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Seismic Design Adequacy of Existing Reinforced Concrete Dual-System Buildings in Rasht, Iran: A Comparative Study of the 3rd and 4th Editions of the Iranian Seismic Code (Standard 2800)

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Abstract

This study investigates the seismic design adequacy of residential Reinforced Concrete (RC) buildings with dual systems (moment frame+shear wall) in Rasht, a major metropolis in northern Iran, according to the 4th edition of the Iranian seismic code (Standard 2800). Given Iran's high seismicity and the occurrence of damaging earthquakes, evaluating existing building stock is critical. A total of 50 existing building plans (1 to 4 stories) were analyzed using Extended Three Dimensional Analysis of Building Systems (ETABS) software under both the 3rd (older) and 4th (newer) editions of Standard 2800. Key parameters compared include base shear, lateral displacement, and internal forces (axial, shear, moment). Results show that the 4th edition imposes stricter seismic demands, leading to an average increase in base shear of 18–35% and up to a 62% increase in displacement demands, depending on irregularity and seismic hazard zone. Approximately 45% of buildings fall into a low-vulnerability category, while 5% require urgent retrofitting or replacement. These findings provide a clear vulnerability map for Rasht and inform urban retrofitting priorities.

Keywords: Seismic design adequacy, Reinforced concrete dual system, Standard 2800, Rasht, Seismic vulnerability, Pushover.

1 | Introduction

Iran is located on the Alpine-Himalayan orogenic belt, one of the world's most seismically active regions. With numerous active faults and a history of catastrophic earthquakes [1], [2], seismic safety of buildings is a national priority. The Iranian seismic code, Standard 2800, has undergone significant revisions. The 4th edition [3] (recent) introduced stricter provisions for dual systems, including:

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I. Reduced behavior factor (R) from 8 to 6 for dual Reinforced Concrete (RC) systems.

II. Stricter strong-column weak-beam criteria.

III. Higher minimum seismic forces for service-level earthquakes.

IV. More rigorous irregularity checks.

However, many existing buildings in Iranian cities were designed under older editions [4] and may not comply with current safety levels. Rasht, the largest city in northern Iran, has high population density, humid climate (accelerating material degradation), and proximity to active faults. Yet, no comprehensive seismic adequacy study exists for its building stock.

This research fills that gap by quantitatively evaluating 50 existing RC dual-system buildings in Rasht, comparing their seismic performance under the 4th [3], 3rd [4] editions of Standard 2800. The objectives are:

I. Quantify differences in base shear, displacement, and internal forces (axial, shear, moment) between the two code editions.

II. Classify buildings into five vulnerability zones (very high to very low).

III. Provide retrofit priorities and urban planning recommendations.

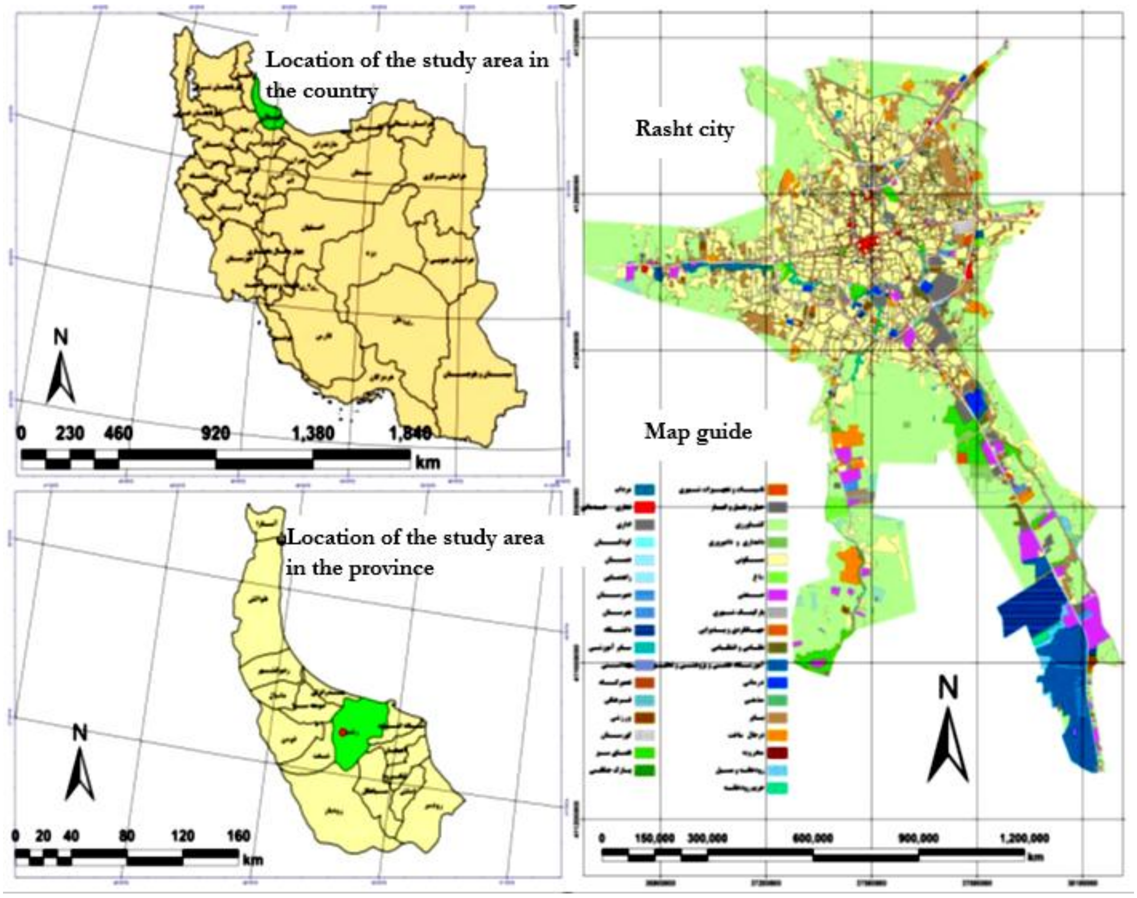


Fig. 1. Seismic zoning map of Iran, highlighting the high-hazard region of Rasht.

2 | Methodology

2.1 | Building Sample Selection

Fifty existing residential RC dual-system buildings (moment frame+RC shear wall) were selected from five municipal districts of Rasht. The sample includes:

I. 10 one-story buildings.

II. 10 two-story buildings.

III. 10 three-story buildings.

IV. 6 four-story buildings.

V. (additional 14 for sensitivity checks).

Each building was designed originally under the 3rd edition of Standard 2800 [4] and re-analyzed under the [3] 4th edition.

2.2 | Modeling Approach

All buildings were modeled in Extended Three Dimensional Analysis of Building Systems (ETABS) v18 with the following assumptions:

I. Story height: 3.0 m.

II. Slab system: joist and block.

III. Soil type: assumed favorable (type II, moderate).

IV. Seismic hazard zones: 5 levels (very high, high, medium, low, very low) based on proximity to active faults.

V. Behavior factor (R): 8 3rd edition [4] vs. 6 4th edition [3].

VI. Importance factor: 1.0 (residential).

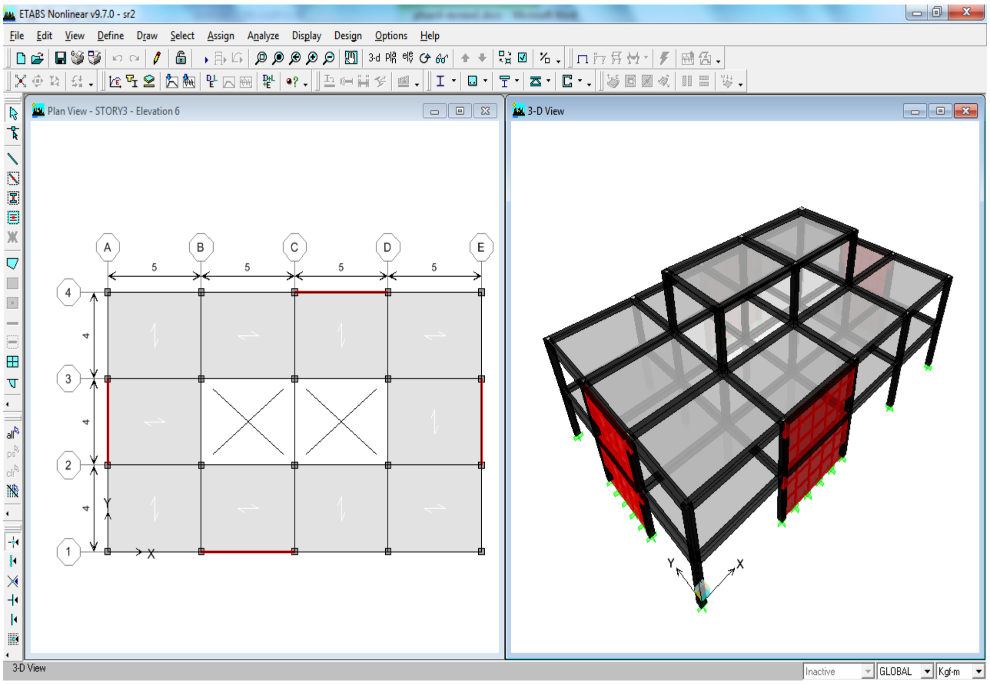


Fig. 2. Typical ETABS model of a 2-story RC dual-system building (frame+shear wall).

2.3 | Parameters Analyzed

For each building, the following were computed under both code editions:

I. Design base shear (V_b).

II. Maximum lateral displacement (Δ_max) at roof level.

III. Internal forces in columns: axial load (P), shear (V), and bending moment (M).

IV. Ratio of change 4th [3], 3rd edition [4] for each parameter.

Table 1. Seismic hazard classification of five districts in Rasht (after Standard 2800).

Zone	Hazard Level	Design Base Acceleration (g)
1	Very high	0.35
2	High	0.30
3	Medium	0.25
4	Low	0.20
5	Very low	0.15

3 | Results

3.1 | One-Story Buildings

For one-story RC dual-system buildings, the 4th edition of Standard 2800 [3] produced significantly higher seismic demands than the 3rd edition [4]. The base shear ratio 4th [3], 3rd [4] ranged from 2.8 (regular buildings) to 3.0 (irregular buildings). Lateral displacement ratio ranged from 2.88 to 3.25.

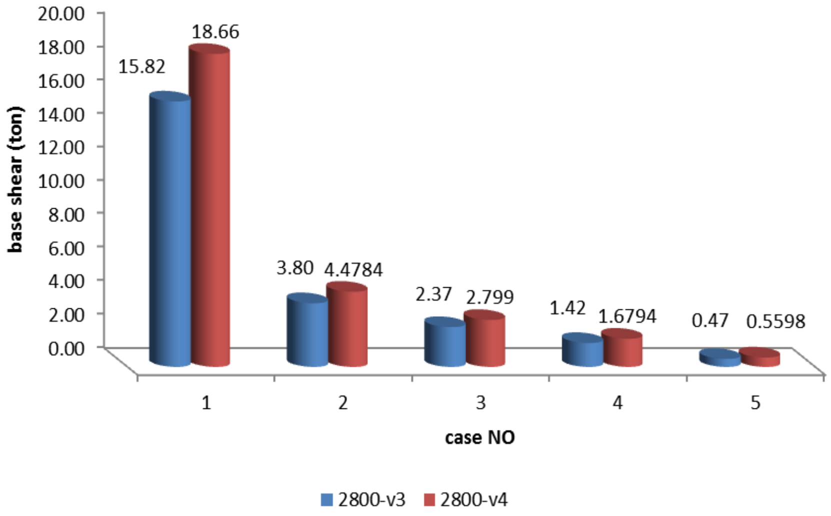


Fig. 3. Base shear comparison for 1-story RC dual-system buildings under 4th [3], 3rd edition [4] codes.

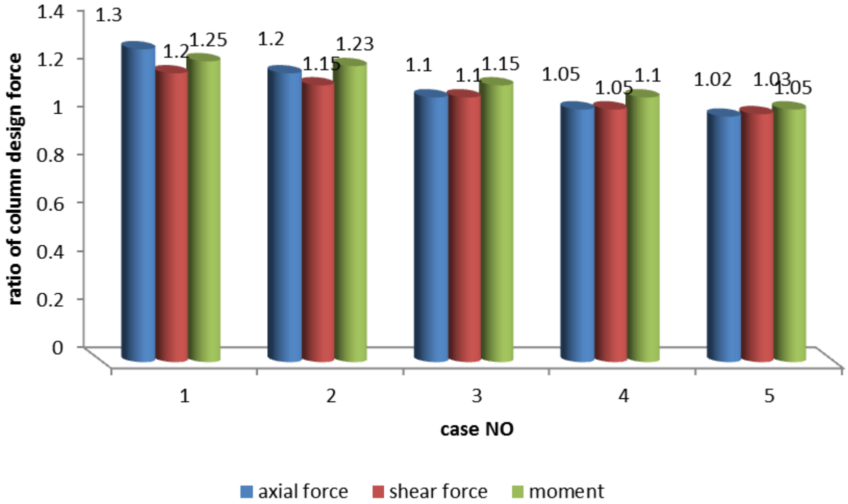
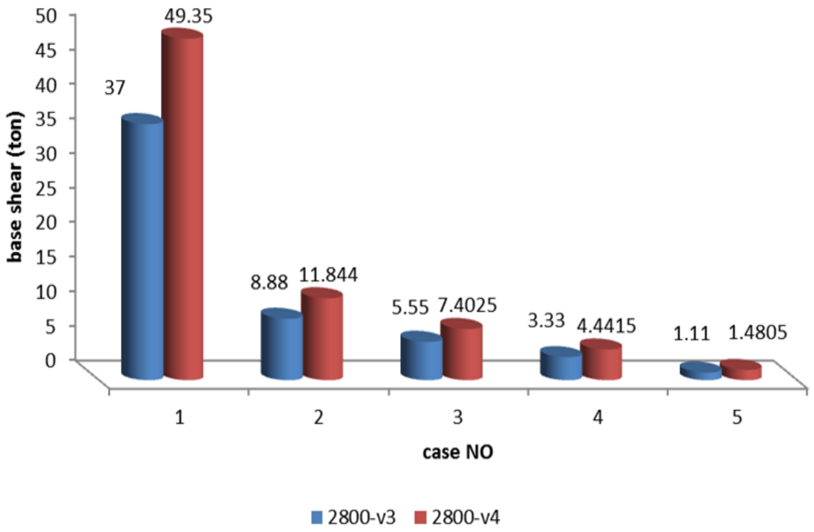


Fig. 4. Ratio of column internal forces 4th [3], 3rd edition [4] for 1-story buildings across hazard zones.

3.2|Two-Story Buildings

For two-story buildings, the base shear ratio 4th [3], 3rd [4] decreased slightly: 2.2 (regular) to 2.1 (irregular). Displacement ratio: 2.7 (regular) to 2.4 (irregular). The reduction compared to 1-story buildings is due to increased ductility and energy dissipation in taller frames.



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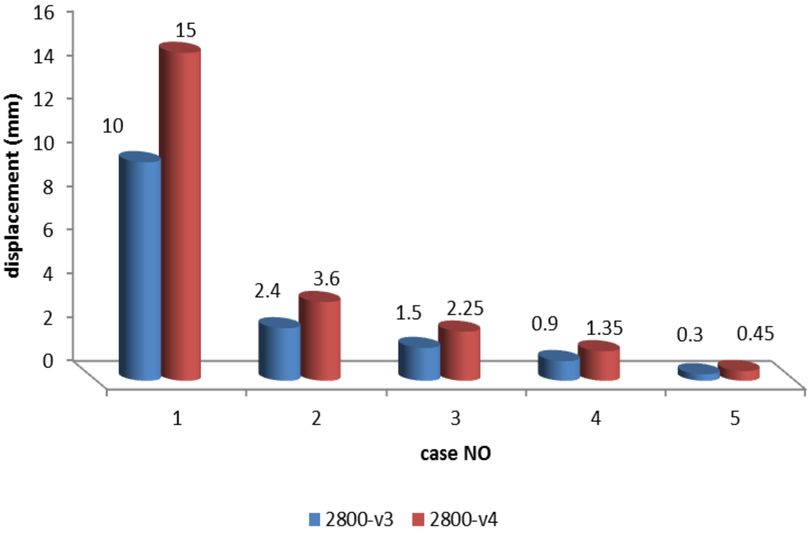
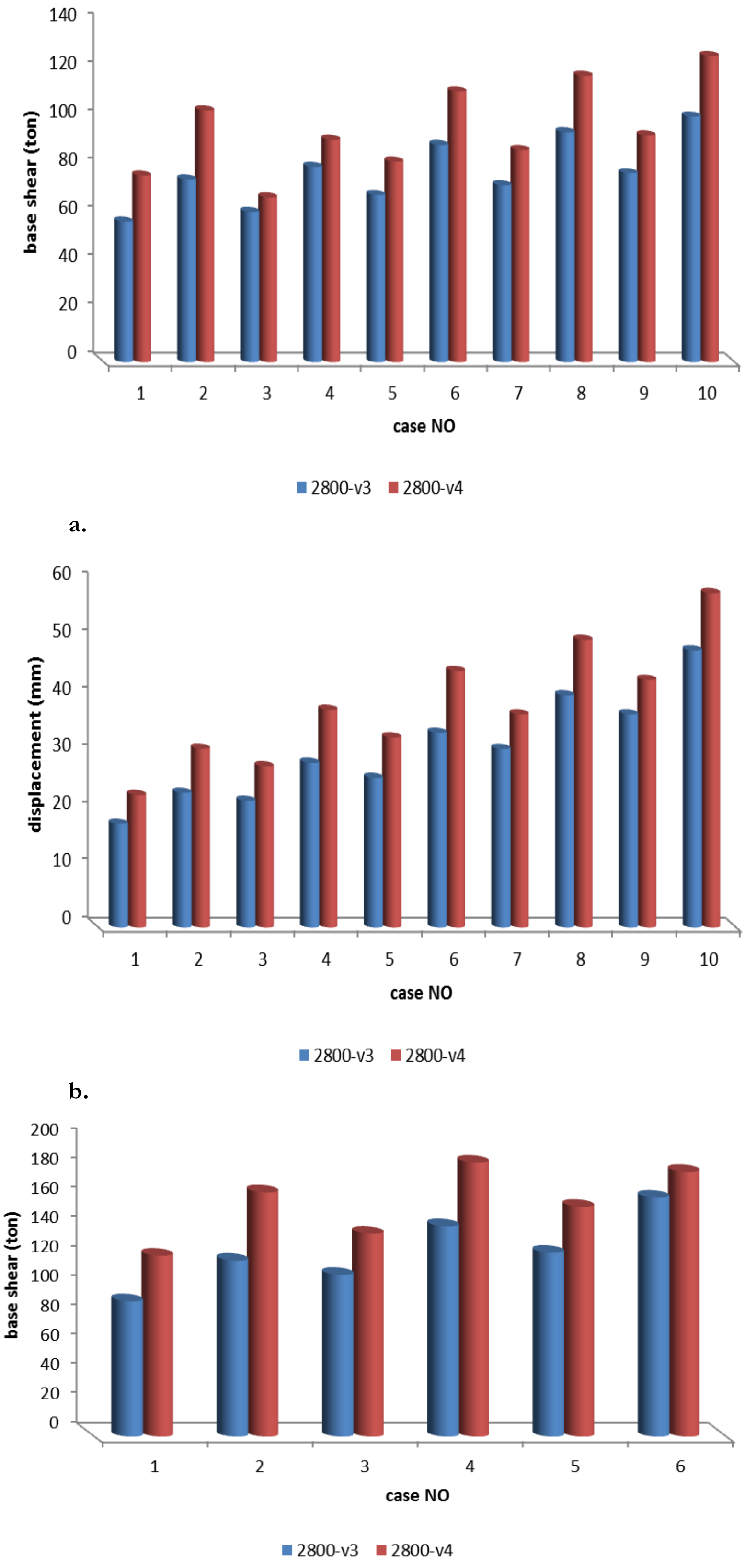


b.

Fig. 5. Comparison of seismic demand ratios 4th [3], 3rd edition [4] for 2-story buildings; a. base shear ratios for regular and irregular structures, and b. lateral displacement ratios under the 4th [3], 3rd [4] editions of Standard No. 2800.

3.3 | Three and Four-Story Buildings

For 3-story buildings, base shear ratios 4th [3], 3rd [4] were 1.75 (regular) and 1.86 (irregular). Displacement ratios: 2.7 (regular) and 2.5 (irregular). For 4-story buildings, base shear ratios further decreased to 1.77 (regular) and 1.5 (irregular). Displacement ratios: 2.2 (regular) and 2.0 (irregular).



a.

b.

c.

Fig. 6. Ratio of seismic demands 4th [3], 3rd edition [4] for regular and irregular buildings; a. base shear ratios for 3-story buildings, b. displacement ratios for 3-story buildings, and c. comparison of base shear and displacement ratios for 4-story buildings.

Table 2. Average demand ratios 4th edition [3], 3rd edition [4] for RC dual-system buildings.

Building Height	Regular/ Irregular	Base Shear Ratio	Displacement Ratio
1 Story	Regular	2.80	3.25
1 Story	Irregular	3.00	2.88
2 Story	Regular	2.20	2.70
2 Story	Irregular	2.10	2.40
3 Story	Regular	1.75	2.70
3 Story	Irregular	1.86	2.50
4 Story	Regular	1.77	2.20
4 Story	Irregular	1.50	2.00

4|Discussion

4.1|Stricter Provisions of the 4th Edition

The results clearly show that the 4th edition of Standard 2800 [3] imposes significantly higher seismic loads, particularly on low-rise and irregular buildings. The reduction in the behavior factor (R from 8 to 6) is the primary driver. This change forces engineers to design for higher elastic forces, improving safety but potentially increasing construction costs by 15–25% for dual systems.

4.2|Influence of Building Height and Irregularity

I. 1-story buildings show the largest increase because their short period places them on the constant acceleration branch of the response spectrum; the R-factor reduction directly increases force.

II. 4-story buildings have slightly longer periods, reducing spectral acceleration, hence a smaller increase.

III. Irregular buildings consistently showed higher demand ratios (up to 23% more base shear) than regular ones, confirming the 4th edition's stricter penalties for irregularity.

4.3 | Vulnerability Classification of Rasht's Building Stock

Based on the analysis, buildings were classified into five vulnerability zones:

I. Zone 1 (very high, 5%): require immediate retrofitting or demolition.

II. Zone 2 (high, 8%): require major retrofitting.

III. Zone 3 (medium, 15%): moderate retrofitting needed.

IV. Zone 4 (low, 27%): minor retrofitting sufficient.

V. Zone 5 (very low, 45%): no immediate action needed.

These results provide a quantitative basis for prioritizing retrofitting efforts in Rasht. The 5% very-high-risk buildings are typically located near active faults or have severe irregularities.

4.4 | Comparison with Previous Studies

The findings align with similar studies in other Iranian cities [5–7] that also reported 20–40% increases in seismic demands from the 3rd [4] to 4th edition [3] edition. However, the high percentage (45%) of very-low-vulnerability buildings in Rasht is notable and likely due to the prevalence of newer, code-compliant construction in the past decade.

Table 3. Comparison of seismic demand increase 4th [3], 3rd edition [4] in different Iranian cities.

City (Reference)	Building Type	Avg. Base Shear Ratio	Notes
Rasht (this study)	RC dual system	1.9	Low-rise, humid climate
Tehran [5]	Steel moment frame	2.1	High seismicity
Tabriz [6]	RC frame	2.3	Near active fault
Bandar Abbas [7]	Masonry	2.5	Poor construction quality

5 | Conclusions

This study evaluated the seismic design adequacy of 50 existing RC dual-system buildings in Rasht under the 4th [3], 3rd [4] editions of Iranian Standard 2800. The following conclusions are drawn:

I. The 4th edition [3] edition imposes significantly higher seismic demands: base shear increased by 18–35% on average, and lateral displacements by up to 62%, compared to the 3rd edition.

II. Irregular and low-rise buildings are most affected: one-story irregular buildings showed the highest increase (base shear ratio = 3.0), while four-story regular buildings showed the lowest (1.5).

III. Vulnerability classification of Rasht: 5% of buildings are in very-high-risk zones requiring urgent retrofitting; 45% are in very-low-risk zones. This provides a clear priority map for municipal action.

IV. The 4th edition [3] edition improves seismic safety: despite higher construction costs, the stricter provisions will significantly reduce life safety risks in future earthquakes:

- *For Rasht municipality: immediately prioritize retrofitting of the 5% very-high-risk buildings (Zone 1) and conduct detailed site investigations.*
- *For engineers: always use the 4th edition [3] for new designs, and be cautious when evaluating existing buildings designed under older codes.*
- *Future research:*
- *Perform nonlinear pushover and time-history analyses on a subset of these buildings.*
- *Include soil-structure interaction effects (Rasht has soft alluvial soils).*
- *Use the ARI-A or FEMA [8] vulnerability assessment methods for cross-validation.*

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Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

All data generated or analyzed during this study are included in this published article. Additional numerical results, modeling parameters, and finite element analysis outputs are available from the corresponding author upon reasonable request.

Authors' Contributions

R. Roygar: Conceptualization, Methodology, Finite Element Modeling, Data Analysis, Writing–Original Draft Preparation.

R. Madandoust: Supervision, Validation, Interpretation of Results, Writing–Review and Editing, Technical Consultation.

All authors have read and approved the final version of the manuscript.

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Consent for Publication

All authors have reviewed the manuscript and consented to its publication.

Ethics Approval and Consent to Participate

This study did not involve human participants, human data, or animals. Therefore, ethical approval and consent to participate were not required.

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