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Replacement of Steel Bar with GFRP Bar as a Reinforcing Material in Concrete Structure

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ABSTRACT -

Since the nineteenth century, reinforced concrete was evolved as a crucial material for construction. This popular composite material is broadly used in different building typologies. However, the decaying of steel rebar due to corrosion is recognized as a challenge that can compromise the quality of reinforced concrete structures. In this context, the use of glass fiber-reinforced polymer (GFRP) bars is crucial due to their resistance to corrosion properties. We performed various tests to know the response of GFRP-reinforced flexural members in shear and bending. Based on studies over the last decade, this study critically analyses the response of flexural member reinforced using glass fiber-reinforced polymer (GFRP) bars. Gaining insight into the performance of the GFRP bar as the alternating reinforcing material will be aided by this review. Hence, a detailed study is needed to understand the behaviour of such structures. This project explores various properties of GFRP-reinforced beams to appreciate the applications of GFRP reinforcement in flexural members.

Keywords: Glass Fiber Reinforced Polymer; Reinforcement; Steel Rebar; Flexural strength

1. INTRODUCTION

The aim of this research was to explore whether a glass fiber reinforced polymer (GFRP) rebar has satisfactory properties to be used as primary reinforcement within concrete structures. This was done by testing flexural strength and final load in terms of toughness and comparing it to a steel bar specimen of the same length and nominal diameter. Traditionally, steel reinforcement bars are used within concrete due to their high performance with regards to strength, co-efficiency and wide availability. The traditional strengthened concrete members such as beams are composed of concrete included Portland cement and steel rebars reinforcement. The function of concrete in these beams is the resistance to compressive loads. The tensile and shear loads will be resisted by steel rebars embedded in the concrete. Such structure is efficient where the concrete inseparable resistance to compressive loads, while the steel enhances tensile and partially shear strengths. However, the problem of corrosion associated with the steel re-bars reduced its live time and the solutions including the layer of steel rebars are costly. Recent technologies have resulted in alternative reinforcing materials such as GFRP materials commercially available in the form of bars or sheets that can be bonded in concrete members to fulfil several desired properties. The most important is that the corrosion resistance feature of the polymer and the elongated strain to failure that give enough time to alert before failure takes place in reinforced concrete structures, quality, design, and strength are salient features. GFRP rebars provide mechanical support to concrete structures. The strength of the composite materials adds to the durability of the concrete structure. Durability is a key to the strength of the concrete structure. Strength is one of the major concerns of construction companies and is also a major demand of clients. A strong foundation is what makes for a strong building.

2. MATERIAL USED AND METHODOLOGY

Cement:

Concrete is created when Portland cement forms a paste with water, which binds with sand and rock to solidify. Cement is produced through a carefully regulated chemical blend of calcium, silicon, aluminum, iron, and other components. Its primary role is to hold together the components of concrete—sand and aggregates. Cement acts as a hydraulic binder, which means it hardens upon the addition of water. PPC, a type of blended cement, contains 15-35% pozzolanic material, 4% gypsum, and the remainder is clinker. According to the BIS code, PPC is comparable to 53-grade cement.

Fine aggregate:

Fine Aggregate help to make concrete mixes more compact. Sand is formed by the erosion of rocks and the breakdown of pebbles, often transported by seas or rivers. It is a mixture of fine grains of rock and granular materials, primarily characterized by its size, which ranges from 0.06 mm to 2 mm—

finer than gravel but coarser than silt. The fineness modulus is also considered as the indication of quality of aggregate. According to IS recommendations the aggregate should possess the F.M to the range of 2.6 to 3.2. Greater than 3.2 should be rejected.

Coarse aggregate:

Coarse aggregate plays a crucial role in enhancing the strength of concrete structures. It consists of materials like gravel, crushed stone, or recycled components, which combine with cement paste to form a solid matrix. Coarse aggregate is a key material in civil engineering projects and is commonly used in roads, bridges, dams, and other major infrastructure. Understanding the properties of coarse aggregate is essential for civil engineering design and construction. This article provides an overview of the different types, applications, and testing methods of coarse aggregate for civil engineers.

Steel:

Steel in its simplest form, is iron metal that's been alloyed with less than 2% carbon. However, many other elements can be added as well to create multiple grades of steel alloys with varying properties. Common alloying elements include chromium, manganese, and nickel.

GFRP rebar:

The synthesis of GFRP rebar involved immersing glass fibers longitudinally in unsaturated polyester resin mixed with 1% hardener, then removing the excess polymer. This process was done without a mold to prevent premature failure of the matrix in tension. Efforts were made to achieve the desired bar diameter by using different quantities of fibers and measuring the diameter each time. An 8 mm diameter bar, common in construction, was eventually obtained with a fibers volume fraction of 80% and a polyester volume fraction of 20%. Once the GFRP bar was produced, its tensile and bend strengths were measured and compared with conventional reinforcement bars. To enhance bonding between reinforcement and concrete, one approach is to coat GFRP bars with coarse sand particles larger than 300 mm.

METHODOLOGY:

The flexural strength properties were primarily assessed through a paired comparison test involving 8 mm diameter steel and glass fiber-reinforced polymer (GFRP) rebar specimens in beam configurations. Compressive strength was examined using nine concrete cube specimens of 150 mm, to determine flexural strength and toughness, a one-point loading test was performed to provide load/extension data on eighteen 700x150x150mm concrete beams. Nine beams were cast with steel rebar and nine were cast with GFRP rebar.

3. TEST ON BEAM

• *Compressive strength: -*

The compressive strength was assessed according to BS 1881: Part 11 using 150 mm cube test samples. Concrete provides sufficient compressive strength for construction applications such as foundations, depending on the mix proportions. The results indicated that the unreinforced samples had good compressive strength at 28 days, making them suitable for foundation applications. Concrete resists compressive loads effectively due to its powdered ingredients.

• *Flexural strength: -*

Flexural properties were measured according to ASTM C-293 using test samples of 700 x 150 x 150 mm beams, subjected to one-point loading. The specimens were evaluated after 7, 14, and 28 days of water immersion to assess the ability of GFRP-reinforced concrete to endure flexural loads and to compare it with steel-reinforced concrete samples. The results indicated that GFRP-reinforced concrete exhibited ductile behavior at all three curing ages (7, 14, and 28 days), offering earlier warning before failure. The flexural strength of steel-reinforced concrete was lower but improved significantly with the use of GFRP reinforcement. The GFRP-reinforced concrete demonstrated high flexural strength, approaching that of steel-reinforced concrete, due to its higher strain capacity, though this came at the expense of a lower flexural modulus.

4. RESULT

Flexural Test Result of Steel Beam

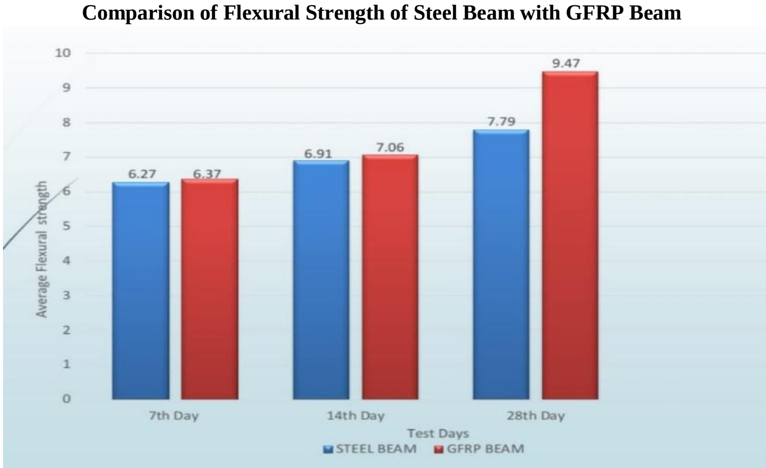
Mix	Test Day	Beam No.	Weight (Kg)	Load (KN)	Effective Span (L)	a (mm)	b (mm)	d (mm)	Flexural Strength (N/mm^2)	Average Flexural Strength (N/mm^2)

M20	7th Day	B1	38.660	42	500	250	150	150	6.22	6.27
		B2	38.670	40	500	250	150	150	5.92	
		B3	38.700	45	500	250	150	150	6.67	
	14th Day	B1	39.180	47	500	250	150	150	6.96	6.91
		B2	39.160	45	500	250	150	150	6.67	
		B3	38.924	48	500	250	150	150	7.11	
	28th Day	B1	39.200	50	500	250	150	150	7.40	7.79
		B2	39.443	52	500	250	150	150	7.70	
		B3	39.250	56	500	250	150	150	8.29	

Flexural Test Result of GFRP Beam

c	Test Day	Beam No.	Weight (Kg)	Load (KN)	Effective Span (L)	a (mm)	b (mm)	d (mm)	Flexural Strength (N/mm^2)	Average Flexural Strength (N/mm^2)
M20	7th Day	B1	37.00	45	500	250	150	150	6.67	6.37
		B2	37.360	41	500	250	150	150	6.07	
		B3	37.405	43	500	250	150	150	6.37	
	14th Day	B1	38.420	48	500	250	150	150	7.11	7.06
		B2	38.845	46	500	250	150	150	6.81	
		B3	38.660	49	500	250	150	150	7.25	
	28th Day	B1	39.720	60	500	250	150	150	8.89	9.47
		B2	39.745	65	500	250	150	150	9.62	
		B3	39.820	67	500	250	150	150	9.92	

Comparison of Flexural Strength of Steel Beam with GFRP Beam



CONCLUSION:

- GFRP reinforcing bars have better corrosion resistance and higher tensile energy than steel rebar.
- In the post-cracking stage, GFRP bar, along with the steel bar, is taking more load, and the beam fails in shear.
- In comparison with steel with corrosion prevention coating or stainless steel, GFRP can sometimes be cheaper.
- The combination of GFRP and steel in reinforced concrete resulted in a significant enhancement in the performance against flexure-shear failures, with fewer shear cracks and narrower crack widths.

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