIS OF A HYBRID BEAM USING GFRP AND STEEL REINFORCEMENT BARS

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ABSTRACT: The project deals with the experimental study on reinforced concrete beams using GFRP (Glass Fiber Reinforced Polymer) and steel reinforcement bars by the percentage replacement technique of replacing Steel on GFRP bars to achieve good flexural strength. The Fiber Reinforced Polymer (FRP) has become a practical alternative construction material for replacing steel bars as reinforcement in concrete structures. As the steel corrosion related problems have turned out to be the heavy burden on countries both economically and socially since many decades. In this study, the objective is exploring the usage of GFRP as the reinforcing material in rectangular beams. As the superior performance of the polymer as compared to the conventional steel bars in terms of corrosion resistance, high fatigue performance, strength – weight ratio exhibit lower ductility due to linear elastic response of fiber reinforcement. In order to achieve a better corrosion resistance, non-conductive properties low density this concept of hybridization helps to be a better adoptable technique.
Keywords: GFRP, Steel, Non-corrosive, Non-conductive, Percentage replacement.

I. PRELUDE

It is well known that the concrete is good in compression and weak in tension. The reinforcement plays a major role in carrying the tension, the steel reinforcement is traditionally used as a reinforcing material due to its economic and ductile properties but as the corrosion of internal reinforcing steel is one of the reason in weakening of structure, as the concrete cracks in the initial stages creating way for chlorides to penetrate into the steel leading to deterioration. The use of GFRP in replacing steel in concrete structural elements has relatively turned a new technique in increasing the serviceability. The GFRP offers an excellent combination of physical and chemical properties such as low weight, non-corrosive, non-magnetic properties, as the fiber material differs a lot from steel reinforcement with low elastic modulus and elastic brittle stress-strain relation. These have been successful in bridge deck slabs, approach slabs, pre-cast elements etc.

The principle aims of this study are summarized as follows:

- To present the test results of 10 beams reinforced with GFRP and steel reinforcement bars.
- To find out the load versus deflection values using universal testing machine (UTM).
- Analyzing the same beams using ANSYS R14.5.

A. R.C Structures Strengthening for Resistance:

There are 3 common types basically in FRP bars.
1. GFRP-Glass Fiber Reinforced Polymer
2. CFRP-Carbon Fiber Reinforced Polymer
3. AFRP-Aramid Fiber Reinforced Polymer

In this study the GFRP material has been used. In recent days a large number of reinforced concrete structures have been damaged due severe chemical attacks and some of these structures have been repaired to prolong its life and strength. A few cases of the repair and reinforcing of strengthened solid building harmed by seismic tremor have been accounted for in earthquake prone nations. The structural repair works are basically done using fiber materials as the cover the surfaces using polymer matting. In few regions, where the reinforcement is degraded in zones like foundations and columns, the concept of fiber wrapping is done by cleaning and removing the dead concrete. The need of the strengthening of the structures also arises in the case where existing structures must comply with more recent code requirements. Different techniques for repair and strengthening of the structural elements such as reinforced concrete walls, infill walls have been suggested using GFRP material. Some of these techniques have been used in saline atmospheric areas. However, because of the high cost and requirement of technical guidance by the structural designers, the strengthening of the structures in most cases has been mainly on engineering judgment. As cost of GFRP is consequently high with few draw backs when prone to continuous acidic attacks, the reinforcing of building structures is moderating chemical dangers particularly in industrial and off shore structures for serviceability. This paper summarizes the hybrid beam analysis of the reinforced concrete beam specimens with percentage replacement of GFRP for a unique design. From this, a better system in reinforced concrete structures can be assessed.

II. DIFFERENT MATERIALS ADOPTED

In the process of strengthening of concrete structures the following reinforcing materials have been taken

- GFRP-Glass Fiber Reinforced polymer
- STEEL

A. GFRP Bars:

The GFRP bars are approximately one fourth the weight when compared to steel bars. As per the requirement GFRP bars with (10mm) as per the design are used as shown in figure.

Figure 1: GFRP rebar

Table 1: Chemical Compositions

Material	Percentage
E-glass	72%
Polyester	20%
Ceramic Resin	3.5%
Corrosion Inhibitor	1.5%

Table 2: Mechanical Properties of GFRP

Tensile strength	760-710MPa
Elastic modulus	43 GP a
Compressive Strength	380 MP a
Bond Strength	15 MP a
Transverse Shear Strength	> 145 MP a
Yield	610 MP a
Water Absorption	0.25% max
Specific Gravity	2.0

B. STEEL:
FE-500 steel has been used in this experiment.

III. METHODOLOGY

A. Mix Design:
Based on number of trials the mix proportion obtained is 1:2.19:2.92 at 0.35 water/cement ratio for M25 grade concrete. (Conplast-430) is used as super plasticizer. A nominal mix of M25 grade concrete is chosen for the members. The study is aimed to investigate the beneficial effects of GFRP bars on structural performance, especially ductility.

B. Specimens:
The beams were 100mm wide, 200 mm high and 1100mm long, with 10 mm diameter steel and GFRP bars with 6mm diameter stirrups have been used with 120mm spacing in all the specimens. The reinforcement cages beside the moulds before concreting are shown in figure 2.

Figure 2: The reinforcement cages before concreting

C. Experimental Program:
A total no of 10 beam specimens are categorized into two groups each one set of five samples with 7 day and 28 day curing method both of the groups are composed as the same set of reinforcement and mix designs. The experimental variable include rebar size of (#10mm) including plain concrete. Which are tested for finding the flexural strength on Universal Testing Machine (UTM).

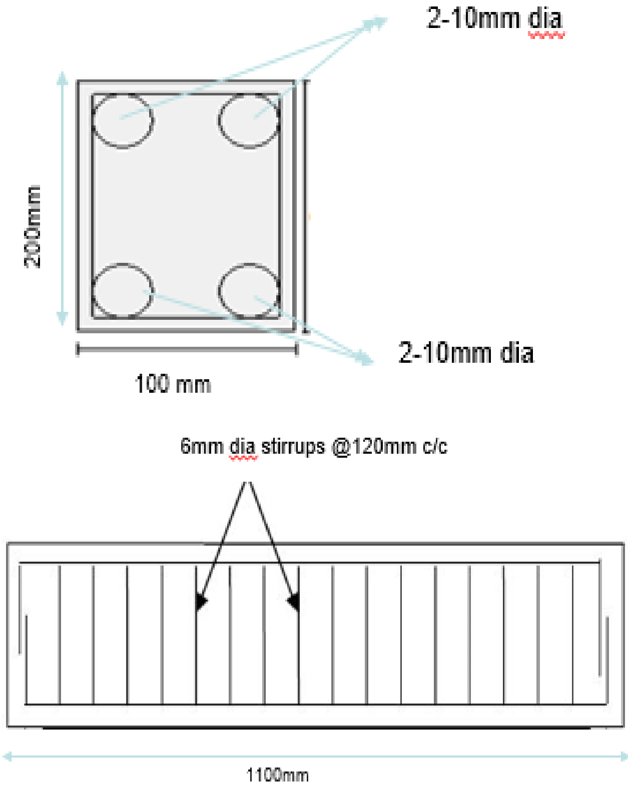


Figure 3: Reinforcement design details

Figure 4: Beam placed on U.T.M

D. Percentage replacement method:

As steel is a basic material preferred as the common construction material as a primary reinforcing material but as per hybridization technique the GFRP has been introduced into the design by percentage replacement.

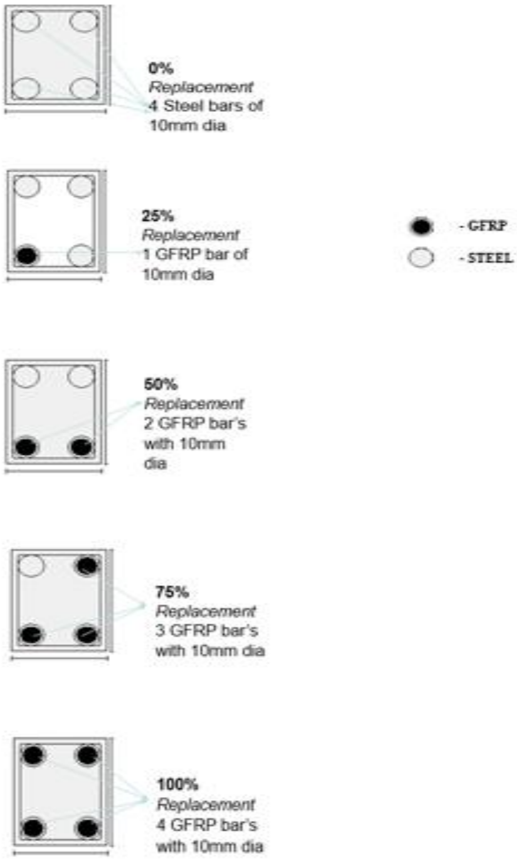


Figure 5: Percentage replacement of GFRP bars with steel

E. Results and Discussions:

The load Vs curves for all the reinforcements were drawn. The beam with different percentages of replacement of Steel by GFRP are shown in figure 6.

X-axis : Deflection

Y-axis : Load

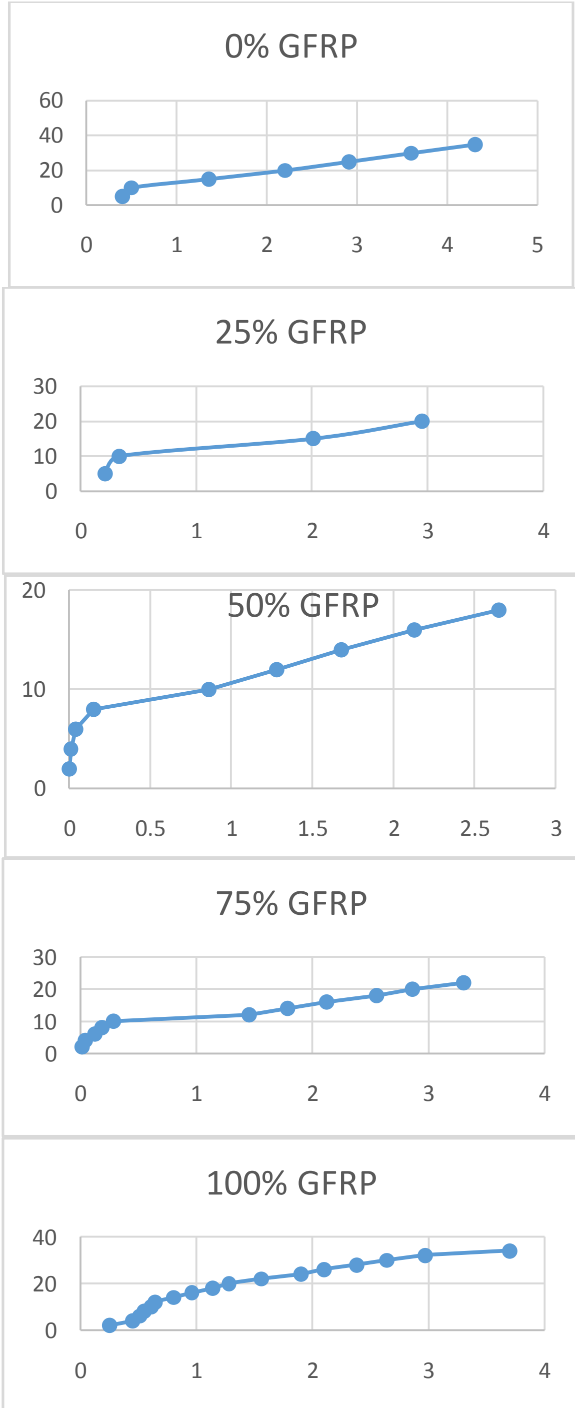
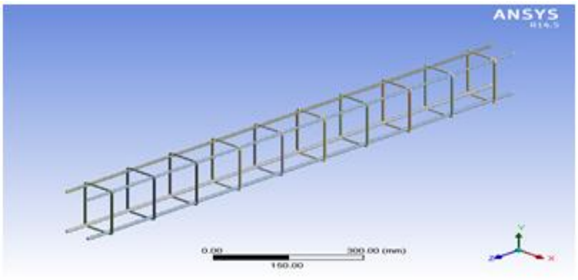


Figure 6: Graphical representation for Load vs Deflection

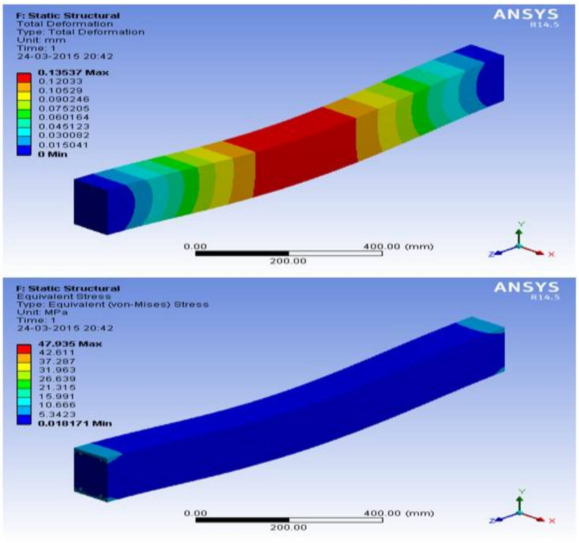
Figure 7: Crack patterns in 50% and 75% GFRP reinforcement

IV. MODELLING

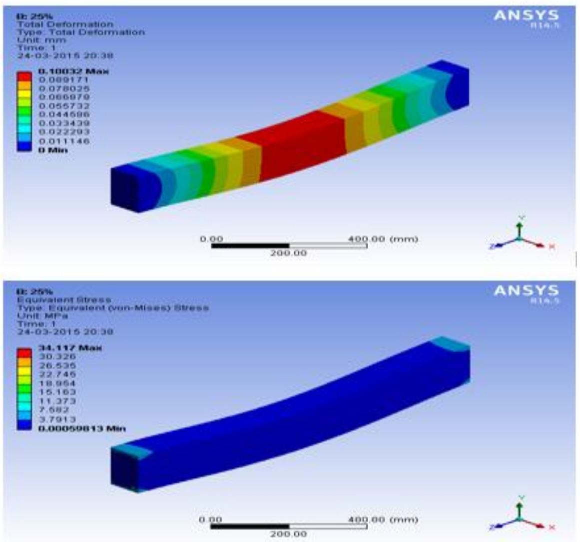
The modelling has been done using ANSYS R14.5 for analysing the deflection patterns in the beam elements. The ANSYS analysis depicts stress disribution in the zones. To study the behaviour of the GFRP material as per the American standard ACI 440.1R-06 FRP Rebar design code has been referred to get a better understanding on material behaviour.



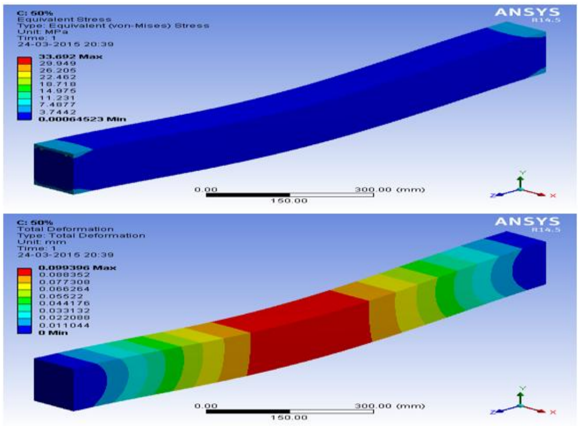
Reinforcement detailing



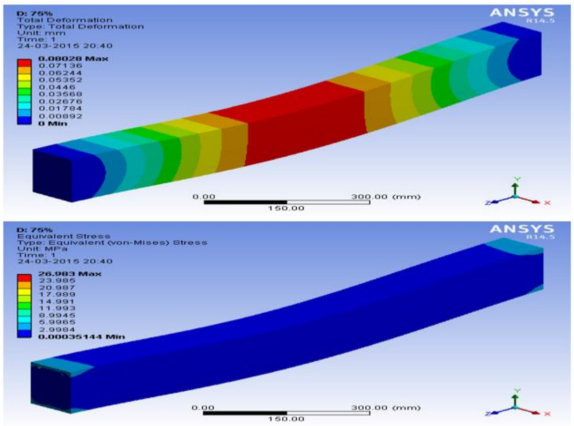
100% Steel Reinforcement



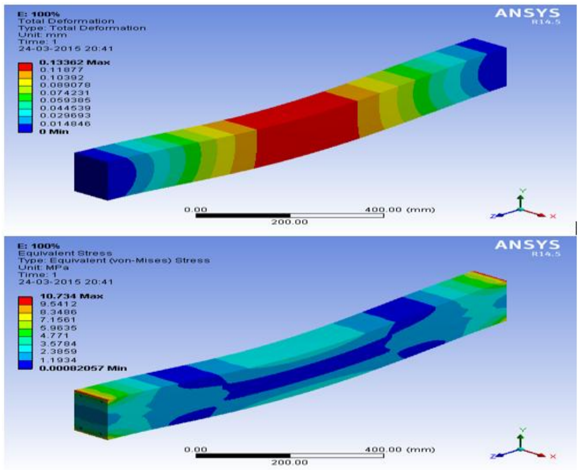
25% GFRP Reinforcement



50% GFRP Reinforcement



75% GFRP Reinforcement



100% GFRP Reinforcement

Figure 8: The above figures demonstrates the bending stresses of hybrid beam models.

V. RESULTS

Table 3, presents the results of deformation and stress values obtained from ANSYS R14.5.

Table 3: Analytical Results

	100% STEEL	25% GFRP	50% GFRP	75% GFRP	100% GFRP
Deformation(mm)	0.135	0.100	0.099	0.080	0.133
Equivalent stress (MPa)	47.935	34.11	33.69	26.98	10.73

VI. COMPARED DEFORMATION RESULTS FROM EXPERIMENTAL AND ANALYTICAL MODELS

Both the results related to the experimental and analytical casted specimens which have been tested are compared and shown in table 4.

Table 4: Comparative Results

	100% STEEL	25% GFRP	50% GFRP	75% GFRP	100% GFRP
Analytical Deformation(mm)	0.135	0.100	0.099	0.080	0.133
Experimental Deformation(mm)	0.136	0.201	0.086	0.025	0.80

VII. CONCLUSIONS

The following conclusion can be drawn.

- It is always better to maintain high grade fibers in concrete to have a better bond in between reinforcement and concrete.
- The technique for utilizing fiber reinforcement is beneficial to be utilized in sea shore structures to avoid corrosion effect and also in electrical retrofit or reinforce the current structures.
- GFRP material helps to enhance the life of structure due to its unique properties when used as reinforcement.
- Temperature effect is another major issue. Since steel has same coefficient of thermal expansion as that of concrete it doesn’t face any problem during expansion and contraction. But GFRP doesn’t have the same benefit. But still it can be very useful regarding non-structural elements where strength is secondary.

VIII. ACKNOWLEDGEMENT

Acknowledgement should also be given to the company, CSK Technologies who contributed the GFRP material for the experiment.

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