International Journal on Science and Technology (IJSAT)

E-ISSN: 2229-7677 ● Website: www.ijsat.org ● Email: editor@ijsat.org

Comparative Seismic Performance of RC Frame Buildings with URM Infill Walls: A Parametric Study of Material Properties and Modeling Approaches

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Abstract

This study investigates the seismic performance sensitivity of reinforced concrete (RC) frame structures with unreinforced masonry (URM) infill walls, focusing on the influence of material properties and modeling methods. URM infills significantly modify lateral stiffness and strength during seismic events, but their influence is often approximated using simplified models with assumed material values. Using a 3-storey RC frame model in SAP2000, a parametric study was conducted varying the modulus of elasticity (Em) and compressive strength (fm) of the infill masonry. Nonlinear static pushover analyses were used to assess base shear, drift, and hinge formation. Additionally, a conceptual comparison was made between the widely used equivalent strut model and the more detailed continuum finite element model. Results show that small variations in Em and fm lead to substantial changes in seismic response. The findings highlight the importance of accurate material characterization and informed modeling approach selection for seismic design. Recommendations are provided for practical design and future research in performance- based seismic assessment.

1. Introduction

Reinforced concrete (RC) frame structures form the backbone of modern urban construction. These frames are often combined with unreinforced masonry (URM) infill walls for architectural and functional purposes. Though traditionally treated as nonstructural, URM infills significantly influence the seismic performance of RC structures by modifying lateral stiffness, strength, and dynamic behavior.

During seismic events, infill walls interact with frames through the formation of compression struts, contributing to lateral load resistance. However, this contribution is complex and non-linear, affected by many factors including material properties, geometry, and the modeling technique adopted. The most common approaches are the equivalent diagonal strut model and continuum-based finite element methods. Additionally, the variability of masonry material properties such as the modulus of elasticity (Em) and compressive strength (fm) leads to uncertainty in performance predictions.

This research investigates how changes in URM material properties influence seismic behavior and critically evaluates the limitations and advantages of different modeling approaches. It aims to bridge the gap between simplified design practice and accurate seismic response prediction.

Literature Review

1.1 Infill-Frame Interaction

Masonry infill walls engage with RC frames through shear and axial actions, forming diagonal compression struts under lateral loads. This interaction changes the load transfer mechanism from purely frame action to combined frame-infill action. The resulting stiffness enhancement reduces inter-storey drift but introduces stress concentrations and potential brittle failure modes.

1.2 Key Mechanical Properties

Property	Symbol	Relevance in Modeling
Modulus of Elasticity	Em	Governs initial stiffness and elastic deformation of the infill panel.
Compressive Strength	fm	Determines crushing capacity and ultimate load of the infill material.
Shear Strength	τ	Influences diagonal cracking and shear sliding failure.

Em and fm are influenced by constituent materials (brick and mortar), workmanship, age, and environmental exposure. Empirical equations such as Em = 550 × fm (as per IS 1905) are commonly used for preliminary estimation.

1.3 Modeling Approaches

Model Type	Description	Pros	Cons
Equivalent Strut	Models infill as a single diagonal strut.	Easy to implement, suitable for linear and nonlinear pushover.	Cannot capture local stress concentrations or cracking patterns.
Continuum Model	Discretizes infill into finite elements (brick and mortar micro-models).	Captures detailed local behavior and damage evolution.	High computational cost and complex calibration.
Hybrid Model	Combines macro and micro-models.	Attempts to balance simplicity and accuracy.	Still under development, lacks standardization.

2. Methodology

A benchmark 3-storey, 3-bay RC frame was developed in SAP2000. The frame geometry, material properties, and loading conditions were selected to match typical mid-rise buildings in Indian seismic zones.

2.1 Geometry and Material

- Storey height: 3.0 m; Bay width: 4.0 m
- Concrete: M25; Steel: Fe500
- URM infill: Fly ash brick with 1:4 cement mortar

2.2 Parametric Study Setup

Case ID	Em (MPa)	fm (MPa)	Description
Base	2024	3.68	Nominal (from thesis)
Case A	1821.6	3.31	-10% Em/fm
Case B	2226.4	4.05	+10% Em/fm
Case C	1619.2	2.94	-20% Em/fm
Case D	2428.8	4.42	+20% Em/fm

2.3 Analysis Technique

- Analysis Type: Nonlinear Static Pushover
- Load Pattern: Inverted triangular
- Hinges: Defined per ATC-40 (flexural hinges in beams/columns)

2.4 Output Parameters

- Base shear capacity
- Roof displacement
- Storey drift profile
- Fundamental period
- Plastic hinge formation sequence

2.5 Conceptual Comparison of Modeling Approaches

While numerical results were based on equivalent strut modeling, a theoretical discussion on continuum models was included to reflect on modeling choices and their design implications.

3. Results and Discussion

3.1 Influence of Em and fm

Case	Em (MPa)	Base Shear (kN)	Drift @ Top (%)	Time Period (s)	Comments
Base	2024	2806	0.04	0.51	Balanced response
A	1821.6	2601	0.06	0.55	Reduced strength, higher drift
B	2226.4	2960	0.033	0.48	Improved strength, reduced drift

C	1619.2	2390	0.07	0.61	Critical drift, early column hinge
D	2428.8	3075	0.028	0.46	Strongest, stiffest, less ductile

3.2 Modeling Method Comparison

Criteria	Equivalent Strut	Continuum FEM Model
Load Path Representation	Good	Excellent
Failure Mode Simulation	Poor	Excellent
Local Crack Prediction	Not Captured	Captured
Post-Peak Behavior	Approximate	Accurate
Computational Effort	Low	High
Applicability	Preliminary Design	Detailed Seismic Assessment

The strut model is effective in capturing global stiffness and capacity, but continuum models are necessary for studying local damage, energy dissipation, and post-peak degradation.

4. Conclusion

The study confirms that RC frames with URM infill walls exhibit notable sensitivity to infill material properties. A 20% change in Em or fm can significantly alter the seismic demand and lateral resistance. While the equivalent strut model offers ease and practicality for design, it oversimplifies the complex nature of infill behavior. Conversely, continuum models, though computationally demanding, provide better accuracy in capturing true structural behavior.

Recommendations

- Structural designers should account for masonry variability by applying safety factors or conducting sensitivity analyses.
- For performance-based design, continuum models are more suitable, particularly for critical or irregular buildings.

Future Research

- Experimental studies to validate material models and failure mechanisms
- Probabilistic modeling to incorporate material uncertainty in seismic design
- Development of hybrid approaches combining strut simplicity with FEM precision

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