

(RESEARCH ARTICLE)



## Impact of changing seismic response reduction Factor (R) from life safety to immediate occupancy on building construction costs

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### Abstract

Seismic design codes typically adopt the Life Safety (LS) performance level using a high response modification factor (R), allowing structures to undergo inelastic deformations during strong earthquakes. However, higher performance objectives such as Immediate Occupancy (IO) require lower R values, resulting in higher design forces and increased construction costs. This study investigates the impact of reducing the response modification factor from R = 8 (LS) to lower values (R = 3, 2, and 1) on building construction costs. A reinforced concrete building was modeled and analyzed using finite element methods under identical loading conditions, with only the R factor varied. Results show that reducing R from 8 to 1 increases total construction cost by approximately 52%, primarily due to significant increases in concrete volume and structural member sizes. The findings highlight a clear trade-off between seismic performance and economic cost, providing valuable insight for performance-based seismic design decisions. Using a lower response reduction factor (R = 3) slightly increases initial costs (under 16%) but is justified by lower future maintenance and repair costs due to improved earthquake resistance.

**Keywords:** Construction costs; RC building; Earthquake; Modification factor (R); Life safety

### 1. Introduction

Earthquake-resistant design seeks to ensure structural safety while minimizing economic losses, with conventional seismic codes primarily targeting the Life Safety (LS) performance level, which permits controlled damage during strong earthquakes to protect occupants. This design philosophy relies on the response modification factor (R) to reduce elastic seismic forces by accounting for structural ductility and energy dissipation capacity. However, modern performance-based design approaches increasingly aim for higher performance levels such as Immediate Occupancy (IO), where damage is minimal and buildings remain functional after seismic events. Achieving this level requires reducing the R factor, which in turn increases design forces and structural demands. Previous research has indicated that while enhanced seismic performance leads to higher initial construction costs, it may reduce long-term economic losses, though the direct relationship between R-factor reduction and construction cost remains insufficiently quantified in practical applications [1,2,3,4]. In this study, a reinforced concrete building is modeled using finite element methods. And the building was designed under a consistent design response spectrum, maintaining identical geometry, loading conditions, and slab thickness (12 cm), while varying only the R factor across four cases (R = 8, 3, 2, and 1) representing performance levels from Life Safety to Immediate Occupancy.

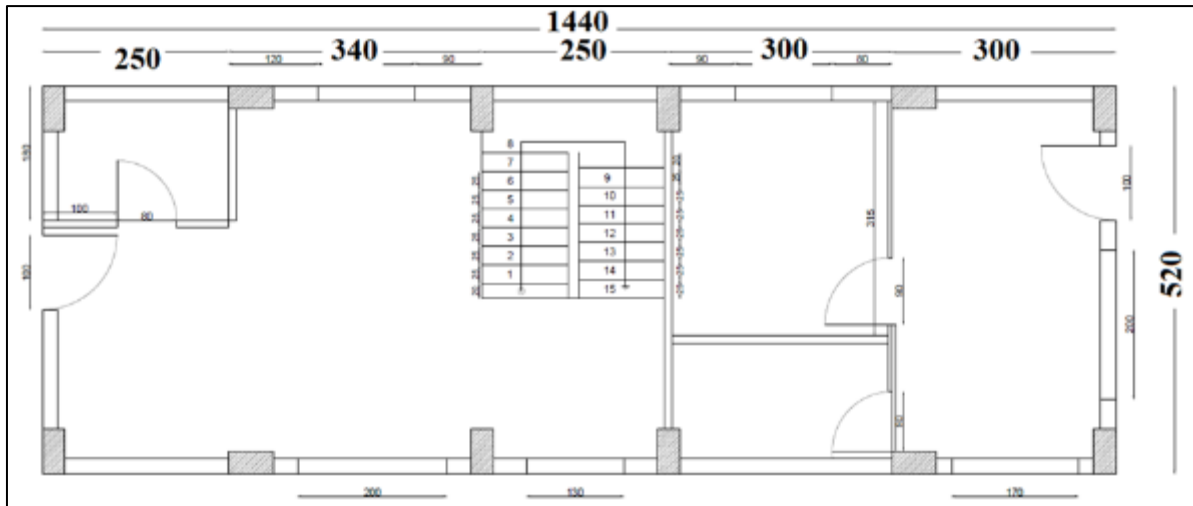
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## 2. Structural Model Description

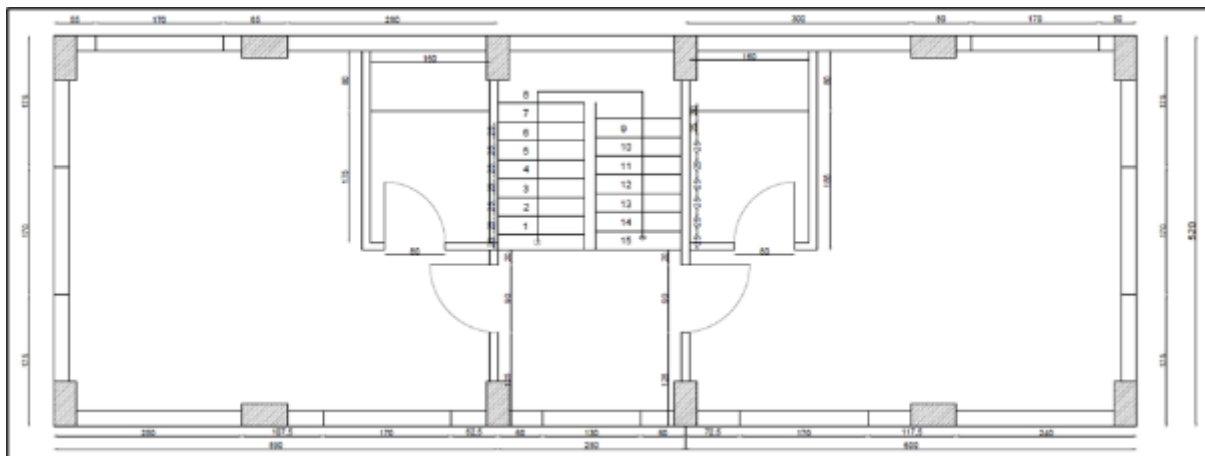
The structural model used in this study is a two-story reinforced concrete (RC) building, designed to represent a typical low-rise structure. The building has a total height of 6 m, with each story measuring 3 m. The plan layout follows a regular grid system to ensure analytical simplicity while maintaining practical relevance:

Transverse (Short) Direction: A single bay with a 5.2 m span.

Longitudinal (Long) Direction: Five bays with spans of 3 m, 3 m, 2.5 m, 3,4 m, and 2.5 m , respectively. The architectural plans of the ground floor and the first floor are shown in Figure 1.



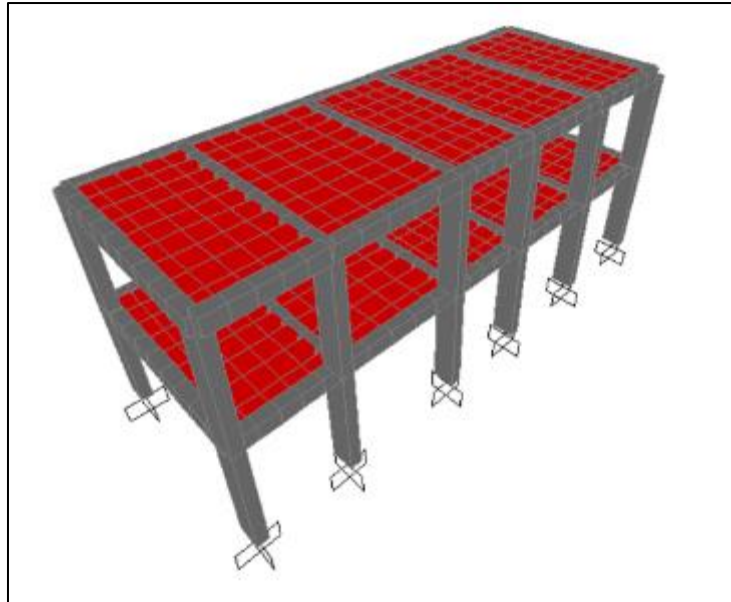
Ground floor plan



First floor plan

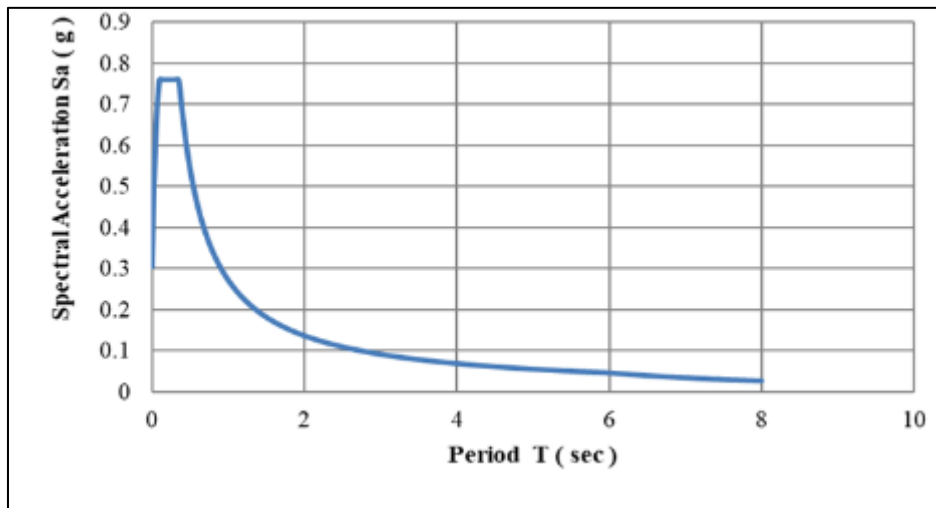
**Figure 1** Architectural plans

The finite element model of the building is shown in Figure 2. This semi-regular configuration reflects common real-world design scenarios and provides a realistic basis for assessing structural behavior under seismic loading. As the R-factor was reduced, structural member dimensions were adjusted to meet the increased seismic demand.



**Figure 2** Finite element model of the study building

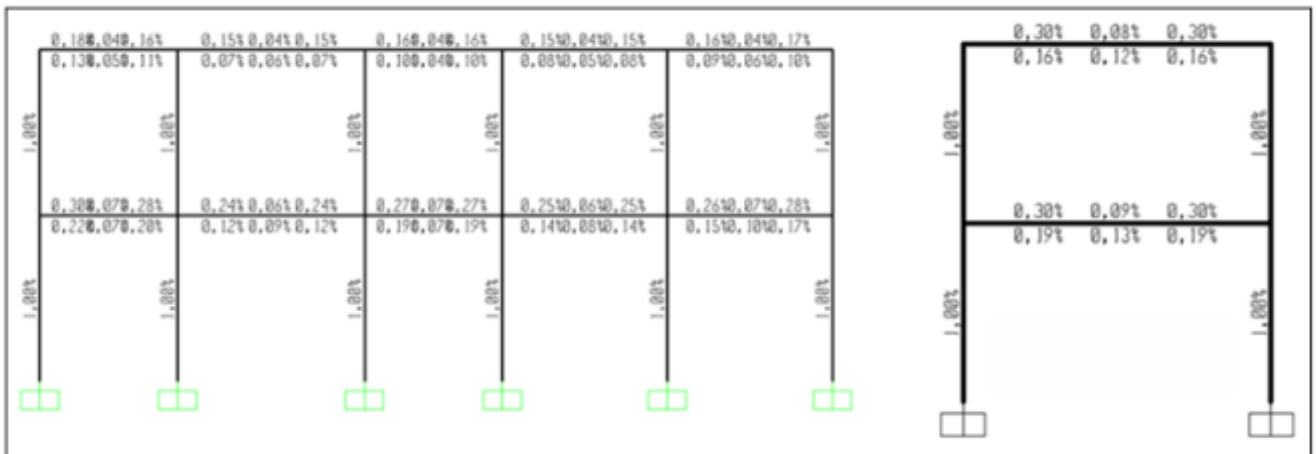
Construction costs were evaluated based on steel reinforcement, concrete, and finishing, with finishing assumed constant. This approach allows assessment of how reductions in the response modification factor  $R$  affect structural dimensions, material quantities, and overall cost. The building was designed in SAP2000 software following, ACI 318-19 and the site-specific response spectrum shown in Figure 3 [5,6,7]. Figures 4–7 illustrate the cross-sectional dimensions of the structural elements and the corresponding reinforcement ratios for  $R$  values from 8 to 1.



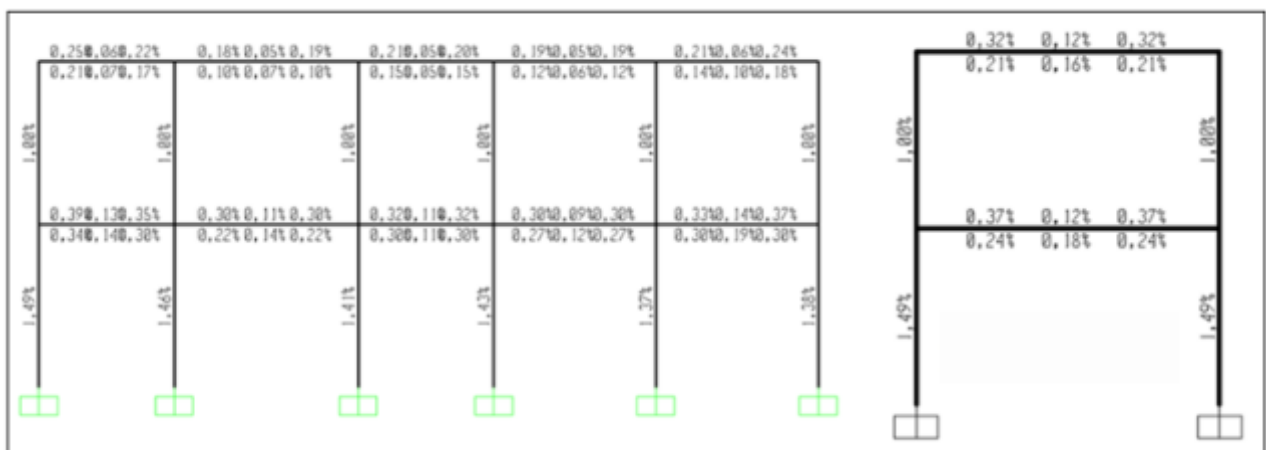
**Figure 3** Design response spectrum



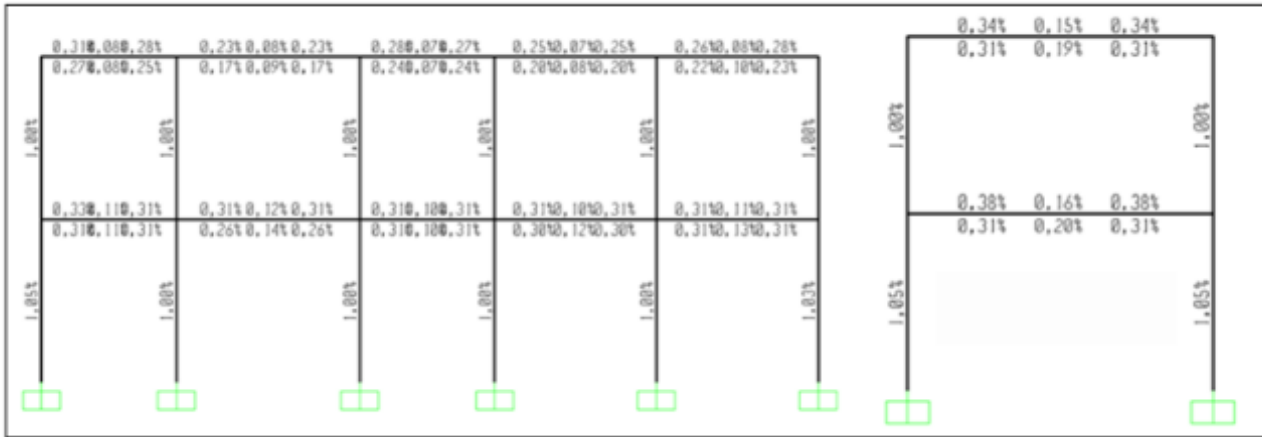
**Figure 4** Reinforcement ratios at R = 8 (column dimensions: 25 × 40 cm; beam dimensions: 25 × 40 cm)



**Figure 5** Reinforcement ratios at R = 3 (column dimensions: 30 × 60 cm; beam dimensions: 30 × 40 cm)



**Figure 6** Reinforcement ratios at R= 2 (column dimensions: 30 × 60 cm; beam dimensions: 30 × 40 cm)



**Figure 7** Reinforcement ratios at R = 1(column dimensions: 60 × 70 cm; beam dimensions: 40 × 60 cm)

### 3. Results

The results demonstrate a clear relationship between the response modification factor (R) and construction cost, as summarized in Table 1, where reducing R from 8 to 1 leads to a substantial increase in total cost from 100% to 152% (a 52% rise), with intermediate increases of 16% (R=3) and 25% (R=2), indicating a nonlinear escalation in cost at lower R values; this trend is primarily driven by concrete costs, which increase dramatically from 23% to 67%, while steel reinforcement shows only a moderate rise from 22% to approximately 30–36%, and finishing costs remain constant at 55% across all cases, suggesting that structural modifications mainly affect load-bearing components rather than architectural finishes. The foundation cost in these calculations is assumed to be 15% of the total building cost.

**Table 1** Variation in structural cost components with response modification factor R

R Factor	Steel (%)	Concrete (%)	Finishing (%)	TotalCost (%)	Cost Increase (%)
8	22	23	55	100	0
3	27	34	55	116	16
2	36	34	55	125	25
1	30	67	55	152	52

Additionally, the reduction in R significantly increases structural dimensions (e.g., column sizes from 25×40 cm to 60×70 cm), which can reduce usable space and impose architectural constraints; these findings align with established seismic design research showing that lower R values increase seismic forces and reduce reliance on ductility, thereby requiring greater stiffness and strength and leading to higher material consumption and cost, particularly in concrete-dominated systems, while the impact on steel is comparatively smaller and non-structural costs remain largely unaffected.

### 4. Performance vs Cost Trade-Off

From a practical perspective, immediate Occupancy design is not economically justified for all building types due to its high initial cost, but it is essential for critical facilities such as hospitals, emergency response centers, and key infrastructure where continuous operation after earthquakes is crucial; in contrast, for conventional residential and commercial buildings, the Life Safety level remains the most cost-effective solution, as it balances acceptable safety with manageable construction costs, a conclusion supported by life-cycle cost and performance-based design studies emphasizing optimization between initial investment and expected seismic losses.

In regions of low seismicity, adopting a response modification factor of R = 8 is recommended to achieve both economic efficiency and adequate safety. Conversely, in high seismic zones, a lower value of R = 3 is advised, as the modest increase

in initial construction cost (typically less than 16% of the total structural cost) can be justified by the reduction in anticipated future maintenance and repair costs resulting from earthquake-induced damage.

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## 5. Conclusion

This study evaluated the impact of varying the seismic response modification factor (R) on overall construction cost and structural performance, showing that reducing R from 8 to 1 results in a significant cost increase of approximately 52%, primarily due to the substantial rise in concrete quantities, which becomes the dominant contributor to cost escalation, while steel reinforcement has only a moderate secondary effect and finishing costs remain unchanged, indicating their independence from structural design variations; additionally, decreasing R leads to a considerable increase in structural member dimensions, which can reduce usable space and impose architectural constraints, clearly illustrating the trade-off between improved seismic performance and higher economic cost, as higher performance levels demand greater strength and stiffness with increased material usage, whereas lower performance levels reduce initial costs but allow greater damage, emphasizing the importance of selecting design objectives based on building function and highlighting the value of performance-based design approaches in achieving an optimal balance between safety, functionality, and cost. Adopting a lower response reduction factor (R = 3) leads to a modest increase in initial construction cost—typically under 16% of the total structural cost—but this is justified by the significant reduction in future maintenance and repair expenses resulting from improved resistance to earthquake-induced damage.

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## Compliance with ethical standards

### *Disclosure of conflict of interest*

No conflict of interest to be disclosed.

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## References

- [1] Vail Karakale and Fathi M Layas. Enhancing seismic design in high-hazard zones: Code gaps and recommended revisions. *World Journal of Advanced Engineering Technology and Sciences*, 2025, 17(03), 173–178. Article DOI: <https://doi.org/10.30574/wjaets.2025.17.3.1543>.
- [2] Layas, F. M., &Karakale, V., (2025). Systemic seismic vulnerabilities: Key construction failures and mitigation strategies. *World Journal of Advanced Engineering Technology and Sciences*, 17(3), 121–128. <https://doi.org/10.30574/wjaets.2025.17.3.1542>
- [3] Karakale, V., & Layas, F. M. (2025)., Rationale for updating earthquake design forces in modern building codes. *World Journal of Advanced Engineering Technology and Sciences*, 14(1), 103–109. <https://doi.org/10.30574/wjaets.2025.14.1.0005>
- [4] V. Karakale, E. Özgür and Ş. Ataoğlu, “Site Observations on Buildings’Performance in Hatay Province after Kahramanmaraş Earthquakes”, *El-Cezeri Journal of Science and Engineering*, vol. 10, no. 3, pp. 506–516,2023, doi: 10.31202/ecjse.1253284
- [5] SAP2000 software, Berkeley, CA: Computers and Structures, Inc
- [6] American Society of Civil Engineers (ASCE). *ASCE/SEI 7-22: Minimum Design Loads and Associated Criteria forBuildings and Other Structures*. Reston, VA: ASCE, 2022
- [7] American Concrete Institute. *Building Code Requirements for Structural Concrete (ACI 318-19) and Commentary*. ACI 2019.