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Eureka Journal of Civil, Architecture and Urban Studies (EJCAUS)

ISSN 2760-4977 (Online) Volume 01, Issue 01, November 2025

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# SEISMIC RESILIENCE ASSESSMENT OF MID-RISE REINFORCED CONCRETE BUILDINGS IN URBAN ZONES

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**Abstract**

Urban environments with mid-rise reinforced concrete (RC) buildings face increasing seismic risks due to rapid urbanization, aging infrastructure, and the impacts of climate change on ground behavior. This research evaluates the seismic resilience of typical 6–12 story RC buildings using nonlinear static pushover analysis, fragility curves, and resilience scoring metrics. Models were developed using contemporary European seismic codes (Eurocode 8) and compared with structural data from India and Turkey. Results show that mid-rise RC buildings with inadequate confinement, heavy infill walls, and non-ductile detailing demonstrate 35–60% lower resilience. Retrofit strategies such as fiber-reinforced polymer (FRP) confinement and base isolation show significant performance improvements. The findings support policymakers, engineers, and urban planners in identifying priority structures for mitigation.

**Keywords:** Seismic Resilience, Reinforced Concrete Buildings, Urban Zones, Pushover Analysis, Fragility Curves, Retrofitting, Earthquake Engineering, Structural Performance.

## 1. Introduction

Urban seismic risk has become a major global concern as densely populated cities expand into seismically active regions. Mid-rise reinforced concrete (RC)

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buildings constitute the majority of residential and commercial structures in cities across Asia, Europe, and South America. Many of these buildings were constructed prior to the adoption of modern seismic codes, making them vulnerable during moderate to severe earthquakes.

Past seismic events — such as the **2015 Nepal Earthquake**, **2020 İzmir Earthquake**, and **2023 Turkey–Syria Earthquake** — highlighted structural deficiencies in mid-rise RC buildings. Observed failures included soft-story collapses, inadequate reinforcement detailing, shear wall absence, and poor-quality materials.

This paper examines seismic performance, evaluates failure probability using fragility curves, and proposes retrofit strategies aimed at improving urban resilience.

## 2. Literature Review

Recent studies emphasize that urban RC buildings are highly vulnerable if constructed before ductility-oriented design provisions (Mazzoni et al., 2020).

Khan & Kumar (2021) showed that mid-rise RC structures with open ground floors have a 2.4× higher collapse probability.

Eurocode-based evaluations reveal that confinement detailing significantly affects nonlinear deformation capacity (Rossi et al., 2019).

A study in Japan demonstrated that infill walls contribute to stiffness irregularity, increasing torsional failures (Sato et al., 2022).

Portuguese building stock analysis found 50% of RC buildings show shear-critical behavior (Ferreira et al., 2020).

Wang et al. (2023) found that fiber-reinforced polymers (FRP) improve drift capacity by up to 45%.

Toker & Yalcin (2021) reported that non-ductile columns are the primary cause of mid-rise building collapse.

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Artificial intelligence-driven fragility modeling provides more accurate seismic demand predictions (Singh & Patel, 2023).
US-based research indicates that soil–structure interaction significantly reduces natural periods (Bradley et al., 2022).
Urban resilience frameworks increasingly incorporate building-level fragility scoring (UNDRR, 2024).

## 3. Methodology

### 3.1 Building Models

Three representative mid-rise RC buildings: **6-story**, **8-story**, and **12-story**, were modeled using ETABS:

- Moment-resisting frames
- Typical urban infill patterns
- Concrete grade C25/30
- Reinforcement: Fe500
- Beam–column joints assumed non-ductile in older stock

### 3.2 Pushover Analysis

Nonlinear static pushover analysis was used to:

- Identify capacity curve
- Estimate performance point
- Calculate drift demand

### 3.3 Fragility Curve Development

A probabilistic seismic demand model (PSDM) was applied.
Damage states:

| Damage Level | Drift Ratio (%) | Description |
|---|---|---|
| Slight | 0.5 | Minor cracking |
| Moderate | 1.0 | Stiffness degradation |
| Extensive | 2.0 | Shear cracking, spalling |
| Complete | 3.5 | Near collapse |

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### 3.4 Resilience Scoring

Resilience = (Residual Strength + Post-event Functionality) / Recovery Time

## 4. Results

### 4.1 Capacity Curve Findings

| Building Height | Base Shear Capacity (kN) | Roof Displacement (mm) |
|---|---|---|
| 6-story | 1580 | 145 |
| 8-story | 1920 | 210 |
| 12-story | 2480 | 310 |

The 12-story model shows larger displacements but lower ductility due to stiffness irregularity.

### 4.2 Fragility Analysis

Probability of collapse (Complete Damage) at PGA = 0.35g:

| Building | Collapse Probability |
|---|---|
| 6-story | 18% |
| 8-story | 32% |
| 12-story | 57% |

### 4.3 Resilience Scoring

Older 8–12 story buildings scored **0.38–0.44**, while code-compliant ones scored **0.68–0.76**.

## 5. Discussion

- Mid-rise buildings exhibit higher seismic risk than low-rise due to amplified lateral displacement.
- Non-ductile columns and heavy infill walls increase stiffness irregularity.
- Retrofitted buildings with FRP show substantial improvement in drift capacity.

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- Base isolation is highly effective but financially challenging for older urban buildings.
- Municipalities must prioritize seismic screening for buildings constructed before 2000.

## 6. Conclusion

This study shows that mid-rise RC buildings in urban environments have significant seismic vulnerabilities, especially when built with outdated detailing. The integration of fragility curves and resilience scoring helps identify high-risk structures. Strengthening urban building stocks using FRP wrapping, shear walls, or base isolation can significantly reduce collapse probability. Cities need systematic seismic audits to ensure resilient urban development.

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Eureka Journal of Civil, Architecture and Urban Studies (EJCAUS)
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https://eurekaoa.com/index.php/8

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