An Experimental Comparison of Glass Fibre Reinforcement Polymer Bars with steel Bar

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Abstract- *In this research we have done comparative study by performing several tests on GFRP Bar and Normal steel bar. The study focuses on the evaluation of glass fiber reinforced polymer (GFRP) bar and also identifying its competency as a tensile reinforcing material in reinforced concrete members. The behaviors of the GFRP reinforced concrete members is also compared to steel reinforced concrete members having same dimensions and reinforcement ratios. The considerably new FRP rebar technology is based on pultruded composite products, which are made from longitudinally bundled fibers along the bar axis embedded in a resin matrix. The fibres are the main load carrying component and the resin binds the fibers together, and therefore, transfers the load between individual fibers while protecting them from chemical and physical attacks. Now a days, the most widely used fiber type for FRP rods in the United States is glass based for the production of Glass Fiber Reinforced Polymer (GFRP) rebars. E and E-CR (Electrical/Chemical Resistant) glass fibres are the most commonly used ones because they possess high tensile strength, offer high chemical resistance, and feature low production cost. Further we are going to investigate the behaviour of steel and GFRP bars in concrete with regards to bonding and flexure. We are going to compare normal steel bar with GFRP bar by using various standard test.*

Keywords- Glass fiber reinforced polymer (GFRP) Bar, resin matrix, bundled fibres, E and E-CR (Electrical/Chemical Resistant) glass fibers, high tensile strength.

I. INTRODUCTION

This Project gives confmation regarding use of GFRP instead of Normal steel bar is apropos or not. GFRP reinforcement can have more than double the tensile strength of steel; however, it has lower flexural (bending) strength, lower yield strength and lower modulus of elasticity. This means GFRP can tolerate greater levels of force than steel when used in situations that place the element in tension such as at the bottom of a simply supported beam or the top of a cantilevered slab. However, steel rebar will tolerate greater levels of elastic deflection than GFRP before yielding or permanent deformation occurs.

Steel is characterized by high ductility, which means it will deform plastically before failure. Compared to steel, GFRP has an elastic behaviour and is not ductile, which means it has a rupture point rather than a yield point.

These characteristic differences mean GFRP-reinforced concrete is usually designed for concrete crushing failure while steel-reinforced concrete is typically designed for yield failure.

II. THEORETICAL ASPECT

There is need for an alternative sustainable material to replace traditional steel bar. FRP bars being a good option solves problems associated to steel bars. These materials are guaranteed to be corrosion resistant and reduces the lifecycle cost of concrete structures. One of the aims is to identify and study the different types of FRP materials and compare their physical and mechanical properties to the conventional steel bar. The main aim of this thesis is to compare the flexural behaviour of steel and GFRP reinforced concrete element experimentally and using finite element analysis (FEA) done by ABAQUS. Will also be tested to determine the mechanical properties and validate the specifications given by the manufacturer. The flexural test will be in two groups, one group will be reinforced with GFRP bar and other group will be reinforced with steel bar. The beams will be subjected to flexural test until failure to determine the ultimate load capacity, failure mode, crack pattern and crack width attributed to each of the beam. Cost comparison will also be done to check how effective GFRP bars are if used as reinforcing materials in concrete members.

Deflection in GFRP-reinforced structures is greater than steel due to GFRP's lower modulus of elasticity. This may require larger section sizes or a higher reinforcement ratio to be used in structural applications.

GFRP has substantially greater bond strength to concrete than steel which makes GFRP-reinforced concrete more resistant to cracking. In addition, crack tolerances in aqueous conditions are higher in GFRP structures (0.7 mm) than steel (0.4 mm) due to GFRP's corrosion resistance.

III. METHODOLOGY

We have purchased a new normal steel bar from local shop in our locality and GFRP Bar from Gujrat state respectively of diameter 10 mm, 12mm, 16 mm& 18 mm.

Following test are performed by group members.

1. Pull out test.

Procedure: -Pull-out test was performed using an apparatus in a universal testing machine. The specimen was prepared similar to the concrete cube. Φ10 GFRP and steel bars of 300mm long was inserted at the centre of cubes after concrete pouring at a depth of 100mm. After 28 days curing, the specimens were inserted in the pull-out apparatus and placed in the universal testing machine.The ultimate bond strength was computed using equation below; $\tau b = Pmax / \pi DL$ (MPa) Where τb is the ultimate bond strength, $Pmax$ is the ultimate pullout load, D and L is the diameter and embedded length of reinforcing bars.

Fig. Pull-out apparatus

Summary of pull-out test results

Specimen	f'c (MPa)	Bar diameter (mm)	Bar type		Embedded length (mm)	Pu (kN)	τmax (MPa)	Failure mode*
S1	30	10	Steel		125	21.8	5.55	BP
S2	30	10	Steel		125	22	5.6	BP
G1	30	10	GFRP		125	24.2	6.16	CS
G2	30	10	GFRP		125	30.3	7.71	CS

*BP – Bar pull-out, CS – Concrete splitting

2. Tensile strength test

Procedure: -The tensile testing of steel bars was performed according to British Standard (BS EN ISO 6892-1) and GFRP bars according to ASTM standard (D7205/D7205M-06) to determine the ultimate stress, percentage elongation and modulus of elasticity. A constant pace rate of 0.6MPa was used for application of load on the steel bars, while displacement type load rate of 1mm/min was used on the GFRP bars, both reinforcement bars where loaded until failure. In preparing GFRP bars anchors are need in order to prevent damage due to the grips of the tensile testing machine, steel tubes are used and filled with either cement grout or epoxy whom have good compressive strength.

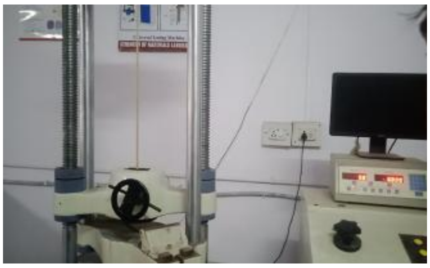


Fig. UTM Machine

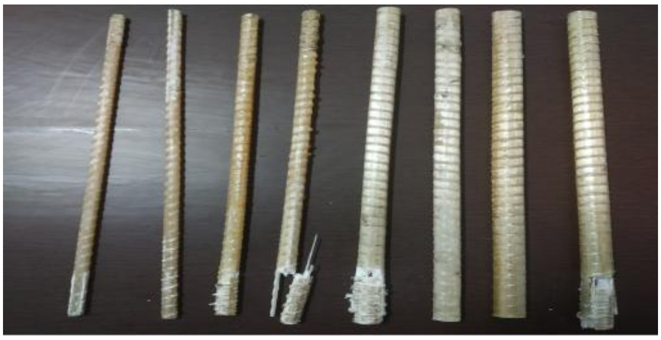


Fig. GFRP after testing on UTM machine

Materials are used in project work.

1. Cement: -UltraTech cement are used
2. Sand: - natural river sand is used
3. Aggregates: - 20mm size of aggregate used
4. Water: - pure water used
5. Steel and GFRP bar used as per available.

Equipmentare used in project work

1. Universal testing machine
2. Pull-out test apparatus
3. Concrete cube moulds 15 x 15 x 15 cm
4. Steel Rod

Density of steel bar and GFRP bars

Types	Steel	GFRP
Density (kg/m³)	7850	1200 – 2100

Summary of tensile test of steel and GFRP results

Types of Bars	Steel															
Diameter of Bar	10				12				16				20			
Sample	1	2	3	Avg	1	2	3	Avg	1	2	3	Avg	1	2	3	Avg
Load at Yield	54	44.75	46.5	48.417	89.45	67.35	68.6	75.133	88.4	89.4	90.4	88.9	189.3	191.[illegible]	198.9	193.08
Elongation at Yield	0	0	0	0	0.04	0	0	0.0133	0	0	0	0	0.15	1.95	0	0.7
Yield Stress	638.1	570.27	592.57	617	789	594	605.1	662.69	439.2	444.64	443.61	441.6	601.5	607.1	603.5	604.11
Load at Peak	67.5	55.95	58.15	60.533	111.9	84.2	85.75	93.933	110.9	111.85	101.85	111.4	236.7	239	237.6	237.72
Elongation at Peak	0	0	0	0	0.04	0	0	0.0133	0	0	0	0	0.15	1.95	0	0.7
Tensile strength	860.2	713	741.04	771.41	986.5	742.7	756.3	828.51	551	556.3	556.1	553.6	752.1	759.5	755	755.53
Load at Break	0	0	0	0	13.3	0	0	4.4333	0	0.25	0.25	0.125	9.9	6.95	9.9	8.9167
Elongation At Break	0	0	0	0	0.05	0	0	0.0167	0	1.5	1.5	0.75	0.26	1.95	1	1.07
Elongation %	8.93	8.39	7.96	8.4267	6.86	13.91	15.65	12.14	15.96	10.83	10.31	13.4	9.72	9.06	7.48	8.7533

Types of Bars	GFRP															
Diameter of Bar	10				12				16				20			
Sample	1	2	3	Avg	1	2	3	Avg	1	2	3	Avg	1	2	3	Avg
Load at Yield	36.25	37.35	32.25	38.317	40	42.4	40	40.8	36.25	37.35	32.25	38.313	88.85	94.75	93.75	92.45
Elongation at Yield	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Yield Stress	461.55	475.6	410.6	449.24	353	374.9	362	363	461.55	475.6	410.6	449.24	282.8	301.6	298.42	294.3
Load at Peak	45.35	46.7	40.35	44.133	50	53	51.2	51.4	45.35	46.7	40.35	44.133	111.2	118.5	117.25	115.6
Elongation at Peak	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tensile strength	577.15	564.6	513.8	561.83	442	468.6	453	454	577.15	504.6	513.8	568.33	353.6	377.2	373.22	368.1
Load at Break	0	0	0	0	0	0	0	0	0	0	0	0	0	9.75	0	3.25
Elongation At Break	0	0	0	0	0	0	0	0	0	0	0	0	0	0.62	0	0.087
Elongation %	0	0	0	0	0	0	0	0	0	0	0	0	1.025	0.93	0.57	0.842

IV. COMPARATIVE STUDY

- COMPOSITION OF GFRP VS STEEL REINFORCEMENT

Glass fibre reinforced polymer (GFRP) – sometimes called glass fibre reinforced plastic or fibreglass – is composed of a polymer plastic matrix with embedded glass fibres. The polymer for GFRP rebar usually consists of a vinyl ester, epoxy or polyester thermosetting plastic. Steel is a metal alloy composed of iron with a small percentage of carbon. The material differences between GFRP and steel means their structural performance and durability differ when used as reinforcement in concrete.

- STRUCTURAL PERFORMANCE OF GFRP VS STEEL REINFORCEMENT

GFRP reinforcement can have more than double the tensile strength of steel; however, it has lower flexural (bending) strength, lower yield strength and lower modulus of elasticity. This means GFRP can tolerate greater levels of force than steel when used in situations that place the element in tension such as at the bottom of a simply supported beam or the top of a cantilevered slab. However, steel rebar will tolerate greater levels of elastic deflection than GFRP before yielding or permanent deformation occurs.

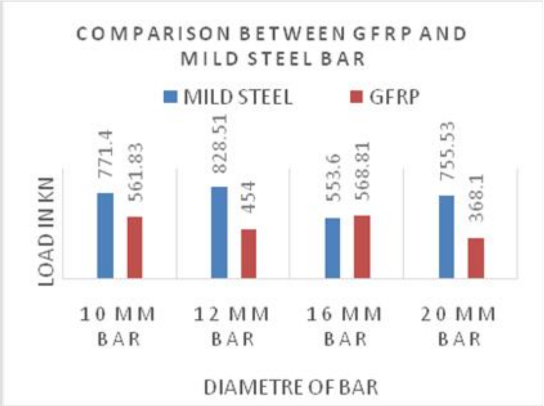
Steel is characterised by high ductility, which means it will deform plastically before failure. Compared to steel, GFRP has an elastic behaviour and is not ductile, which means it has a rupture point rather than a yield point.

- DURABILITY PERFORMANCE OF GFRP VS STEEL REINFORCEMENT

1. The durability of steel rebar ultimately depends on the amount of concrete cover provided to keep it protected in a stable, alkaline environment within the hardened concrete. Over time, carbon dioxide and chlorides in the air or water penetrate into the pores of the concrete and reduce the alkalinity or pH level of the hardened concrete.
2. GFRP's corrosion resistance eliminates carbon- and chloride-induced corrosion, removing the need for excessive concrete cover, protective coatings or an expensive cathodic prevention system. As a result, GFRP bar slightly reduces concrete consumption and substantially reduces whole-of-life asset maintenance costs associated with steel-reinforced concrete structures.

Advantages and disadvantages of ordinary rebar and fiberglass rebar

- High bearing capacity, strong tensile capacity, the strength of the rod body is twice that of the threaded steel bar of the same diameter, but the weight is only 1/4 of the steel bar.
- The elastic modulus is stable, about 1/3~2/5 of the steel bar.
- Electrical and thermal insulation, the thermal expansion coefficient is closer to cement than steel.
- Good corrosion resistance, suitable for use in wet or other corrosive environments such as water conservancy, bridges, docks and tunnels.
- The shear strength is low, and the shear strength of ordinary glass fiber bars is only 50~60MPa, which has excellent cutting performance. It is basically similar to steel bars in performance, has good adhesion to concrete, and at the same time has high tensile strength and low shear strength, which can be easily cut directly by the composite shield machine without Causes abnormal tool damage.



V. RESULTS CONCLUSIONS

The summary of the experimental and analytical result findings is presented in this chapter.

- During tensile strength test of GFRP bars is significantly doesn't get as per as per information available in network when compared to that of steel bars but the GFRP specimen should be well prepared according to standard in order to achieve the satisfactory result.
- The average tensile strength of the GFRP bars is about 65% higher than that of steel bars.
- The life of GFRP Bar is too much more than steel bar there for it increase the life of structure.
- The bond strength of the GFRP bars mainly rely upon the ribs and the inner cores of the reinforcing bars.
- GFRP's corrosion resistance

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