Retrofitting and Restrengthening of RC Beam Using FRP Technology

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Abstract.

This External interaction of creative FRP (fiber reinforced polymer) polymer composite material has developed in popularity in recent years because it offers a supplementary profitable and theoretically excellent compared to conventional procedures in several circumstances due to its durability, lightweight, resistance to corrosion, fatigue resistance, easy and quick construction, and least modification in structural configuration. Because several in-situ RC (Reinforced concrete) beams were consecutive in structure construction, there was not enough scientific interest in beam strengthening using FRP mechanism. The foremost objective of this investigation involved is to propose procedures for restoration of RC beam utilizing FRP material. The characteristics of FRP and their impact on beam strengthening are illustrated. The research concentrate on self-compacted RC beams that have been strengthened by wrapping CFRP (Carbon fiber reinforced polymer) & GFRP (Glass fiber reinforced polymer) layers in epoxy adhesive.

Keywords. Self-compacting concrete, Steel bars, FRP sheets, Epoxy resin and Hardener.

1. INTRODUCTION

From the past two decades construction of structures has increased significantly. Concrete has a significant part in building engineering due to its advantages in several areas like as economy, strength, and durability. SCC (Self compacting concrete) is used to improve the structural performance and sufficient filling of narrow sections and massively reinforced structural components reported by Okamura et al.,[1]. An elementary proposal for the SCC was given by Nan Su et al., [2]. In this mix design Portland cement was utilized. The aggregate percentage required for the concrete is determined first, and then binder numbers required is determined for which concrete can conquer decent flow capability, self-compressing capability and remaining SCC assets. More knowledge of a good performance SCC is required for such a performance concrete to reach wider acceptability for casting tough and crowded structural components with significant reinforcements, particularly in seismic zones.

1.1. FRP Technology for Strengthening and Rehabilitation of Structures

Since major renovation or rebuilding of the structure is not cost efficient, reinforcing or remodelling is an effective technique to improve it. The use of FRP sheets for strengthening of RC beams will reduce the deflections and increase the load carrying capacity described by Grace [3]. Renovating concrete constructions with FRP sheets provides a supplementary cost-effective and properly excellent advantages over traditional methods in various circumstances because it provides heartiness, light mass, rusting defiance, higher exhaustion resilience, to wrap up quick construction, and slight alteration in physical geometry. Strengthening of RC beam using CFRP sheets will decrease the ductility when compared to conventional RC beam member designated by E1-Refaie [4]. N. Pannirselvam [5] stated that the load bearing of FRP reinforced beams contained, GFRP sheets were enhanced compared to controlled beam. The increasing in load sustaining ability of a structural associate dependent upon the number of FRP layers wrapped on RC beam. FRP systems can also be employed in regions where traditional methods would be impossible due to limited access. However, due to a absence of suitable understanding on the structural performance of reinforced concrete constructions, the application of FRP materials for renovation existing concrete structures falls short of the expectations.

2. MATERIALS

- Portland cement: Across the experiment, OPC (ordinary Portland cement) of 53 Grade approving IS:12269-2013[6] was chosen from a single collection. It was fresh and free of lumps. Cement is carefully stored to avoid deterioration of its characteristics due to humidity interaction.
- Fly Ash: By-product which is formed by combustion of coal that mostly contains of silicon dioxide (SiO_2) and calcium oxide (CaO). When it was mixed with concrete, fly ash undergoes a primary pozzolanic reaction with the moisturized cement paste, resulting in a denser microstructure over time. NTPC (National Thermal Power Corporation) fly ash was obtained from Ramagundam during the experimentation.
- Coarse Aggregate: Samples approving IS:383-2016[7] retained at 10mm and passing through 12.5mm were used. The specific gravity is 2.78. The aggregates were cleaned to eliminate dirt and dust before being dried to the surface.
- Fine aggregate: Sand authorising IS: 383-2016[7] with 2.70 fineness modulus and the specific gravity is 2.65.
- Longitudinal steel (Top &Bottom bars) and Lateral steel(stirrups):Steel bars with Fe415 yield strength were used. The beam's reinforcing design is determined in accordance with IS456:2000[12]. Figure 2.1 represents the beam reinforcement details.

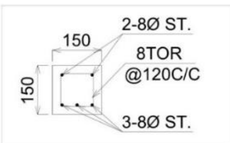


Figure 2.1.Beam Reinforcement Details

- CFRP sheets: CFRP refers for composite materials. The composite in this experiment is made up of two segments: a matrix and reinforcement. Generally, the matrix is a polymer resin, for example epoxy, which provides bond between two components. The CFRP sheet is bidirectional with tensile strength of 3500N/mm².Figure 2.2(a) shows the image of CFRP sheets used in the present work. Two layers of CFRP was wrapped to beams.
- GFRP sheets:GFRP composites were the frequently used materials in complex product manufacturing. Polyester, thermostable, vinyl ester, phenolic, and epoxy resins were applied in the matrix. Afiber reinforced composite's mechanical performance is essentially determined by strength of fiber and magnitude, chemical strength, matrix stability, and interactive bond between the fiber and matrix to permit stress transmission. GFRP composites offered the equivalent physical and efficient assets as steel, were stiffer than aluminium with a specific gravity one-quarter to steel. The GFRP sheet is bidirectional with tensile strength of 3400N/mm². Figure 2.2(b)shows the image of GFRP sheets used in the present work. Two layers of GFRP was wrapped to the beams.

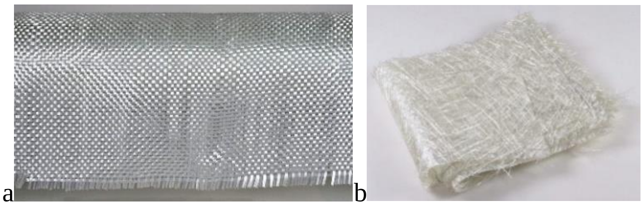
a b


Figure 2.2. (a)CFRP Sheets;(b) GFRP sheets

- Epoxy Resin and Hardener: Epoxy resin is a liquid chemical compound that is utilized for a number of purposes across a wide range of industries. The epoxy resin and hardener pair are the ideal working combination, giving excellent durability, tensile strength, and working compatibility.
- Super Plasticizer: The chemicals which reduce water content in manufacturing of high strength concrete referred as super plasticizers (SP). By using these chemicals in concrete mixing, we can reduce the water content up to 30%. To ensure high workability, Bento polymix PCE 3000 was utilized.

3. METHODOLOGY

3.1. Mix Design of Concrete

The design mix for M35 grade SCC is done as per IS 10262:2019 guidelines [8]. Mix ratio of the SCC is 1:2.71:2.15. The W/C ratio (water cement) is locked at 0.40 and a slump of 70 to 75cm and properties were represented in Table 1.

Table 1 SCC mix proportion(kg/m³)

Cement	*Fine aggregate*	*Coarse aggregate*	*W/C*
341.25	925.00	734.32	195
1	2.71	2.15	0.40

3.2. Mixing

I combined the materials according to the mixed design after measuring the materials quantity. To begin, mix coarse aggregates and fine aggregates for a few min to obtain a uniform mix, then add cement and fly ash to the mixture and mix for another few minutes to obtain the same mix throughout the material. To produce newly prepared concrete for M35 grade concrete, added water according to the calculations from the mix design.

3.3. Workability tests

Workability tests were conducted on freshly prepared SCC to establish the capacity under filling and passing according to IS:1199 part-6[9].

3.3.1Slump Flow Test

The filling performance of SCC is measured by using slump flow test. It evaluates two mechanisms: flow distribution and T50 flow time. The flow distribution denotes unrestricted, clear deformability, whereas T50 denotes deformation rate within certain flow distance.

3.3.2 V-Funnel Flow

Duration for the definite capacity of SCC passes through a thin introductory is called as V-funnel flow, and it specifies SCC's filling ability in the absence of blockage and/or segregation. To some extent the flow duration of the V-Funnel trial is related towards plastic velocity.

3.3.3 L-Box Test

Passing capability for SCC is examined via L-Box trial. It measures the height ratio achieved by newly prepared SCC subsequently passing over the detailed holes of steel bars and passing inside a definite passage distance.

3.4. Casting of Spacemen

Three beam moulds were connected, and the inside of the mould was carefully greased. To maintain the desired effective depth of the beam, cover blocks of sufficient depth were placed at the bottom of the mould. The required volume of the materials for casting one batch of beams were mixed thoroughly on a platform to get a uniform mix. First, the reinforcement cage was kept on cover blocks in the mould. Then, the concrete is situated in the beam. Nine concrete cubes and nine cylinders were cast. The beam moulds, cylindrical moulds and cubes moulds were stripped after 24 hours of concreting.

3.5. Curing

After casting, all specimens were stored for curing to preserve the environmental conditions, namely a temperature of 27±2ºC later a day. Casted members were demoulded and placed in water for 28 days.

3.6. Compressive Strength Test

Compressive strength testing machine by means of a capacity of 2000kN referenced by IS:516-1959[10] was used to test the cube specimens.

The area of the sample that can sustain the greatest force applied to it during the test is used to calculate compressive strength. The compressive testing sample represented in Figure 3.1(a).

3.7. Split Tensile Strength Test

Trail was directed referenced by IS5816-1999[11]. Split tensile strength is an alternative test for direct tension. The standard 150mmx300mm chambers were utilized. The Split tensile strength testing illustration represented in Figure 3.1(b).

Figure 3.1. (a)Compressive strength test;(b) Split tensile strength test;

(c) Flexural strength test

3.8. Flexural Strength Test

According to IS:516-1959[10] the flexural strength test was executed. As per Indian standards, I prepared the concrete specimen with a dimension of 150mm width, 150mm depth, and a span of 700mm.The test was carried out immediately after removing from the water and even when they are still wet. The load must be supplied without creating any disturbance. The load must be raised until the sample breaks, and the peak load attained during the experiment must be noted. Pictorially beam flexural strength testing shown in Figure 3.1(c).

3.9. Strengthening of Beams with FRP sheets

After flexural strength testing, an adhesive with a thickness of about 2mm was applied on the concrete surface, followed by two layers of CFRP sheets with a thickness of approximately 1mm. To eliminate any air bubbles and establish a strong adhesion, the sheets were applied with moderate pressure using a roller. Similarly, two layers of GFRP sheets were applied on beams. After wrapping FRP sheets, beams were maintained at room temperature for 24 hours before subjected to a flexural strength test. Figure 3.2(a) &Figure 3.2(b) signifies the flexural strength of RC beam strengthened by wrapping GFRP and CFRP sheets. Flexural Strength (fb)= pl/bd^2; Here, p = Extreme load induced in N; l = beam span; b = beam breadth; d = beam depth.

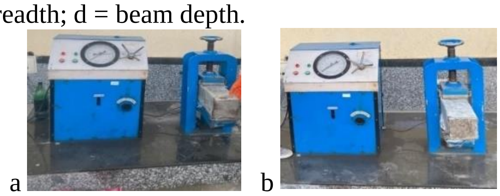


Figure 3.2.(a) Flexural strength test after wrapping GFRP sheets;(b) Flexural strength test after wrapping CFRP sheet

4. RESULTS AND DISCUSSIONS

4.1. *Workability*

Filling and passing capability of SCC properties of SCC were measured according to code provisions IS:1199 part6, results were represented in Table 2.

Table 2 SCC workability test results

S.No	*Description*	*Experimental Results*
1.	Slump Flow(mm)	715
2.	T_{50} Slump flow in (sec)	3
3.	V-Funnel in (sec)	9.60
4.	T_{50} V-Funnel in (sec)	11.80
5.	L-Box ratio ($H2/H1$)	0.90
6.	$H1$ (mm)	104
7.	$H2$ (mm)	93

4.2. *Compressive Strength Test*

After 7, 21, and 28 days of curing the cubical members were assessed under compression loading and the mean value was reported as the 41.25MPa optimum after 28days of testing, experiment results were represented in Table 3.

Table 3Compressive strength in MPa

7 days	*21 days*	*28 days*
20.56	38.49	41.255

4.3. *Split Tensile Strength Test*

Examined at 7, 21, and 28 days after required curing finished. After 28days of testing, the mean value of these cylinders was reported as 4.65MPa optimum, Table 4 represents the experimental results.

Table 4Split Tensile strength in MPa

7 days	*21 days*	*28 days*
1.76	3.45	4.65

4.4. *Flexural Strength Test*

The RC beams were designed as under reinforced section and beams tested under three-point bending after 28 days of curing. As the steel provided was less than balancing steel then the concrete beam failure was observed at flexural zone and a crack initiated at support section was extended from bottom to the load point with 45 degrees angle.

The widening of cracks was observed after peak load was attained. It was observed that the maximum load value noted for conventional reinforced beam was 75 KN, whereas beams wrapped up with CFRP sheets were sustained a maximum load of 77.5 KN and load carrying capacity greatly increased in beam member GFRP wrapped resulted 78.9 KN.

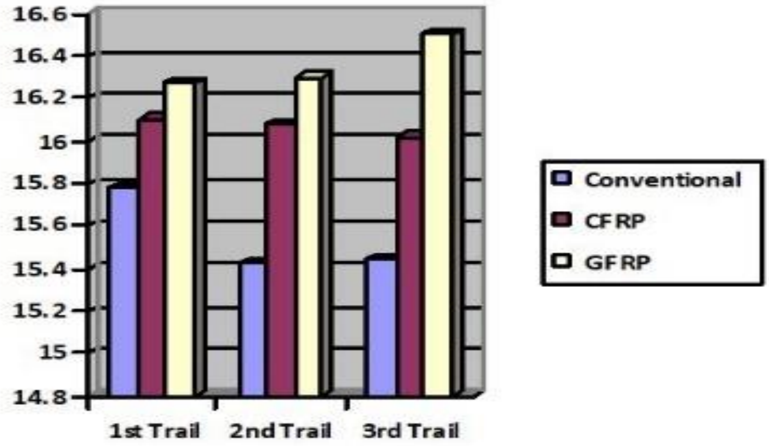


Figure 4.1Flexural strength test results

By Figure 4.1 it was clearly noted that strength value was enhanced by application of CFRP and GFRP, strength value noted for conventional reinforced concrete beam was 15.55 MPa, 16.07 MPa noted for beam member wrapped with CFRP sheets strength gain was 3.34 %. Beam members with GFRP sheets resulted 16.36 MPa strength was 5.20% more as contrasted to conventional RC beam.

5. CONCLUSIONS

The present research concluded on flexural performance of SCC-based beams of RC that were reinforced by wrapping FRP sheeting. The following conclusions are obtained from the experimental observations.

- SCC mix attained high flowability under filling and passing capability.
- Optimum compressive strength 41.25MPa was noted for cubes after 28days of testing.
- Maximum split tensile strength 4.65MPa observed after 28days trail investigation.
- Load carrying capability of RC beam remained enhanced after wrapping FRP sheets. It was observed that GFRP give more strength when compared CFRP.
- The flexural strength was 3.34% enhanced by wrapping CFRP sheets whereas there is 5.20% over conventional beam by wrapping GFRP sheets. Strength value improved for a flexure member as results of adding FRP sheets.
- Flexural strength is higher in RC beams with GFRP sheets than in RC beams with CFRP sheets.

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Biographies

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