EXPERIMENTAL STUDY OF CONCRETE BEAM REINFORCED WITH GFRP BARS

Dr. Sundari S[1], Ranjith Raja P[2]
[1]Associate professor, Dept of Civil Engineering, Government college of engineering, Salem
[2] PG Student, Dept of Civil Engineering, Government college of engineering, Salem

Abstract -This study Examines the structural behavior of concrete beams reinforced with Glass Fiber Reinforced Polymer (GFRP) bars, particularly for use in aggressive environmental conditions. Experimental results confirm that GFRP bars provide excellent tensile strength and outstanding corrosion resistance, making them a strong alternative to traditional steel reinforcement. Among all tested configurations, hybrid beams—combining GFRP reinforcement, optimized geometry, and enhanced concrete strength—delivered the most Favorable results and the highest structural strength. These beams showed superior resistance to shear-induced failure, developed multiple fine cracks instead of a dominant shear crack, and delayed the onset of major damage. They also withstood significantly greater ultimate loads, indicating improved ductility and overall stability. The close match between experimental findings and finite element analysis (FEA) further validated the accuracy of the predictive model. The study concludes that hybrid GFRP-reinforced beams offer the most effective solution for structures requiring high strength, durability, and corrosion resistance.

1. INTRODUCTION

The Development of FRP Reinforcement can be traced to the expanded use of composites after World War II. The aerospace industry had long recognized the advantages of the high strength and light weight of composite materials, and during the Cold War, the advancements in the aerospace and defense industry increased the use of composites. Furthermore, the rapidly expanding economy of the U.S. demanded inexpensive materials to meet consumer demands.

1.1 LITERATURE REVIEW

[1] **A.Mohamed Firdows, R.Mohamed Zakkaria:** Corrosion has necessitated repairing or replacing steel reinforcing in many concrete structures. Non-corrosive reinforcing bars made of polymers with fiber reinforcement (fiber-reinforced polymer (FRP)) have seen a significant uptick in utilization over the last decade due to their improved characteristics and cost-effectiveness in concrete construction. It is recommended that fiber-reinforced concrete (FRC) be used instead of plain concrete in FRP-reinforced beams to mitigate the issue of excessive crack width caused by using FRP bars as flexural reinforcement. Adding fibers to concrete has been found to increase its durability and resilience against cracking. Flexural capacities and the cracking response of beams reinforced with FRP bars are examined to see whether FRC may improve them. Failure loads and cracking response in the constant-momentum zone were determined after beams were immersed/exposed to saline and alkaline solutions under accelerated conditions for 180 days (6 months). The beams used either plain or FRC reinforcing bars (glass fiber–reinforced plastic (GFRP)-twisted and GFRPsand-coated). FRC and glass-reinforced polymer rebar (GFRP) are defined in terms of the bending behavior of a hybrid system with discontinuous parts. Maximum fracture widths and flexural strength of beams reinforced with GFRP reinforcing bars may be improved using FRC.

[2] **Nooshin G. Amirabad, Farshid J:** Fiber reinforced polymers (FRPs) have received considerable research attention because of their high strength, corrosion resistance, and low weight. However, owing to the lack of ductility in this material and the quasi-brittle behavior of concrete, FRP-reinforced concrete (FRP-RC) beams, even with flexural failure, do not fail in a

PCCBs were cast and tested under four-point bending conditions. The control beam failed due to shear, and the PCCBs exhibited different confinements and perforations. The goal was to find an appropriate PCCB for use in the compression zone of the beams, which not only improved the ductility but also changed the failure mode of the beams from shear to flexural. Among the employed blocks, a ductile PCCB with low equivalent compressive strength increased the ductility ratio of the beam to twice that of the control beam.

1.2 GFRP Rebars

As shown in fig.1 Glass Fiber Reinforced Polymer bars having with a helical wrapping surface the manufacturing involves a combination of pultrusion and wrapping processes.

- **Manufacturer- ASLAN**
- **Density- 2100 kg/m3**
- **Modulus of elasticity- 45 Gpa**
- **Ultimate strength- >750Mpa**
- **Ultimate shear strength- >150**
- **Ultimate strain- 2.5%**

Figure 1 GFRP Rebars

2. NUMERICAL MODELING USING ABAQUS SOFTWARE

Abaqus is a software suitable for finite element analysis. It can be used for both static and dynamic problems. Abaqus CAE is a software application used for both the modelling and analysis of components and assembling and visualizing the finite element analysis result. Abaqus CFD denotes computational fluid dynamics software application which provides advanced computational fluid dynamic capabilities with extensive support

3. PROCESSING STAGE

Pre-processing:

In this stage the model of the physical problem is defined and an Abaqus input file was created.

Simulation:

Abaqus simulation offers complete and powerful solutions for routine and sophisticated engineering problems.

Post processing:

The results can be evaluated once the simulation has been completed and the displacements, stresses, or other fundamental variables have been calculated. The evaluation is generally done interactively using the visualization module.

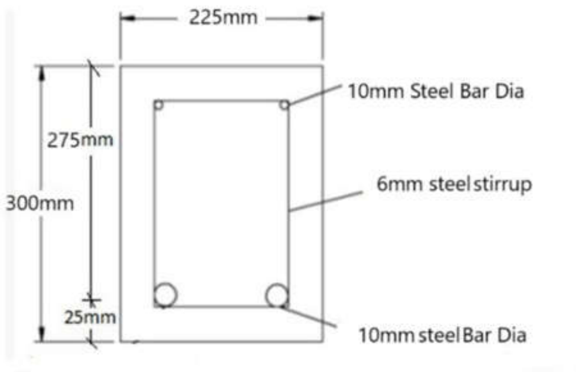
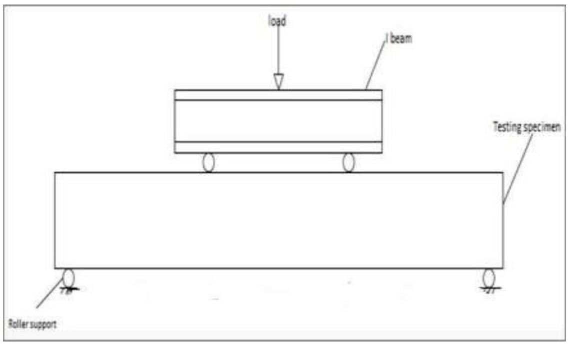


Fig. 2 Required section and then extrude for the required length.



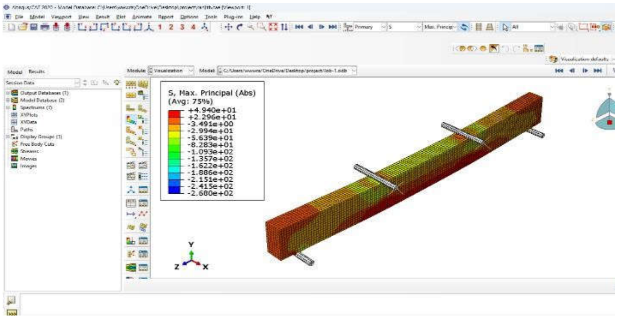


Fig. 3 cracking pattern of the GFRP-reinforced beam

Fig. 5 GFRP-reinforced beam

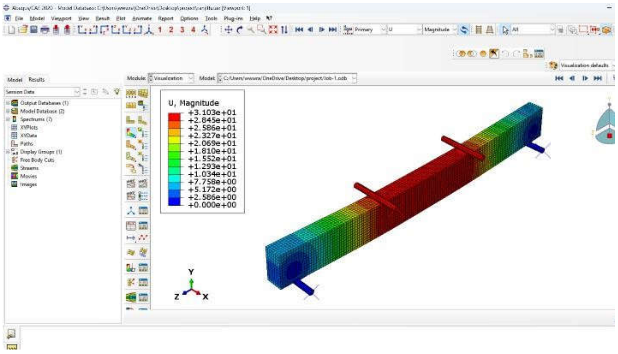
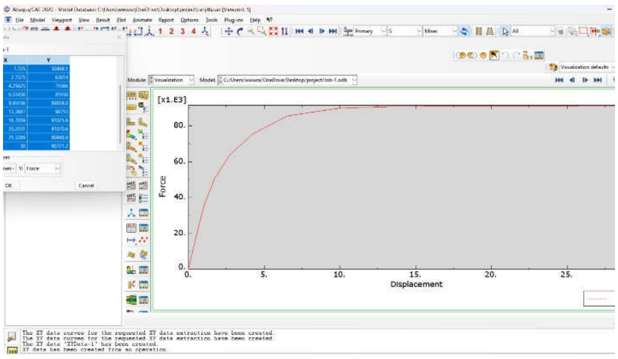


Fig. 4 Deflection pattern of GFRP reinforced beam

Fig. 6 Loading Frame beam Testing



4.EXPERIMENTAL INVESTIGATION

Preparation of Mould:

A Wooden Mould of the specified dimensions (2000 mm × 225 mm × 300 mm) was thoroughly cleaned and oiled to prevent adhesion of concrete to the sides.

Mixing:

The concrete was mixed using a mechanical mixer to ensure uniformity. The dry ingredients were mixed first, followed by the gradual addition of water and admixtures

Placing:

The concrete was placed in the mould in layers of approximately 100 mm. Each layer was compacted using a mechanical vibrator to remove air voids and ensure homogeneity.

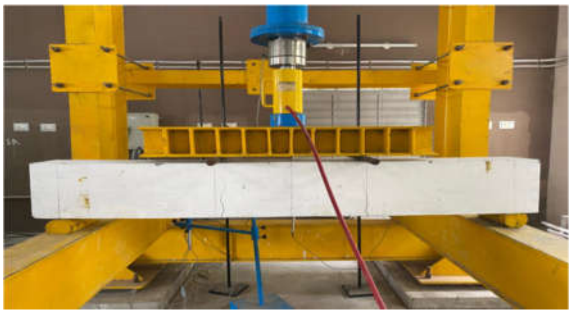


Fig. 7 Fully Steel Reinforced beam Testing

Load Vs Deflection Diagram of Fully Steel Reinforced Beam

Fully Steel Reinforced Beam	
Load(kN)	Deflection(mm)
9.899	0.9
19.334	1.3
28.995	2.2
39.584	3.8
50.656	4.3
59.897	4.5
67.632	5.5
79.337	6.9
90.455	12.1

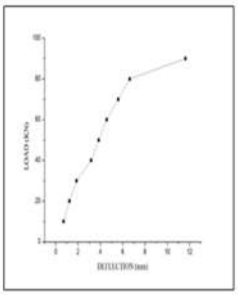


Fig. 8 Fully GFRP Reinforced beam Testing

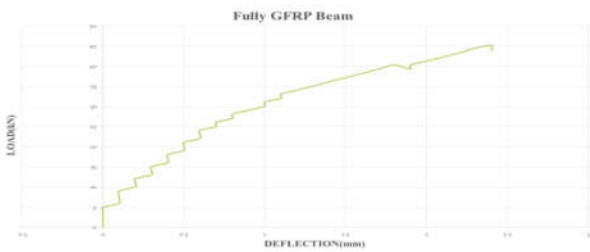
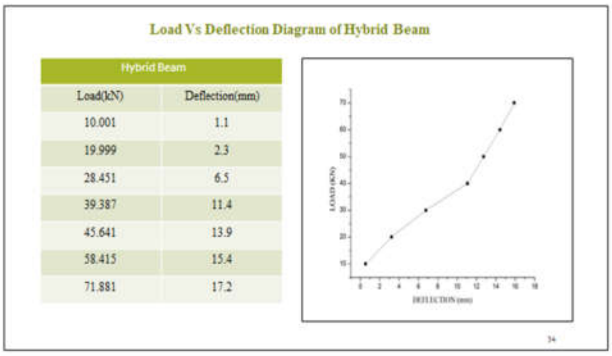


Fig. 9 Hybrid Reinforced beam Testing



Load Vs Deflection Diagram of Hybrid Beam

Hybrid Beam	
Load(kN)	Deflection(mm)
10.001	1.1
19.999	2.3
28.451	6.5
39.387	11.4
45.641	13.9
58.415	15.4
71.881	17.2

Crack patterns in beams provide important insight into the type of stress and failure mode occurring within the structure. In reinforced concrete beams cracks typically develop due to bending flexural stress, shear stress, or a combination of both

Flexural Cracks: These appear vertically near the mid-span of the beam where bending moments are highest. They usually start at the bottom of the beam and propagate upward as the tensile stress exceeds the concrete's capacity.

Shear Cracks: These are diagonal cracks that form near the supports, where shear forces are Dominant. They often angle between 45° and 60° and indicate the beam's resistance to sliding failure along planes.

Flexure-Shear Cracks: These occur due to a combination of bending and shear, usually forming diagonally but starting in the tension zone near mid-span and propagating toward the supports.

5.CONCLUSIONS

[1] GFRP bars demonstrated superior tensile strength and excellent corrosion resistance ,positioning them as a viable alternative to steel reinforcement in aggressive environmental conditions

[2] The hybrid beams exhibited enhanced resistance to shear-induced failure, with improved crack control and delayed onset of major structural damage. Notably, these beams withstood greater ultimate loads before failure, affirming the effectiveness of combining GFRP reinforcement with optimized beam geometry and concrete strength.

[3] The findings confirm that hybrid GFRP-reinforced beams can offer a viable alternative to traditional reinforcement, particularly in applications where corrosion resistance, long-term durability, and high shear capacity are critical. The collected data further serve to validate the FEA model, reinforcing its credibility as a predictive tool for the design and analysis of advanced concrete structures

[4] Hybrid beams exhibited multiple, finer cracks rather than one dominant shear crack ,contributing to more ductile and stable behavior.

[5] GFRP-reinforced members are particularly well-suited for applications in coastal, marine, and chemically aggressive environments, where traditional steel reinforcement is susceptible to corrosion and long-term degradation.

[6] The maximum load sustained by the beams in the experimental setup was within a 5% deviation of the values predicted numerically. Furthermore, the FEA accurately captured the onset and propagation of cracking.

6. REFERENCES

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