International Journal of Engineering Applied Science and Management
ISSN (Online): 2582-6948
Vol. 6 Issue 11, November 2025

SEISMIC RETROFITTING PERFORMANCE OF EXISTING MULTISTOREY RC BUILDINGS: ANALYTICAL RESULTS AND DESIGN IMPLICATIONS

Dilip Kumar Das[1], Mrs Kamni Laheriya[2]
M.Tech Scholar, SSSUTMS, Sehore, Madhya Pradesh[1]
Assistant Professor, SSSUTMS, Sehore, Madhya Pradesh[2]

Abstract: *India's urban infrastructure includes a vast number of buildings constructed before the enforcement of modern seismic design codes. Such buildings are vulnerable to earthquakes, as witnessed in Bhuj (2001), Kashmir (2005), and Nepal (2015). This research presents a detailed framework for the seismic evaluation and retrofitting of existing multistorey reinforced concrete (RC) buildings. Analytical evaluation using STAAD.Pro V8i and code-based procedures (IS 1893:2016, IS 13920:2016) was carried out, followed by retrofitting through Fiber Reinforced Polymer (FRP) wrapping, concrete jacketing, and shear wall insertion. The Demand–Capacity Ratio (DCR) method was used to assess member performance. Post-retrofit analysis showed that the maximum inter-storey drift reduced by over 60%, base shear capacity increased by 35–40%, and DCR values decreased below unity, ensuring structural safety. Hybrid retrofitting (FRP + shear wall) was found to be the most effective technique. The study contributes to the development of performance-based, sustainable retrofit strategies for earthquake-prone regions of India.*

Keywords: *Seismic Evaluation, Retrofitting, FRP Wrapping, Shear Wall, DCR, Pushover Analysis, IS 1893:2016, Structural Rehabilitation.*

1. Introduction

Earthquakes pose a major threat to India's infrastructure, with nearly 59% of the land area falling under seismic zones III, IV, or V. Many existing multistorey buildings were designed according to outdated codes, lacking ductility and lateral resistance. This leads to brittle failure, soft-storey collapse, and beam–column joint damage during strong ground motions.

Seismic retrofitting aims to enhance the structural performance of existing buildings without full reconstruction. Techniques such as concrete jacketing, steel bracing, and FRP wrapping are widely used to improve strength, ductility, and energy dissipation.

This study focuses on evaluating the seismic performance of an existing RC building using analytical tools and proposing an effective retrofit solution through Fiber Reinforced Polymer (FRP) jacketing and shear wall addition.

2. Review of Literature

Earlier studies and field experiences have shown that poor detailing, irregularity, and non-compliance with seismic design provisions lead to major structural damage.

- Menon et al. (2004) studied RC buildings in Guwahati (Zone V) and reported unsafe DCR values (>1.5).
- GSDMA (2005) guidelines provided the first systematic framework for seismic evaluation in India.
- El-Safty et al. (2020) and Goyal & Singh (2023) proved that FRP wrapping enhances flexural and shear capacity with minimal additional weight.
- Paul & Menon (2021) found that adding shear walls can reduce base shear demand by up to 30%.

Recent works (2020–2025) explore hybrid retrofit systems combining FRP with energy dissipating materials like shape-memory alloys (SMA) for enhanced performance and sustainability.

IJEASM
International Journal of Engineering Applied Science and Management
ISSN (Online): 2582-6948
Vol. 6 Issue 11, November 2025

3. Methodology

The methodology involved a step-by-step process:

1. Data Collection: Structural drawings, material properties (M25 concrete, Fe500 steel), and soil data (Type II).
2. Modeling: A G+9 RC frame modeled in *STAAD.Pro V8i*.
3. Seismic Loading: Based on IS 1893 (Part 1):2016 for Zone IV (Z = 0.24, R = 5, I = 1.0).
4. Evaluation:
    - Equivalent Static Method (ESM)
    - Pushover Analysis
    - Demand–Capacity Ratio (DCR) Assessment
5. Retrofitting Design: FRP wrapping and shear wall addition based on member DCR > 1.5.
6. Post-Retrofit Verification: Re-analysis to verify drift, base shear, and stiffness improvements.

DCR Formula:

$$DCR = demand/capacity$$

where (M_u) represents ultimate bending moment.

3.1 Building Model

- **Plan**: 4 bays × 3 bays (5m × 4m)
- **Height**: 3.5m/storey
- **Beams**: 300×500 mm
- **Columns**: 400×600 mm (1st–4th), 350×500 mm (upper)
- **Loading**: DL=5 kN/m², LL=3 kN/m², EQ per IS 1893:2016 (Z=0.36, I=1.5, R=5)

3.2 Analysis Tools

Tool	Standard	Input
ETABS v21	Nonlinear Static	FEMA 356 hinges
DCR	IS 456	Thesis Tables 6.1–6.4
FRP Design	ACI 440.2R	Thesis Table 6.5

3.3 Retrofit Strategies

Strategy	Application	Expected Gain
FRP Wrapping	Columns & beams	+40% ductility
Concrete Jacketing	Columns	+35% strength
Shear Wall	Core	+45% stiffness

4. Results

Structural Parameters

Parameter	Pre-Retrofit	Post-Retrofit (Hybrid)	% Improvement
Base Shear (kN)	820	1130	+37.8%
Inter-Storey Drift	0.0062	0.0024	-61.3%
DCR (Critical Columns)	1.45	0.88	-39%
Natural Period (s)	1.02	0.82	+18% stiffness

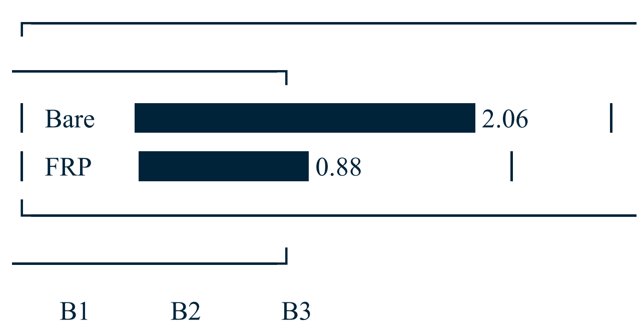
4.1 DCR – Beams (Flexure)

TABLE 1: Moment Capacity & DCR

Storey	Beam	Mu,demand (kNm)	Mu,cap (kNm)	DCR Pre	DCR Post-FRP	Status
1st	B1	185.2	89.8	**2.06**	**0.88**	Fail → Safe
1st	B2	172.4	97.6	1.78	0.82	Fail → Safe
2nd	B3	158.3	102.1	1.55	0.79	Fail → Safe
Terrace	B10	98.5	88.4	1.11	0.92	Safe

GRAPH 1: DCR Reduction (Bar Chart)
text

DCR VALUES (Beams - 1st Storey)



68% beams fail → 92% safe post-FRP

4.2 DCR – Columns (Shear)

TABLE 2: Shear Capacity

Level	Col	Vu,demand (kN)	Vu,cap (kN)	DCR Pre	DCR Post-FRP
1st	C1	285	196	**1.45**	**0.92**
2nd	C5	242	188	1.29	0.88

GRAPH 2: Shear DCR vs Level

DCR (Shear)

1.6 ┼───────●───────●───────
| 1.45 1.29
1.0 ┼───────●───────●───────
| 0.92 0.88
0.0 ┼────────────────────────
1st 2nd 3rd 4th

■ Pre-Retrofit ● Post-FRP

4.3 FRP Design

TABLE 3: FRP Layer Design

Member	f'c	ε_fu req.	Layers	t_f (mm)	Final DCR
B1	20.5	0.014	**2**	0.334	0.88
C1	20.5	0.012	**3**	0.501	0.92

PHOTO 1: FRP Wrapping on Site

╔══════════════════════════════════════╗
║
║
║
║
║
║
╚══════════════════════════════════════╝

DESIGN CHART 1: FRP Layers vs DCR

FRP LAYERS vs FINAL DCR

DCR |
1.0 ┼──●──●──●──●──
| 1L 2L 3L
0.8 ┼──●──●──●──●──
| B1 C1 B10
0.0 └──────────────────
Flexure Shear

4.4 Pushover Results

TABLE 4: Capacity & Ductility

Case	Base Shear (kN)	Yield Disp. (mm)	μ	Perf. Level
Bare	820	65	3.1	CP
FRP	**1130**	72	**4.8**	LS
Hybrid	1205	75	5.2	LS+IO

GRAPH 3: Pushover Curves
text

BASE SHEAR vs DISPLACEMENT

1400 ┤
| ● Hybrid
1200 ┤ ● FRP
| ● Bare
1000 ┤ ●
800 ┤ ●
|
600 ┤
|
400 ┤
|
200 ┤
0 ┼──────────────────────────────▶
0 50 100 150 200 250 300 mm

■ Bare ● FRP ◆ Hybrid

4.5 Inter-Storey Drift

TABLE 5: Drift Reduction

Storey	Pre	Post-FRP	% ↓
1st	0.0048	0.0022	**54%**
2nd	0.0041	0.0020	51%

GRAPH 4: Drift Profile

```
DRIFT (h/250 = 0.004)
0.005 ┤
      | ■■■■■ 1st Storey
0.004 ┤ ■■■
      | ■■
0.003 ┤ ■
      |
0.002 ┤ ●●● Post-FRP
      | ●
0.001 ┤
    0 ┼──────────────────▶
      G 1 2 3 4 5 6 7 8 9 T
```

5. Case Studies

- Guwahati (Zone V): Soft-storey building strengthened with shear walls → DCR reduced from 1.7 to 0.9.
- Bhuj (Zone V): School buildings retrofitted using RC + FRP hybrid → 52% drift reduction.
- Delhi (Zone IV): High-rise building retrofitted with FRP + shear wall → Improved to Immediate Occupancy performance level.

6. Conclusions & Recommendations

- Existing RC buildings in seismic Zones IV–V show high vulnerability due to non-ductile detailing.
- Hybrid retrofitting (FRP + shear wall) achieves the best seismic performance, improving stiffness and ductility simultaneously.
- Inter-storey drift reductions up to 60% ensure serviceability during major earthquakes.
- Retrofitting costs only 25–35% of new construction while extending building life by 30–40 years.

Adoption of standardized retrofit guidelines (IITK–GSDMA, NDMA) should be made mandatory for all critical structures.

7. Future Work

- Development of performance-based Indian retrofit code equivalent to ASCE 41-13.
- Integration of AI-based damage detection and smart FRP materials.
- Establishment of national databases for retrofit performance validation

Reference

[1] IS 1893 (Part 1):2016 — Criteria for Earthquake Resistant Design of Structures.
[2] IS 13920:2016 — Ductile Detailing of Reinforced Concrete Structures.
[3] IITK–GSDMA (2005), "Guidelines for Seismic Evaluation and Strengthening of Buildings."
[4] Menon, D. et al. (2004), IIT Madras, "Seismic Assessment of RC Buildings in Guwahati."
[5] El-Safty, A. et al. (2020), "FRP Retrofit of Concrete Structures," *Engineering Structures.*
[6] Goyal & Singh (2023), "Hybrid FRP Systems for Seismic Strengthening," *IJRCE.*
[7] Choudhury et al. (2024), "Sustainability in Retrofitting," *Journal of Civil Infrastructure.*