Experimental Investigation on The Behaviour of Flexural Strengthening of Beams Using BFRP Sheet

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Abstract— Fiber Reinforced Plastic (FRP) materials, including wraps, laminates, and sheets, are gaining significant attention in civil engineering, particularly for the repair and strengthening of reinforced concrete (RC) structures. These materials offer several advantages over traditional methods, such as their high strength-to-weight ratio, corrosion resistance, and ease of application. Basalt Fiber Reinforced Polymer (BFRP) is emerging as a highly effective material for the repair and strengthening of structures that have deteriorated or become structurally weak over time. BFRP offers several advantages, making it a viable alternative to traditional repair methods. Experimental investigations on the cube, cylinder & flexural RC beams strengthened using basalt fiber unidirectional cloth are carried out. Concrete beams externally reinforced with epoxy-bonded cloth underwent failure testing using a symmetrical one-point concentrated static loading system. Nine beams were cast, out of which conventional beams were tested using general procedure. After the testing process, the beams are to be strengthened using a BFRP sheet in flexure. The strengthening of the beam is done with different amounts and configurations of the BFRP sheet. Bonding between the BFRP sheet and pre-damaged beams is done by using epoxy resin adhesive. After strengthening was made to beams, flexural tests were conducted for ultimate load-carrying capacity. Experimental data on the load, deflection, and failure modes of each of the beams were obtained. The detailed procedure and application of the BFRP sheet for strengthening RC beams are also included. The effect of several BFRP layers and their orientation on the ultimate load-carrying capacity and failure mode of the beams are investigated. A comparative study was made between the control beams and strengthened beams. From the result, it has been seen that the BFRP sheet can be used as a strengthening material for damaged beams when the current results of specimens by conventional method and lamination method are to be tabulated. The graphical representation for each specimen is done using the above methods.

Index Terms- Basalt Fiber Reinforced Polymer (BFRP), Repair and strengthening, Experimental investigation.

I. INTRODUCTION

1.1 GENERAL

Many buildings need civil engineers to strengthen their services. Civil engineering in the construction industry now has problems from the excessive load on the structure due to poor quality materials, extension of building height, and irregular planning etc., every building has to stand with the load of where it is designed, but some structures need reinforcement for its vertical incremental load requirements. The strengthening of existing programs should be delivered in economic and environmental terms. The same requirements are needed today and in the future to live in a renovated building and make it affordable and environmentally friendly. In that case, to maintain service capacity, rehabilitation of old or damaged buildings must be carried out so that the building retains the same requirements as built today and in the future Rehabilitation Should its maintenance work be economically and environmentally unsound.

In that context, the FRP sheets have gained attention as potential structural and reinforcing elements on structural debris. FRP is a type of sheet typically converted into fibers with varying degrees of spacing near the intersections of the sheets. The paper should be made of steel and other suitable materials. These sheets are made of metal or other suitable materials.

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Maintenance, rehabilitation, and architectural optimization are perhaps one of the most important problems in civil engineering applications. Safety standards and design codes for buildings evolve as technology advances and lessons are learned from experience Construction using older building codes does not meet current safety standards and, consequently, can be considered structurally unsafe by today's standards.

II. MATERIAL PROPERTIES

CEMENT

Portland Pozzolana cement (PPC) confirming to IS 12269 (53 Grade) was used for the experimental work. Laboratory tests were conducted on cement to determine specific gravity, fineness, standard consistency, initial setting time, and final setting time. The properties of cement are present in Table 1.

Table 1. Properties of Cement

Particulars	Values
Grade	OPC 53 Grade
Specific gravity	3.15
Fineness	4%
Standard consistency	35%
Initial setting time	45 minutes

FINE AGGREGATE

Natural river sand is used as fine aggregate. As per IS: 2386 (Part III)- 1963. The primary component in concrete is fine aggregate, which comprises natural sand or crushed stone. The hardened characteristics of the concrete are significantly affected by the quality and density of the fine aggregate.

The concrete or mortar mixture can be made more durable, stronger, and cheaper if you make the selection of fine aggregate based on grading zone, particle shape and surface texture, abrasion and skid resistance absorption, and surface moisture.

COARSE AGGREGATE

Crushed stones of a maximum size of 20 mm are used as coarse aggregate. As per IS: 2386 (Part III)- 1963.Concrete aggregate serves as a structural filler and plays a crucial role beyond its basic function. The majority of the concrete volume is filled with aggregate, which is then coated and bound together by the cement paste..

The composition, shape, and size of the aggregate all have a significant impact on the workability, durability, strength, weight, and shrinkage of the concrete. The appearance of the cast surface can be affected by the aggregate, which is a crucial factor to consider in concrete countertop mixes.

Property	Unit	Value
Sheet size	m	3.5 x 3.5
Tensile strength	MPa	3000 - 4800
Modulus of elasticity	GPa	110
Density	g/cm^3	1700

Table 2 Properties of basalt fiber-reinforced polymer sheet

EPOXY RESIN

An epoxy resin coating is a strong adhesive coating that is designed to adhere to objects and provides surfacing for floors, walls, and ceilings. It is also the trade name for a type of chemical group called the epoxide functional group. Epoxy resin coatings can either be made to react with themselves, or with several co- reagents. Each of these different co-reagents, or "hardeners", provides a different level of strength, flexibility, adhesion, and waterproofing for epoxy flooring. Depending on the type of co-reagent, an epoxy resin coating can bond better to different types of metals, alloys, and substrate materials. Epoxy resin coatings have been used for several applications, including industrial, commercial, electrical, and marine applications.

Some of these epoxy resin coatings are specifically designed to meet certain building needs. For example, epoxy novolac floor coatings have a high tolerance for heat and electrical current, making them a good choice for electrical laminating. In addition, epoxy novolac flooring is perfect for containment systems, such as wastewater treatment tanks or commercial swimming pools, as they are highly chemical-resistant. Specific resins, like epoxy novolac epoxy, vapor-barrier epoxy, and anti-static epoxy, are included in a floor coating plan to meet the needs of each application.

III. EXPERIMENTAL INVESTIGATION

WORKABILITY TEST

The workability of concrete influences its strength, durability, labor cost, and final appearance. Concrete is considered workable if it can be easily placed and compacted uniformly without experiencing bleeding or segregation.

Degree of workability	Very low	Low	Medium	High
Slump mm	0-25	25-50	50-100	100-175

Table 3 Slump based on degree of workability

DESCRIPTION	RESULT
Slump value	69mm
Vee- Bee densitometer	8 sec
Flow table	34.6%
Compaction factor	0.84

Table 4 Result of fresh concrete

COMPRESSIVE STRENGTH RESULT

The test results of experiments conducted on twelve cubes (conventional cubes and cubes wrapped with BFRP) at 28 days are furnished below. The values of corresponding loads were recorded for ultimate load capacity. Three layers were strengthened by using epoxy resin. Each layer of BFRP strengthened and the ultimate load was tested.

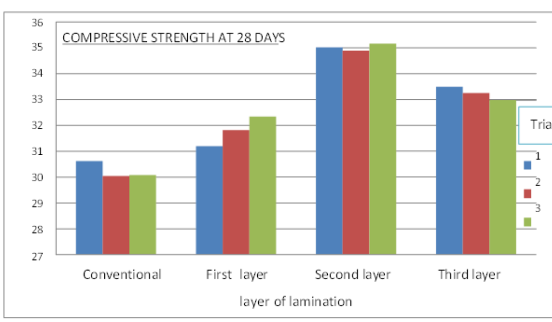

Figure 1 Compressive strength at 28 days

Trial	1	2	3	Average (N/mm^2)
Conventional	30.62	30.04	30.08	30.25
First layer	31.20	31.82	32.34	31.78
Second layer	35.02	34.89	35.16	35.02
Third layer	33.50	33.25	32.98	33.24

Table 5 Compressive strength result at 28 days

SPLIT TENSILE STRENGTH RESULT

The test results of experiments conducted on twelve cylinders (conventional cylinders and cylinders wrapped with BFRP) at 28 days are furnished below. The values of corresponding loads were recorded for ultimate load capacity. Three layers were strengthened by using epoxy resin. Each layer of BFRP strengthened and the ultimate load was tested.

Trial	1	2	3	Average (N/mm^2)
Conventional	10.53	10.81	10.92	10.75
First layer	10.98	11.02	11.25	11.08
Second layer	13.77	13.34	13.05	13.05
Third layer	11.68	12.05	12.56	12.09

Table 6 Split tensile strength result at 28 days

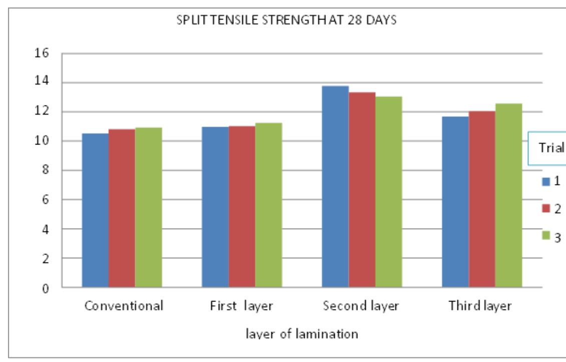

Figure 2 Split tensile strength at 28 days

FLEXURAL STRENGTH RESULT

The test results of experiments conducted on four RC beams (control beams, pre-loaded beams, and beams wrapped with BFRP) at 28 days are furnished below. The values of deflections due to corresponding loads were recorded one control beams were tested for ultimate load capacity and 75% preloaded six beams were tested for deflection. Three preloaded beams wrapped with BFRP beams were tested.

Preload = 50 KN	FIRST LAYER(B2)	SECOND LAYER(B3)	THIRD LAYER(B4)
Load (KN)	Deflection (mm)		
0	0	0	0
5	0	0	0
10	0.05	0.03	0.01
15	0.13	0.25	0.19

20	0.32	0.33	0.22
25	0.48	0.58	0.43
30	0.52	0.90	0.60
35	1.04	1.09	0.77
40	1.32	1.14	0.95
45	1.45	1.32	1.49
50	1.66	1.50	1.60

Table 7 Flexural strength for preloaded beams (B2, B3, B4)

TEST RESULTS OF 75% PRELOADED BEAMS WRAPPED WITH BFRP SHEET

Three RC beams (B2, B3, B4) wrapped with a BFRP sheet. Three BFRP layers strengthened, and each layer of RC beam was tested for ultimate load-carrying capacity corresponding deflection.

Preload = 50 KN	FIRST LAYER(B2)	SECOND LAYER(B3)	THIRD LAYER(B4)
Load (KN)	Deflection (mm)		
0	0	0	0
5	0.3	0.40	0.49
10	0.5	0.90	0.95
15	0.76	1.15	1.10
20	1.08	1.32	1.24
25	1.32	1.59	1.51
30	1.76	1.68	1.60
35	2.24	1.86	1.72
40	2.80	1.97	1.95
45	3.62	2.04	2.41
50	4.48	2.13	2.81

Table 8 Flexural strength for preloaded beam BFRP sheet (B2, B3, B4)

CONCLUSION

- In this project investigations were made on the flexural behavior of reinforced concrete beams strengthened with different layers of BFRP sheets and outcomes were studied.
- Final comparisons about all elements such as cubes, cylinders, and beams having a more effective strength in the second layer Lamination method [Strengthened elements] by using "Basalt Fibre Reinforced Polymer sheets".
- The final result of this project was studied at the Lamination Method was suitable for the retrofitting works of the damaged buildings. The reason was Lamination method is more effective than the Conventional Method.
- For the cube, cylinder &RC beam of the mold compared to the controlled RC elements to increase the first and second layers then increase the compression, tension, and flexural strength.
- But in case the third layer does not increase the strength after one more layer is presented decreases the strength. The experimental study that adding a "Basalt Fiber Reinforced Polymer sheet" on the beam surface for strengthening provides a good effect on stiffness, reduction in deflection, and increased load-carrying capacity.
- Using a layer of Basalt Fiber Reinforced polymer sheets provides better stiffness on rehabilitated beams.

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