International Journal for Multidisciplinary Research (IJFMR)

E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

Redesigning Residential Building for Improved Seismic Performance

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Abstract

The seismic performance of existing buildings is crucial for ensuring structural safety in earthquake-prone regions. This study focuses on the seismic redesign of an existing building located in Pudukad, Thrissur district, Kerala. The structural elements, including columns, beams, and foundations, were analysed using ANSYS software to evaluate their response to seismic forces. Based on the analysis, necessary modifications were incorporated to enhance the seismic resistance of the structure. The redesigned model was then subjected to further analysis to assess the improvements in performance. The study also provides recommendations for implementing seismic-resistant features to improve the overall resilience of buildings in similar seismic-prone areas. The findings contribute to the development of safer construction practices and retrofitting strategies for existing structures, ensuring improved earthquake resistance and structural integrity.

Keywords: Seismic analysis, structural safety, Analysis, Ansys, Modifications, column, beam , foundation.

1.INTRODUCTION

Earthquakes pose a significant threat to buildings, especially in regions with moderate to high seismic activity. In recent years, structural safety has become a critical concern, necessitating the evaluation and enhancement of existing buildings to withstand seismic forces effectively. Pudukad, located in Thrissur district, Kerala, is an area that experiences seismic activity, making it essential to assess the structural integrity of buildings in this region.

This project focuses on the seismic redesign of an existing building in Pudukad to improve its earthquake resistance. The study involves analysing key structural elements such as columns, beams, and foundations using ANSYS software. The initial analysis helps identify structural weaknesses and deficiencies in the existing design. Based on the findings, necessary modifications are introduced to enhance seismic performance, followed by a reanalysis of the modified structure to evaluate the effectiveness of the improvements.

Additionally, this study provides recommendations for incorporating seismic-resistant features in building design, which can be applied to similar structures in seismic-prone areas. The research aims to contribute to safer construction practices by optimizing structural elements to better withstand seismic forces, thereby ensuring improved resilience and longevity of buildings.

2. METHODOLOGY

2.1 Collection of soil and building data’s

The project site is located in Pudukad, Thrissur district, Kerala. The site has natural sandy soil on the surface, and the terrain was fairly level at the time of investigation. A soil study was conducted to determine the suitability of the foundation. Three boreholes (BH1, BH2, and BH3) were drilled at different locations using the Calyx core helical drilling method. Standard penetration tests (SPT) were performed at various depths to analyze soil strength. Samples were collected and studied, and a sub-soil report was prepared with recommendations for a suitable foundation.The investigation found variations in soil conditions across the site. In BH1, the top 3.70m consists of very dense lateritic silty clayey sand with an SPT value greater than 50. Below this, medium dense lateritic silty sand with gravel extends up to 6.00m, followed by hard rock at 6.50m. The water table was recorded at 2.00m below ground level. In BH2, the top 0.30m consists of fill material, followed by very loose lateritic silty clayey sand (SPT 3) up to 1.70m. Below this, layers of loose to medium dense sand and gravel extend up to 8.90m, with hard rock underneath. The water table was recorded at 3.00m below ground level. In BH3, the top 2.30m consists of very loose lateritic silty clayey sand with an SPT value between 1 and 3. Below this, dense sand and gravel layers extend up to 9.00m, followed by hard rock. The water table was noted at 3.00m below ground level.Based on the soil study, different foundation recommendations were made. In BH1 and BH3, the very dense sand layers can support a shallow foundation at depths of 1.00m in BH1 and 2.30m in BH3. A safe bearing capacity of 18t/m² is recommended for a footing width of 1m. Depending on the building load, wall footing, isolated footing, strip footing, or raft foundation can be used. However, in BH2, the soil is loose at the top, which may cause large settlement if a shallow foundation is used. Therefore, deep foundation or raft foundation is recommended for this area to ensure stability.The findings from this investigation help determine the best foundation design for the project. The presence of dense sand and hard rock in some areas allows for shallow foundations, while weaker soil layers in other areas require stronger foundation solutions. By following these recommendations, the building’s stability and seismic resistance can be improved.

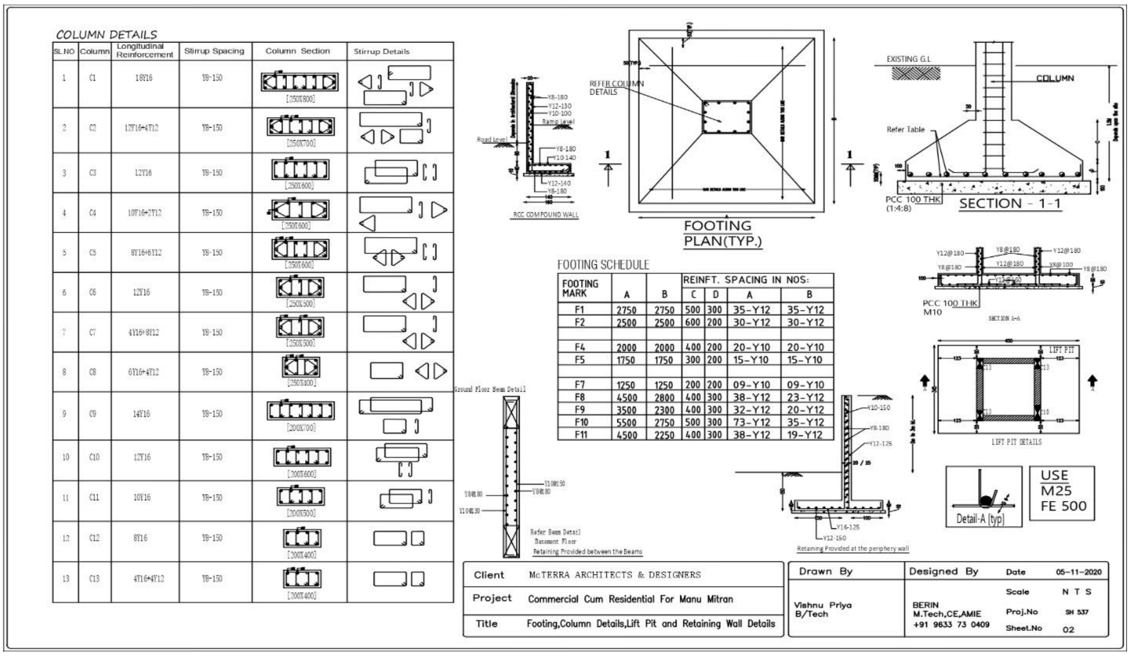

Fig 1 : - Existing foundation and column

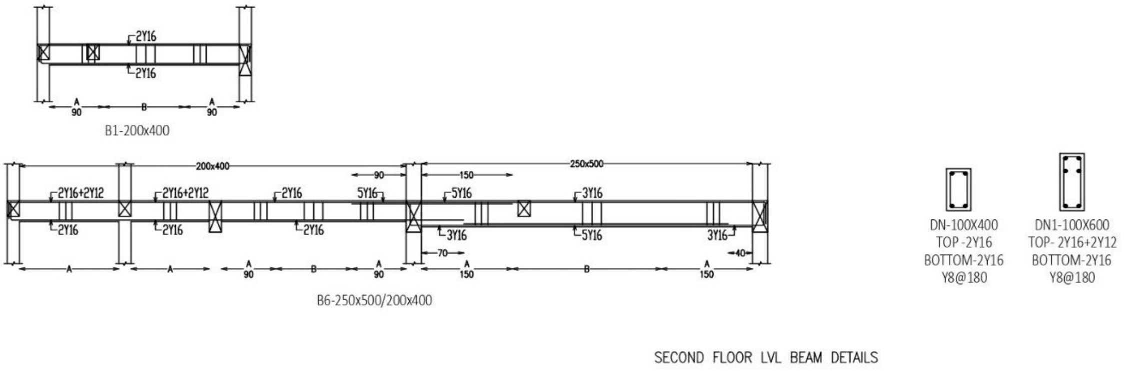

Fig 2 :- Existing Beam

2.2 Seismic Analysis of existing building structures

Foundation and column Analysis

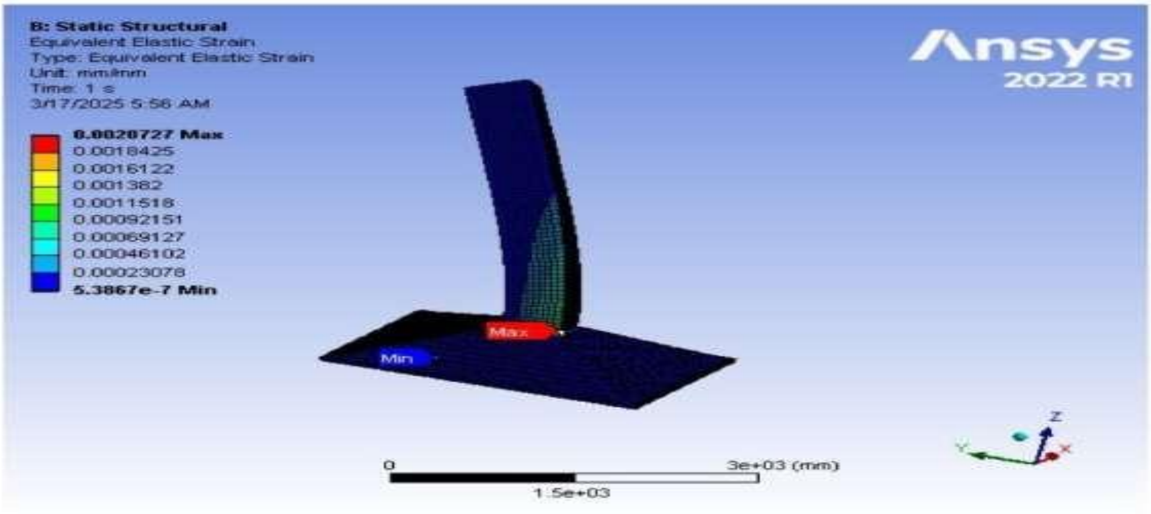

Fig 3 :- Foundation & column analysis

Beam analysis

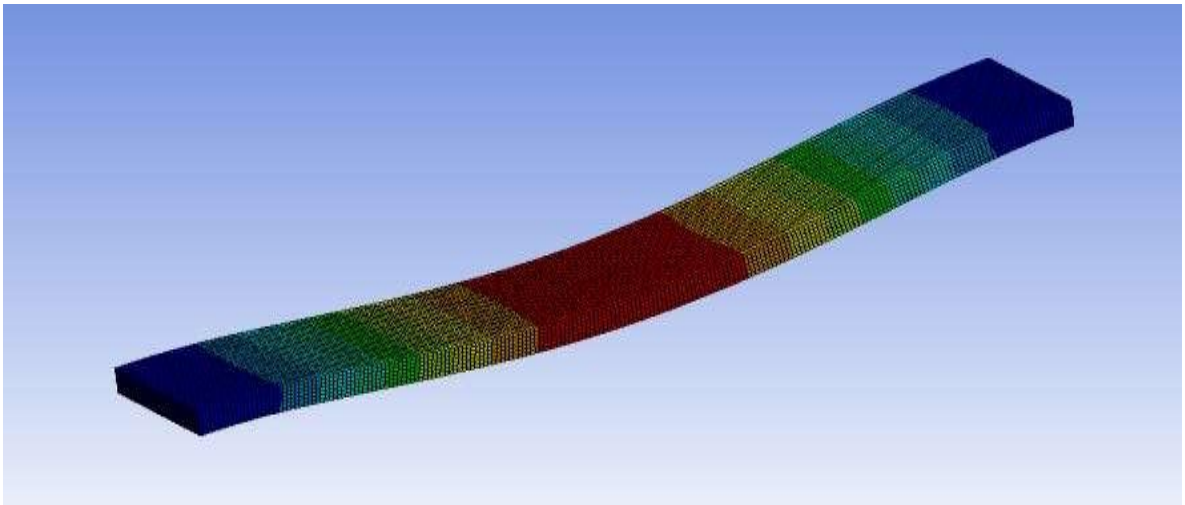

Fig 4 :- Beam Analysis

2.3: Redesign of structural elements

Modifications in foundation

Provide Raft foundation for improved seismic performance

Assume Raft thickness = 600 mm

Short dimension of column (b) = 250mm

$Zu = Vu \div (u \times d)$

A1 = 250×800

= 0.2 m^2

$Vu \; = Pu - (A1 \times SBC)$

= 4764 – 0.2×250

= 4714 KN

Zu = (4714× 10^3) ÷ (3400 × 600)=2.3 N/m m^2

Zc = 0.25 Vfcu+0.25×5=1.25 N/m m^2

Zv > Zc puncing shear failure occurs New depth

d^1= (4714× 10^3) ÷(3400× 1.25)= 1109 = 1110 mm

Zv = (4714× 10^3) ÷ (5440 × 1110)=0.78< Zc

Hence safe

- Provide 20 mm dia bars @ 150 mm c/c both x & y direction to improve rigidity
- Increase cover 50mm for durability
- Seismic face requires strong boundary conditions so introduce edge beams and reduce differential settlements
- Stirrups with in raft thickness of resist shear force 8 mm dia @ 200 nn c/c

Modifications in column

As per IS13920 Longitudinal reinforcement δ min =0.8% of Ag δ max =6% of Ag Ag=250x800 δ min =250x800x0.8% =1600 mm^2 δ max=250x580x0.8% =1200 mm^2 Existing reinforcement = 18x π/4x 16^2 = 3619 mm^2 Pu=0.4fck Ac+0.67fyAsc=3176 KN

Provide a longitudinal bar to 24Y 22 mm to Improve axial capacity New reinforcement area

Asc = 24 x π/4 x 22^2 = 9123.18 Ac= 250x800-Asc=190876.82 Pu=4965 KN

4965>4764 KN

Hence safe.

Provide stirrups@ 100mm c/c in plastic hinge zones as per IS13920:201

Modification in beam

Mu=4764× 4^2/5=9528.64 Nm As=(9528.64) ÷(0.87fy(9-0.42×Xu)

For fy=500 Xu=0.48d
$=(9528.64\times10^4) \div(0.87\times 500(400-0.42\times 192)$ s=
$685.90mm^2$
2y 16mm for top and bottom
$2\times \pi \times8^2 = 402mm^2$
Increase the bar size and number to meet $686mm^2$
4y 16mm $4 \times \pi \times8^2 = 804\ mm^2$

1.4 Seismic analysis of redesigned structure

Foundation analysis

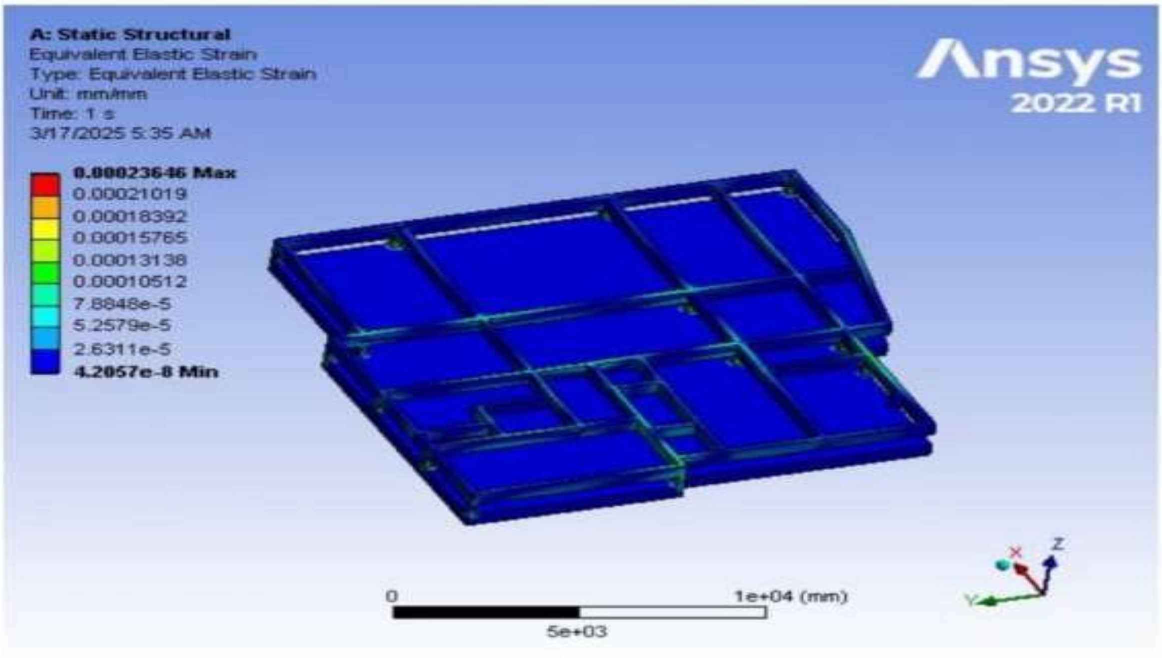

Fig 5 :- Foundation analysis

Column analysis

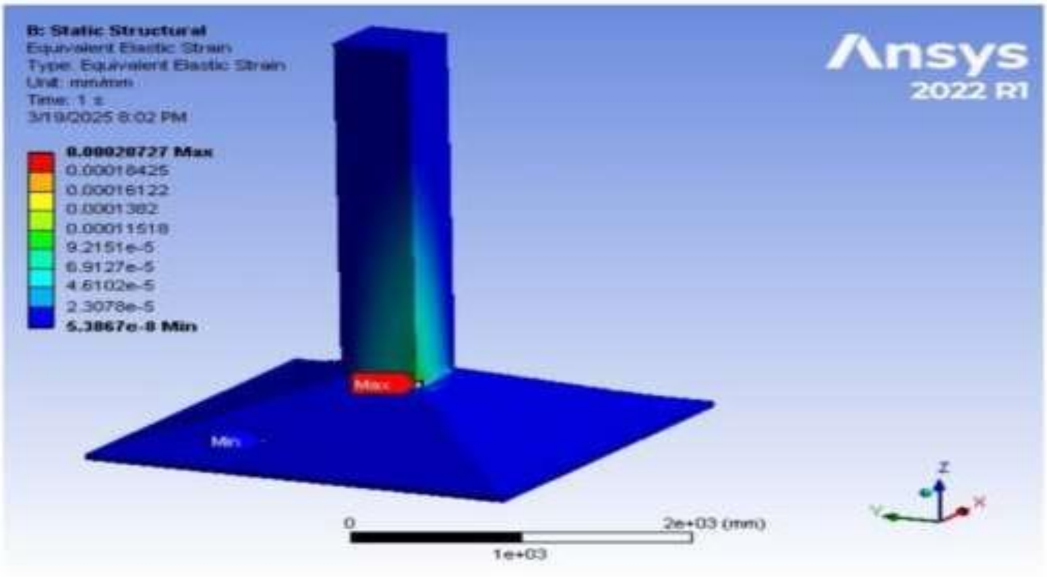

Fig 6 :- column analysis

Beam analysis

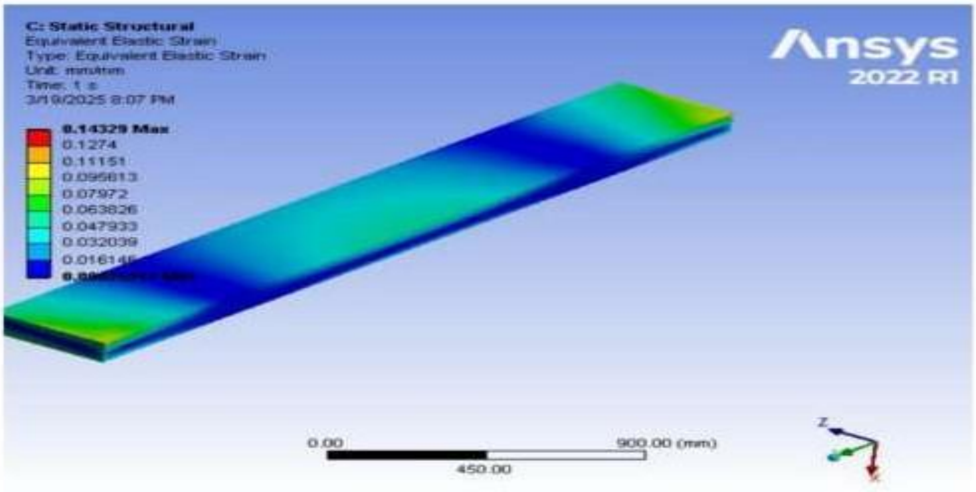

Fig 7 :- Beam analysis

2.5 Result and discussions

Parameter	Existing building	Modified building
Column size	250×800 mm	250×800 mm
Concrete strength (fck)	25 N/ mm^2	25 N/ mm^2
Steel grade (fy)	500 N/ mm^2	500 N/ mm^2
Longitudinal reinforcement	18 bars of 16 mm dia	Increased reinforcement to improve axial capacity
Stirrups (transverse reinforcement)	8 mm dia @ 150 mm spacing	Additional stirrups in plastic hinge zones for better seismic resistance
Axial load capacity (Pu)	3176 kN	4965 kN (higher capacity with additional reinforcement)
Seismic load consideration	Seismic factor = 1.5 to 2.0 times Pu	Enhanced ductility for seismic loads
Beam size	200×400 mm	200×400 mm
Moment capacity (Mu)	4764 kNm	Reinforcement optimized for better seismic performance
Beam reinforcement	4 bar of 16 mm dia	Additional bars added for higher ductility

Foundation type	Isolated footing risk of failure due to excessive soil pressure	Increased depth to avoid punching shear failure
Safe bearing capacity of soil (SBC)	Exceeds safe limits, leading to risk of foundation failure	Depth increased additional measures for stability
Punching shear capacity	Failure occurs at initial depth	Increased depth and reinforcement to improve strength
Seismic performance	Designed for static loads, minimal seismic reinforcement	Enhanced ductility additional stirrups better lateral load resistance
Seismic foundation	Designed for static loads minimal seismic reinforcement	Enhanced ductility, additional stirrups, better lateral , load resistance
Overall structural safety	Risk of failure under seismic loads	Higher strength . improved durability, and seismic safety

Structural System Enhancements

- Strong & Ductile Frame: Use moment-resisting frames or braced frames to allow controlled deformation.
- Shear Walls: Provide lateral stiffness and resistance to earthquake forces.
- Cross Bracing: X-shaped braces help distribute seismic loads.
- Base Isolation System: Uses rubber bearings, lead core bearings, or sliding bearings to absorb ground motion.
- Energy Dissipation Devices (Dampers): Helps absorb and reduce seismic energy (e.g., viscous, friction, or tuned mass dampers).

Material Selection

- Ductile Materials: Use steel, reinforced concrete with high-strength rebar, and engineered wood for flexibility.
- Lightweight Materials: Reduces the seismic load (e.g., lightweight concrete, AAC blocks, or fiber-reinforced composites).

Foundation Design

- Deep Foundations (Piles or Caissons): If soil conditions are weak, deep foundations improve stability.

- Raft or Mat Foundation: Distributes load evenly and prevents differential settlement.
- Soil Improvement Techniques: Ground compaction, grouting, or using geo grids can improve soil stability.

Building Configuration

- Symmetrical & Regular Shape: Reduces torsional effects during an earthquake.
- Balanced Mass Distribution: Avoids excessive weight on upper floors.
- Soft-Story Prevention: Design strong ground floors with bracing to prevent collapse.

Connection & Joint Reinforcement

- Beam-Column Joint Strengthening: Use proper detailing, hooks, and reinforcement to ensure joints remain intact.
- Flexible Connections: Expansion joints allow controlled movement without damage.
- Anchoring Non-Structural Elements: Secure partitions, ceilings, and facades to avoid falling hazards.

3. CONCLUSION

The seismic redesign of the existing building was successfully implemented to enhance its resilience against earthquake-induced forces. Structural analysis using ANSYS identified vulnerabilities such as stress concentrations in load-bearing elements, excessive lateral displacement in columns, and beam failures due to weak joint connections and inadequate reinforcement. To address these issues, the redesign incorporated a strengthened foundation, improved columns and beams, shear walls, and advanced damping mechanisms.A critical aspect of the redesign was foundation improvement. The original foundation lacked sufficient strength to withstand seismic forces, leading to instability. A deeper and more robust raft foundation with increased reinforcement was introduced. Soil stabilization techniques, including compaction and geosynthetic materials, minimized liquefaction risks, enhancing stability during seismic events. Columns and beams, being primary load-bearing elements, required reinforcement. Existing columns were prone to buckling and shear failures under seismic loads. They were redesigned with larger cross-sections, high-strength concrete, and high-grade steel reinforcements to improve ductility. Beams were reinforced with additional rebars and improved anchorage, increasing their load capacity and resistance to flexural stresses. Shear walls were integrated at strategic locations to reduce lateral displacements and enhance stability.Damping mechanisms played a crucial role in the redesign. Base isolators, consisting of elastomeric bearings with lead cores, absorbed seismic energy, preventing direct ground motion transmission. Flexible joints at beam-column intersections allowed controlled movement, reducing stress concentrations and preventing brittle failure.Further improvements include real-time structural health monitoring, the use of advanced materials like fiber-reinforced polymers, and strict adherence to seismic codes. Retrofitting adjacent structures and community earthquake preparedness programs can also reduce risks. This redesign significantly enhances seismic resilience, ensuring better load distribution and energy dissipation. Future research should focus on optimizing materials and incorporating AI-driven monitoring for improved seismic performance.

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