

Upgradation of Existing Reinforced Concrete Beams Using CFRP and Steel Mesh-Epoxy Strengthening Techniques

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Abstract: The rehabilitation and strengthening of existing reinforced concrete (RC) structures have become essential due to aging, increased service loads, deterioration, and environmental effects. This study investigates the structural behavior of RC beams strengthened using Carbon Fiber Reinforced Polymer (CFRP) sheets and Steel Mesh with Epoxy and Mortar (SME&M). Experimental testing was conducted using a Universal Testing Machine under monotonic loading conditions. Control beams and strengthened beams were evaluated based on load-carrying capacity, load-deflection response, crack propagation, stiffness, and failure behavior. Different strengthening configurations including CFRP crack-area wrapping, full U-wrap, 45° wrapping, 90° wrapping, and steel mesh strengthening were investigated. Results indicated that CFRP significantly enhanced flexural and shear performance, delayed crack formation, and increased ultimate load capacity. CFRP at 45° orientation showed the highest load resistance among all specimens. Steel mesh with epoxy and mortar improved ductility and provided a cost-effective strengthening solution. The findings demonstrate that CFRP and SME&M are effective retrofitting systems for upgrading existing RC beams and extending their service life.

Keywords: CFRP, RC Beam, Retrofitting, Strengthening, Steel Mesh, Epoxy, Load Deflection.

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I. INTRODUCTION

Reinforced concrete beams are fundamental structural members used extensively in buildings and infrastructure. Over time, these structures experience deterioration due to environmental exposure, corrosion, design deficiencies, increased loading requirements, and aging. Conventional strengthening methods such as steel plate bonding and section enlargement increase dead load and are susceptible to corrosion.

Carbon Fiber Reinforced Polymer (CFRP) has emerged as an effective strengthening material because of its high tensile strength, lightweight characteristics, corrosion resistance, and ease of installation. CFRP systems have been widely adopted worldwide for strengthening beams, slabs, columns, and bridges. In addition, Steel Mesh with Epoxy and Mortar (SME&M) offers a practical and economical strengthening alternative.

The objective of this study is to evaluate the performance of CFRP and SME&M strengthening systems through experimental testing and comparative analysis.

II. LITERATURE REVIEW

Previous studies have demonstrated significant improvements in load-carrying capacity and stiffness of RC members strengthened using CFRP systems. Researchers reported improvements ranging from 20% to 90% depending on wrapping configuration and bonding quality. CFRP effectively delays crack propagation and improves ductility while reducing structural weight.

Recent investigations also explored steel mesh strengthening techniques. Although the strength enhancement is generally lower than CFRP, steel mesh systems provide economical strengthening and improved crack control. The literature indicates limited comparative studies between CFRP and SME&M systems under identical testing conditions, which forms the basis of the present investigation.

III. MATERIALS AND EXPERIMENTAL PROGRAM

➤ Materials

The following materials were used:

- M25 Ready Mix Concrete (RMC)

- Carbon Fiber Reinforced Polymer (CFRP)
- Sikadur-300 Epoxy Resin
- Steel Mesh
- Cement Mortar

➤ *Beam Specimens*

Six beam categories were investigated:

- Control Beam (CB)
- CFRP at Crack Area
- CFRP Full U-Wrap
- CFRP at 45°
- CFRP at 90°
- Steel Mesh with Epoxy and Mortar Beam size: 150 mm × 150 mm × 700 mm

➤ *Test Setup*

All specimens were tested using a Universal Testing Machine (UTM). Load and cross-head travel (CHT) readings were recorded continuously. Crack development and failure modes were visually monitored. Below diagram measurements is in mm.

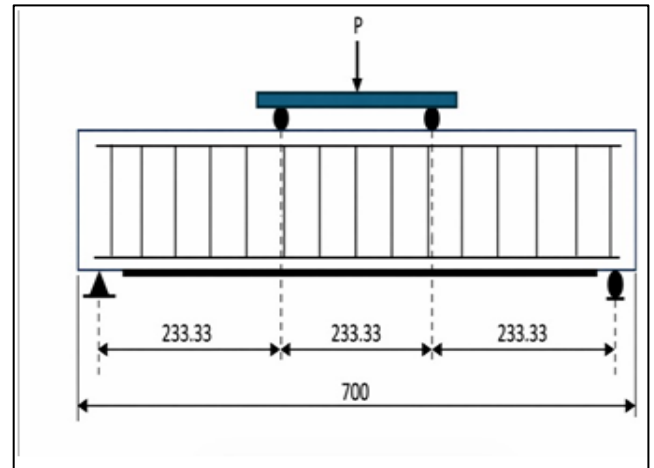


Fig 1 Experimental Test Setup

IV. RESULTS AND DISCUSSIONS

➤ *Compressive Strength*

The average 28-day compressive strength obtained from cube testing was 31.99 MPa, confirming compliance with M25 grade concrete requirements.

Table 1 Compressive Strength After 7 Days

Date of Testing	Cube Ref. No.	Cube Dimensions (mm)	Weight of Cube (kg)	Density (kg/m ³)	Compressive Load (kN)	Strength (N/mm ²)
23/01/2026	TRIAL MIX	150 × 150 × 150	8.48	2513	541.00	24.05
23/01/2026	TRIAL MIX	150 × 150 × 150	8.51	2521	546.00	24.28
23/01/2026	TRIAL MIX	150 × 150 × 150	8.45	2504	537.00	23.86

Average 7-Day Compressive Strength = 24.06 N/mm²

Table 2 Compressive Strength After 28 Days

Date of Testing	Cube Ref. No.	Cube Dimensions (mm)	Weight of Cube (kg)	Density (kg/m ³)	Compressive Load (kN)	Strength (N/mm ²)
13/02/2026	TRIAL MIX	150 × 150 × 150	8.42	2496	741.00	32.94
13/02/2026	TRIAL MIX	150 × 150 × 150	8.55	2533	730.00	32.44
13/02/2026	TRIAL MIX	150 × 150 × 150	8.43	2498	688.00	30.58

Average 28-Day Compressive Strength = 31.99 N/mm²

➤ Load-Deflection Behavior

The control beam exhibited larger deflections and early crack formation. CFRP strengthened beams demonstrated increased stiffness and improved load-carrying capacity. The CFRP 45° configuration exhibited the Test highest ultimate load due to improved resistance against diagonal shear cracks.

Steel mesh strengthening improved post-cracking behavior and energy absorption while providing moderate increases in strength.



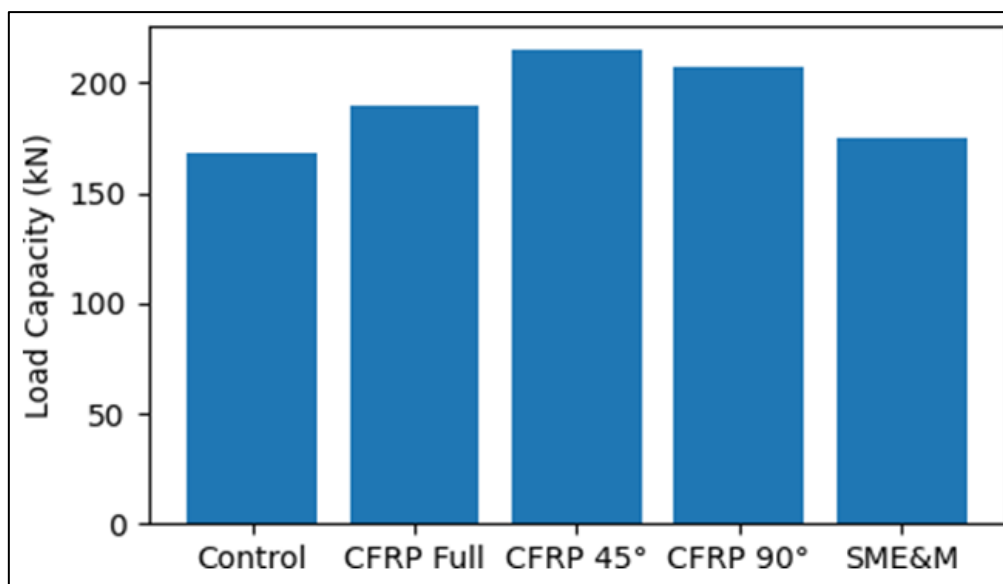
Fig 2 Wrapping of C.F.R.P. on Beam

➤ Failure Pattern

Control beams failed through flexural cracking followed by crushing of concrete. CFRP strengthened specimens showed delayed crack propagation and improved confinement. Steel mesh strengthening resulted in distributed crack formation and increased ductility.



Fig 3 C.F.R.P. at 90 Degree



Graph 1 Comparison of Ultimate Load Capacity

Table 3 Comparison of Ultimate Load Capacity

Specimen	Load Capacity (kN)	Deflection (mm)
Control Beam	168.42	4.875
CFRP Full Wrap	189.732	9.010
CFRP 45°	214.830	9.40
CFRP 90°	207.730	8.270
SME&M	174.732	2.27

I. CONCLUSION

➤ *The Following Conclusions are Drawn:*

- CFRP strengthening significantly improves load-carrying capacity and stiffness of RC beams.
- CFRP at 45° orientation achieved the highest ultimate load capacity of 214.83 kN.
- Full CFRP wrapping effectively controlled crack propagation.
- Steel Mesh with Epoxy and Mortar enhanced ductility and crack distribution.
- CFRP systems provide superior strengthening performance, whereas SME&M offers an economical alternative.
- Both techniques are suitable for rehabilitation and upgrading of deteriorated RC structures.

➤ *Future Scope*

- Investigation under cyclic and fatigue loading.
- Long-term durability studies under environmental exposure.
- Numerical modeling using finite element analysis.
- Evaluation under seismic loading conditions.
- Cost-benefit analysis for large-scale rehabilitation projects.

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