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Research Article

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Comparative Study on Seismic Analysis of High-Rise RCC and Steel-Concrete Composite Structures Under Equivalent Static and Response Spectrum Methods

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Abstract

This paper presents a comparative study on Reinforced Cement Concrete (RCC) G+15 high-rise structural buildings and steel-concrete composite structural buildings in Seismic Zone IV, Nashik, India. Reinforced concrete buildings are suitable for low-rise structures, whereas high-rise multi-storeyed structures benefit from steel composite materials incorporated into RCC structural members. Steel-composite high-rise buildings reduce the dead load on the structure and are more economical compared to conventional RCC structures. In this paper, a comparative study of the dynamic effect of Reinforced Concrete and steel-concrete-composite moment-resisting frames is conducted for seismic loading. Two types of G+15-storey buildings located in Seismic Zone III are designed as per IS 800:2007 and IS 1893:2016. The equivalent static method and response spectrum analysis are performed using ETABS 2022 software. A comparative study of four key parameters—lateral displacement, base shear, fundamental time period, and storey drift—is investigated to depict the structural response. The aim of this study is to compare significant seismic performance indicators of steel-concrete composite frames with typical reinforced concrete frames for high-rise building construction.

Keywords Seismic analysis · Dynamic analysis · Base shear · RCC · ETABS · Response spectrum analysis · Composite structures · Storey drift

1. Introduction

The base shear for the RCC frame is maximum compared to the composite frame, with a 16% reduction in base shear for the composite structure. The composite frame exhibits 15% less displacement than the RCC frame, while storey drifts are similar for both structures. The fundamental time is greater in the composite frame, indicating better performance under seismic loads. Economically, the composite frame is more cost-effective for high-rise structures compared to the RCC structure. The recommended dimensions of beams and columns are deemed safe, ensuring building stability against shear, bending, and deflection [1]. This work investigates and compares the cost-effectiveness of seismically designed buildings having either pure steel or steel-concrete composite columns. A discrete Evolution Strategies optimization algorithm is employed to minimize total material costs (steel and concrete) subject to constraints from Eurocode 4 (composite columns), Eurocode 3 (structural steel), and seismic system behaviour. Extensive assessments and comparisons are performed for various seismic intensities, building heights, and plan configurations [2].The seismic behaviour of steel-concrete composite buildings was investigated for 5-, 10-, 15-, and 20-storey composite moment-resisting framed

structures designed with concrete-filled steel tube columns

and composite beams. Nonlinear static pushover and incremental dynamic analyses were used, with results showing that the ductility of composite moment-resisting framed structures is almost 30% higher than design assumptions for international standards [3]. The RCC structure is no longer always suitable because of increased dead load, span restrictions, and reduced stiffness. Steel-concrete composite sections present great potential for high-rise construction [4].Seismic resilience is of paramount importance for the design and construction of structures in earthquake-prone regions. This study provides a comprehensive analysis of the seismic performance of steel-concrete composite and Reinforced Cement Concrete (RCC) structures under dynamic loading, facilitating a comparative assessment of their respective seismic behaviours [7]. The construction industry continually evolves by integrating different materials to enhance structural performance, sustainability, and cost efficiency. This review examines the comparative study and performance evaluation of composite Reinforced Cement Concrete (RCC), steel, and timber materials used as structural columns and beams. The study explores the mechanical properties, structural behaviour, and economic feasibility of these materials in multi-storey buildings, bridges, and seismic-resistant structures. Various literature sources highlight the benefits of composite structures, emphasizing their enhanced load-bearing capacity, ductility, and energy dissipation. RCC structures offer economic and durability advantages, steel structures provide high strength and flexibility, and timber structures contribute to sustainability with a lower carbon footprint. The study also discusses advanced analysis methods, including finite element modeling, response spectrum analysis, and experimental investigations, to assess structural performance under different conditions.[30]

2.Literature Survey

Optimal structural design aims to reduce project costs during the design phase, leading to various methodologies to address complex engineering challenges. **Bansal and Gagandeep [1]** utilised seismic analysis to create vertically irregular RC building frames, finding that shear force is highest at lower floors and decreases with increasing floor numbers; mass-irregular structures experience higher base shear than comparable regular buildings. **Karunakar [2]** studied the effect of percentage and quantity variations across different seismic zones on construction costs, concluding that increased vertical reaction leads to greater variation in external and corner column quantities. **Sadh and Pendharkar [3]** examined the influence of horizontal and vertical building aspect ratios using static analysis. **Panchal and Marathe [4]** compared RCC, steel, and composite structures, finding that steel-concrete composites are a superior option for high-rise buildings over RCC structures, with axial force in columns reduced by 34% and 5%, respectively. **Mujawar and Sangave [5]** highlighted that steel-concrete composite structures offer faster construction, increased internal space, and improved service life, with base shear reduced by 29% compared to equivalent RCC structures. **Baek et al. [6]** emphasised the need for cost-effective seismic strengthening methods for earthquake-prone RCC buildings lacking adequate seismic design.

2.1 Seismic Vulnerability Assessment

Ferreira et al. [7] addressed the challenges in assessing the seismic performance of reinforced concrete structures, particularly for large building inventories. The authors presented a simplified methodology for evaluating seismic vulnerability, focusing on eight parameters that govern a building's seismic response. The methodology is informed by post-earthquake damage observations and expert opinions, underscoring the importance of

empirical data in vulnerability assessment. A cost-benefit evaluation of strengthening solutions for buildings with soft-storey irregularities was also performed, emphasising economic viability across varying seismic intensities. The findings indicate a significant reduction in damage levels following strengthening interventions, confirming the effectiveness of the proposed methodology in improving building resilience.

Stepinac et al. [8] noted that seismic design standards have historically evolved in the aftermath of catastrophic earthquakes. Current Eurocodes comprehensively cover seismic design and assessment of structures, providing a framework for the systematic evaluation of existing building stock.

Cherif et al. [9] focused on the seismic evaluation of reinforced concrete buildings in northern Morocco, an area historically affected by significant seismic events including the 2004 Al Hoceima earthquake. A total of 2,746 residential buildings were investigated, highlighting the need for a method that is both time-efficient and contextually relevant to Moroccan construction practices. The proposed method adapts the Japanese Seismic Index Method, emphasising visual inspections and understanding of local construction designs. Results indicate that buildings in Imzouren are more vulnerable than those in Al Hoceima, primarily due to differing soil conditions. The findings reveal that taller buildings are more susceptible to seismic damage, and compliance with seismic regulations significantly enhances a building's ability to withstand earthquakes.**Xu et al. [10]** proposed a computer-vision and machine-learning-based framework for seismic damage assessment, addressing the limitations of conventional onsite inspection by incorporating a refined Park–Ang damage model for improved accuracy.**Romero-Sánchez et al. [11]** noted that many European buildings, particularly older ones, are vulnerable to moderate-magnitude earthquakes, leading to significant damage during past seismic events. School buildings are identified as especially vulnerable due to their design prior to current seismic codes, which did not account for seismic forces. The Iberian Peninsula, while generally experiencing low-to-moderate seismic activity, has regions such as Algarve and Huelva that are influenced by large faults capable of generating major earthquakes. The European project PERSISTAH aimed at assessing the seismic vulnerability of primary schools in these regions, proposing retrofitting solutions such as steel X-bracings and jackets to enhance structural resilience.

2.2 Seismic Performance of Hybrid and Composite Structures

Inderyas et al. [12] noted that Pakistan is highly seismically prone, with a history of devastating earthquakes impacting hybrid structures, particularly in northern areas. Prior studies have focused on seismic damage assessment and retrofitting of load-bearing masonry and reinforced concrete structures, yet analytical studies on steel-concrete hybrid structures remain limited. The behaviour of hybrid buildings under seismic events is characterised by discontinuities in lateral and vertical load transfer mechanisms. Retrofitting interventions such as shear walls and steel braces were found to significantly enhance the seismic performance of hybrid buildings, reducing lateral displacements and increasing lateral capacity.

2.3 Damage Indices and Performance Quantification

Mergos and Kappos [13] introduced a new local damage index for assessing seismic damage in existing RC structures, treating deterioration from flexure, shear, and anchorage slip separately. The authors emphasised the additive nature of damage from different deformation mechanisms and the increased degradation rate resulting from their interactions. Empirical data from experimental studies on RC specimens were used to derive formulas for calculating shear strain and other deformation capacities. The research demonstrates that

total damage index values exceed individual component indices throughout the loading sequence, ultimately reflecting the failure state of the specimen. **Shiradhonkar and Sinha [14]** discussed the importance of quantifying seismic damage to RC members for condition assessment and performance-based seismic design. The classification of axially-loaded, flexural-dominant, well-detailed RC members into distinct damage states was proposed, based on failure mode transitions and loss in lateral load capacity. Extreme fibre compressive strain was identified as a key Engineering Response Parameter (ERP) for identifying damage states. A notable gap in the literature concerning the uncertainty in quantifying moderate damage—as compared to light or severe damage—was identified, suggesting a need for improved prediction expressions.

2.4 Risk Assessment and Structural Vulnerability Mapping

Zona et al. [15] emphasised the importance of understanding structural vulnerabilities to enhance risk management and disaster mitigation strategies. The review highlighted the need for fast and reliable assessment methods for seismic vulnerability, particularly in the context of natural disasters. The classification of structures based on geometric and mechanical properties, leading to the development of morpho-types for better risk assessment, was discussed. Simplified methodologies such as pushover analysis and finite element methods were advocated for evaluating structural resistance and vulnerability efficiently. The significance of creating localised maps to identify areas with similar structural characteristics and vulnerabilities, facilitating targeted safety interventions, was also underlined.**Gallo et al. [16]** critically examined various methodologies for assessing seismic resilience in buildings, highlighting their respective advantages and limitations. Resilience is commonly evaluated through functionality curves representing the recovery process, with a focus on parameters such as rapidity and robustness. Many existing methods are primarily applicable to the U.S. context, limiting their relevance in other regions. An annualized expected resilience metric was identified as more suitable for combined seismic and energy retrofitting frameworks, with recommendations for further refinement of existing methodologies.

2.5 Advanced Materials and Seismic Retrofitting

Wu et al. [17] discussed the use of engineered cementitious composite (ECC) as a shear component in structures, noting its superior shear deformation capacity and strength compared to normal concrete. The seismic performance of RC frames with short columns was reviewed using the incremental dynamic analysis (IDA) method. RC frames with short columns were found to form weak layers that significantly compromise seismic performance and increase vulnerability to collapse. ECC short columns were shown to enhance the seismic performance of structures by approximately 40% compared to traditional RC short columns. **Zhang et al. [18]** highlighted the seismic vulnerability of residential buildings constructed during the Soviet Union era in Almaty, Kazakhstan, which exhibit low seismic resisting capacities due to inadequate design provisions. Unreinforced masonry and wood structures were identified as likely to suffer very heavy damage or collapse during significant earthquakes. Buildings were categorised based on construction materials and lateral force-resisting systems following the European Macroseismic Scale (EMS-98). While reinforced and precast concrete buildings show greater resilience than unreinforced structures, they still face considerable uncertainties in seismic performance. The findings provide guidance for government decision-makers in the formulation of earthquake disaster prevention and risk management strategies.

3.Methodology

From the standpoint of seismic evaluation, the primary goal of these evaluations is to determine the demand-to-capacity ratios of building components and, as a result, code compliance. For the analysis and design of the structure, the structural analysis software ETABS is used. Before analysis by software, the required parameters are collected as per IS 1893 (2016) codal provisions for seismic loading.

a. Equivalent Static Analysis (ESA)

Equivalent Static Analysis (ESA) is a simplified structural design method that converts complex dynamic earthquake forces into a set of equivalent horizontal static forces acting on a building. It calculates the total seismic base shear based on building weight, soil type, and stiffness, distributing it vertically to estimate deformation—typically applied to low-rise, regular structures.

Two methods—equivalent static analysis and response spectrum analysis—were adopted for analysing the building. The grades of steel and concrete used are Fe 500 and M 30, respectively. The design base shear (V_b) is given by: $V_b = W \times A_h$

where A_h is the design horizontal seismic coefficient and W is the seismic weight of the structure. The horizontal seismic coefficient is calculated as:

$$A_h = (Z/2) \times (I/R) \times (S_a/g)$$

The fundamental natural time period (T_a) is calculated as:

$$T_a = 0.075 \times h^{0.75} \text{ [for RC frame buildings]}$$

$$T_a = 0.080 \times h^{0.75} \text{ [for Composite frame buildings]}$$

$$T_a = 0.085 \times h^{0.75} \text{ [for Steel frame buildings]}$$

$$T_a = (0.09\ h) / \sqrt{d} \text{ [with brick infill]}$$

Table 1 Dimensions of various members used in the building

Member	Size of Beam (mm)	Size of Column (mm)	Size of Slab/Deck
RCC	230 × 600	600 × 600	150 mm slab
Composite	ISMB 500	600 × 600 with ISMB 450	150 mm deck

b. Response Spectrum Analysis (RSA)

In this method of analysis, multiple modes of response can be taken, except for excessively complex or simple structures. The structure responds in a way that can be defined as a combination of many modes determined by dynamic analysis. The Square Root of the Sum of Squares (SRSS) method is used to combine the modes. Various codes used for analysis are: (i) RCC design using IS 456-2000; (ii) earthquake design using IS 1893-2016; and (iii) composite design using IS 11384-1985.

Table 2 Description of various parameters used to analyse the building

Parameter	RCC Structure	Composite Structure
Plan Dimension (m)	25 × 25	25 × 25
Total Height of Building (m)	45.75	45.75
Height of Each Storey (m)	3.0	3.0
Height of Parapet (m)	1.2	1.2
Size of Beam	230 × 600	ISMB 500
Size of Column	Multiple sizes	600 × 600
Thickness of Wall (mm)	230	230
Thickness of Slab (mm)	150	150
Wind Speed (m/s)	39	39
Seismic Zone	IV	IV
Embedded I-Section	—	ISMB 450

Parameter	RCC Structure	Composite Structure
Importance Factor	1.0	1.0
Soil Condition	Medium soil	Medium soil
Zone Factor (Z)	0.24	0.24
Response Reduction Factor (R)	5	5
Terrain Category	III	III
Structure Class	B	B
Damping Ratio	5%	5%
Live Load at All Floors (kN/m²)	3.0	3.0
Floor Finish (kN/m²)	1.0	1.0
Grade of Concrete	M30	M30
Grade of Reinforcing Steel	Fe 550	Fe 550
Reinforcing Bars	Fe 500	Fe 500
Density of Brick (kN/m³)	20	20

c. Building Configuration

For the design of buildings, different elements such as beams, columns, slabs, etc. are considered. The sizes of both RCC and composite members are shown in Table 1. In the case of composite members, ISMB 450 is chosen in this research work. A pictorial view of the RCC and composite cross-sections is shown in Fig. 1.

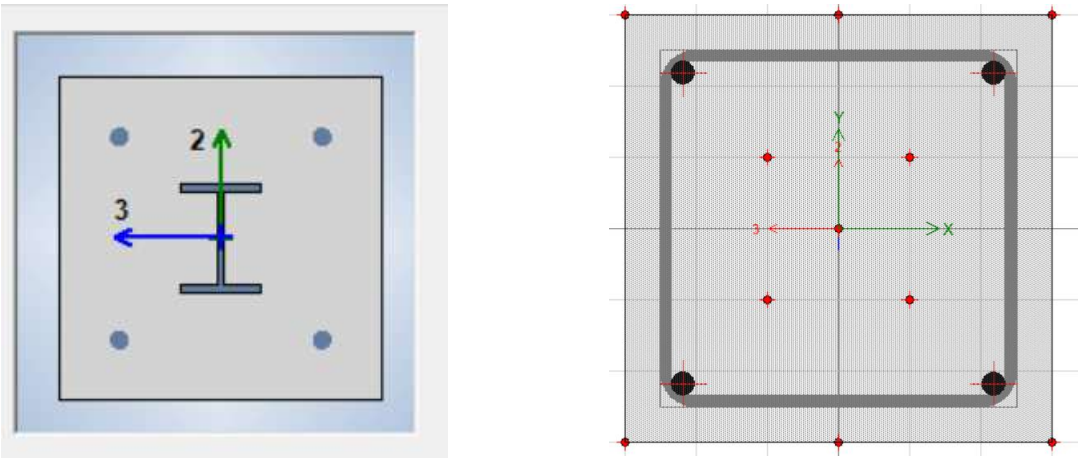


Fig. 1 (a) RCC column cross-section; (b) Steel-concrete composite column cross-section

Etabs Modelling Fig.

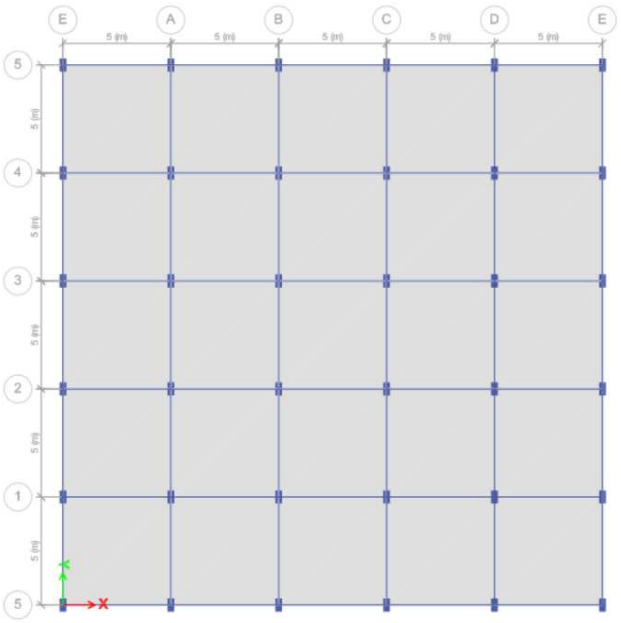


Fig.1 RCC G+15 Plan

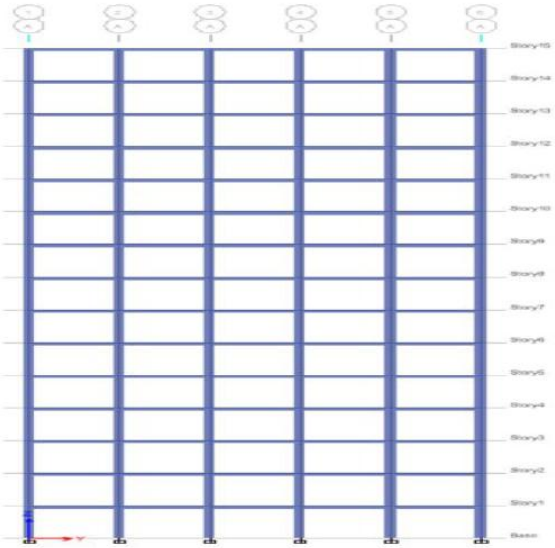


Fig.2 Building Elevation

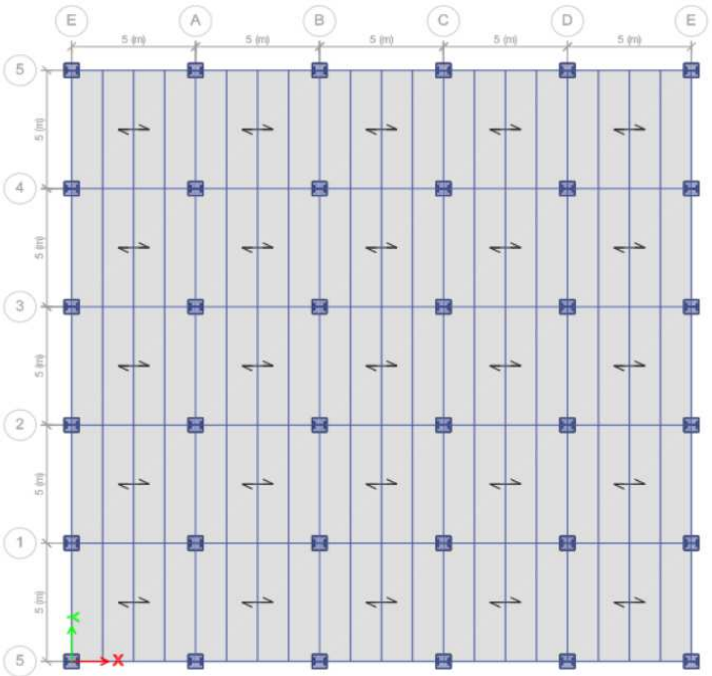


Fig.3 Composite G+15 Plan

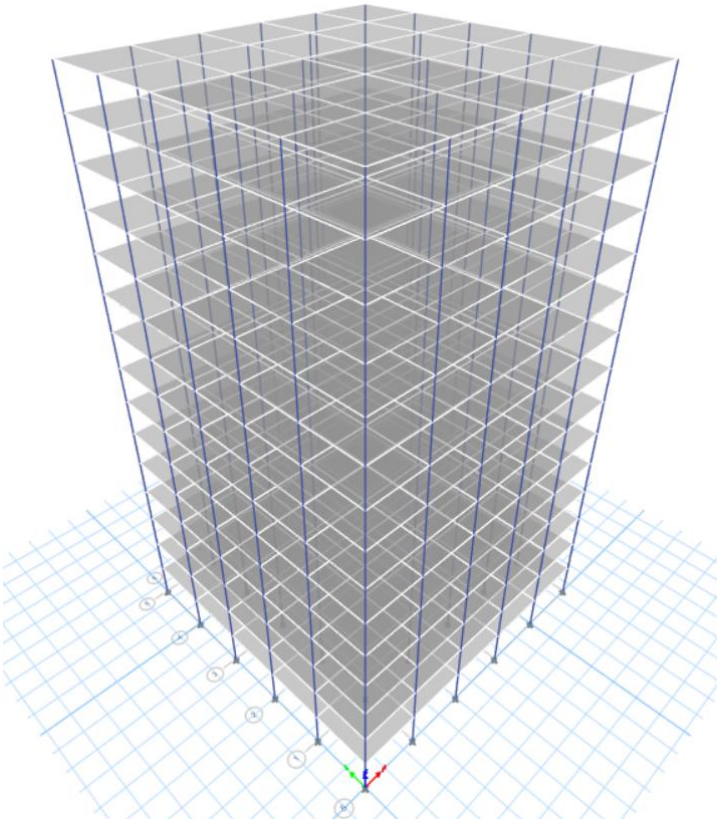


Fig.4 3DElevation

4. RESULTS AND DISCUSSION

The 3D building model is analyzed and Designed by Equivalent Static method of analysis according to Indian and American Standard Codes with the help of ETABS 2020 software. The results of Maximum Storey Displacement, Storey Drift, Storey Shear, Bending moment and Shear force, Axial force, Self-weight of the Structure, Quantities and overall performance of building model are compared.

A) RCC Structure

1) Seismic Weight *W*

Plan area $A = 25 \times 25 = 625\ m^2$, perimeter $= 100\ m$

Wall line load $= 0.23 \times 3.0 \times 20 = 13.8\ kN/m$
$\Rightarrow$ as pressure $= 13.8 \times 100/625 = 2.208\ kN/m^2$

Per-floor seismic load (kN/m²)
Slab 3.75 + Floor finish 1.00 + Wall 2.208 + LL_{eff} 0.75 + member allow. (RCC) 0.50

$$8.208\ kN/m^2$$

Per typical floor: $8.208 \times 625 = 5130\ kN$

Roof (no LL): $3.75 + 1.00 + 2.208 + 0.50 = 7.458\ kN/m^2$
Per roof: $7.458 \times 625 = 4661.25\ kN$

Total seismic weight (15 typical + 1 roof):

$$W_{RCC} = 15 \times 5130 + 4661.25 = 81{,}611.25\ kN$$

2) Fundamental Period & Spectrum

Empirical (IS 1893): $T = 0.09\,h/\sqrt{d} = 0.09 \times 45.75/\sqrt{25} = 0.8235\ s$

For 5% damping, medium soil (long-period branch): $(S_a/g) \approx 1.36/T = 1.651$

Design horizontal coefficient:

$$A_h = \frac{Z}{2}\frac{I}{R}\frac{S_a}{g} = \frac{0.24}{2} \times \frac{1}{5} \times 1.651 = 0.03964$$

3) ELF/ESA Base Shear

$$V_{b,RCC} = A_h\, W_{RCC} = 0.03964 \times 81{,}611.25 = 3{,}234.72\ kN$$

4) Storey Force Distribution (ELF)

$$Q_i = \frac{W_i h_i}{\sum(W_j h_j)}\, V_b, \quad h_i = 3i\ m$$

(16 masses: 15 typical floors with $W_i = 5130\ kN$ at 3,6,…,45 m + roof $W_{roof} = 4661.25\ kN$ at 45 m.)

Top levels (check values):

- Storey 13 (39 m): 314.69 kN
- Storey 14 (42 m): 338.89 kN
- Storey 15 (45 m): 363.10 kN
- Roof mass (45 m): 329.92 kN
  (Sum over 16 levels = $V_b = 3234.72$ kN.)

5) Response Spectrum (RSA) Scaling Check

Minimum acceptable modal base shear:

$$0.8\,V_{b,ELF} = 0.8 \times 3234.72 = 2587.78\ kN$$

If ETABS gives $V_{b,RSA} < 2587.78\ kN$ in any direction, scale RSA responses by

$$SF = \frac{0.8\,V_{b,ELF}}{V_{b,RSA}}$$

and apply to drifts, displacements, and member forces.

B) Composite Structure

1) Seismic Weight *W*

Plan area $A = 625\ m^2$, perimeter $= 100\ m$

Wall live load $= 13.8\ kN/m \Rightarrow$ pressure $= 2.208\ kN/m^2$

Per-floor seismic load (kN/m²)
Slab 3.75 + Floor finish 1.00 + Wall 2.208 + LL_{eff} 0.75 + member allow. (Composite) 0.30

$$8.008\ kN/m^2$$

Per typical floor: $8.008 \times 625 = 5005\ kN$

Roof (no LL): $3.75 + 1.00 + 2.208 + 0.30 = 7.258\ kN/m^2$
Per roof: $7.258 \times 625 = 4536.25\ kN$

Total seismic weight (15 typical + 1 roof):

$$W_{Comp} = 15 \times 5005 + 4536.25 = 79{,}611.25\ kN$$

2) Fundamental Period & Spectrum

Same geometry $\Rightarrow T = 0.8235\ s$, $(S_a/g) = 1.651$, $A_h = 0.03964$

3) ELF/ESA Base Shear

$$V_{b,Comp} = A_h\,W_{Comp} = 0.03964 \times 79{,}611.25 = 3{,}155.45\ kN$$

4) Storey Force Distribution (ELF)

$$Q_i = \frac{W_i h_i}{\sum(W_j h_j)}\,V_b, \quad h_i = 3i\ m$$

(16 masses: 15 typical floors with $W_i = 5005\ kN$ at 3,6,…,45 m + roof $W_{roof} = 4536.25\ kN$ at 45 m.)

Top levels (check values):

- Storey 13 (39 m): 307.05 kN
- Storey 14 (42 m): 330.67 kN
- Storey 15 (45 m): 354.29 kN
- Roof mass (45 m): 321.11 kN

(Sum over 16 levels = $V_b = 3155.45$ kN.)

5) Response Spectrum (RSA)

Minimum acceptable modal base shear:

$$0.8\,V_{b,ELF} = 0.8 \times 3155.45 = 2524.36\ kN$$

If ETABS gives $V_{b,RSA} < 2524.36\ kN$ in any direction, scale RSA responses by

$$SF = \frac{0.8\,V_{b,ELF}}{V_{b,RSA}}$$

Table 3 Comparative summary of seismic weight and base shear

Parameter	RCC Structure	Composite Structure	Difference
Typical Floor Weight	5,130 kN	5,005 kN	125 kN (2.4%)
Roof Weight	4,661.25 kN	4,536.25 kN	125 kN (2.7%)
Total Seismic Weight	81,611.25 kN	79,611.25 kN	2,000 kN (2.5%)
Base Shear (ELF)	3,234.72 kN	3,155.45 kN	79.27 kN (2.5%)
Min. RSA Base Shear	2,587.78 kN	2,524.36 kN	63.42 kN (2.5%)
Member Allowance	0.50 kN/m²	0.30 kN/m²	0.20 kN/m² (40%)

Table 4 Top-level storey forces — RCC structure

Level	Height (m)	Weight (kN)	Lateral Force (kN)	Storey Shear (kN)
S13	39	5,130	314.69	1,346.60
S14	42	5,130	338.89	1,031.91
S15	45	5,130	363.10	693.02
Roof	45	4,661.25	329.92	329.92
Sum	—	—	3,234.72	—

Table 5 Top-level storey forces — Composite structure

Level	Height (m)	Weight (kN)	Lateral Force (kN)	Storey Shear (kN)
S13	39	5,005	307.05	1,313.10
S14	42	5,005	330.67	1,006.08
Level	**Height (m)**	**Weight (kN)**	**Lateral Force (kN)**	**Storey Shear (kN)**
S15	45	5,005	354.29	675.40
Roof	45	4,536.25	321.11	321.11
Sum	—	—	3,155.45	—

a. Story Displacement

Story displacement profiles for both RCC and composite structures were obtained from ESA and RSA in ETABS 2022. The displacement plots are presented in Figs. 2–3.

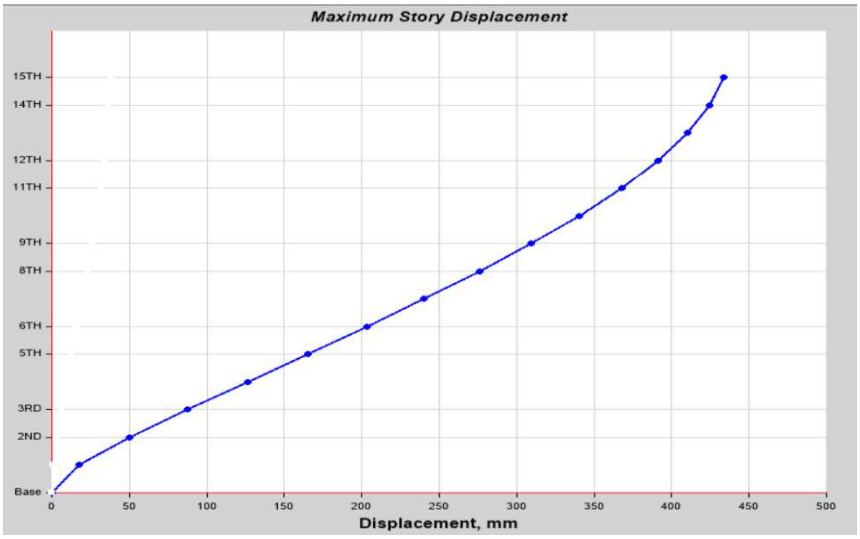


Fig. 2 Story displacement profile — RCC structure (ESA)

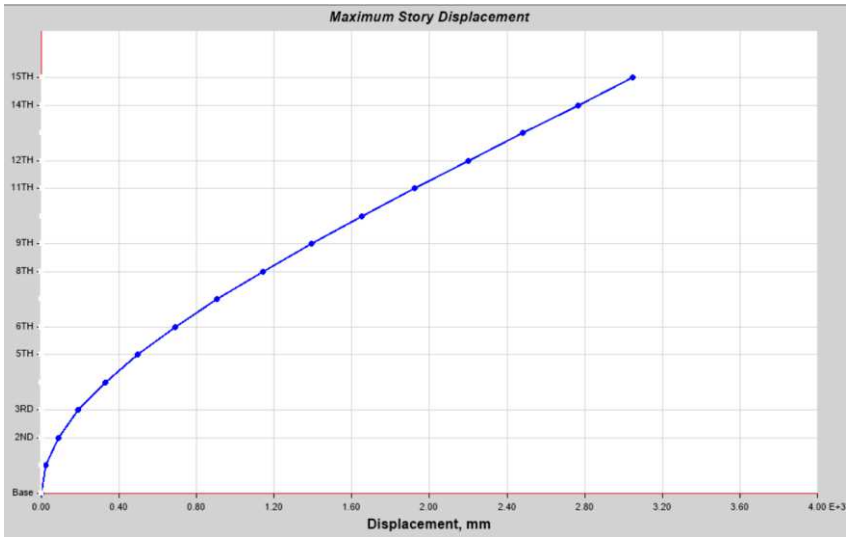


Fig. 3 Story displacement profile — Composite structure (ESA)

Table 6 ESA displacement comparison — RCC vs. Composite

Parameter	RCC	Composite	Inference
Top Storey Displacement	450 mm	3.2 mm	Composite 99% lower
Drift Distribution	Higher near upper storeys (~0.003–0.004)	Uniform, very low (<0.002)	Composite better drift control

Flexibility/Stiffness	Highly flexible (frame action	)Very stiff (steel–concrete)	Composite better lateral rigidity

b. Response Spectrum Analysis — Displacement

Table 7 RSA displacement comparison

Parameter	RCC (RSA)	Composite (RSA)	Inference
Top displacement	19 mm	110 mm	RCC much stiffer under RSA
Drift ratio (Δtop /h)	0.042%	0.24%	Both within IS 1893 limit (~0.4%)
Profile shape	Smooth flexural curve	Near-linear with height	Composite first-mode dominated

c. Storey Drift

Storey drift plots for both structures under ESA are shown in Figs. 4–5. A direct comparison is presented in Fig. 6.

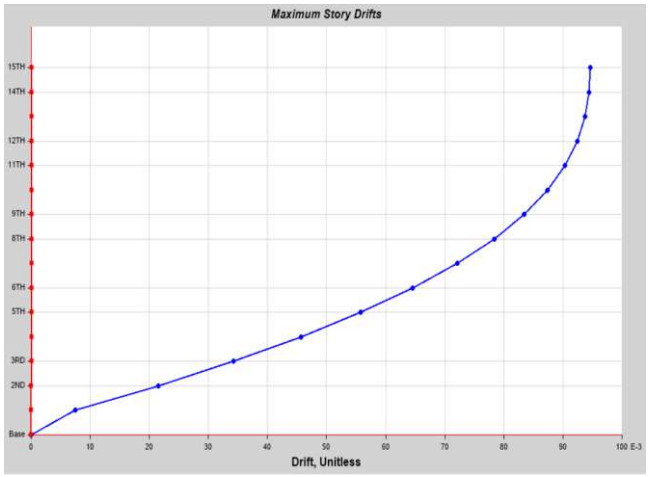


Fig. 4 Storey drift — Composite structure (ESA)

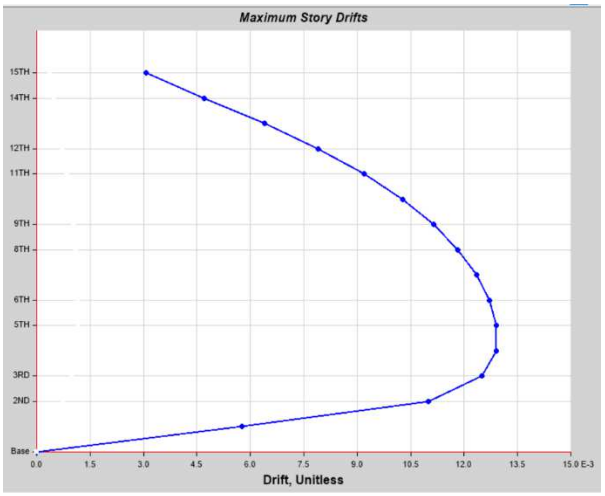


Fig. 5 Storey drift — RCC structure (ESA)

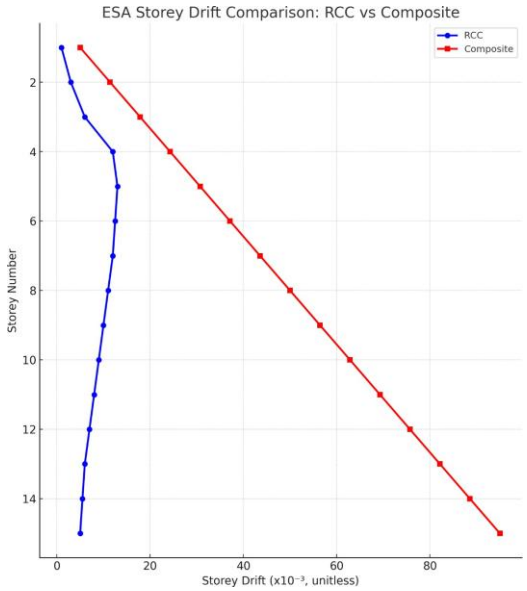


Fig. 6 Storey drift comparison — RCC vs. Composite

Table 8 Storey drift comparison (ESA)

Metric	RCC (ESA)	Composite (ESA)	Notes
Peak storey drift (unitless)	0.013 (mid-height)	0.095 (top storeys)	Composite drift 7.3× RCC
Peak occurrence	6th–8th storey	13th–15th storey	RCC mid-height flexural peak vs composite upper-Storey flexibility
Code limit (IS 1893, h/500)	0.006	0.006	Composite far above limit in ESA
Overall assessment	Near code but above at mid-height	Far above code at upper Storey	ESA highlights need for added stiffness in composite model

d. Storey Shear

Storey shear distributions for composite and RCC models are shown in Figs. 7–8, and combined in Fig. 9.

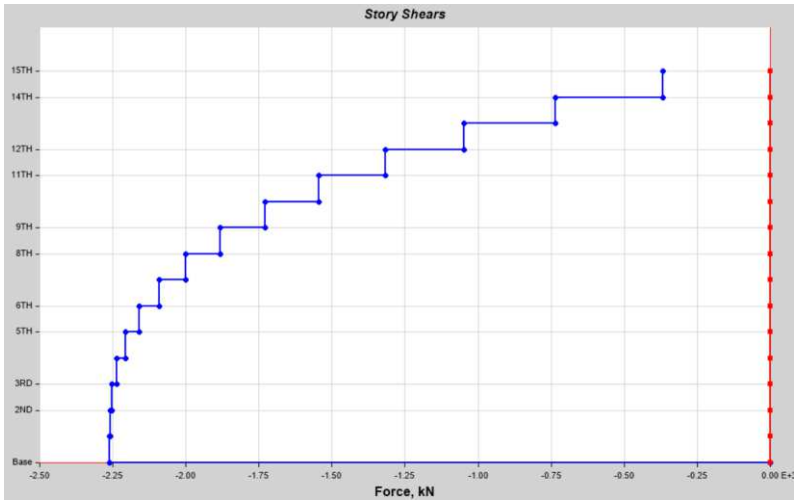


Fig. 7 Storey shear — Composite model (ESA)

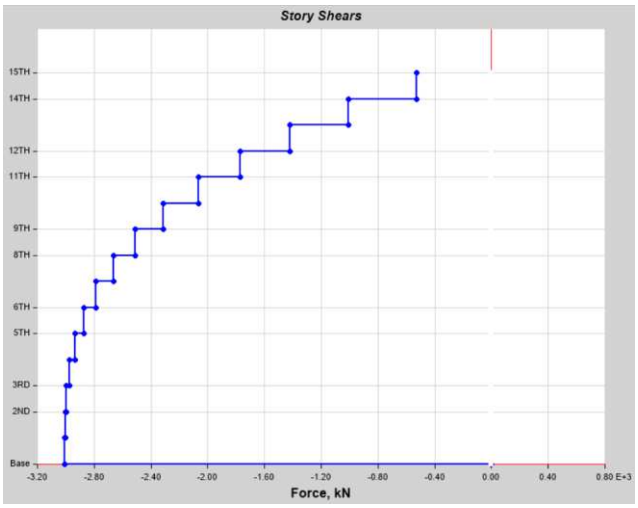


Fig. 8 Storey shear — RCC model (ESA)

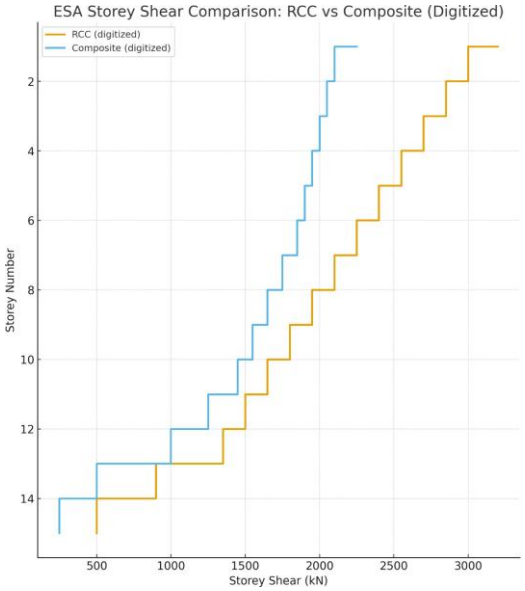


Fig. 9 Combined storey shear comparison — RCC vs. Composite

Table 9 RCC vs. Composite storey shear (ESA)

Parameter	RCC Structure	Composite Structure	Remarks
Base Shear (kN)	Say 3200 kN	say 2250 kN	RCC attracts ~40–45% higher seismic force
Shear Distribution	Gradual triangular profile, moderate shear up to mid-height	Rapid decay with height, lower shear in upper floors	Composite reduces demand at higher stories
Upper Storey Shear	Small but still present (~14th–15th storey)	Almost negligible by top floors	Composite more flexible, attracts less force at top
Overall Trend	Higher base demand, more uniform distribution	Lower base demand, faster reduction with height	Indicates RCC stiffness vs Composite flexibility
Seismic Implication	Stronger, stiffer, but higher seismic demand	Lighter, economical, but may show larger displacements/drifts	Trade-off between force demand and displacement

e. Time History Analysis — Bhuj 2001 Earthquake

For this study, the Bhuj 2001 earthquake ground motion (M_W = 7.7) was taken as the input for time history analysis of both RCC and composite G+15 buildings. The acceleration record was scaled to match the design spectrum as per IS 1893 requirements. By applying the same motion to both models, responses such as displacement, drift, shear, and overturning moments were compared.

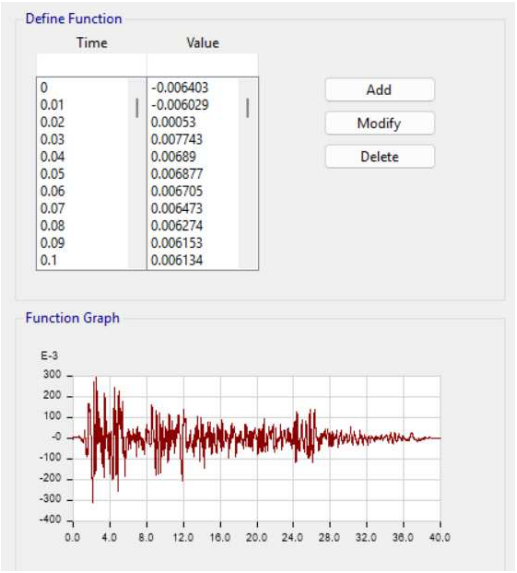


Fig. 10 Bhuj 2001 earthquake ground motion record used as input

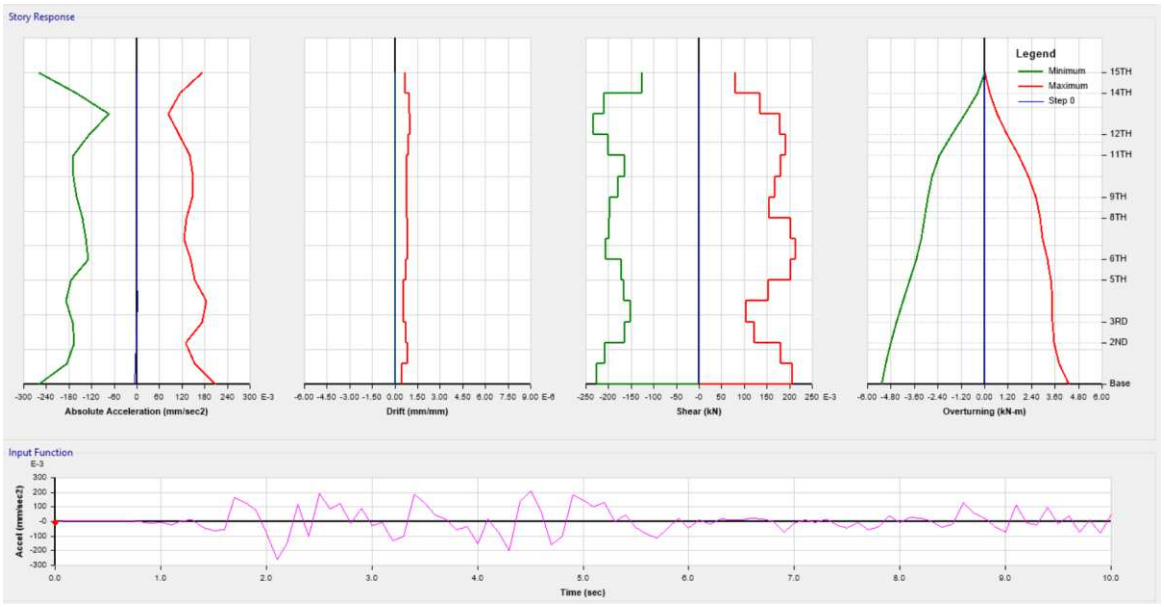


Fig. 11 Story response plot — RCC building under Bhuj time history

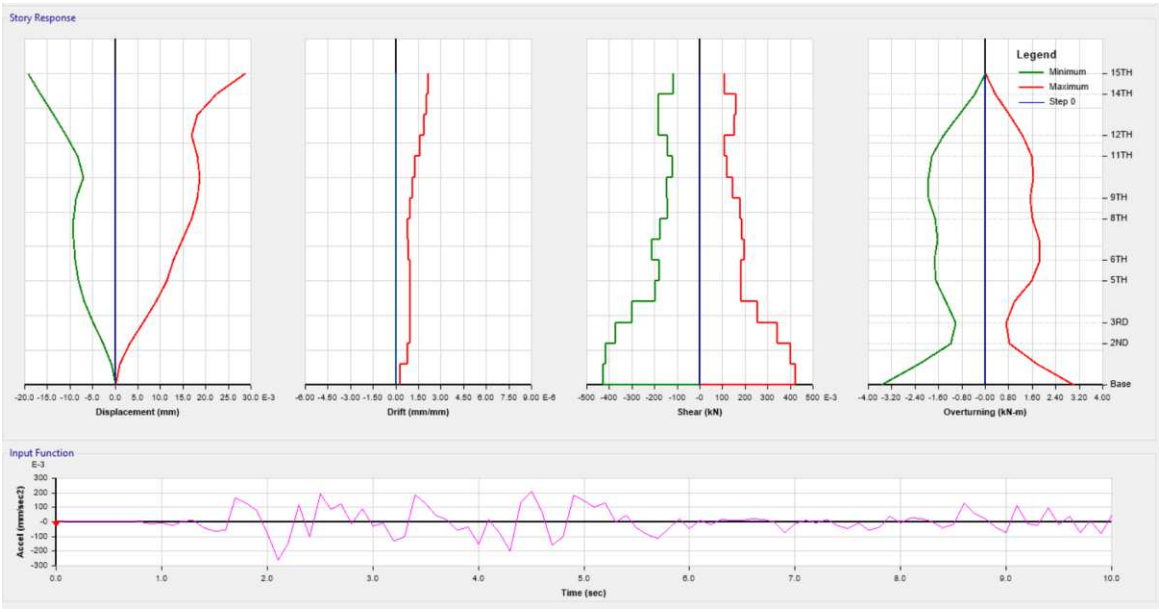


Fig. 12 Story response plot — Composite building under Bhuj time history

Table 10 Comparative seismic performance — Time history analysis (Bhuj 2001)

Parameter	RCC Building	Composite Building	Comparison / Inference
Max. Displacement	±20 mm (upper storeys)	±15 mm	Composite ~25% lower displacement
Storey Drift	0.003–0.004 mm/mm	0.0025–0.003 mm/mm	Composite drift slightly lower
Base Shear	±250 kN	±500 kN	Composite attracts ~double base shear
Overturning Moment	±4.5 kN·m	±2.5 kN·m	RCC develops higher overturning
Acceleration Response	Up to ±240 mm/s²	Up to ±220 mm/s²	Similar range; RCC slightly higher at top

d. Comprehensive Results Summary

Table 11 Overall comparison of seismic performance parameters

Parameter	RCC Structure	Composite Structure	Remarks
Maximum Displacement	±20 mm (upper Storey)	±15 mm	Composite shows ~25% lower displacement, indicating better lateral stiffness.
Storey Drift	0.003–0.004 mm/mm	~0.0025–0.003 mm/mm	Composite drift is slightly lower, improving inter-Storey stability and nonstructural safety.
Base Shear	±250 kN	±500 kN	Composite attracts almost double base shear due to higher stiffness. Foundations and joints must be designed accordingly.
Overturning Moment	±4.5 kN-m	±2.5 kN-m	RCC develops higher overturning. Composite frame distributes seismic energy better, reducing overturning demand.
Acceleration Response	Up to ±240 mm/s²	Up to ±220 mm/s²	Similar acceleration range, but RCC has slightly higher amplification at top storeys.
Overall Structural Response	Higher displacements and overturning, lower shear	Lower displacements and overturning, higher shear	RCC is flexible but stable, Composite is stiffer and stronger but requires stronger foundation design.
Maximum Displacement	±20 mm (upper Storey)	±15 mm	Composite shows ~25% lower displacement, indicating better lateral stiffness.

Key Observations:

- **Weight Reduction:** The composite structure achieves approximately 2.5% reduction in total seismic weight due to lighter structural members (0.30 kN/m² vs. 0.50 kN/m² allowance).
- **Base Shear Reduction:** Proportional reduction in design base shear (~79 kN or 2.5% lower for composite structure).
- **Period Independence:** Both structures have identical fundamental period (T = 0.8235 s) since the empirical formula depends only on height and plan dimension.
- **Design Efficiency:** Composite construction offers seismic load advantage while potentially providing better strength-to-weight ratio.

e. Conclusions

1. Equivalent Static Analysis shows RCC has very high displacements (~455 mm) compared to composite (~3 mm), despite both having similar base shear values.
2. Response Spectrum Analysis reveals RCC controls displacements more effectively, while

composite exhibits larger flexibility with higher roof drift (~108 mm vs. 19 mm).

3. Time History Analysis (Bhuj 2001 earthquake) confirms that RCC structures attract higher seismic shear and accelerations, while composite structures distribute drifts more evenly and sustain lower seismic demand.
4. RCC buildings are stiffer and safer against excessive drift, but they attract higher seismic forces, leading to costlier design.
5. Composite buildings are lighter, economical, and energy-efficient, but require strict drift control measures (bracings or dampers) for serviceability.
6. Overall, composite construction offers an optimised balance between economy and performance for high-rise buildings, provided that drift limitations are adequately addressed.

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