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Experimental Study on Retrofitting of Reinforced Cement Concrete Members using Fiber Reinforced Polymer Wraps

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Abstract

Old concrete buildings and bridges are wearing down across the globe. Weather, repeated stress, rust inside the metal bars, along with earthquakes slowly weaken them - many become unsafe long before they should. Fixing them the usual way works, yet those methods add heavy layers on top and keep structures closed too long. Instead of old fixes like thick steel wraps or making parts thicker, new materials made from fibers and plastic offer better strength gains. These lightweight sheets bond tightly to damaged areas, breathe fresh life into worn beams, last longer against decay, plus avoid messier construction setbacks.

From tests done at Priyadarshini College of Engineering in Nagpur, data came through on how M30 concrete acts when left bare or wrapped with steel fiber sheets. Six cube samples - each 150 mm on every side - and six beam pieces measuring 100 by 100 by 500 mm took shape in the lab. Half of each group stayed untouched before being pushed to failure. The rest got coated in steel fiber mesh glued tightly with epoxy just ahead of stress trials. Strength climbed slightly under squeeze: average numbers jumped from 34.21 to 36.14 newtons per square millimeter - a rise near 5.6 percent. When bent instead of crushed, they showed bigger gains - one step up by nearly thirty-eight percent, going from 3.2 megapascals to 4.4. Such shifts mark wrapped repairs not flashy tricks but solid fixes that last, hold well, cost less.

Keywords: *FRP Wraps, RCC Retrofitting, Steel Fiber, Compressive Strength, Flexural Strength, M30 Concrete, Structural Rehabilitation*

1. Introduction

Concrete mixed with steel holds up most modern structures, shaping how we build since the early 1900s. Yet common doesn't mean lasting - hidden damage grows behind flat facades. Moisture slips past barriers; air pollution seeps into pores; salt rides in on coastal winds; ice expands within tiny gaps until chunks split away. At first, nothing looks wrong. Then inspections uncover weakness under decades of quiet change: outdated layouts can't handle heavier loads, wider spaces, stricter quake standards.Heavy concrete, steel plates stuck on with glue, or wet cement flung through sprayers - these are usual choices when mending worn-down buildings.

While functional, they pile on weight, tend to corrode eventually, also demand major work that pushes people out during renovations. Something shifts, however, when ultra-tough fibers - think carbon, glass, aramid, basalt, sometimes even

fine steel strands - get trapped inside stiff plastic molds. Strength hides in these mixes; light frames fight rot effectively, slip over old surfaces quietly, leave walls mostly untouched. At this site, M30 concrete pieces got wrapped with steel fibers and put through tests. While many trials track only one type of stress, this run checks how they handle being crushed as well as bent. Every sample used identical mix designs, dimensions, and testing routines. The outcomes line up closely with actual field demands - those repairing houses or bridges across central India might find these figures helpful. Earlier reports often skip a key performance angle or differ too much in approach; what's recorded here steps into those gaps.

2. Literature Review

2.1 How FRP strengthening standards have changed over time

Back in the early nineties, work started shifting from heavy steel plates to lightweight polymer composites for reinforcing structures. Though once new, those methods now feed into current standards through steady updates - like the 2023 revision of ACI 440.2 - that adjust safety margins, redefine failure points, and sharpen inspection rules. Meanwhile, across Europe, guidance took shape under fib Bulletin 14, laying down firm math-based rules covering bending, sliding, twisting, and peeling risks. That framework remains a go-to reference even today, quietly shaping modern studies without fanfare.

2.2 Confinement and Flexural Strengthening

Wrapped in FRP, columns handle much higher compression loads while stretching further past their breaking point. Instead of complex tests, engineers often turn to Lam and Teng's model - its formulas match real-world results closely. Countries like Japan and the U.S. saw retrofitted bridges bend more than twice as far during quakes without failing. Performance spikes where bending damage hits hardest stand as proof it works.
Beams get stronger in bending when FRP strips stick to their bottom surfaces. On the other hand, wrapping them partway or completely around helps handle weakness against sliding forces. A key study by Triantafillou for ACI still shapes how people see links among fiber angle, stretch limits, and boost in resistance to sideways stress. Later lab tests adjusted how ends are secured, aiming to stop early peeling at strip tips - a problem that often decides how well reinforced beams perform under load.

2.3 Steel Fiber Composites

Out in the range of reinforced polymers, steel fiber jackets stand apart. Not like carbon or glass, these blends bring stiffer responses - elastic modulus nears 200 GPa - and handle shocks better. Tension capacity sits between 1,000 and 2,000 MPa, strong enough to brace columns firmly, whereas stretch ability (about 5–10% elongation) helps soak up sudden loads. Trouble begins if rust sets in once epoxy shielding cracks, so prep work on surfaces must be thorough, finishes solid. Research shows right installations lift compression limits about as much as fiberglass versions do, positioning steel wraps as cheaper picks wherever carbon proves too pricey.

3. Materials and Methodology

3.1 Concrete Mix Design

A blend of M30 concrete stuck to the 2019 version of IS 10262. Thanks to careful work on location, strength averaged 38.25 megapascals, usually swinging by around 5. To handle light environmental stress over time, standards from IS 456 (year 2000) fixed the water-to-cement ratio at 0.45. Given that stones reached sizes of 20 millimetres, each cubic metre called for close to 190 litres of water. Heavy on cement, the mix hit 422 kilograms each cubic meter - way past the needed 300. Pulling data from IS 10262 graphs, they settled on proportions: one portion cement tied to 1.6 portions

fine rock, along with 2.8 coarse, all weighed out.

3.2 Material Testing

Checking every material in labs came first, before any pouring happened. Coarse stone, tested using the wire basket method from IS 2386 (Part 3), had a density reading of 3.5 and absorbed just 1.65% water - this stayed below the permitted 2%. Three sand samples gave an average swelling of 9.1%, which fits neatly within the safe zone of 5% to 30%. Silt, though, measured 11.11%, nudging above the set maximum of 8% by IS 2386 (Part 2); that might slow down flow, leading to closer attention on water control. For cement, reaching normal consistency took 28% water - it started setting after thirty minutes, fully hardened by ten hours, results falling right in line with IS 4031.

3.3 Specimen Prep and Retrofit Steps

From a spinning drum, the mixture dropped loose before sliding into steel molds. Pressed in three rounds, every layer packed tight using a straight tool. A full day passed before workers pulled the bricks free from their frames. Under water they stayed, soaked through four whole weeks in a holding pool. Work moved through six stages, one after another. Discs spun fast, peeling grime off the surface while stiff brushes pulled out what came loose. Underneath, clean rock showed where old layers cracked free. Edges were rounded first, every curve brought to ten millimeters minimum to stop pressure from gathering at bends. Then blasts of air ran over everything, chasing dust into nothing and leaving only dry, open space behind. Out appeared the coating - epoxy parts mixed, spread light, kept tacky on purpose. Following that, steel fiber strips slid into position, pre-cut, drenched in resin, pressed hard onto the primed zone. Starting mid-point, a ribbed roller crept forward, herding pockets of air, smoothing ridges flat. Then silence: three whole days untouched, resting at normal room temperature. Last step arrived - the surface got sealed under a shield against sunlight damage.

4. Experimental Results and Discussion

4.1 Concrete Cube Strength

Cube by cube, six specimens - three plain, three coated in fiber-rich polymer - were fed into the testing rig, all precisely 150 by 150 by 150 millimeters. Force came down steadily, never wavering in pace. Each outcome, plus mean values, shows plainly in Table 1. Identically made, yet they cracked a bit differently when pressed.

Specimen Group	Cube 1 (N/mm²)	Cube 2 (N/mm²)	Cube 3 (N/mm²)	Mean (N/mm²)
Plain Concrete	33.33	35.55	33.77	34.21
Steel Fiber Wrapped	35.11	36.88	36.44	36.14

Table 1: Compressive Strength Results — Plain vs. FRP-Wrapped Cubes

One step beyond the original, the retrofitted cubes reached an average compression resistance of 36.14 N/mm² - up 5.6% from the starting point of 34.21 N/mm². Not every boost was dramatic, yet each of the three wrapped samples showed similar gain, suggesting minimal setup still does something useful. Where columns are concerned, full-wrap methods go further than part ial coverage, leading to stronger squeezing effects along the sides. Because of that tighter grip, studies note jumps in strength between 20% and 30%, far above what these test cubes achieved.

Fig No. 1 Steel Fiber Wrapped

Fig No. 2 Compressive Strength

4.2 Concrete Beam Bending Strength

From one end to the other, beams measuring 100 mm by 100 mm across their face carried an active reach of 400 mm during testing through dual contact forces. Because load distribution matters, bending resistance came from multiplying force times distance then dividing by width and depth squared. Where things stood after calculations shows up down below in the second table.

Specimen Group	Beam 1 (MPa)	Beam 2 (MPa)	Beam 3 (MPa)	Mean (MPa)
Plain Concrete	3.2	2.8	3.6	3.2
Steel Fiber Wrapped	4.4	4.0	4.8	4.4

Table 2: Flexural Strength Results — Plain vs. FRP-Wrapped Beams

Beams with wraps showed a flexural strength around 4.4 MPa, rising above the unwrapped ones at 3.2 MPa by roughly 37.5%. That jump? It's much bigger than what happens under compression - which makes sense when you look closer. Regular concrete barely handles tension, snapping suddenly when bent. But here, the steel fiber sleeve takes over that role, holding cracks together while shifting stress to stronger nearby areas. Out on real job sites, similar results pop up: wrapped members using composite materials often see way more boost in bending performance than they do when squeezed.

Fig No. 1 Steel Fiber Wrapped

Fig No. 2 Flexural Strength

4.3 Synthesis of Findings

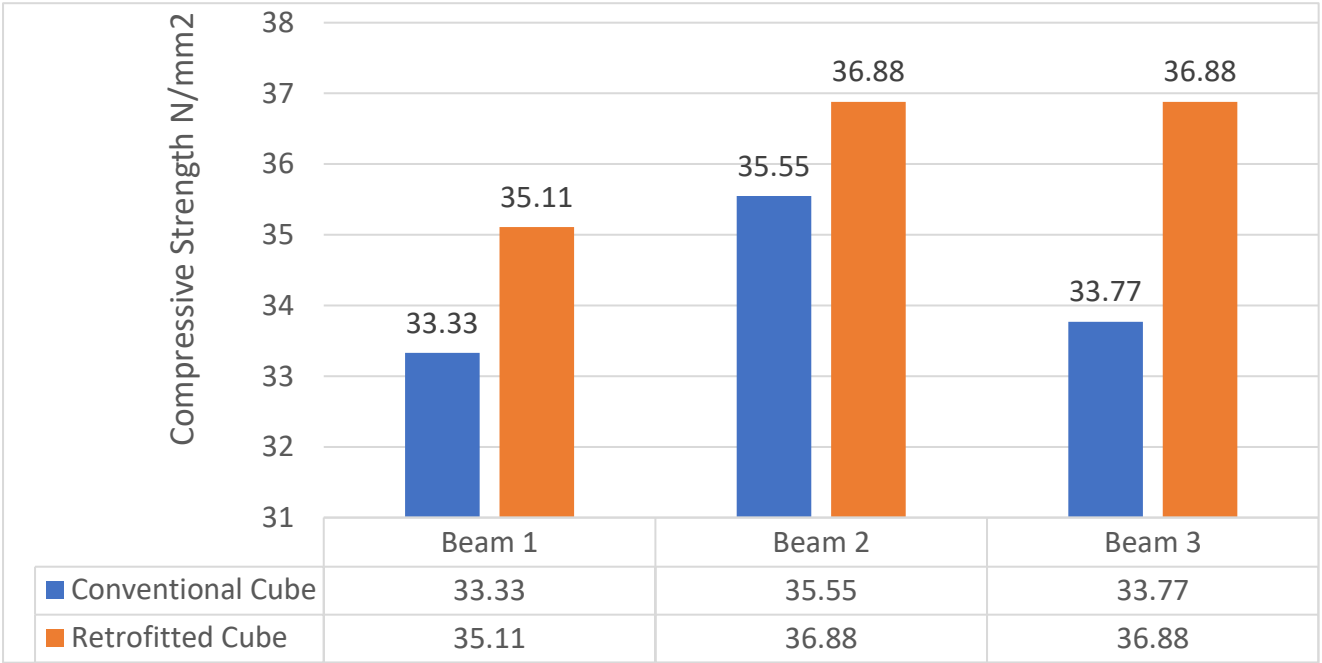
Looking at Table 3, you see gains shown as percentages from both testing methods, compared next to the IS code's approval limits for each material part.

Parameter	Plain Specimen	Wrapped Specimen	% Improvement
Compressive Strength (N/mm²)	34.21	36.14	+5.6%
Flexural Strength (MPa)	3.2	4.4	+37.5%

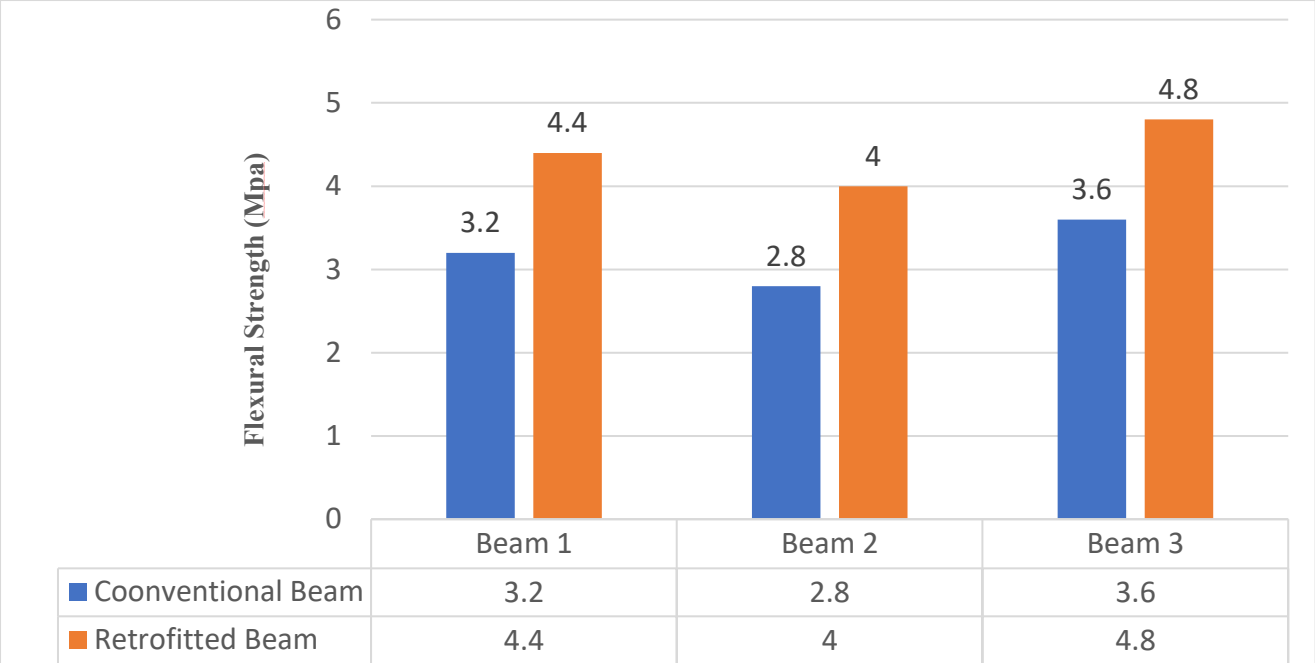
Table 3: Summary of Strength Improvements

When you look at how much better materials handle squeezing versus bending, it becomes clear that FRP wraps help most when pulling forces lead to breakage - this lines up well with what theory predicts. Tension rules the behavior of most beams used in real-world construction, so these results fit neatly into how engineers strengthen such elements. Columns work differently; they mainly resist loads pressing down, which means holding them tightly together matters more than anything else. Here, boosting their squish resistance only showed small gains because the wrap did not go all around - but if it had, that improvement likely would have grown quite a bit.

Graphical Result Representation



Compressive Srength N/mm²



Flexural Strength N/mm^2

5. Practical Case Application

Picture an older concrete building, built during the nineties, standing where earthquakes happen. Because it sits in a shaky zone, its frame has been checked closely. Some vertical supports lack enough wrapping bars around them. Their ability to bend without breaking is lower than needed near likely failure points. Tiny cracks are starting on some surfaces, hinting at rust inside the steel rods. Modern safety rules expect these parts to handle three times their yield shift. Right now, they manage only about half that stretch before risking collapse.

Fiber-reinforced polymer jackets went into use during the upgrade because they handle tension well - stiffness sits between 230 and 240 GPa - and have worked reliably in past quake fixes. Around each column bottom, covering the entire 1.0-meter zone where bending damage usually occurs, installers applied two full rings of wrapping material. Before bonding anything, crews stripped off broken concrete pieces, sealed cracks using injected epoxy resin, then shaped sharp edges into smooth curves with a 25 mm arc. After modeling performance post-upgrade, engineers saw compression capacity climb roughly one-quarter higher while movement tolerance reached up to 3.2 times its original limit, meeting today's safety rules. When tested against back-and-forth shaking forces, energy absorption doubled; instead of sudden cracking across sections, beams now bend gradually - a key change avoiding total floor-level breakdowns.

About 60% less expensive than traditional concrete wrapping, the fiberglass fix saved money by skipping molds, messy materials, and long drying waits. With people still inside, crews finished the upgrade - proving useful when you can't empty a building.

6. Future Scope

Ongoing research is broadening the applicability and sustainability profile of FRP retrofitting in several directions:

Starting strong with plants instead of plastic, researchers now test natural threads like jute, flax, hemp, and sisal inside plant-made glues. These green mixes aim to cut carbon compared to regular fiberglass or carbon setups. Even though they aren't quite as tough just yet, mixing them with stronger materials helps close the difference. Tweaking how the fibers connect to the glue also lifts their strength bit by bit.

using composite laminates," Construction and Building Materials, vol. 25, no. 2, pp. 591–597, 2011. Start with mixing fiber types. Engineers stack carbon alongside glass, or blend natural with manmade strands in one layer cake of materials.

This mix hits around 80 to 90 percent of full-carbon toughness. Cost stays low - about four to five out of ten compared to pricier versions. Balance shifts where it matters. Savings pile up without losing much muscle.

Fire safety improves when materials hold up under heat. Resins in FRP weaken as things get hot. Scientists test special paints that swell to shield them. Tiny silica bits mixed into epoxy help too. Layers of ceramic fibre add another barrier. Progress means these systems may soon meet common fire codes.

Inside smart FRP, tiny sensors live within the material. These include fiber optics that catch light shifts when stretched. Piezoelectric bits respond to pressure by creating small signals. Carbon fibers woven throughout can track electrical changes tied to damage. Instead of just holding things together, the composite now reports how it's doing. Strain spreads? Temperature climbs? Tiny cracks forming? The structure speaks up. Monitoring happens while the part stays in place. No extra tools needed - everything is built right in.

Deep inside the concrete skin, grooves cradle FRP rods held fast by thick epoxy glue - this is how near-surface mounting works instead of gluing flat strips on top. Because the bars tuck into the material, they resist slipping far better than surface-stuck versions. Slabs and brick walls often gain more strength this way. Hidden within cuts, the rods hold tighter when stress builds.

7. Conclusion

When steel fiber FRP wraps are added, M30 concrete deals with pressure and bending better - test results confirm it. On average, squeeze strength climbs a bit, about 5.6 percent. Yet bending holds up far stronger, jumping by 37.5 percent. Sample after sample shows nearly the same change. That steady pattern points to the wrap making the difference, not just chance in measurements.

Surprisingly, those outcomes line up closely with earlier research into FRP jackets and resistance to bending. Core behaviors - holding back crack growth, moving tension loads around, pressing inward on edges - remain active even in small-scale samples. With full wraps placed onto real structural elements, improvements tend to become clearer. Bending distance before collapse increases. Energy soaked up during repeated shaking also rises noticeably.

Heavy gear doesn't need upgrading when FRP goes in, since the load shifts barely at all. Even if raw pricing sits higher, faster installation chips away at crew hours. Confidence climbs as standards such as ACI 440.2-23 evolve year by year. Steps drop off the checklist - no forms mean fewer pieces to manage upfront. Daily routines keep rolling because most users notice no drag on operations. As output grows, costs tend to drop gradually. Actual field data supports its place in today's fix methods.

Should we test multiple wraps on M30 under repeated stress? Years of heat and dampness could challenge steel fiber performance across central India. Plant-based strands may suit lighter repairs where extreme toughness isn't key.

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