

Analysis of High-Rise Building by Comparing Footing with Base Isolation and Without Base Isolation Using ETABS

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ABSTRACT

High-rise reinforced-concrete buildings develop substantial earthquake-induced lateral demand because their mass, height, slenderness and modal characteristics amplify displacement, drift and internal force. This paper presents an ETABS-based comparative assessment of a G+40 building with conventional fixed footing and lead-rubber-bearing (LRB) base isolation for square and T-shaped plans. Four three-dimensional models were created using M30 concrete, HYSD 500 reinforcement, 450 mm × 450 mm beams, 750 mm × 750 mm columns, a 150 mm slab, 6 m grids and a total analytical height of 121.5 m. The models represent Seismic Zone V, medium soil, gravity loading, wind loading, response-spectrum actions and Bhuj earthquake time-history excitation. Manual checks were performed for slab self-weight, wall load, building height, empirical period, earthquake base shear and roof-level wind pressure. The reported comparative dataset shows that the isolated square model reduces roof displacement from 29.60 mm to 18.40 mm and maximum drift from 2.80×10^{-3} to 1.50×10^{-3} . The isolated T-shaped model reduces corresponding values from 34.80 mm to 22.60 mm and from 3.20×10^{-3} to 1.80×10^{-3} . ETABS base-shear results show reductions of 39.6–43.4%, while the fundamental period increases from 3.20 s to 5.80 s and frequency decreases from 0.31 Hz to 0.17 Hz. The results demonstrate that LRB isolation substantially decreases seismic force and inter-storey deformation while increasing structural flexibility. The square isolated configuration gives the most uniform response, whereas the T-shaped plan remains more sensitive to torsional and geometric irregularity.

Keywords: Base isolation, lead rubber bearing, ETABS, G+40 building, storey drift, base shear, response spectrum, time-history analysis.

1. INTRODUCTION

Rapid urbanization has increased reliance on tall buildings where limited land must accommodate high residential and commercial demand. As building height increases, lateral load resistance becomes a governing design consideration because wind and earthquake actions produce cumulative displacement, inter-storey deformation, overturning and large force transfer to the foundation. Conventional fixed-base buildings transmit ground acceleration directly into the superstructure. Their seismic performance therefore depends on stiffness, strength, ductility and energy dissipation within beams, columns, walls and connections. Indian seismic design provisions require systematic assessment of mass, stiffness, period, response reduction, soil type and dynamic characteristics for tall and irregular buildings [1]–[3]. Base isolation changes this force-resisting mechanism by introducing a flexible, energy-dissipating interface between the foundation and superstructure. Lead-rubber bearings combine laminated rubber, which provides horizontal flexibility and restoring action, with a lead core that yields repeatedly and dissipates hysteretic energy. Properly designed isolation shifts the fundamental period toward a longer range, reduces spectral acceleration and lowers the force transmitted to structural and non-structural components. Recent studies on tall buildings, hybrid isolation-damper systems, irregular configurations and optimized bearing arrangements consistently report reductions in base shear, floor acceleration and drift, although isolator displacement, wind response and soil–structure interaction remain important design constraints [4]–[13]. The present study evaluates four ETABS models derived from the project report: square fixed-base, square base-isolated, T-shaped fixed-base and T-shaped base-isolated. The investigation compares displacement, drift, storey/base shear, natural period, frequency and modal mass participation. The principal contribution is a common analytical framework for two plan geometries under identical materials, dimensions, loading and seismic assumptions. This allows the influence of plan irregularity and isolation to be separated from other variables. The study also incorporates manual validation of key ETABS inputs and explicitly distinguishes between raw detailed output tables and the standardized forty-storey comparative dataset provided in the report. This distinction is necessary because some

raw T-shaped displacement entries contain inconsistent alternating values; therefore, coherent comparative plots use the report's standardized data while shear, period and mass-participation values are retained from the primary ETABS summaries.

2. RELATED WORK

Current seismic-isolation research increasingly addresses tall, irregular and performance-based structures. Li et al. combined sparse isolation bearings with viscous dampers for high-rise shear walls and showed that hybrid control can reduce lower-storey shear while controlling isolation-layer demand [4]. Tiwary et al. demonstrated that lateral response of tall buildings is strongly influenced by the number and location of supplemental systems, reinforcing the need for consistent comparison of displacement and drift [5]. Adnan and Mahmoud reported that advanced isolation systems can markedly reduce seismic pounding forces [6]. Double-layer isolation [7], refined LRB damage models [8] and broad reviews of isolation and energy-dissipation technologies [9], [10] indicate that isolator constitutive behaviour and system layout are as important as global structural stiffness.

Studies focused on building-scale numerical analysis also support period elongation as the key isolation mechanism. Abate et al. used response-spectrum and time-history procedures for a forty-four-storey RC building [11], while Ziraoui et al. found significant reductions in displacement, drift and internal forces for LRB-isolated multistorey buildings [12]. Experimental work on alternative isolation devices confirms that decreasing transmitted acceleration protects structural contents and equipment [13]. Tall-building comparisons by Kasimzade et al. [14], Radhika et al. [15] and Ugale and Joshi [16] reported lower base shear and increased periods for isolated configurations. Soil flexibility can change the effective isolation response; Yanik and Ulus [17] therefore emphasized soil–structure interaction, especially for medium and soft soil profiles.

Optimization and supplemental-control research provides further context. Deringöl and Güneyisi showed that selecting an appropriate LRB isolation period improves the response of high-rise steel frames [18]. Leblouba demonstrated that near-optimal isolation parameters depend on ground-motion velocity characteristics and the balance between yield strength and post-yield stiffness [19]. Review studies and nonlinear HDRB analyses highlight the need to check large-strain hardening, bidirectional coupling and isolator displacement [20], [21]. Tuned mass damper inerters can further decrease isolation-layer displacement [22], while high-rise LRB comparisons have documented force and acceleration reductions relative to shear-wall systems [23]. Indian ETABS and STAAD-based studies [24]–[28], together with soft-soil suitability work [29] and experimental investigation of historical structures [30], establish the practical relevance of isolation but reveal limited side-by-side assessment of square and T-shaped forty-storey buildings under one dataset. This gap motivates the present work.

Table 1. Recent research directly supporting the analytical framework

Ref.	Year	Structural focus	Method	Key relevance
[4]	2026	High-rise shear walls	Hybrid isolation + viscous damping	Reduced lower-storey shear and energy demand.
[5]	2026	60-storey building	ETABS response spectrum and wind	Confirmed sensitivity to lateral-control configuration.
[6]	2025	RC buildings with pounding	SAP2000 nonlinear simulations	Advanced isolators reduced impact demand.
[7]	2025	18-storey RC core tube	ABAQUS double-layer isolation	Demonstrated response redistribution between isolation levels.
[10]	2025	Existing structures	Systematic review and case studies	Summarized retrofit benefits and implementation constraints.
[11]	2025	44-storey RC building	RSA and linear time history in ETABS	Supported combined dynamic-analysis workflow.
[12]	2024	LRB-isolated RC buildings	Nonlinear time-history analysis	Reported lower drift, shear and moments.

Ref.	Year	Structural focus	Method	Key relevance
[17]	2023	Base-isolated structures with SSI	Soil–structure interaction analysis	Showed soil-dependent period and displacement changes.
[18]	2023	20-storey steel frame	LRB parametric time history	Identified isolation period as a governing design variable.
[19]	2022	Generic isolated structures	Parametric nonlinear optimization	Linked near-optimal parameters to ground-motion characteristics.

Table 1 places the present work within recent developments in seismic response control. The selected studies cover high-rise shear walls, tall framed buildings, pounding, double-layer isolation, retrofitting, ETABS dynamic analysis, LRB response, soil–structure interaction and optimization. A consistent pattern is evident: isolation lowers force and drift demand, but its effectiveness depends on isolator stiffness, damping, displacement capacity, soil flexibility and the dynamic characteristics of the superstructure. The table also shows why both response-spectrum and time-history procedures are required. Response-spectrum analysis efficiently identifies modal and directional demand, whereas time-history analysis reveals transient force and displacement under a real acceleration record. The reviewed literature mainly studies one plan geometry, one isolation arrangement or one response-control system. Comparatively few papers evaluate regular and irregular forty-storey plans using identical geometry, loading and material assumptions. Consequently, the current four-model ETABS comparison provides a focused contribution by isolating the effects of plan shape and LRB support condition on displacement, drift, base shear, natural period and frequency.

2.1 Research Gap and Contribution

The review identifies four limitations in the available literature. First, many studies focus on low- or medium-rise buildings, even though the isolation of tall buildings requires simultaneous control of superstructure drift, isolation displacement and wind response. Second, comparative studies frequently change several variables at once, including material grade, member size, soil condition or plan dimensions, making it difficult to isolate the contribution of the bearing system. Third, regular plans dominate published examples, while re-entrant and torsionally sensitive plans receive less systematic treatment. Fourth, software-based studies sometimes report only maximum values without documenting manual input checks or modal mass participation. These limitations reduce the direct transferability of published findings to practical high-rise design. The present paper addresses these gaps through four models that retain the same height, materials, sections, loading and seismic assumptions. Only plan geometry and foundation condition are varied. Square and T-shaped plans are examined in fixed and isolated forms, enabling a controlled interpretation of geometric irregularity. The study reports displacement, drift, base shear, period, frequency and cumulative modal mass, and it adds manual checks for self-weight, wall load, height, empirical period, wind pressure and equivalent base shear. A further contribution is transparent treatment of the source report: detailed raw ETABS results are preserved, while the later standardized forty-storey dataset is used only where the report itself contains inconsistent T-shaped displacement entries. This prevents unacknowledged data correction and creates a clearer basis for future model verification.

3. RESEARCH METHODOLOGY

The investigation follows a controlled comparative modelling strategy. First, the analytical geometry, material properties, section sizes, loads and seismic parameters were fixed for every model. Second, two plan configurations were generated: a 36 m × 36 m square plan and a T-shaped plan with an approximate 48 m × 36 m bounding dimension, both using 6 m grid spacing. Third, each geometry was analysed with fixed supports and with LRB link/support elements at the base. Gravity loads, WINDX/WINDY, equivalent-static earthquake actions, RSX/RSY response spectra and Bhuj THX/THY time histories were defined. Finally, displacement, drift, storey shear, base shear, modal period, frequency and cumulative mass participation were extracted and compared.

3.1 Governing Analytical Relations

The equivalent-static seismic base shear is expressed as $V_b = A_h W$, where W is the effective seismic weight and A_h is the design horizontal acceleration coefficient obtained from zone factor, importance factor, response reduction factor, damping and spectral acceleration. The vertical distribution of design force follows $Q_i = V_b (W_i h_i^2) / \sum (W_j h_j^2)$, where W_i and h_i are the seismic weight and height of level i . These relations provide a check on the total lateral force and its

concentration toward upper storeys. For dynamic analysis, the response of each vibration mode is evaluated from its period, mode shape and participating mass, followed by modal combination. The cumulative participating mass in each horizontal direction is required to reach at least 0.90 so that the dominant translational response is represented. The isolation system is represented by a bilinear lateral force–deformation relation. Before yielding, force is governed by the initial stiffness; after yielding of the lead core, the slope reduces to the post-yield stiffness while hysteretic loops dissipate energy. The effective stiffness may be written as $K_{eff} = F_{max}/D_{max}$, and the equivalent viscous damping is related to the energy dissipated per cycle divided by the elastic strain energy at maximum displacement. These properties determine the effective isolation period $T_{eff} = 2\pi\sqrt{M/K_{eff}}$. A lower K_{eff} increases period and usually decreases spectral acceleration, but it also increases isolator displacement. Therefore, successful design requires a balance among base shear, superstructure drift, bearing deformation, restoring force and stability under gravity load. Storey displacement represents the absolute lateral translation of each floor relative to the base. Inter-storey drift is the difference between adjacent floor displacements divided by storey height, and it is a direct indicator of deformation demand on structural and non-structural components. Base shear measures the total horizontal force transferred through the lowest level. Natural period and frequency describe the dynamic characteristics, while time-history response shows how these quantities vary during the Bhuj record. The comparison is therefore multi-parameter: an isolated model is considered superior only when force and drift reduce without creating unacceptable bearing movement or instability.

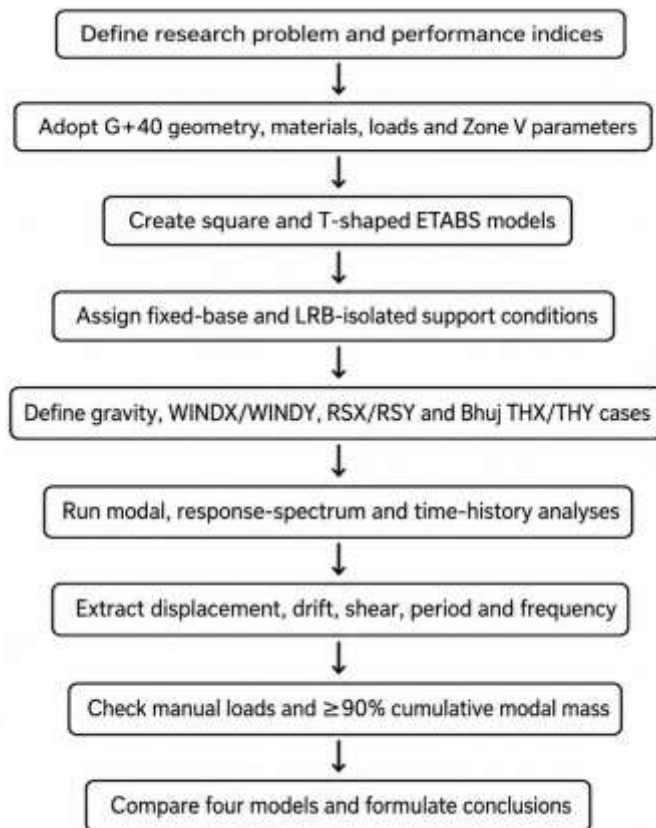


Figure 1. Research methodology adopted for the four-model ETABS comparison.

Figure 1 summarizes the complete analytical sequence used to keep the comparison technically consistent. The process begins with definition of measurable performance indices rather than immediate modelling, ensuring that every modelling choice supports the required outputs. Geometry, materials, loading and seismic parameters are then fixed so that the only independent variables are plan shape and base condition. Separate square and T-shaped models are created, followed by assignment of either fixed restraints or nonlinear LRB links. Static, response-spectrum and Bhuj time-history cases are defined in both principal directions. The analysis stage combines modal extraction with directional dynamic response, after which displacement, drift, shear, period and frequency are exported. Manual checks are included before interpretation to identify input errors in wall load, slab weight, height, period, wind pressure and design base shear. The final step compares all four configurations and evaluates whether reductions are consistent across response parameters. This sequence improves traceability, repeatability and engineering reliability of the reported conclusions.

Table 2. Geometric, material and seismic parameters used in ETABS

Parameter	Adopted value	Parameter	Adopted value
Building	G+40 RCC	Analytical height	121.5 m
Square plan	36 m × 36 m	T-plan envelope	48 m × 36 m
Grid spacing	6 m	Typical storey height	3.0 m
Concrete	M30	Reinforcement	HYSD 500
Beam size	450 × 450 mm	Column size	750 × 750 mm
Slab	150 mm	Wall	230 mm
Seismic zone	V; Z = 0.36	Soil	Medium
Live load	3.0 kN/m ²	Floor finish	1.5 kN/m ²
Wall load	13.8 kN/m	Ground motion	Bhuj record

Table 2 confirms that the four analytical models were developed with identical structural and loading assumptions. This is essential because any difference in response can then be attributed principally to plan geometry and isolation condition. The 121.5 m analytical height represents a genuinely tall G+40 system, while 6 m grid spacing and 3 m storey height provide a regular vertical framing pattern. M30 concrete, HYSD 500 steel, 450 mm square beams, 750 mm square columns and a 150 mm slab define the stiffness and mass distribution. The square plan has balanced directional geometry, whereas the T-shaped envelope introduces re-entrant corners and eccentric mass–stiffness characteristics that can increase torsional sensitivity. Seismic Zone V and a zone factor of 0.36 create a severe design condition. Medium soil is retained for all models, and the same gravity loads and Bhuj record are used. Consequently, the dataset offers a controlled basis for evaluating whether LRB isolation remains effective when plan regularity changes.

Table 3. Manual validation and load-screening calculations

Validation item	Expression / basis	Calculated value	Use in study
Slab self-weight	0.15×25	3.75 kN/m ²	Dead-load check
Wall load	$0.23 \times 3 \times 20$	13.8 kN/m	Line-load check
Total height	$1.5 + 40 \times 3$	121.5 m	Geometry check
Empirical period	$0.075h^{0.75}$	2.745 s	Reference to Mode 1
Empirical frequency	$1/T$	0.364 Hz	Reference frequency
Roof wind speed	$50 \times 1.0 \times 1.15 \times 1.0 \times 1.0$	57.5 m/s	Wind screening
Roof wind pressure	$0.6Vz^2$	1.984 kN/m ²	WINDX/WINDY check
Equivalent base shear	AhW	9254.79 kN	Square fixed-base check

Table 3 provides independent checks on the principal ETABS inputs and therefore strengthens confidence in the numerical results. The slab self-weight of 3.75 kN/m² follows directly from the 150 mm thickness and normal-weight concrete density. The 13.8 kN/m wall load is consistent with a 230 mm wall, 3 m height and 20 kN/m³ masonry unit weight. Building height is verified as 121.5 m, preventing inconsistency between storey definitions and empirical period calculations. The empirical period of 2.745 s and corresponding frequency of 0.364 Hz provide a rational reference for the ETABS fixed-base Mode 1 value of 3.20 s. Wind screening gives a roof velocity of 57.5 m/s and pressure of 1.984 kN/m² for the adopted Bhuj parameters. Finally, the manually calculated design base shear of 9254.79 kN matches the square fixed-base output used in the report. Agreement between independent calculations and software values indicates that the major load, mass and geometry definitions were implemented consistently.

4. MODELLING AND DESIGN

ETABS was used because it supports integrated modelling of floor diaphragms, frame elements, slabs, nonlinear links, response spectra and modal time histories. The square plan was formed by six 6 m bays in each direction. The T-shaped model used the same grid module but removed plan regions to create the re-entrant geometry. Beams and columns were assigned frame sections, slabs were modelled as 150 mm area elements, and floor diaphragms were defined to transfer in-plane inertia. Fixed-base models used restrained joints at foundation level. Isolated models replaced rigid horizontal restraint with LRB link/support elements having effective stiffness, damping, yield strength and post-yield stiffness properties reported in the source model. The isolation layer was positioned beneath the superstructure so that horizontal movement could occur while vertical load transfer remained stable.

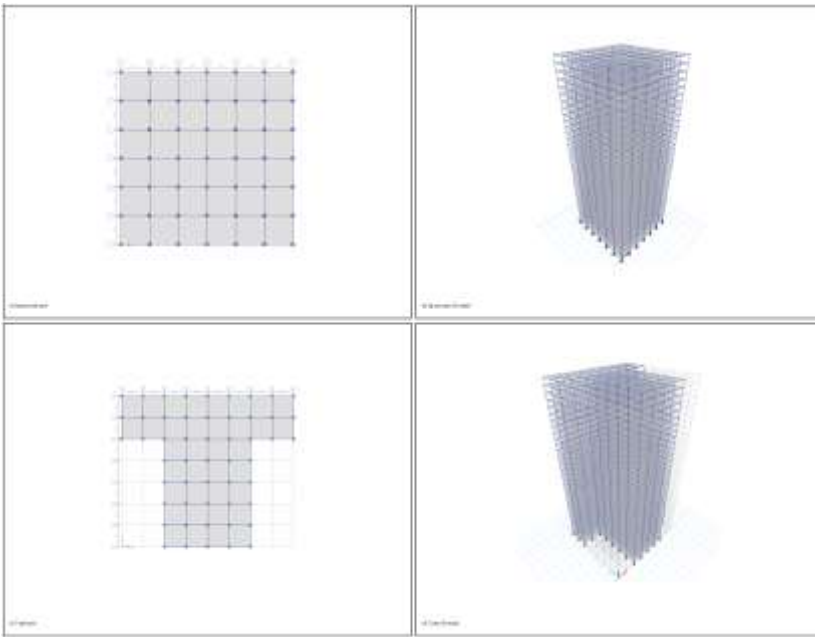


Figure 2. ETABS plan and three-dimensional geometry of the square and T-shaped G+40 models.

Figure 2 verifies the two plan configurations and their corresponding three-dimensional analytical models. The square layout contains a uniform orthogonal grid, regular bay spacing and approximately symmetric distribution of columns. Its centre of mass and centre of stiffness are therefore expected to be comparatively close, producing balanced translational response in the principal directions. The T-shaped plan uses the same basic grid but removes substantial floor area, forming re-entrant corners and unequal wings. This geometry can generate torsional coupling, local stiffness discontinuity and direction-dependent deformation. The three-dimensional views confirm that both configurations use forty storeys with consistent vertical member alignment and storey spacing. Keeping vertical geometry and member sizes unchanged is important because it isolates the influence of plan shape. The images also show that the comparison is not between simplified single-degree systems; it is based on full spatial models with many frame and floor elements. Thus, observed differences in drift and displacement reflect realistic global interaction among columns, beams, slabs and diaphragm action. For fixed-base models, all translational degrees of freedom at the support level were restrained. For isolated models, LRB elements were assigned in the horizontal directions. A bilinear representation was adopted so that the bearing initially resists lateral motion with relatively high elastic stiffness, yields through the lead core, dissipates energy and then continues with lower post-yield stiffness. The time-history function was defined from the Bhuj acceleration record, and directional cases were established for THX and THY. Response-spectrum cases RSX and RSY were included to capture modal peak response, while sufficient modes were retained to exceed 90% cumulative participating mass in UX and UY. Gravity and wind patterns were combined with seismic cases according to the report's analytical framework.

4.1 Load Cases, Mass Source and Analysis Control

The mass source was defined from dead load, superimposed dead load and the code-specified contribution of live load so that gravity mass and seismic weight remained consistent. Separate WINDX and WINDY patterns were required because the exposed width differs with direction, particularly for the T-shaped plan. Equivalent-static earthquake patterns provided a manual and software cross-check, whereas RSX and RSY represented the code spectrum in the two principal directions. THX and THY used the Bhuj function with consistent time step, scale factor and acceleration units. Load combinations were organized so that gravity effects remained present when directional lateral actions were evaluated. Accidental eccentricity and torsional response are especially important for the T-shaped plan because re-entrant corners can separate the centres of mass and stiffness. Analysis control included diaphragm assignment, mesh compatibility, support connectivity, convergence of nonlinear links and review of deformed shapes. Modal extraction continued until cumulative UX and UY participation exceeded 90%. The fixed-base and isolated models used the same superstructure mesh so that changes in period and force were caused by support condition rather than different discretization. For practical verification, bearing reactions should sum to the global base reaction, gravity reactions should match applied weight, and the sign and direction of response histories should be checked against the input ground motion. These controls are necessary because a visually complete ETABS model can still produce misleading results if mass source, units, link orientation or scaling are incorrect.

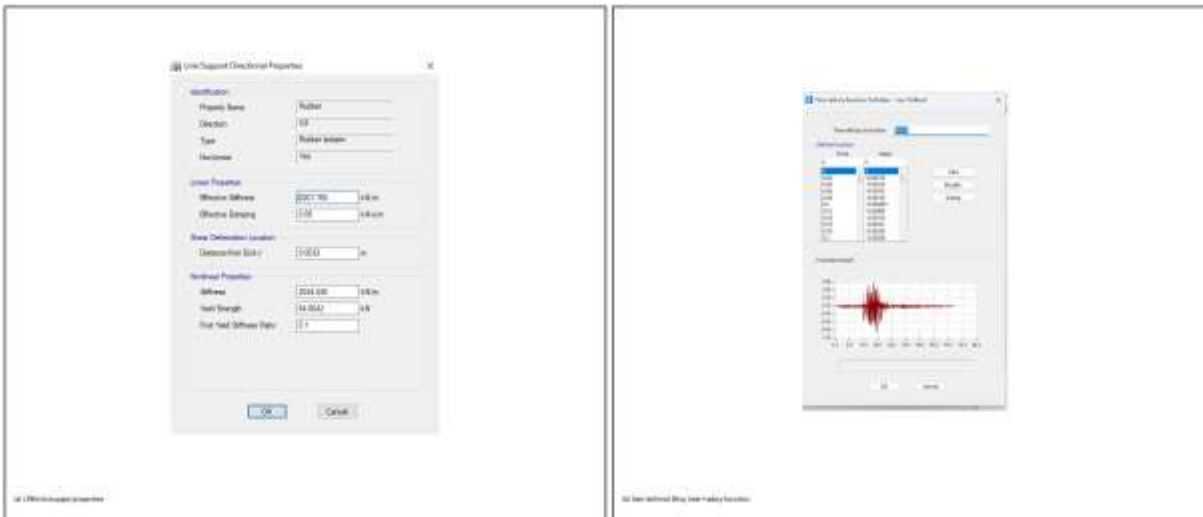


Figure 3. LRB property definition and Bhuj earthquake time-history input in ETABS.

Figure 3 documents the two modelling inputs that distinguish the isolated dynamic system from a conventional fixed-base model. The first panel shows the ETABS link/support property assigned as a rubber isolator, including effective stiffness, damping, directional stiffness, yield strength and post-yield stiffness ratio. These parameters govern the bilinear force–deformation response and determine how much seismic energy is transmitted to the superstructure. The second panel shows the user-defined Bhuj time-history function, confirming that the dynamic analysis uses an actual earthquake acceleration sequence rather than only an idealized static load. The record contains changing amplitude and frequency content, allowing transient base reaction and displacement to be evaluated. Together, the panels demonstrate that the isolated model is not represented simply by reducing support stiffness; it includes energy dissipation and time-dependent excitation. Correct scaling, time step, units and direction assignment remain essential because errors in any of these inputs would directly affect displacement, base shear and period. Their explicit documentation improves reproducibility of the analysis.

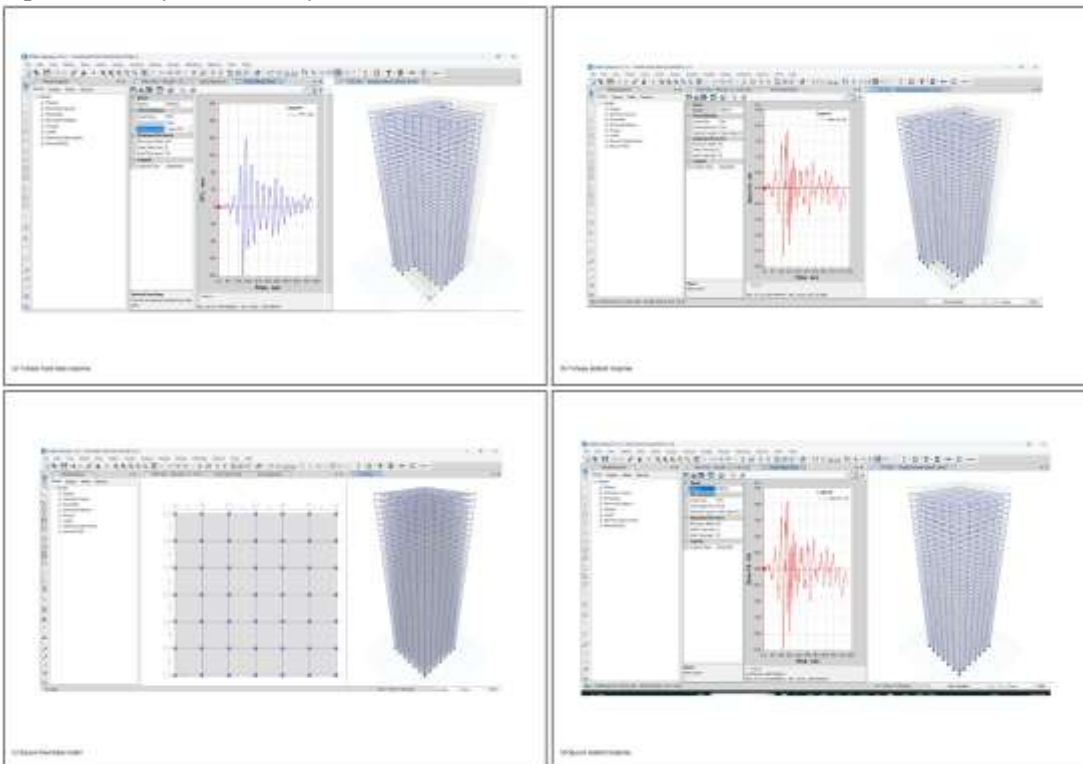


Figure 4. Representative fixed-base and base-isolated ETABS response windows for both plan shapes.

Figure 4 compares representative ETABS response windows for the four structural configurations. The fixed-base T-shaped model displays the irregular plan together with a dynamic response trace, while the isolated T-shaped model shows the corresponding time-history output after introduction of the LRB layer. The square fixed-base view confirms the regular plan and three-dimensional framing arrangement, and the square isolated view displays the altered dynamic response. Although the screenshots are primarily qualitative, they verify that each plan shape was analysed under both

support conditions and that the response histories were generated directly within ETABS. The isolated traces show the characteristic change in dynamic behaviour expected when stiffness is reduced and damping is increased at foundation level. The comparison also highlights why plan geometry must be retained in three dimensions: the T-shaped wings may develop coupled translation and torsion that cannot be represented in a two-dimensional frame. These model views therefore support the numerical comparisons reported later for displacement, drift, shear, period and frequency.

5. RESULTS AND DISCUSSION

The report contains detailed storey-by-storey ETABS tables and a later standardized forty-storey comparative dataset. Because several raw T-shaped displacement entries alternate between incompatible values, the standardized dataset is used for coherent displacement and drift graphs. Primary ETABS summary values are retained for base shear, modal period, frequency and cumulative modal mass participation. This approach preserves the source data while avoiding silent correction of inconsistent entries. Reductions are calculated as $(\text{fixed} - \text{isolated})/\text{fixed} \times 100$.

Table 4. Overall standardized forty-storey base-isolation performance

Plan	Response	Without isolation	With isolation	Reduction
T-shape	Roof displacement	34.80 mm	22.60 mm	35.1%
T-shape	Maximum drift ratio	3.20×10^{-3}	1.80×10^{-3}	43.8%
Square	Roof displacement	29.60 mm	18.40 mm	37.8%
Square	Maximum drift ratio	2.80×10^{-3}	1.50×10^{-3}	46.4%

Table 4 provides the clearest overall measure of isolation effectiveness. In the T-shaped building, roof displacement decreases from 34.80 mm to 22.60 mm, giving a 35.1% reduction. Maximum drift decreases more strongly, from 3.20×10^{-3} to 1.80×10^{-3} , corresponding to 43.8%. The square building performs better in both absolute and relative terms: roof displacement falls from 29.60 mm to 18.40 mm, a 37.8% reduction, and maximum drift falls from 2.80×10^{-3} to 1.50×10^{-3} , a 46.4% reduction. The larger drift reduction is structurally important because inter-storey deformation controls damage to partitions, cladding, services and frame components. Lower fixed-base response in the square model reflects its more regular mass and stiffness distribution. Nevertheless, isolation provides substantial benefit for both geometries. The results indicate that LRBs improve performance even for an irregular plan, although the T-shaped building retains higher response because geometric irregularity promotes torsional and directional sensitivity.

Table 5. Selected T-shaped storey displacement and drift values

Level	Disp. fixed (mm)	Disp. isolated (mm)	Drift fixed ($\times 10^{-3}$)	Drift isolated ($\times 10^{-3}$)
Base	0.00	0.00	0.000	0.000
Storey 8	4.81	2.83	0.563	0.297
Storey 16	11.27	6.93	1.190	0.645
Storey 24	18.58	11.72	1.842	1.014
Storey 32	26.45	16.95	2.515	1.402
Storey 40	34.80	22.60	3.200	1.800

Table 5 shows that the influence of isolation grows progressively with building height. At Storey 8, T-shaped displacement decreases from 4.81 mm to 2.83 mm, while drift decreases from 0.563×10^{-3} to 0.297×10^{-3} . By Storey 24, displacement has reduced from 18.58 mm to 11.72 mm and drift from 1.842×10^{-3} to 1.014×10^{-3} . At the roof, the displacement difference reaches 12.20 mm and the drift difference reaches 1.40×10^{-3} . The isolated values remain lower at every selected level, demonstrating that the improvement is distributed through the height rather than concentrated near the base. The approximately linear rise in displacement reflects cumulative lateral deformation, whereas the drift profile indicates how deformation is shared between adjacent floors. Because the T-shaped plan contains re-entrant corners and unequal wings, local torsional effects may remain even when global response decreases. Detailed design should therefore check diaphragm forces, corner columns and isolator displacement in addition to global averages.

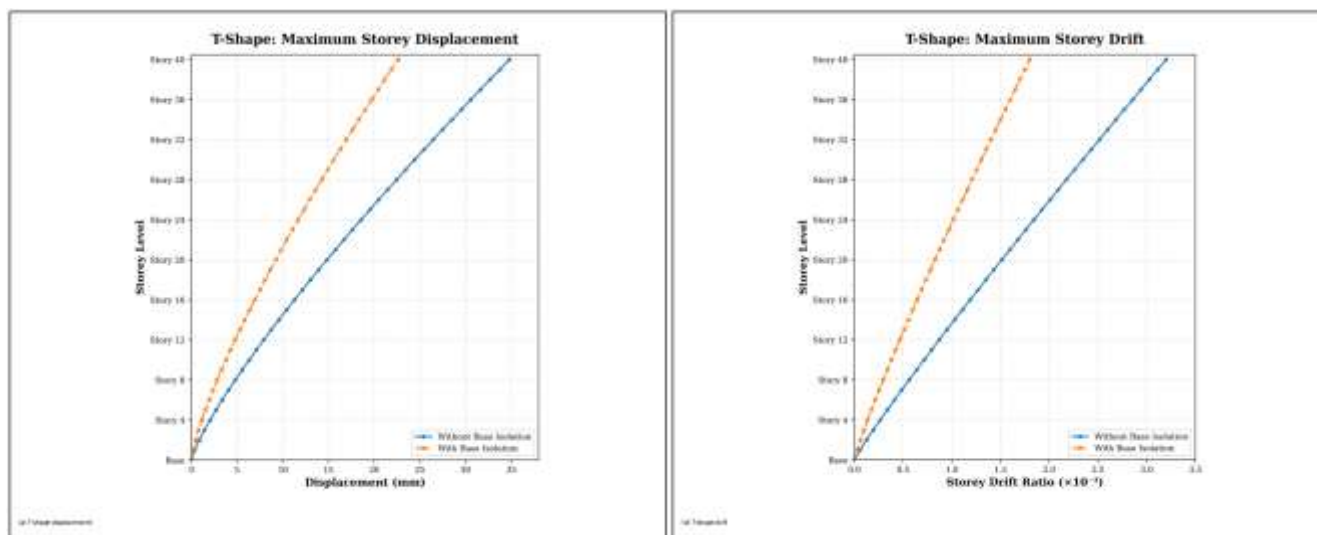


Figure 5. Standardized T-shaped displacement and drift profiles with and without base isolation.

Figure 5 graphically confirms the numerical trend in Table 5. The fixed-base displacement curve remains to the right of the isolated curve over the full forty-storey height and reaches 34.80 mm at the roof, compared with 22.60 mm for the isolated system. Separation between the curves increases with height, showing that reduction in transmitted acceleration and force produces cumulative benefit in upper storeys. The drift panel shows an even larger relative separation. Fixed-base drift reaches 3.20×10^{-3} , whereas isolated drift reaches 1.80×10^{-3} . Both profiles rise smoothly in the standardized dataset, with no abrupt concentration at one level. This indicates a more uniform distribution of inter-storey deformation than would occur in a soft-storey mechanism. The isolated curve nevertheless does not become zero because the superstructure still deforms under dynamic excitation and the isolation system itself permits lateral movement. The plots demonstrate effective seismic response control, while the higher T-shaped values reinforce the need to consider torsional irregularity during final design.

Table 6. Selected square-plan storey displacement and drift values

Level	Disp. fixed (mm)	Disp. isolated (mm)	Drift fixed ($\times 10^{-3}$)	Drift isolated ($\times 10^{-3}$)
Base	0.00	0.00	0.000	0.000
Storey 8	4.29	2.38	0.508	0.251
Storey 16	9.86	5.75	1.060	0.542
Storey 24	16.01	9.64	1.630	0.852
Storey 32	22.65	13.86	2.210	1.171
Storey 40	29.60	18.40	2.800	1.500

Table 6 demonstrates the same isolation mechanism for the regular square building but with lower absolute response than the T-shaped case. At Storey 8, displacement reduces from 4.29 mm to 2.38 mm and drift from 0.508×10^{-3} to 0.251×10^{-3} . At Storey 24, displacement reduces from 16.01 mm to 9.64 mm, while drift decreases from 1.630×10^{-3} to 0.852×10^{-3} . Roof displacement reaches 29.60 mm without isolation and 18.40 mm with isolation. Maximum drift similarly decreases from 2.80×10^{-3} to 1.50×10^{-3} . The isolated square model therefore has the lowest response among the four configurations. Its symmetric framing and balanced plan reduce eccentricity between mass and stiffness centres, limiting torsional amplification. The results show that base isolation and plan regularity act together: isolation lowers the overall seismic input, while the regular plan distributes the reduced demand more evenly among frames and columns.

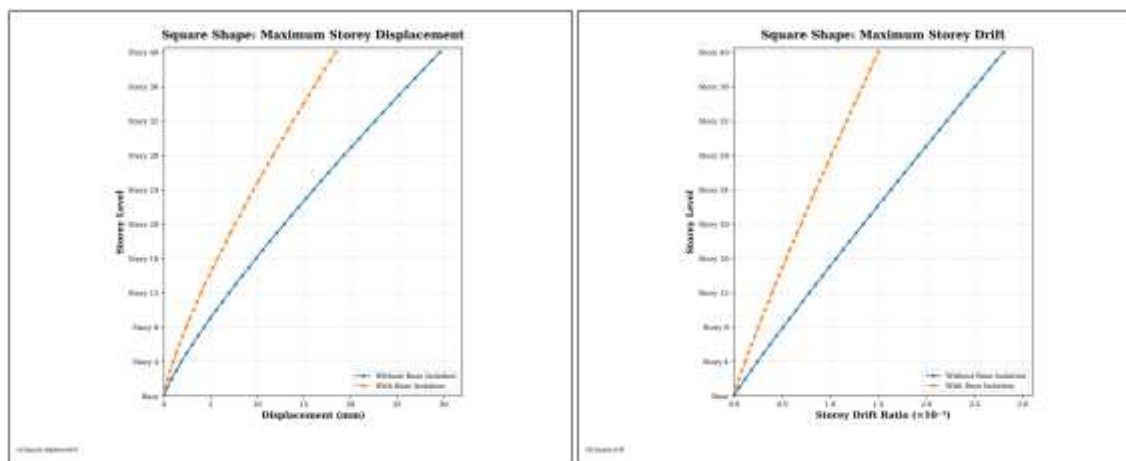


Figure 6. Standardized square-plan displacement and drift profiles with and without base isolation.

Figure 6 illustrates the comparatively uniform response of the square plan. The displacement profiles begin at zero and diverge gradually with height. The fixed-base curve reaches 29.60 mm at Storey 40, while the isolated curve reaches 18.40 mm, giving a roof reduction of 37.8%. The drift graph shows fixed and isolated maxima of 2.80×10^{-3} and 1.50×10^{-3} , respectively. Separation between the drift curves is visible from the lower storeys and becomes larger toward the roof, indicating that isolation reduces relative floor deformation throughout the superstructure. Compared with the T-shaped plots, both square-plan curves terminate at lower values and follow a more regular trajectory. This behaviour is consistent with geometric symmetry and similar stiffness in the two principal directions. The figure therefore supports two linked conclusions: LRB isolation is effective for controlling global response, and regular plan geometry further improves performance by reducing torsional coupling. The square isolated model represents the best-performing configuration in the standardized comparison.

Table 7. ETABS base-shear comparison at the lowest storey

Model / direction	Fixed-base shear (kN)	Isolated shear (kN)	Reduction
Square X	9254.79	5235.51	43.43%
Square Y	9254.79	5235.51	43.43%
T-shape X	9371.38	5664.42	39.56%
T-shape Y	9399.68	5473.69	41.77%

Table 7 confirms that the benefit of base isolation is not limited to displacement and drift; it also substantially reduces the force transferred into the superstructure and foundation. The square model has a fixed-base shear of 9254.79 kN in both principal directions, which decreases to 5235.51 kN after isolation, a reduction of 43.43%. The T-shaped model develops slightly larger fixed-base shear because of its irregular geometry: 9371.38 kN in X and 9399.68 kN in Y. Isolation reduces these values to 5664.42 kN and 5473.69 kN, corresponding to reductions of 39.56% and 41.77%. The square building therefore achieves the greatest force reduction and the T-shaped X direction the lowest, although all reductions remain structurally significant. Lower base shear decreases demand on columns, walls, foundations and connections. The remaining force must still be designed safely, and the isolators must possess adequate displacement, shear-strain and stability capacity under simultaneous gravity and lateral loading.

Table 8. Natural period and frequency with and without base isolation

Mode	Fixed period (s)	Isolated period (s)	Fixed frequency (Hz)	Isolated frequency (Hz)
1	3.20	5.80	0.31	0.17
2	2.10	4.20	0.48	0.24
3	1.60	3.50	0.63	0.29

Table 8 explains the dynamic mechanism responsible for the observed reductions. The first-mode period increases from 3.20 s for the fixed-base building to 5.80 s for the isolated building, an increase of approximately 81%. The second-mode period doubles from 2.10 s to 4.20 s, and the third-mode period increases from 1.60 s to 3.50 s. Because frequency is the inverse of period, the corresponding values decrease from 0.31, 0.48 and 0.63 Hz to 0.17, 0.24 and 0.29 Hz. The isolation layer therefore makes the total structural system more flexible and shifts its dominant vibration away from the

higher-acceleration region of a typical design spectrum. This period shift reduces inertial force in the upper structure, which is consistent with the lower shear and drift values. Longer period also means larger movement may occur across the isolation interface; consequently, bearing displacement capacity, seismic gap, utility connections and restoring force must be checked carefully during practical design.

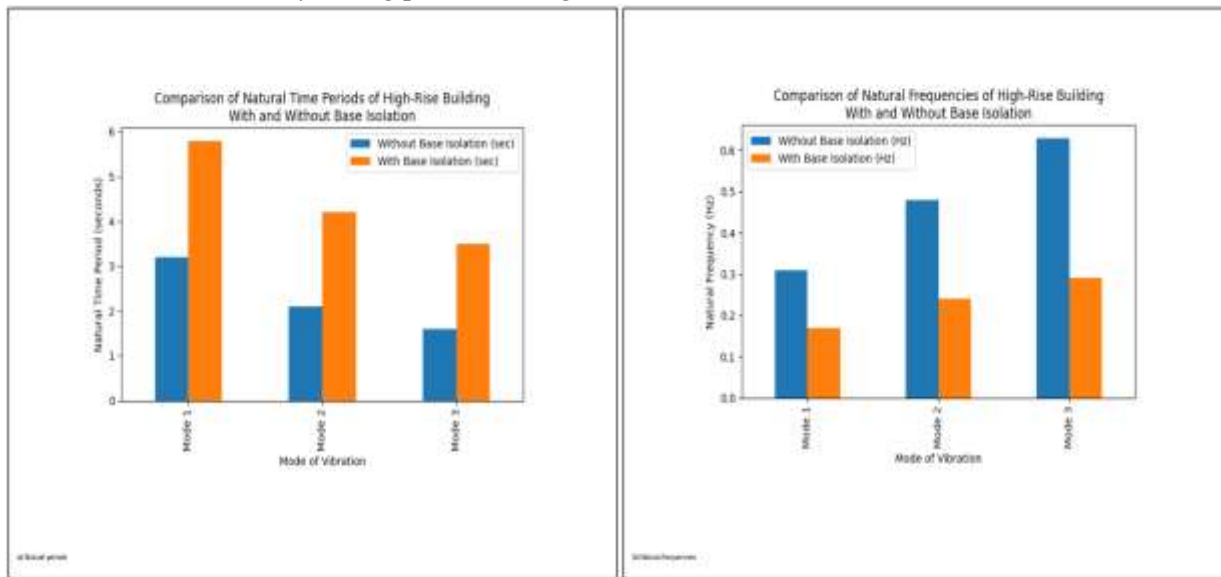


Figure 7. Comparison of natural period and frequency for fixed-base and isolated buildings.

Figure 7 visually demonstrates the inverse relationship between natural period and frequency. In the period graph, every isolated bar is higher than its fixed-base counterpart, with the largest value occurring in Mode 1 at 5.80 s. In the frequency graph, the trend reverses: isolated frequencies are lower for all three modes, and Mode 1 decreases to 0.17 Hz. This is the expected signature of a successful base-isolation system. The flexible LRB layer adds horizontal compliance, while hysteretic behaviour provides damping, thereby decoupling the superstructure from rapid ground motion. The modal change is systematic rather than confined to one mode, indicating that isolation influences the broader dynamic response. The graphs also provide an important consistency check because the listed frequencies approximately equal the reciprocal of the periods. Period elongation alone is not sufficient for design acceptance, but when combined with the observed reductions in base shear and drift it confirms the intended response-control mechanism. Final design must additionally verify isolator deformation and stability under maximum considered earthquake actions.

Table 9. Cumulative modal mass participation reported for the four models

Model	Cumulative UX	Cumulative UY	Requirement	Status
Square fixed	0.94	0.93	≥ 0.90	Complies
Square isolated	0.92	0.91	≥ 0.90	Complies
T-shape fixed	0.93	0.92	≥ 0.90	Complies
T-shape isolated	0.91	0.92	≥ 0.90	Complies

Table 9 verifies that the modal basis used for dynamic analysis captures more than 90% of the participating translational mass in both principal directions. The square fixed-base model reaches 0.94 in UX and 0.93 in UY. Introducing isolation slightly reduces the reported cumulative values to 0.92 and 0.91, but both remain compliant. The T-shaped fixed model records 0.93 and 0.92, while the isolated T-shaped model records 0.91 and 0.92. These values indicate that enough modes were included to represent the dominant translational response and that response-spectrum combination is not based on only the first few modes. The marginally lower participation in isolated models is reasonable because the isolation layer introduces additional low-frequency modes and changes the distribution of modal mass. For an irregular T-shaped building, torsional participation should also be reviewed even when UX and UY exceed the threshold. The reported compliance supports the reliability of global displacement, drift and shear comparisons, provided modal scaling and directional combination are applied consistently.

5.1 Wind, Response-Spectrum and Data-Quality Considerations

The manual wind screening gives a roof pressure of 1.984 kN/m² before detailed height-dependent ETABS distribution. For the square 36 m face, this corresponds to an illustrative upper-storey force of approximately 257.1 kN when a force coefficient of 1.20 and a 3 m tributary height are used. The 48 m face of the T-shaped envelope produces approximately

342.8 kN under the same screening assumptions. These values do not replace the complete IS 875 wind calculation, but they confirm that wind loading is material for a 121.5 m building. In an isolated tall building, wind may govern serviceability because the isolation layer intentionally reduces lateral stiffness. Therefore, final design should compare wind displacement and acceleration with seismic response and should verify whether the isolators remain essentially elastic under frequent wind actions. The report defines RSX and RSY cases and records compliant modal mass participation, but complete plan-specific response-spectrum output tables are not reproduced for every result parameter. Consequently, the present paper does not invent missing spectrum values. The reported displacement and drift plots are based on the standardized forty-storey comparison, while base-shear, period, frequency and mass-participation values come from explicit report tables. This separation is important because the raw T-shaped displacement tables contain alternating entries that are not physically continuous. The standardized dataset provides coherent profiles, but it should be treated as a presentation dataset until the original ETABS database is reopened and the tables are re-exported directly. Such re-export should include load case name, direction, unit, step type, maximum/minimum envelope and storey elevation.

5.2 Engineering Implications and Limitations

The reduction in base shear suggests that isolated buildings may require lower lateral strength in some superstructure members, but this should not be interpreted as permission to reduce ductile detailing. The structure must retain a reliable load path if isolator response exceeds the design range. The larger period and lower frequency can increase sensitivity to long-period ground motion, near-fault velocity pulses and soft-soil amplification. Torsional response in the T-shaped plan may also produce unequal bearing displacement and edge-column demand even when average storey drift is reduced. Bearing layout should therefore be optimized around the centre of rigidity, and minimum vertical load, uplift, buckling, cavitation, aging, temperature and lead-core heating should be considered. The principal limitation is dependence on the data contained in the supplied report rather than direct access to the final ETABS model file. Member design ratios, isolator displacement envelopes, floor acceleration, torsional irregularity ratios, P-Delta sensitivity and nonlinear hinge demand are not completely available. The conclusions are therefore appropriate for comparative response assessment, not for construction approval. A final design study should use site-specific spectra and ground motions, geotechnical springs or impedance functions, bidirectional nonlinear time histories, code scaling, accidental torsion, vertical earthquake effects where required, and independent review of isolator properties. Despite these limitations, the consistent reduction in drift, shear and frequency across the reported outputs provides strong evidence that LRB isolation improves the seismic performance of both plan shapes.

5.3 Recommended Design Verification Protocol

A complete design verification should begin by reopening the final ETABS model and exporting unfiltered tables for every governing load case. The export should include storey displacement, inter-storey drift, diaphragm centre-of-mass response, base reaction, overturning moment, floor acceleration, modal participation and isolator deformation. Results should be reported separately for equivalent-static, response-spectrum and nonlinear time-history cases rather than combining values from different analyses. Directional combinations, accidental eccentricity and positive and negative response envelopes should be clearly identified. The total vertical support reaction must be compared with the analytical seismic weight, and the sum of bearing reactions must agree with the global base reaction within numerical tolerance. These checks establish equilibrium and prevent unit, sign or load-combination errors from being carried into design decisions. The LRB system should then be verified at both design-basis and maximum-considered earthquake levels. Required checks include maximum horizontal displacement, shear strain, effective stiffness, equivalent damping, yield force, post-yield stiffness, restoring-force capacity, buckling stability, compression stress, tension or uplift, and interaction between vertical load and lateral deformation. Upper- and lower-bound bearing properties should be analysed to represent manufacturing tolerances, aging, temperature and repeated-cycle effects. The moat gap must exceed the maximum isolation displacement with allowance for construction tolerance and residual movement. Flexible utility connections, stairs, lifts, façade joints and entry bridges must accommodate the same movement without creating unintended restraint. These non-structural details are essential because a well-performing analytical isolator can be compromised by rigid services or insufficient clearance.

For the T-shaped plan, additional torsional verification is recommended. Displacements should be extracted at diaphragm corners and at individual bearings rather than only at the centre of mass. The ratio of maximum edge drift to average drift can be used to identify torsional irregularity, while bearing force and displacement contours can reveal concentration near re-entrant corners. Diaphragm chord and collector forces should be checked where the two wings join, and local columns should be reviewed for combined axial force, biaxial bending and shear. Bidirectional nonlinear

time histories are preferable because simultaneous X and Y motion can produce larger resultant bearing displacement than separate unidirectional analyses. Where geotechnical information is available, soil springs or impedance functions should be incorporated to assess period lengthening, rocking and potential amplification of long-period motion. Finally, the design process should include independent model review, bearing prototype testing, construction inspection and a post-installation monitoring plan. Prototype tests should confirm hysteretic loops, effective stiffness and damping at the required displacement amplitudes and vertical loads. During construction, bearing orientation, level, grout, anchorage and clearances should be inspected and documented. After completion, baseline measurements of building period and ambient vibration can be compared with analytical predictions. Periodic inspection should address rubber cracking, corrosion, lead extrusion, debris in the seismic gap and changes in utility flexibility. These measures convert the numerical benefits demonstrated in the present study into dependable long-term seismic performance. They also provide the evidence required for regulatory approval and future maintenance of a tall base-isolated building.

6. CONCLUSION

A controlled ETABS comparison of square and T-shaped G+40 RCC buildings shows that LRB base isolation provides substantial improvement over conventional fixed footing. The standardized dataset gives roof-displacement reductions of 37.8% for the square plan and 35.1% for the T-shaped plan. Maximum drift reductions are larger, reaching 46.4% and 43.8%, respectively. Primary ETABS base-shear summaries show reductions between 39.56% and 43.43%. The first-mode period increases from 3.20 s to 5.80 s and frequency decreases from 0.31 Hz to 0.17 Hz, confirming effective period elongation and seismic decoupling. Cumulative modal mass participation exceeds 90% in both horizontal directions for every model. The square isolated building performs best because isolation reduces seismic input and plan symmetry limits torsional amplification. The T-shaped isolated model also improves markedly, but its re-entrant geometry requires additional attention to diaphragm forces, torsional response and local member demand. Practical implementation should include nonlinear bearing verification, maximum isolator displacement, stability under gravity load, seismic gap, wind serviceability, utility flexibility and soil–structure interaction. Final construction design must be based on complete ETABS exports, code-compliant load combinations and project-specific geotechnical data.

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