# Numerical Analysis of GFRP Rod in a Reinforcement Concrete Beam Using ANSYS

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***Abstract-*** **This project focuses on the replacement of steel rebars in concrete beam with Glass Fiber Reinforced Polymer rod in reinforced concrete beam. And analyzing its behaviour under 2-point load using a FEM software called ANSYS. The load and deflection are observed. GFRP is a type of composite material. The use of composite materials has been studied and developed nowadays. There are different types of composite materials, manufactured to meet the necessity and the requirement of the structures. The main property is high strength to weight ratio, durability, corrosion resistance, and long-term integrity. The composite materials are also used in structures exposed to cyclic loads. The required data are taken from ACI-1r-06 and ACI-440.1R-15 codes.**

**Key words: GFRP rods, ultimate load and deflection, ANSYS.**

## I. INTRODUCTION

Fiber reinforced polymer (FRP) rod is a composite material. It composes of two main components that are reinforcing fibers and a polymer matrix. The reinforced fibers can be made of materials like glass, carbon, or aramid. These fibers are embedded in the polymer matrix which can be epoxy or polyester resin. The polymer matrix acts as a binder and protects the fibers from external damage.

Recently, FRP rods are used in many countries to construct bridge decks and roads owing to sea corrode. It exhibits high tensile strength and light in weight.

The durability is the property related to the effective life of the construction or the structures. The FRP has many advantages to replace the steel rebars. The structure constituted with FRP rebars and RC is called FRP- reinforced concrete structure. The disadvantage is that it possesses less ductility in general. In order to improve ductility, steel rebars can be added. There is ongoing research and development continuing to enhance the properties of the FRP rods. The adoption is expected to increase, revolutionizing the field of structural engineering and construction.

Most of the time, the FRP bars are used in aggressive environments such as coastal environments, water treatment plants that includes sea walls, reinforced piles, culverts, tanks, retaining walls.

## II. GFRP BARS

FRP are available in different sizes and fibers such glass fiber, carbon fiber and aramid fiber. The available sizes are 6mm, 8mm, 10mm, 12mm, 16mm, 20mm, 25mm, etc. By pultrusion method, the bars are manufactured. This composite material is also available in the form of laminate plates. It can be used in frame and panel works.

There are different types of glass fiber reinforced such as plain rebar, sand coated, spiral wound and ribbed bars. Even hybrid rebars are available, in which the steel rebars are coated with glass fiber.

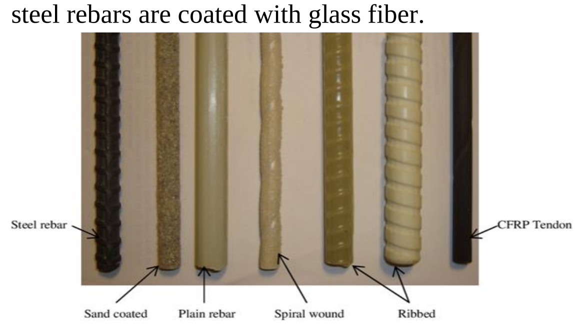



FIG.1 TYPES OF GFRP BARS

Usually, the glass fibers are brittle in nature and the ductility can be achieved by using these rods partially with steel rebars. The Hybrid GFRP bar has more ductility compared to other GFRP bars.

## III. PROPERTIES OF GFRP BARS

In the GFRP bars, the glass fibers are embedded in the polymer matrix.

PHYSICAL PROPERTIES

The physical properties of GFRP include light weight, high strength to weight ratio, corrosion resistance, non-conductivity, dimensional stability, thermal expansion, fatigue resistance.

GFRP rods are lighter than steel rebars. Since, the density of the GFRP rod is less. It can be used in the structures where weight reduction is necessary. It exhibits a high tensile strength that can withstand significant loads and stresses. It is highly resistance to corrosion even when exposed to moisture, chemical or harsh environment conditions. Since it is non-conductivity, it does not conduct heat or electricity and can be used in structures near power transmission lines. The GFRP rods exhibit excellent dimensional stability to maintain the shape and dimensions over time, even under the cyclic load or the varying condition to ensure the long-term structural integrity and performance.

These rods have low coefficient of thermal expansion compared to normal steel rebars.

It has a good fatigue resistance that helps the structure to withstand cyclic load and repetitive stresses without any decrease in the performance of the structure over time.

The properties and the values vary according to the binders used by the manufacturer.

ADVANTAGES OF GFRP BARS

1. The coefficient of temperature expansion of the rods is close to the coefficient of thermal expansion of concrete.
2. Great chemical and corrosion resistance.
3. Easy transportation and storage.
4. Easy installation.
5. The length of rods can be customized.
6. It can be used at temperatures from -70 to +120 degrees Celsius.

DISADVANTAGES OF GFRP BARS

1. The modulus of elasticity of these rods are 4 times lower than that of regular steel rebars with an equal diameter.
2. When heated to a temperature of 600 °C, the binder gets softened, and the reinforcement loses its elasticity.
3. The material cannot be bent on site. It can only be prefabricated as per the requirements.

Application of GFRP rods

It can be used in ground slabs, RCC roads, platforms, paths, parking lots and roads. It can also be used in the construction of compound walls, swimming pools, reservoirs, canals, septic tanks, water tanks, precast panels.

Even it can be used in foundation of houses up to 3 floors, walls made of fixed formwork, embankments, piers, slabs to strengthen the coastal strip.

REAL TIME STRUCTURE

FIG.2 SEA WALL CONSTRUCTION

IV. MODELING AND ANALYSIS

The beam of span 1000 mm long, with 150mm deep and 150mm width is modeled in ANSYS software and load and deflection is analyzed. The main reinforcement is provided with GFRP rods with 10mm diameter, and the stirrups are provided with 8mm diameter of GFRP rods with 100mm spacing between each stirrup. The grade of concrete is taken as M35 grade.

ACI440-1R 15 code is referred to check whether the beam is tension controlled or compression controlled. To check the beam,

- fc′= specified compressive strength of concrete, psi (MPa)
- $d_b$ = diameter of reinforcing bar, in. (mm) =10 mm
- Af,bar = area of one FRP bar, in.2 (mm2) =78.5 mm^2

Design material properties:

- CE = 0.8 (exposure cond.)
- $f_{fu} = C_E f_{fu}^*$ = (0.8) (535) = 428 Mpa
- Determine the strength reduction factor.

- d = 150 – 20 – 8 – (10/2) = 117 mm
- Af = Area of bars= (3) (78.53) = 235.5 mm2
- $\rho_{fb} < \rho_f$
- *So, the beam is tension controlled.*
- *Properties of the GFRP*
- *Youngs modulus – 44800 Mpa*
- Poisson ratio -0.3

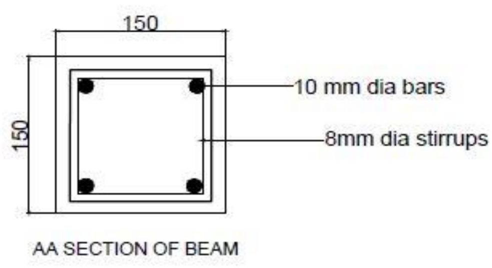



FIG.3.1 BEAM CROSS SECTION

The reference diagram is drawn using the CAD software.

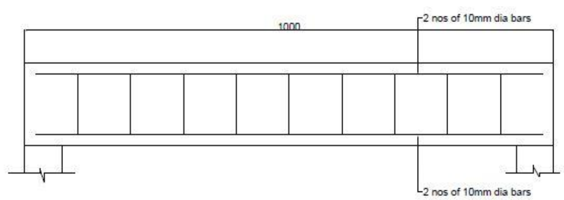



FIG.3.2 BEAM CROSS SECTION

**STEPS IN ANSYS SOFTWARE**

1.The cross section is drawn in the ANSYS or can be exported from the CAD software. Then the cross section is extruded for the specified length of beam needed.

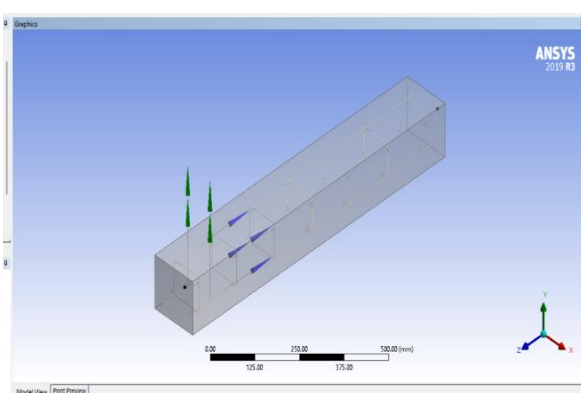



FIG.4. SOLID BEAM

2. The reinforcement is provided in the solid beam.

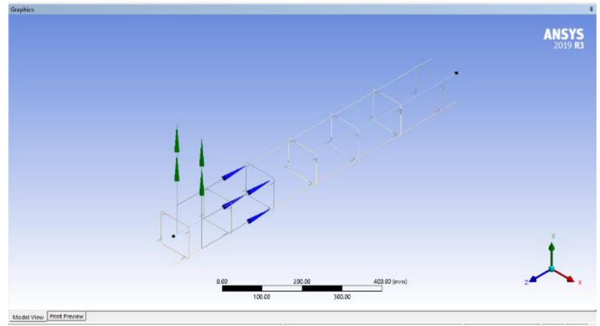



FIG.5. THE REINFORCEMENT

Stirrups can also be provided.

3. The needed material properties are fed in the engineering data or selected if already exists in the data.

4.The properties are assigned to the elements and generated.

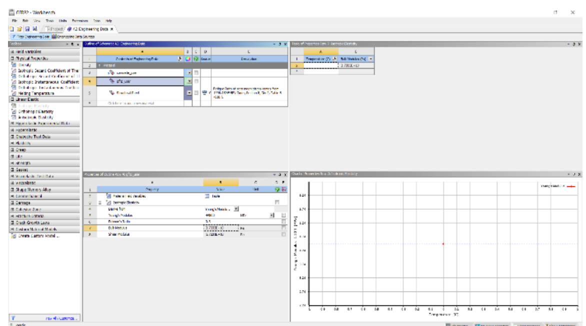


FIG.6. ASSIGN PROPERTIES

5. The mesh is applied to the RC beam.

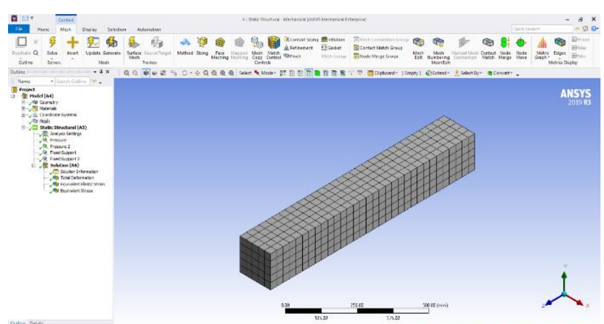



FIG.7. ASSIGN MESH

6. Support at the ends of the beam is assigned and the load is applied, and the loads are applied according to the 2-point load test on the beam. Finally, the beam is analysed and observed.

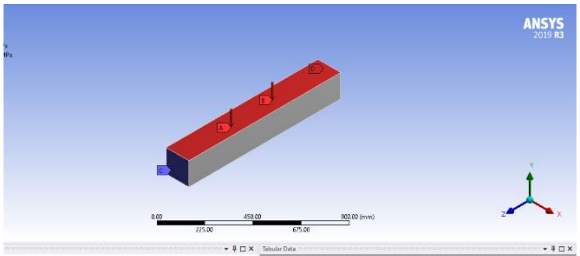



FIG.8. APPLYING LOAD

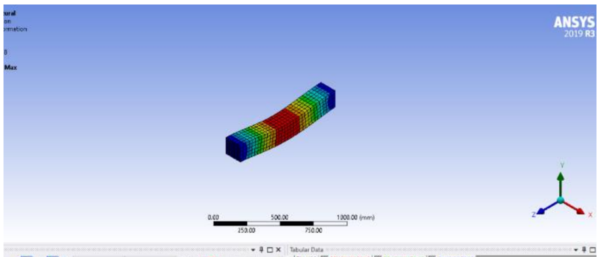



FIG 9.1. DEFORMATION

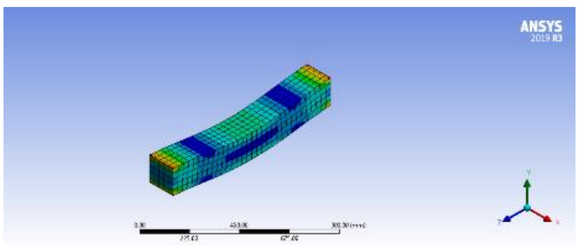



FIG.9.2. STRAIN

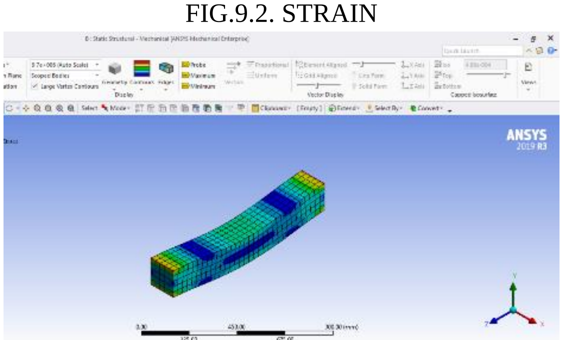
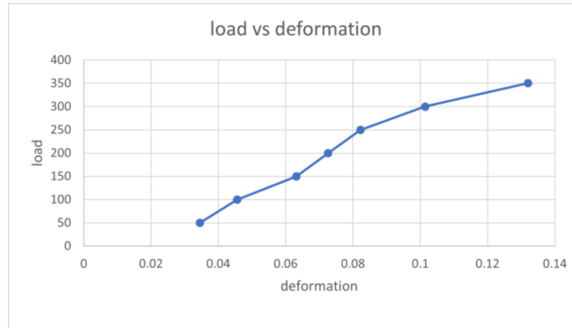



FIG.9.3. STRESS

ANALYSIS OF RC BEAM REINFORCED WITH STEEL RODS

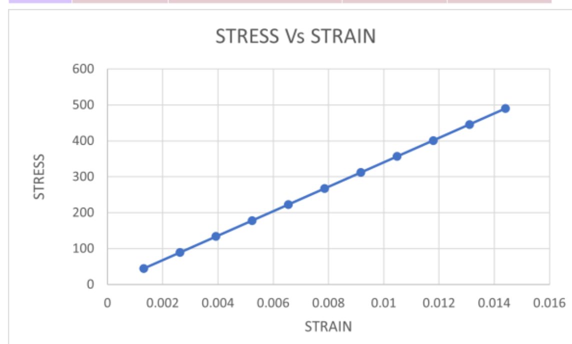
| S.NO | LOAD (KN) | DEFORMATION (mm) | STRESS (N/mm^2) | STRAIN |
|---|---|---|---|---|
| 1 | 50 | 0.0345 | 5.1438 | 0.000238 |
| 2 | 100 | 0.0456 | 9.3061 | 0.000432 |
| 3 | 150 | 0.0632 | 16.5431 | 0.000656 |
| 4 | 200 | 0.0726 | 19.8732 | 0.000723 |
| 5 | 250 | 0.0822 | 24.9860 | 0.000431 |
| 6 | 300 | 0.1015 | 28.9860 | 0.000487 |
| 7 | 350 | 0.1320 | 36.7654 | 0.000523 |



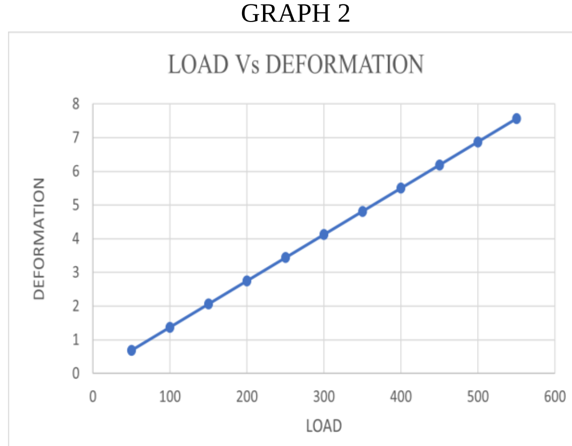

GRAPH 1

ANALYSIS OF RC BEAM REINFORCED WITH GFRP RODS

| S.NO | LOAD (KN) | DEFORMATION (mm) | STRESS (N/mm^2) | STRAIN |
|---|---|---|---|---|
| 1 | 50 | 0.68766 | 44.54 | 0.0013099 |
| 2 | 100 | 1.3753 | 89.08 | 0.0026198 |
| 3 | 150 | 2.063 | 133.62 | 0.0039297 |
| 4 | 200 | 2.7506 | 178.16 | 0.0052394 |
| 5 | 250 | 3.4383 | 222.7 | 0.0065493 |
| 6 | 300 | 4.1259 | 267.24 | 0.0078591 |
| 7 | 350 | 4.8136 | 311.78 | 0.009169 |
| 8 | 400 | 5.5013 | 356.32 | 0.0104792 |
| 9 | 450 | 6.1890 | 400.86 | 0.0117891 |
| 10 | 500 | 6.8767 | 445.4 | 0.013099 |




GRAPH 2




GRAPH 3

## CONCLUSION

The ANSYS software can be used to design any type of structures and reduce our time to analysis the structure easily. The detailed study on the behaviour of the concrete beam reinforced with glass reinforced polymer rod is done using the Ansys software. The property and the design were studied from the literature review. From the above investigation it concludes that the steel rebars can be replaced by the GFRP rods. Since the deformation is more, it has a more brittleness natural, the GFRP rods can be used to replace the steel rods partially. Also can be used in weak beam strong column structures.

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