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Pushover Analysis of Seismic Behaviour in Masonry-Infilled RC Frames using ETABS and FEMA-356 Standards

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ABSTRACT: The present study investigates the seismic performance of reinforced concrete (RC) framed buildings with a focus on the influence of brick masonry infill walls and shear walls using nonlinear static pushover analysis. With increasing emphasis on performance-based seismic design, the need to evaluate the actual behavior of structures under seismic loading has become critical.

The primary objectives include the assessment of various types of masonry infill walls and their contribution to lateral strength and stiffness, as well as the role of shear walls in enhancing seismic resistance. The study involves the comparative evaluation of different structural configurations through pushover analysis using parameters such as storey base shear, storey displacement, and storey drift. Additionally, response parameters including base shear versus monitored displacement, spectral acceleration versus spectral displacement, and mode versus period (as per FEMA-356 guidelines) are analyzed to gain a comprehensive understanding of structural performance.

A key focus is placed on identifying the performance point of the building, which defines the expected structural behavior under design-level earthquakes. By comparing results across configurations, the study also aims to determine the optimal combination of structural systems that provide a balance between cost-effectiveness and seismic efficiency. The findings contribute to improved design strategies for RC buildings in seismic zones, promoting safety, serviceability, and economical construction practices through informed structural system selection.

I. INTRODUCTION

In recent decades, the increasing frequency and intensity of earthquakes have highlighted the urgent need for robust seismic design strategies, particularly in reinforced concrete (RC) framed buildings. Among these, masonry-infilled RC frames are widely used in low- to mid-rise construction due to their structural efficiency and economic viability. However, while masonry infill walls are often treated as non-structural elements during design, their interaction with the RC frame significantly influences the building's seismic behavior—altering stiffness, strength, and failure mechanisms.

Pushover analysis, a nonlinear static analysis method, has emerged as a practical tool in performance-based seismic design (PBSD). It allows engineers to evaluate the progressive failure pattern and seismic capacity of buildings under lateral loading. Through simplified yet realistic representation, pushover analysis provides insights into key performance parameters such as base shear, storey displacement, storey drift, and plastic hinge formation, leading to a better understanding of expected performance under design-level ground motions.

This study aims to examine the seismic response of RC framed buildings with different types of masonry infill walls and shear walls, using ETABS software and adhering to the FEMA-356 guidelines. By modeling various configurations, the research evaluates and compares the impact of infill and shear wall placement on critical response parameters. The study also determines the performance point of the building, helping to quantify its expected seismic resilience.

Additionally, spectral performance plots such as Base Shear vs. Displacement, Spectral Acceleration vs. Spectral Displacement, and Mode vs. Period are generated to deepen the understanding of dynamic characteristics. Ultimately,

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the goal is to identify an optimal structural configuration that ensures safety, serviceability, and cost-effectiveness, especially for constructions in earthquake-prone regions.

II. MODELING METHODOLOGY

This study involves the development of analytical models for pushover analysis using ETABS v18.0 to investigate the seismic behavior of masonry-infilled RC framed buildings in accordance with FEMA-356 guidelines. The focus is on modeling various configurations to compare the performance of bare frames, infilled frames, and frames with shear walls under seismic loading specific to Zone V.

1. Building Configuration
Structure Type: G+5 RC moment-resisting frame (Special RC Moment Resisting Frame – SMRF)
Plan Dimensions: 18 m × 15 m (5 bays each in X and Y direction, 3.6 m per bay)
Storey Height: 3.0 m (uniform for all floors)
Support Condition: Fixed at base

2. Material Properties

Material	Property	Value
Concrete (M25)	Modulus of Elasticity	25,000 MPa
Steel (Fe500)	Modulus of Elasticity	200,000 MPa
Masonry Infill	Equivalent Diagonal Strut Stiffness	As per FEMA 356
	Compressive Strength	5 MPa

3. Element Specifications
Beams: 300 mm × 450 mm
Columns: 450 mm × 600 mm
Slab Thickness: 150 mm (modeled as rigid diaphragm)
Masonry Infill: Modeled using Equivalent Diagonal Strut (as per FEMA 356)
Shear Wall Thickness: 200 mm (modeled as shell elements)

4. Seismic Load Parameters (As per IS 1893: 2016)

Parameter	Value
Seismic Zone	V
Zone Factor (Z)	0.36
Importance Factor (I)	1.0
Response Reduction (R)	5 (for SMRF)
Soil Type	Medium (Type II)
Damping	5%
Time Period (Ta)	Calculated as per IS Code

5. Load Considerations
Dead Load (DL): Self-weight + finishes
Live Load (LL): 3 kN/m² (residential occupancy)
Seismic Load (EL): As per IS 1893 (Part 1): 2016 for Zone V

6. Pushover Analysis Setup
Analysis Type: Nonlinear static pushover
Load Pattern: Lateral static load in X and Y directions
Hinge Definitions: FEMA-356 defined plastic hinges (M3 for beams, PMM for columns)

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Control Node: Roof center (top storey center of mass)
Monitored Parameters: Displacement, base shear, inter-storey drift, performance point

7. Model Variants

Model ID	Description
M1	Bare RC Frame
M2	RC Frame with Full Infill Walls
M3	RC Frame with Partial Infill (Soft Storey)
M4	RC Frame with Shear Walls Only
M5	RC Frame with Full Infill + Shear Walls (Hybrid System)

III. RESULTS

Model ID	Structural Configuration	Performance Point Displacement (mm)	Performance Point Base Shear (kN)
M1	Bare Frame	152.8	470.2
M2	Full Masonry Infill	78.3	765.5
M3	Partial Infill (Soft Storey)	113.6	605.7
M4	Shear Wall Only	64.2	810.3
M5	Full Infill + Shear Wall (Hybrid)	51.4	892.5

Table 1: Performance Point (Displacement and Base Shear)

Model ID	Configuration	Max Storey Drift (%)	Storey Level
M1	Bare Frame	2.48	3rd
M2	Full Infill	1.32	4th
M3	Partial Infill (Soft Storey)	2.12	2nd
M4	Shear Wall	0.98	3rd
M5	Full Infill + Shear Wall	0.76	3rd

Table 2: Maximum Storey Drift (% Drift at Critical Storey)

IV. CONCLUSION

1. Effect of Masonry Infill and Shear Walls on Seismic Performance
The inclusion of masonry infill walls significantly improves seismic performance. Model M2 (full infill) showed a 62% increase in base shear capacity and 48% reduction in displacement at the performance point compared to the bare frame (M1).

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The best performance was observed in Model M5 (full infill + shear wall), which exhibited maximum base shear capacity (892.5 kN) and minimum displacement (51.4 mm) at the performance point, indicating a highly stiff and strong system.

2. Storey Drift Control
The bare frame (M1) and soft storey frame (M3) exceeded the drift limits specified by FEMA-356, making them vulnerable to non-structural and even structural damage.
Shear wall systems (M4 & M5) effectively controlled storey drift within safe limits. M5 had the lowest drift (0.76%), confirming its suitability for high-seismic zones like Zone V.

3. Time Period and Structural Stiffness
The fundamental time period was highest for the bare frame (1.11 sec) and lowest for the infill + shear wall model (0.58 sec).
Lower time periods indicate increased stiffness. Hence, infill walls and shear walls contribute to higher lateral stiffness, reducing lateral displacements during seismic events.

4. Performance Point Assessment
From the capacity spectrum method, it was observed that performance points shifted toward lower displacements and higher base shears in models with structural enhancements (M2, M4, M5).

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