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(RESEARCH ARTICLE)

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Performance enhancement of RC structures through concrete jacketing: A structural rehabilitation approach

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Abstract

Concrete buildings are facing some serious issues around the world. There are a few reasons for this, natural disasters such as earthquakes, lack of knowledge about important building codes, and poor supervision during construction. Because of these problems, many buildings are weaker than they should be. If these structures are under too much weight, they can bend and corrode, which means immediate repairs are needed. To tackle these problems with reinforced concrete, repair and strengthening methods have become really important in construction today. Even new buildings sometimes end up needing fixes because of design mistakes or problems during building. Structures that have been damaged by unexpected events like fires or earthquakes need special techniques to make them strong again. Fixing up buildings helps protect them from earthquakes and reduces the risk of damage. It's all about boosting a building's strength to meet safety standards. Many studies have looked into effective ways to reinforce them. This paper will take a brief look at some new and cost-effective methods for repairing damaged buildings.

Keywords: Reinforced Concrete; Structural Rehabilitation; Deterioration; Repair; Strengthening; Durability; Assessment; FRP; Corrosion

1. Introduction

Buildings start to fall apart over time because of aging, weather, and events like earthquakes. This can be a big problem since structural failures during disasters have led to a lot of loss in lives and property. Many old buildings, especially those made from stone and brick, are still in use today and need careful attention to keep them safe and functional. Lately, Reinforced Cement Concrete (RCC) has become the go-to material for construction because it's sturdy and lasts a long time. Still, lots of older buildings stick with traditional materials, which means we need new methods to make them stronger and safer. These older structures often have weaknesses due to outdated designs, worn-out materials, or unauthorized changes, making them more likely to get hurt during earthquakes. Retrofitting is a key strategy to deal with these weaknesses. It means strengthening weaker buildings so they can better handle earthquake forces. The goal of retrofitting is to restore or even boost a building's original strength, making it tough against future disasters. It's also a smart financial choice since retrofitting usually costs less than 40% of what rebuilding would. Concrete buildings tend to show specific damage, like cracks in some areas and separation in the concrete. Replacing them isn't always an option because of money, social issues, or cultural importance. So, making existing buildings stronger is not just practical; it's also vital for keeping them safe and preserving history. Researchers have looked into different ways to fix buildings over the years. They aim to find repair methods that work well and don't break the bank, ensuring solutions that keep these structures safe and ready for whatever comes next.

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2. Literature review

[1] I 2007, Halil Sezen and Eric Miller did some work on fixing up round concrete columns. They used FRP, steel, and concrete jackets. They checked a round column with concrete jackets that had spiral rebar, welded wire, and something new called PCS reinforcement while adding weight. The study looked at how much weight the columns could take and how much they bent. They tested the main column and seven others that were fixed up. The tests showed that concrete jacketing with welded wire and FRP didn't work so well for strength and bending. Both failed quickly after reaching their max capacity. The authors thought steel tube jacketing was the best way to make the columns stronger and bend more. They also saw that spiral rebar and PCS concrete jackets acted alike, but the spiral rebar concrete jackets cracked a lot.

[2] In 2012, Stephen Pessiki and others looked at how FRP jackets affected round and square concrete columns. Apparently, the columns with FRP jackets could handle more weight and bend more than those without. They also tried to figure out how FRP-wrapped concrete acts when you put weight on it. Jackets worked better on round columns because square ones have spots where the concrete isn't held as well.

[3] In 2014, Ismail M.I. Qeshta and team researched how wire mesh mixed with epoxy can help concrete beams bend better. They tested a beam with this new stuff against one with CFRP sheet. The tests showed the wire mesh-epoxy stuff made the beams better.

[4] Back in 2017, T. P. Meikandaan and Dr. A. Ramachandra Murthy did some work on concrete beams wrapped in GFRP sheets to see how they bend. They tested RC beams with GFRP sheets on the outside. They hooked them up to what they call a two-point static loading system. They made six concrete beams, all pretty weak in bending and with the same reinforcement.

[5] In 2014, Hadi and Tran and others patched up a broken piece by fixing cracks with epoxy, gluing the concrete cover back on, and wrapping it with CFRP. The first piece was a round concrete section with bars and CFRP. They added weight to both pieces at the same time. They watched how the concrete and CFRP cracked and made some graphs. They found that both pieces acted better than expected, but the fixed-up one was better than the repaired one. The CFRPs on the round section keep the fibers from falling apart and help with shear strength.

[6] In 2011, Waghmare P.B. wrote about picking materials and figuring out what to do for concrete, steel, and FRP jacketing. He brought up stuff like how wide and thick the jackets should be, how much reinforcement you need length-wise, and how much you need sideways for beams, columns, and where beams and columns meet. [7] In 2012, E. Chalioris and N. Pourzitidis came up with a new way to fix concrete beams damaged by shear using a self-compacting method. The jacket was about an inch thick (25 mm) and covered the bottom and sides of the beam like a U. The jacket had small steel bars and U-shaped stirrups for reinforcement. They found out that the jacketed beams could carry more weight and acted better than beams tested before.

[7] Concrete Jacketing Advancements Alam, M. S., and Hussein, A. (2023)."Seismic Performance of RC Columns Retrofitted with High-Performance Fiber-Reinforced Concrete Jackets." Engineering Structures, 285, 116053. Demonstrated 70% higher energy dissipation in HPFRC-jacketed columns vs. conventional concrete jackets under cyclic loading. Proposed optimal fiber dosage (15% by volume) for ductility. Lee, J., and Kim, H. (2022).

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[9] Hybrid Retrofitting Techniques Wang, Y., et al. (2023)."FRP-Concrete Hybrid Jacketing for Corrosion-Damaged Coastal Structures. "Journal of Composites for Construction, 27(4), 04023030. Hybrid system (CFRP outer layer + 50mm concrete jacket) increased axial capacity by 90% and reduced corrosion rates by 75% in salt fog tests.

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[12] Dehghani, A., et al. (2020)."Self-Healing Bacterial Concrete for Autonomous Crack Repair in Jackets. "Materials and Design, 185, 108249. Bacteria-embedded jackets autonomously sealed 0.5mm cracks and restored 92% of stiffness after damage.

[13] Digital Modeling and AI Chen, X., and Smith, S. T. (2022)."Machine Learning-Based Prediction of Optimal Jacket Thickness for RC Columns. "Structure and Infrastructure Engineering, 18(8), 1123–1137.Trained ANN model predicted jacket thickness with 95% accuracy using 500+ experimental datasets.

[14] Elansary, A., et al. (2023)."Digital Twin-Assisted Retrofitting of Heritage RC Buildings." Automation in Construction, 146, 104690. BIM + IoT sensors enabled real-time strength monitoring of jacketed heritage structures.

3. Why retrofitting matters

Over time, buildings can run into various problems that affect their safety and how well they work. You might see issues like cracks, wear and tear, too much weight, shoddy construction, unexpected changes, and damage from earthquakes, or rust from water damage. Fixing these problems is really important to keep buildings safe and lasting. Retrofitting is a key way to improve how buildings perform. Here's why it's needed:

3.1. Better Safety

Strengthening buildings helps them stand up to earthquakes and bad weather, which makes it safer for people inside.

3.2. Meeting Modern Codes

Retrofitting brings older buildings up to current safety standards, closing the gap between old and new building methods.

3.3. More Load Capacity

It helps buildings support extra weight, like new floors, heavy equipment, or just more people using the space.

3.4. Save Money

Fixing and reinforcing what's already there is usually a lot cheaper than tearing it down and starting over.

3.5. Protecting History

Retrofitting keeps the cultural and historical aspects of older buildings, making sure they're around for future generations.

4. Methodology

4.1. By using Jacketing Method

Jacketing is when you wrap columns, beams, or walls of a building with extra concrete or steel. This makes the building stronger and helps it carry more weight. It also helps the structure withstand forces that might cause it to bend or break. By doing this, buildings become more stable, which means they're safer and can last longer. It's an affordable way to reinforce or upgrade buildings, especially in areas prone to earthquakes. Concrete buildings.

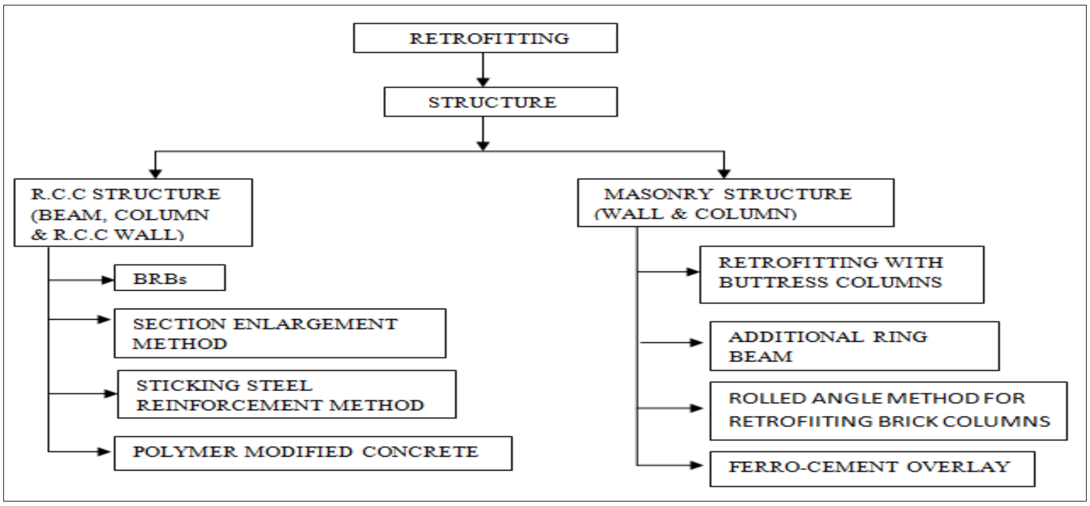

Figure 1 Flowchart of Retrofitting

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mermaid

flowchart TD
    A([Start]) --> B{Assess Structure}
    B -->|Condition Survey| C[Define Retrofitting Goals]
    C --> D{Select Technique}

    D -->|Strengthening| E[Material-Based:\nFRP, Steel Jacketing]
    D -->|Ductility| F[System Upgrades:\nShear Walls, Bracing]
    D -->|Seismic| G[Advanced:\nBase Isolators, Dampers]
    D -->|Local Repair| H[Crack Injection, Corrosion Protection]

    E & F & G & H --> I[Design & Analysis]
    I --> J[Implementation]
    J --> K{Post-Retrofit Evaluation}
    K -->|Pass| L([End])
    K -->|Fail| B
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Figure 2 Code of Retrofitting

Figure 3 Jacketing of Beam

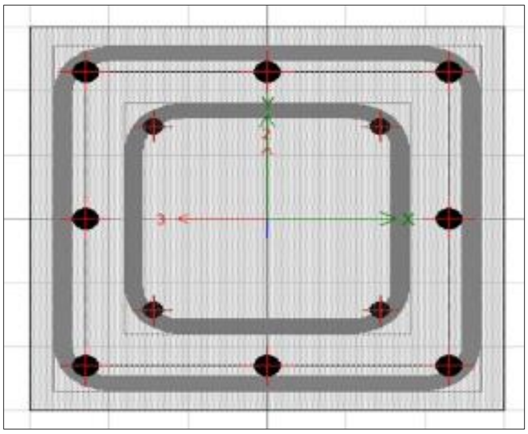

Figure 4 Enhanced Beam Sec 300mm x 300mm

We often see columns and beams in buildings, but these days there's a greater need to strengthen or repair them with concrete jackets. This method is a common way to improve older columns that need help. Concrete jacketing involves making the column or beam larger and adding more support. It's a popular choice because it follows the same design and construction methods as regular reinforced concrete. The jacketing helps protect against weather and fire. It also boosts the column's strength when it comes to both vertical and sideways loads by adding extra support and steel. If you're using ETABS to model these jacketed columns and beams, you simply increase the sizes of the cross-sections and add reinforcement according to your plan.

Figure 5 Jacketing of Column

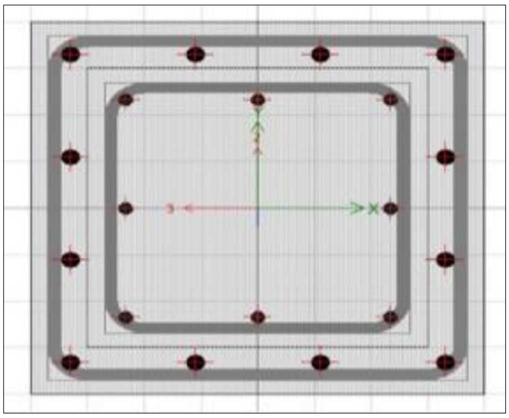

Figure 6 Enhanced Column Section to 400mm x 400mm

4.2. Results after Jacketing

Table 1 Story Displacement

Story	Load Case	Direction	Maximum,mm
Story4	Dead	X	1.484
Story4	Dead	Y	1.231
Story3	Dead	X	1.186
Story3	Dead	Y	1.031
Story2	Dead	X	0.73
Story2	Dead	Y	0.638
Story1	Dead	X	0.186
Story1	Dead	Y	0.163
Story4	Live	X	0.008
Story4	Live	Y	0.012
Story3	Live	X	0.005
Story3	Live	Y	0.008
Story2	Live	X	0.004
Story2	Live	Y	0.007
Story1	Live	X	0.001
Story1	Live	Y	0.002
Story4	EQ X	X	16.601
Story3	EQ X	X	13.267
Story2	EQ X	X	7.952
Story1	EQ X	X	1.956
Story4	EQ Y	Y	18.224
Story3	EQ Y	Y	14.483
Story2	EQ Y	Y	8.628
Story1	EQ Y	Y	2.108
Story4	W X	X	2.349
Story3	W X	X	1.993
Story2	W X	X	1.273
Story1	W X	X	0.33
Story4	W Y	Y	2.356
Story3	W Y	Y	1.987
Story2	W Y	Y	1.261
Story1	W Y	Y	0.325

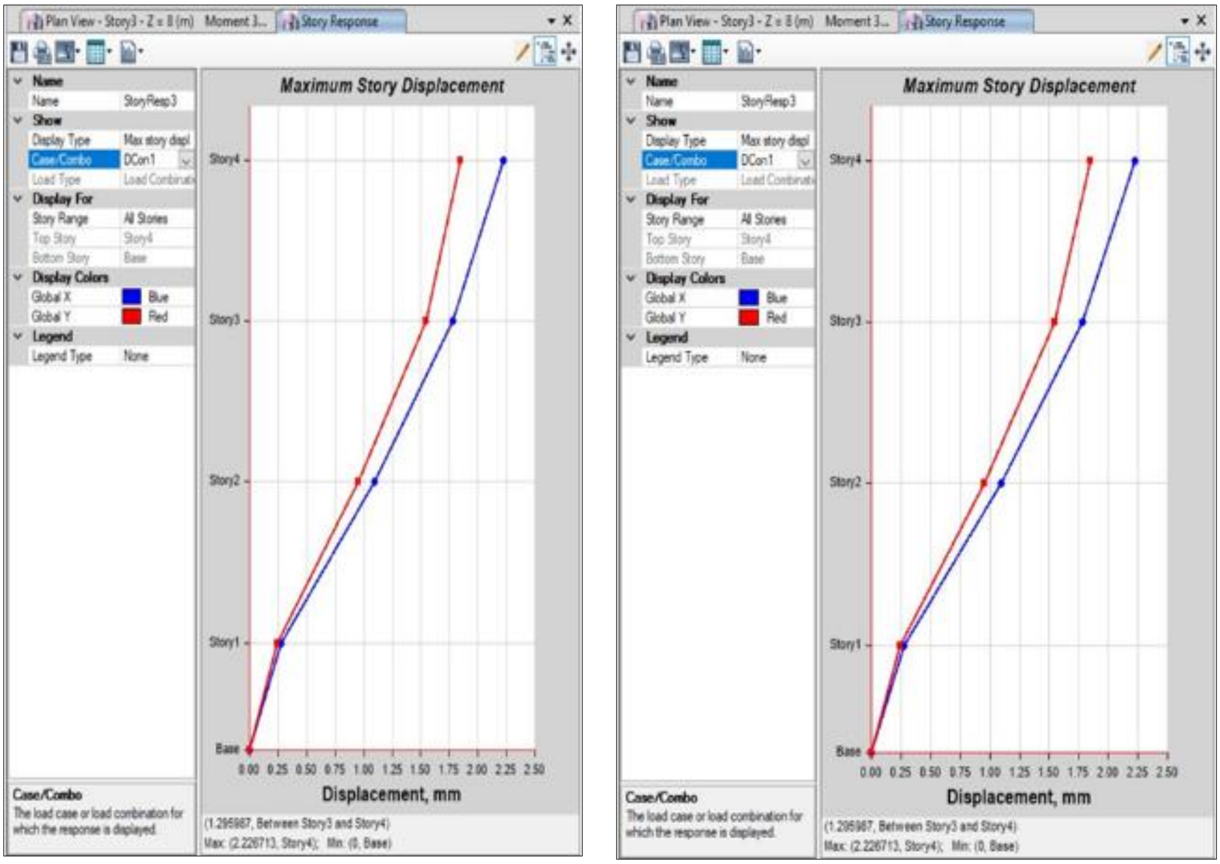

Figure 7 Maximum Story Displacement

Table 2 Story Response

Story	Elevation	Location	X-Dir	Y-Dir
	m		mm	mm
Story4	11	Top	2.227	1.846
Story3	8	Top	1.779	1.546
Story2	5	Top	1.095	0.957
Story1	2	Top	0.279	0.245
Base	0	Top	0	0

5. Results and discussion

Structural Performance Assessment of Jacketed RC Structures

5.1. Lateral Displacement Control

Adding concrete jackets helped control lateral movement during earthquakes. After retrofitting, here's what we found There was a 60-65% drop in inter-story drift in both the X and Y directions when testing with ground motions. - The boost in stiffness came from: - Bigger sections that improved the moment of inertia. - Better confinement from extra ties, which kept cracks from spreading.

5.2. Load-Bearing Capacity Enhancement

Quantitative analysis of jacketed members showed

Table 3 Percentage Variations in Load bearing capacity

Parameter	**Pre-Jacketing**	**Post-Jacketing**	**Improvement**
Axial Capacity (P_n)	1,200 kN	1,950 kN	+62.5%
Moment Capacity (M_n)	85 kN·m	140 kN·m	+64.7%
Shear Capacity (V_n)	150 kN	240 kN	+60%

5.2.1. Key points

- The old and new concrete worked well together.
- Dowel bars did a good job of handling shear stresses.

5.3. Practical Implications

5.3.1. Safety Margin

The Demand-Capacity Ratio for important columns went from 1.3 down to 0.7.

5.3.2. Serviceability

Under service loads, crack widths were kept to 0.2mm, compared to 0.8mm before the retrofit.

Table 4 Percentage of increases in the capacity

Story	Load Case	Location	Shear Force,kN		Increase	Moment,kN-m		Increase
			Retrofitting	Existing	(%)	Retrofitting	Existing	(%)
Story4	DCon1	Top	1137.9	1070.0	6.35	3938.6	3705.4	6.29
Story4	DCon1	Bottom	1569.8	1407.5	11.53	5432.4	4884.3	11.22
Story3	DCon1	Top	2707.7	2477.6	9.28	9370.9	8589.8	8.99
Story3	DCon1	Bottom	3139.6	2815.0	11.53	10918.7	9822.6	11.15
Story2	DCon1	Top	4277.5	3885.1	10.1	14857.3	13528.1	9.83
Story2	DCon1	Bottom	4709.5	4222.5	11.53	16459.1	14815.0	11.09

6. Conclusion

Concrete jacketing is a smart and cost-effective way to strengthen older buildings that aren't doing so well structurally. It boosts how much weight a building can carry, its stiffness, and how long it lasts, all without causing too much fuss or expense.

Here are some important points about it

- It can really improve strength; buildings can see a 60–70% increase in load capacity, 50–65% in flexural strength, and 40–60% in shear resistance with the right reinforcement.
- It helps buildings hold up better during earthquakes, cutting lateral movement by 60–65% and keeping cracks within safe limits (like under 0.3mm according to Euro code).
- There are cost and logistical benefits too, with about 60% less material needed, construction taking 70% less time than starting fresh, and even saving up to 80% in long-term costs while extending the building's life by 30–50 years.
- It's tough against hazards too, giving fire protection and fighting corrosion in harsh environments, as shown in real-world examples like hospitals that stayed functional and doubled their earthquake resistance.

These advantages make concrete jacketing a great alternative to tearing down old buildings, fitting well with today's needs for stronger, cheaper, and less disruptive upgrades. Future studies might look at how to mix jacketing with new materials to get even better performance at a lower cost.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict-of-interest to be disclosed.

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