

Analysis on Behavior of High-Rise Irregular R.C. Structure Against Influence of Strong Strength of Wind Load.

Sawant Anant Dnyanoba¹, Prof. S.B. Anantwad²

¹M. Tech Scholar, Civil Structures, M.S. Bidve Engineering College, Latur, Maharashtra, India

²Assistant Professor, M.S. Bidve Engineering College, Latur, Maharashtra, India

ABSTRACT

This research paper presents a controlled ETABS investigation of six 50-storey reinforced-concrete buildings having rectangular, square, C-shaped, T-shaped, L-shaped and hollow-rectangular plans. The uploaded dissertation was used as the governing source for the model images, input assumptions, storey-wise results and original result graphs. All configurations have a common 3.0 m storey height, fixed base, rigid floor diaphragm, comparable material and section assignments and wind actions applied in the global X and Y directions. Structural performance is compared through roof displacement, storey drift, cumulative storey shear, fundamental time period and reported modal frequency. The square model produced the lowest roof displacement in both directions, equal to 291.770 mm under WDX and 269.754 mm under WDY. The T-shaped model governed the deformation response in WDY with 391.607 mm and also recorded the longest fundamental period of 4.797 s. The square model attracted the largest base shear, reaching 65,261.86 kN in WDX and 76,663.95 kN in WDY, confirming the expected trade-off between stiffness, deformation control and force attraction. The L-shaped and hollow-rectangular models recorded comparatively low maximum drift, although their re-entrant corners and diaphragm discontinuities require torsional and local-force checks. The paper reproduces all eight result graphs from the report, adds verified summary tables and interprets every model and result image. The findings demonstrate that wind efficiency must be judged from displacement, drift, shear and modal response collectively rather than from one parameter alone.

Keywords : *ETABS, high-rise reinforced concrete, plan irregularity, strong wind load, storey displacement, storey drift, base shear, time period, natural frequency.*

1. INTRODUCTION

Rapid urbanization and restricted land availability have increased the use of tall reinforced-concrete buildings with complex floor plans. As the height and slenderness of a building increase, lateral wind action becomes a major design consideration because the distributed pressure acts over the entire elevation and generates translation, overturning, vibration and torsional rotation. The response is particularly important for serviceability because excessive displacement and inter-storey movement can damage partitions, glazing, cladding, elevators and building services even when member strength remains adequate. Reviews of wind-vibration mitigation emphasize that structural stiffness, damping, aerodynamic form and load-path continuity must be considered together [1]. Plan irregularity modifies both structural and aerodynamic behaviour. Projecting wings and re-entrant corners disturb wind flow, create asymmetric pressure and shift the resultant load away from the centre of rigidity. Computational optimization studies have shown that relatively small changes to irregular tall-building geometry can reduce wind loads and maximum structural deflection [2]. Performance-based wind research further indicates that drift, acceleration, non-structural damage and recovery consequences should be evaluated alongside conventional force checks [3]. Therefore, a configuration attracting a smaller base shear is not necessarily the best; it may simply possess lower effective stiffness and experience larger deformation. The present work uses the complete results and ETABS images contained in the uploaded dissertation. Six 50-storey configurations are compared under WDX and WDY using the same overall modelling framework. The study focuses on the exact response parameters reported in the source: displacement, storey drift, storey shear, time period and frequency. Its principal objective is to identify how plan form changes directional stiffness, force attraction and dynamic characteristics, while retaining the original report graphs and values for traceability.

2. RELATED WORK

Recent wind-engineering research confirms that building form has a direct effect on pressure distribution, vortex shedding and structural response. Large-eddy simulation of setback towers demonstrated that geometrical discontinuities can improve cross-wind aerodynamic performance when the setback arrangement disrupts coherent flow structures [4]. Experimental and CFD investigation of rectangular towers showed that across-wind base shear and moment vary with aspect ratio, terrain and incidence angle [5]. Studies of complicated and Y-shaped geometries also found that certain irregular forms can reduce wind demand when the geometry creates favourable pressure redistribution [6]. These results indicate that irregularity cannot be classified as beneficial or adverse without direction-specific analysis. Parametric investigation of T-form towers demonstrated that the size of the projecting portion changes local wind acceleration and the surrounding flow field [7]. Computational optimization of corner modifications on non-rectangular towers showed that aerodynamic treatment can reduce force demand without fundamentally changing the architectural concept [8]. Data-driven prediction of aerodynamic coefficients for Y-plan buildings further illustrates the need for geometry-specific wind information where conventional code coefficients are limited [9]. Experimental work on rectangular models has also shown that torsional, bending and shear coefficients vary significantly with orientation and side ratio [10]. For structural control, contemporary research has examined shear walls, outriggers, tuned mass dampers and performance-based design. Structural-form comparisons indicate that enhanced lateral stiffness reduces drift, although effectiveness can diminish as building height increases [11]. Outrigger studies show that optimum location and stiffness depend on building morphology [12], while tuned mass-damper systems can improve occupant comfort by reducing wind-induced acceleration [13]. Reviews of nonlinear tall-building response emphasize that geometric, material and aerodynamic nonlinearities become more important as towers become taller and more flexible [14]. These findings support a multi-parameter comparison rather than a ranking based only on maximum displacement. The research gap addressed here is the lack of a uniform ETABS comparison of common regular and irregular reinforced-concrete plan forms under the same height, loading and modelling assumptions. The uploaded report provides six comparable models and complete response tables, allowing the relationship between geometry, stiffness, drift and shear to be evaluated directly. The current paper strengthens that report by reproducing the actual result graphs, consolidating the governing values and providing technical interpretation for every table and figure.

3. RESEARCH METHODOLOGY

The study adopts a deterministic comparative simulation method. The independent variable is plan configuration, while the dependent variables are storey displacement, storey drift, cumulative storey shear, modal period and natural frequency. All models contain 50 storeys with a typical storey height of 3.0 m, giving an analytical height of approximately 150 m. Common material grades, member sections, diaphragm assumptions, support conditions, mass source and load definitions are retained as far as documented in the report. Wind is applied in the global X and Y directions and the response is extracted storey-wise from ETABS.



Figure 1. Research methodology adopted for the ETABS comparison.

Figure 1 presents the complete analytical sequence used to convert the dissertation model into a reproducible research workflow. The process begins with definition of the structural problem and selection of six plan configurations. Common model inputs are then fixed so that differences in response can be attributed mainly to geometry rather than inconsistent storey height, material, support or loading assumptions. Each configuration is developed in ETABS, checked for connectivity and diaphragm assignment, and subjected to gravity and code-based wind load patterns. Modal analysis establishes the time period and frequency, while linear wind analysis provides displacement, drift and shear. The outputs are exported storey-wise and compared in both principal directions. The final stage combines the response parameters to identify the governing model and design implications. This sequence is important because it prevents conclusions from being based on a single output. It also includes quality-control checks, such as examination of the reciprocal relationship between modal period and frequency and review of critical storeys.

4. MODELLING AND DESIGN

The ETABS models represent reinforced-concrete frame buildings with floor slabs idealized as rigid diaphragms. The base is fixed and the columns, beams and slabs are connected continuously over the 50-storey height. The report adopts common modelling ranges comprising M30/M40 concrete, Fe500 reinforcement, 150–200 mm slabs, 300 × 600 mm beams and 200–300 mm walls where present. A 150 mm slab, 300 × 600 mm beam and height-wise column zoning provide the baseline representation in the methodology. The comparison is intended to study global response and does not replace final member reinforcement design.

Table 1. Principal modelling and analysis parameters

Parameter	Adopted modelling basis
Storeys / height	50 storeys; 3.0 m typical height; approximately 150 m total
Plan configurations	Square, rectangular, T, C, L and hollow rectangular
Concrete / reinforcement	M30 baseline (M40 where verified); Fe500 steel
Typical slab / beam	150 mm slab; 300 × 600 mm beam baseline
Column zoning	900 × 900 mm lower, 750 × 750 mm middle, 600 × 600 mm upper
Support / diaphragm	Fixed base; rigid diaphragm at each floor
Wind cases	WDX and WDY under common code-based assumptions
Primary outputs	Displacement, drift, shear, period and frequency

Table 1 consolidates the common modelling basis used to compare the six buildings. Maintaining 50 storeys and a 3.0 m typical storey height ensures that every configuration has the same nominal elevation and is exposed to a comparable vertical wind-pressure profile. The use of common concrete, reinforcement, slab and beam properties limits variation caused by material stiffness or section selection. Height-wise column zoning reflects the reduction in gravity and lateral demand toward the roof while preserving the same zoning logic in every model. A fixed-base assumption isolates superstructure behaviour and excludes soil–structure interaction. Rigid diaphragms distribute wind forces to the vertical resisting elements according to their stiffness and location, which is particularly important in the T-, C- and L-shaped plans. WDX and WDY are treated separately because projected area and lateral stiffness differ by direction. The selected outputs provide complementary information: displacement and drift describe serviceability, shear defines force demand, and modal period and frequency indicate global flexibility and dynamic sensitivity.

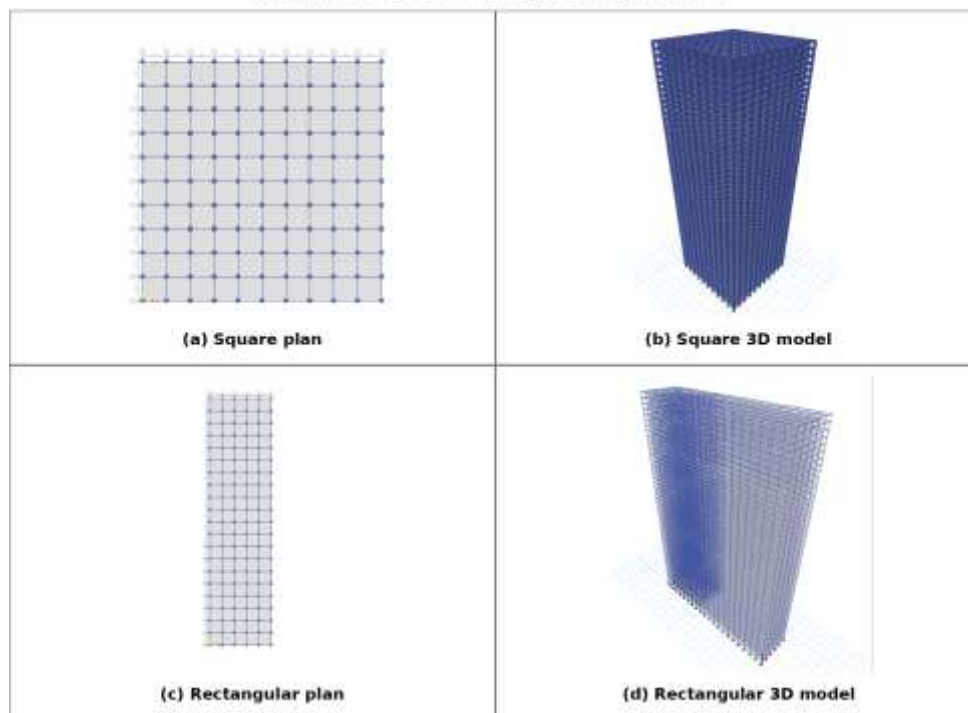
Regular ETABS Building Configurations

Figure 2. Square and rectangular ETABS models reproduced from the uploaded report

Figure 2 shows the regular reference configurations used in the comparison. The square plan has approximately balanced dimensions and a nearly symmetric grid, which promotes similar stiffness and load distribution about the principal axes when the framing layout is also symmetric. Its three-dimensional model forms a compact vertical cantilever with uniform floor plates and direct diaphragm load paths. The rectangular model is also geometrically regular, but its unequal plan dimensions create strong directional behaviour. Wind acting normal to the broad face produces a different projected area and bending stiffness from wind acting normal to the narrow face. The 3D image confirms that the model retains the same height and vertical continuity as the square building, allowing the influence of aspect ratio to be isolated. These two configurations provide essential benchmarks for interpreting the irregular models. The results later show that the

square form controls displacement most effectively, whereas the rectangular form develops larger WDX displacement and the highest WDY drift, demonstrating that regularity alone does not guarantee directionally uniform performance.

4.1 Irregular T- and C-Shaped Models

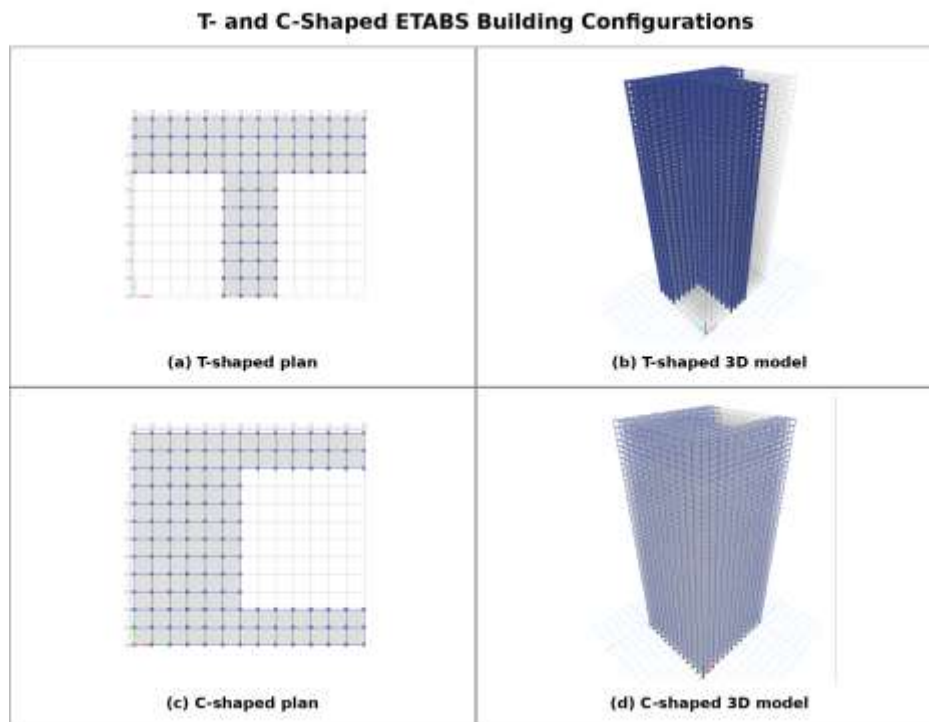


Figure 3. T-shaped and C-shaped ETABS models reproduced from the uploaded report

Figure 3 presents the two open and projecting-wing configurations that show the strongest directional sensitivity in the result set. The T-shaped plan consists of a long flange and a central stem. Under one wind direction, the flange attracts substantial pressure, while in the orthogonal direction the stem and flange participate differently in resisting translation and torsion. The corresponding 3D model reveals a continuous 50-storey form without setbacks, so the observed response is linked primarily to plan geometry and stiffness distribution. The C-shaped plan contains a large re-entrant opening and two projecting wings connected by a spine. This arrangement can separate the centres of mass and rigidity, amplify diaphragm rotation and concentrate force near the internal corners. The 3D image shows that these features continue over the full height. In the results, the T-shaped model records the maximum WDY roof displacement and longest fundamental period, while the C-shaped model also develops high WDY displacement and drift. Both therefore require explicit torsional, edge-drift and diaphragm-force checks.

4.2 Hollow Rectangular and L-Shaped Models

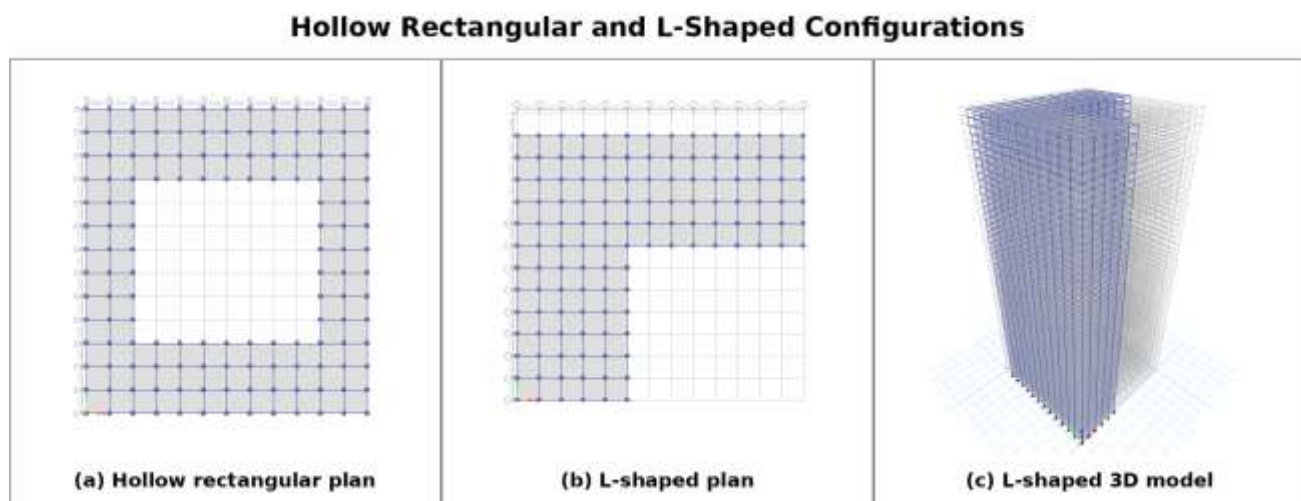


Figure 4. Hollow-rectangular and L-shaped ETABS models reproduced from the uploaded report

Figure 4 illustrates two configurations with internal or re-entrant geometric discontinuity. The hollow-rectangular model forms a perimeter frame around a large central opening. Such a layout can provide efficient perimeter action and

distribute resisting elements away from the centre, but the opening also interrupts slab continuity and can increase in-plane diaphragm demand. The report includes the plan view, which clearly identifies the ring-like floor plate used in ETABS. The L-shaped model contains two perpendicular wings joined at a re-entrant corner. Its plan and 3D views show a continuous vertical extrusion, allowing wind response to be compared without the additional influence of vertical setback. The L-plan can develop translation–torsion coupling because each wing has different stiffness and exposure in the two global directions. Nevertheless, the reported global displacement and drift are comparatively favourable. This apparent advantage must be interpreted carefully: low centre-of-mass displacement does not eliminate local edge movement or stress concentration. Detailed design should therefore check diaphragm shear, collector forces and corner-element demands.

4.3 ETABS Property, Load and Analysis Definition

ETABS Property and Wind-Load Definitions

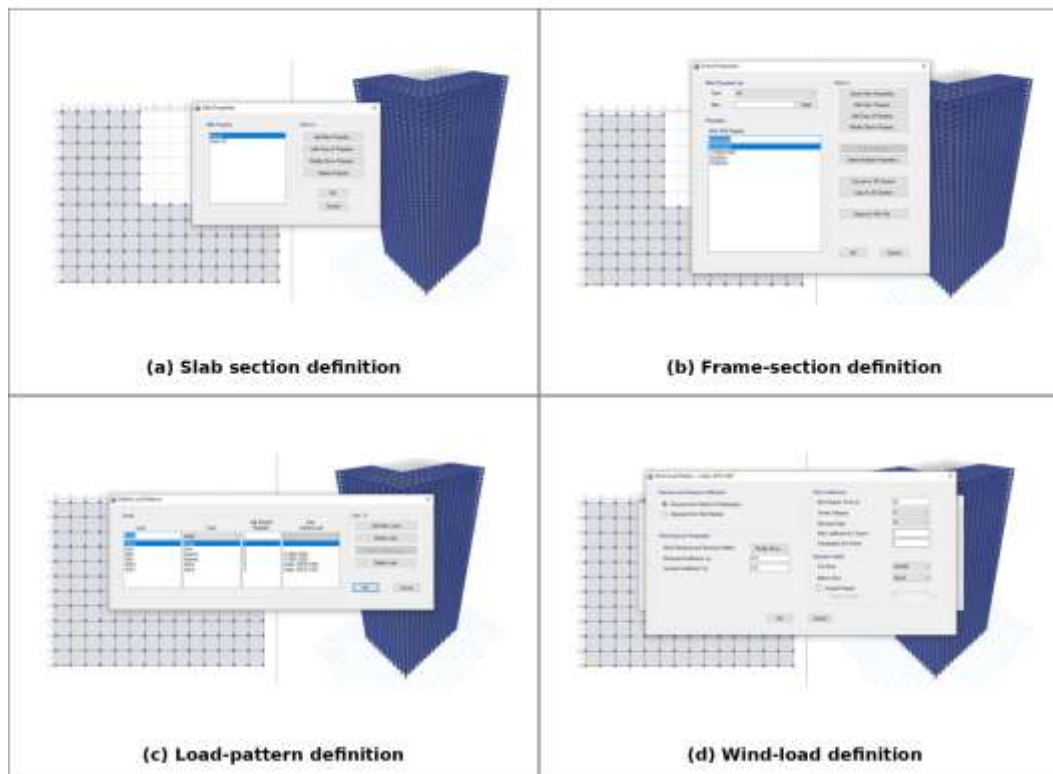


Figure 5. Representative ETABS section, load-pattern and wind-load definitions from the report.

Figure 5 documents the principal ETABS input stages used to create the analytical models. The slab-section window confirms that floor areas are assigned explicit shell properties rather than treated only as weight. The frame-section definition controls beam and column stiffness, self-weight and member-force distribution, making consistent section assignment essential for a fair comparison. The load-pattern window establishes dead, live and lateral load cases and enables self-weight to be included correctly. The wind-load definition shows the code-based automatic wind procedure used for directional analysis. Together, these screenshots provide traceability between the reported numerical results and the actual modelling process. They also identify the most important quality-control points: consistent units, correct local axes, fixed supports, common mass source, diaphragm assignment at every level, compatible meshing near re-entrant corners and absence of instability warnings. Because irregular buildings are sensitive to eccentricity, the load application and diaphragm definition must be reviewed in plan. Modal mass participation should also be checked before interpreting the reported periods and frequencies. The design wind speed is determined in the report using the IS 875 (Part 3):2015 framework, $V_z = V_b k_1 k_2 k_3 k_4$, followed by pressure $p_z = 0.6V_z^2$. A worked methodology value of $V_b = 39$ m/s is used, subject to final verification for the exact project location. Gravity actions include automatic self-weight, slab weight, finishes, partition allowance and imposed load. Serviceability combinations are used for displacement and drift, while factored wind combinations are required for force and member design. Modal analysis is performed before interpreting wind sensitivity, and P-Delta effects are included consistently where specified.

5. RESULTS AND DISCUSSION

This section reproduces all eight graphs contained in the report and supports them with summary tables calculated directly from the reported storey-wise values. The source graphs compare Story 50, Story 25 and Story 1 for the six configurations, while the accompanying tables identify the governing roof, maximum-drift and base-shear values. Results are interpreted jointly because stiffness that reduces displacement can increase equivalent lateral force. All numerical values are retained in the units and directions used in the uploaded report.

Table 2. Governing response values extracted from the report

Model	Roof DX (mm)	Roof DY (mm)	Max drift DX (mm)	Max drift DY (mm)	Base shear DX (kN)	Base shear DY (kN)	T1 (s)
Rectangular	373.504	319.617	4.540 (S1)	5.1924 (S1)	49,288.30	49,677.16	4.542
Square	291.770	269.754	4.432 (S1)	4.2104 (S1)	65,261.86	76,663.95	4.372
C-shape	361.818	379.613	4.408 (S1)	5.044 (S1)	36,214.61	33,321.67	4.615
T-shape	340.206	391.607	4.757 (S1)	4.526 (S1)	28,394.97	32,440.05	4.797
L-shape	294.580	280.612	3.404 (S8)	3.947 (S8)	48,227.50	47,272.52	4.390
Hollow rectangular	358.931	314.253	3.295 (S8)	3.101 (S7)	57,134.23	57,509.13	4.426

Table 2 provides the integrated result summary needed to understand the structural ranking. The square model has the lowest roof displacement in both directions and the shortest fundamental period among the six models, demonstrating the greatest effective global stiffness. Its base shear is simultaneously the largest, showing that deformation control is accompanied by greater lateral-force attraction. The T-shaped model has the longest period, the lowest WDX base shear and the highest WDY roof displacement, which is a consistent signature of a comparatively flexible system. The C-shaped configuration also shows high WDY movement and drift, reflecting the influence of its open side and re-entrant corners. The rectangular model is regular but records the largest WDX roof displacement and the highest maximum WDY drift, confirming strong aspect-ratio sensitivity. The L-shaped and hollow-rectangular models develop lower maximum inter-storey movement at Storeys 7–8 rather than at the first storey. This shift indicates a different vertical stiffness distribution and requires local review even though their global translation is moderate.

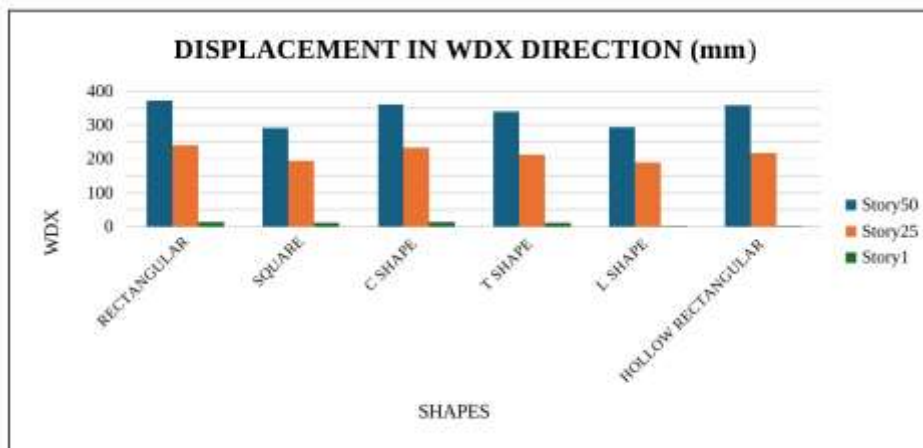


Figure 6. Original report Graph 4.1: displacement in the WDX direction.

Figure 6 reproduces the exact WDX displacement graph from the uploaded dissertation. The chart compares response at Story 50, Story 25 and Story 1 and shows the expected accumulation of lateral translation toward the roof. At Story 50, the rectangular model governs with 373.504 mm, followed by the C-shaped model at 361.818 mm and the hollow-rectangular model at 358.931 mm. The T-shaped model reaches 340.206 mm, while the L-shaped and square models record 294.580 mm and 291.770 mm. The square configuration therefore reduces the rectangular roof displacement by approximately 21.88% and provides the best WDX deformation control. Story 25 values preserve a similar ranking, indicating that the difference is distributed through the height rather than caused by a single weak storey. Story 1 displacements are small for all cases, as expected near the fixed base. The L-shaped and hollow models show especially low first-storey translation, which should be reviewed together with their drift profiles to identify where deformation becomes concentrated.

5.1 Displacement Response in WDY

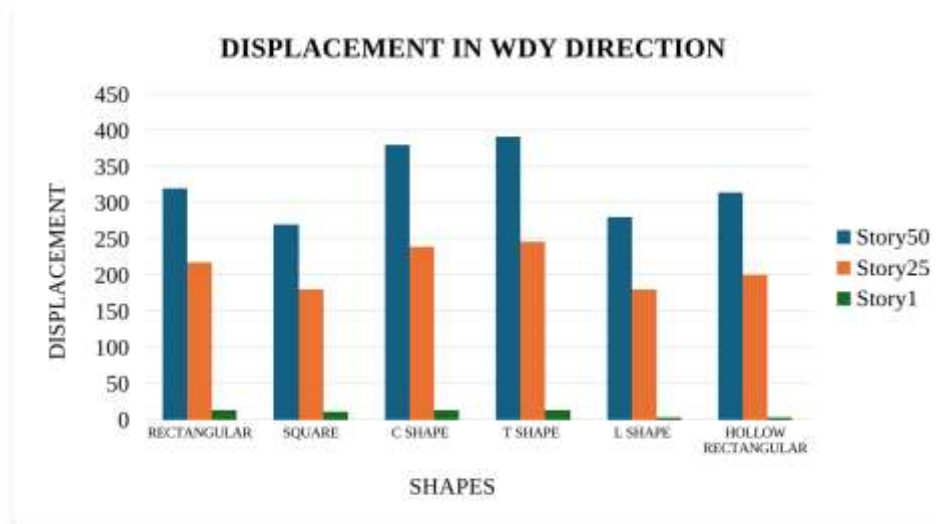


Figure 7. Original report Graph 4.2: displacement in the WDY direction.

Figure 7 reproduces the source WDY displacement graph and demonstrates a major change in ranking relative to WDX. The T-shaped model becomes the governing case with a roof displacement of 391.607 mm, while the C-shaped model follows closely at 379.613 mm. The rectangular and hollow-rectangular models record 319.617 mm and 314.253 mm, respectively. The L-shaped model reaches 280.612 mm and the square model remains the minimum at 269.754 mm. Thus, the square configuration reduces the T-shaped roof response by approximately 31.12%. The Story 25 values show the same pattern: T-shaped 246.457 mm, C-shaped 238.874 mm and square 179.611 mm. The continuous increase from Story 1 to Story 50 indicates global cantilever-type deformation rather than a sudden local discontinuity. The directional reversal is structurally significant. The T-plan is not the governing WDX case but becomes the most flexible WDY case because the stem, flange, projected area and stiffness distribution interact differently under orthogonal wind. Direction-specific design is therefore essential.

Table 3. Displacement at Story 50 / Story 25 / Story 1.

Model	WDX displacement (mm)	WDY displacement (mm)
Rectangular	373.504 / 240.725 / 13.527	319.617 / 217.181 / 12.871
Square	291.770 / 194.271 / 11.280	269.754 / 179.611 / 10.429
C-shape	361.818 / 233.604 / 13.222	379.613 / 238.874 / 13.126
T-shape	340.206 / 212.000 / 11.563	391.607 / 246.457 / 13.574
L-shape	294.580 / 189.380 / 2.524	280.612 / 180.478 / 2.433
Hollow rectangular	358.931 / 218.307 / 2.623	314.253 / 200.904 / 2.647

Table 3 supplements the two report graphs with the exact three-storey values used in the bar charts. For every configuration, Story 50 displacement is substantially larger than Story 25 and Story 1, confirming cumulative deformation over the 150 m height. The regular square building has the smallest value at all three selected levels in both wind directions. The rectangular model is most critical in WDX, whereas the T-shaped model is most critical in WDY, illustrating the influence of plan orientation. The C-shaped building remains among the highest-response cases in both directions, with particularly severe WDY movement. The L-shaped and hollow-rectangular models have very small Story 1 displacement compared with their roof displacement. This does not imply zero lower-storey demand; instead, it indicates that much of the total translation develops above the lowest level. Their drift profiles confirm that critical relative movement occurs around Storeys 7–8. The three-level comparison is useful for visual presentation, but final design should continue to use the complete 50-storey tables contained in the report.

5.2 Storey Drift in WDX



Figure 8. Original report Graph 4.3: storey drift in the WDX direction

Figure 8 reproduces the WDX storey-drift graph from the report. The values represent relative movement between consecutive floor levels and are therefore more directly related to damage in partitions, glazing and cladding than total roof translation. For the rectangular, square, C-shaped and T-shaped buildings, the maximum occurs at Storey 1, reaching 4.540, 4.432, 4.408 and 4.757 mm, respectively. The T-shaped configuration is the governing WDX drift case. The L-shaped and hollow-rectangular models behave differently: their Storey 1 values are below 1 mm, while the complete storey tables show maxima of 3.404 mm and 3.295 mm at Storey 8. The Storey 25 bars for these two configurations are approximately 2.92 mm, showing that relative movement is redistributed upward. Assuming a 3,000 mm storey height, the largest reported WDX drift ratio is about 0.00159 for the T-shaped model. This remains a comparative indicator; code compliance should be checked using the exact governing load combination, edge drift and diaphragm rotation rather than centre displacement alone.

5.3 Storey Drift in WDY

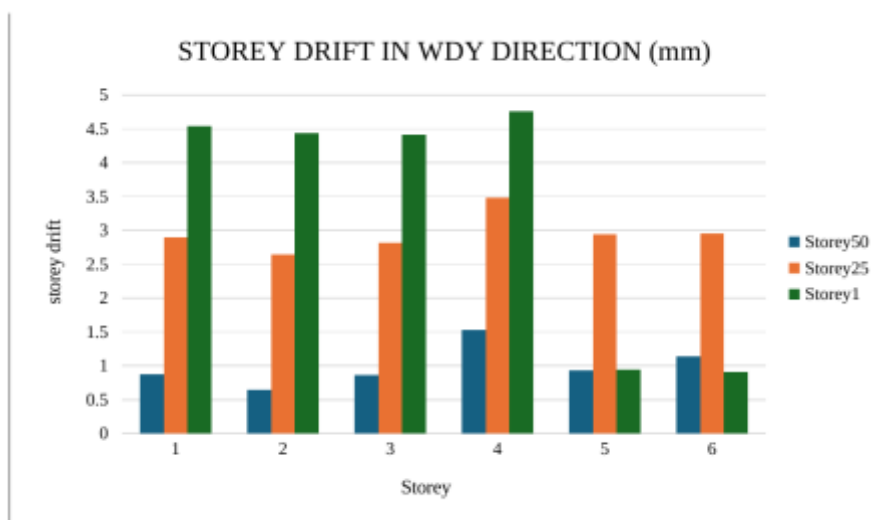


Figure 9. Original report Graph 4.4: storey drift in the WDY direction.

Figure 9 presents the original WDY storey-drift comparison. The rectangular configuration governs with a maximum reported value of 5.1924 mm at Storey 1, followed by the C-shaped model at 5.044 mm. The T-shaped and square buildings reach 4.526 mm and 4.2104 mm at Storey 1. The L-shaped model has a maximum of 3.947 mm at Storey 8, while the hollow-rectangular building records the lowest maximum, 3.101 mm at Storey 7. For a 3,000 mm storey, the rectangular maximum corresponds to a normalized ratio of approximately 0.00173. The graph shows that the ranking based on drift differs from the ranking based on roof displacement. The T-shaped model has the largest WDY roof movement, but the rectangular model has the largest local inter-storey movement. This distinction is important because

total displacement describes overall sway, whereas drift identifies where non-structural damage is most likely. The C-shaped response also confirms that an open plan can combine high global displacement with high local drift, requiring enhanced stiffness and torsional control.

Table 4. Maximum reported storey drift and critical level.

Model	Max WDX drift (mm)	Critical storey	Max WDY drift (mm)	Critical storey
Rectangular	4.540	Story 1	5.1924	Story 1
Square	4.432	Story 1	4.2104	Story 1
C-shape	4.408	Story 1	5.044	Story 1
T-shape	4.757	Story 1	4.526	Story 1
L-shape	3.404	Storey 8	3.947	Storey 8
Hollow rectangular	3.295	Storey 8	3.101	Storey 7

Table 4 identifies the critical drift level for each model rather than relying only on the three bars displayed in the report graphs. Four configurations develop their maximum relative movement at the first storey in both directions, which is consistent with high cumulative shear and lower-storey deformation. The L-shaped and hollow-rectangular models shift the critical location to Storeys 7–8, revealing a different vertical stiffness pattern. This shift is technically important because a designer examining only Story 1 could incorrectly conclude that these models have negligible drift demand. In WDX, the T-shaped model is the maximum at 4.757 mm, whereas in WDY the rectangular model governs at 5.1924 mm. The hollow-rectangular configuration has the smallest maximum drift in both directions, although its roof displacement and base shear remain substantial. This combination suggests that deformation is distributed more uniformly over the height. Final serviceability verification should use maximum edge drift, include torsional rotation, check load-combination signs and compare the normalized ratio with the applicable project limit.

5.4 Storey Shear in WDX

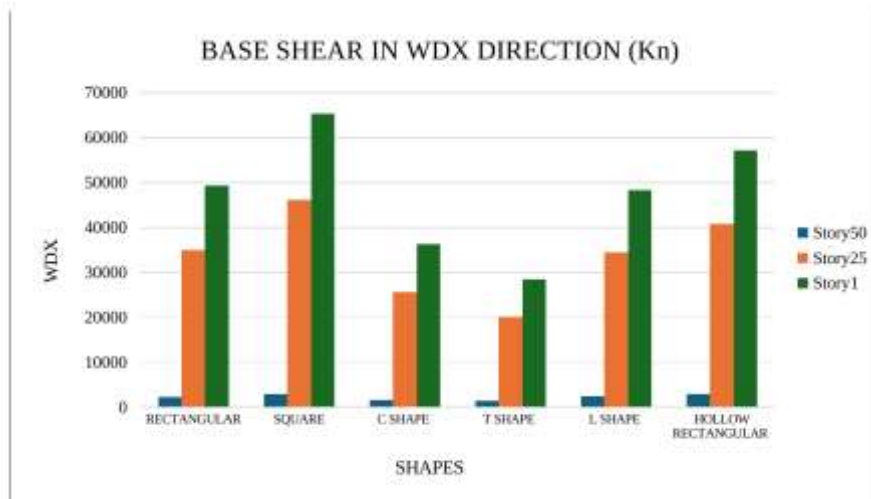


Figure 10. Original report Graph 4.5: storey shear in the WDX direction

Figure 10 reproduces the WDX cumulative storey-shear graph. Shear increases from Story 50 toward Story 1 because each lower level transfers the wind force acting on all floors above it. The square building attracts the largest Story 1 shear, equal to 65,261.86 kN. The hollow-rectangular model follows at 57,134.23 kN, while the rectangular and L-shaped cases reach 49,288.30 kN and 48,227.50 kN. The C-shaped and T-shaped models attract lower values of 36,214.61 kN and 28,394.97 kN. The square shear is approximately 129.84% greater than the T-shaped shear. This result must be interpreted together with displacement: the square building is stiffer and therefore moves less but attracts a larger equivalent lateral force, whereas the T-shaped model attracts lower force and experiences greater flexibility. At Story 25 the same general order is maintained, demonstrating consistent force accumulation. Lower-storey columns, walls, joints and foundations should be designed for the full force envelope, not for roof-level shear alone.

5.5 Storey Shear in WDY

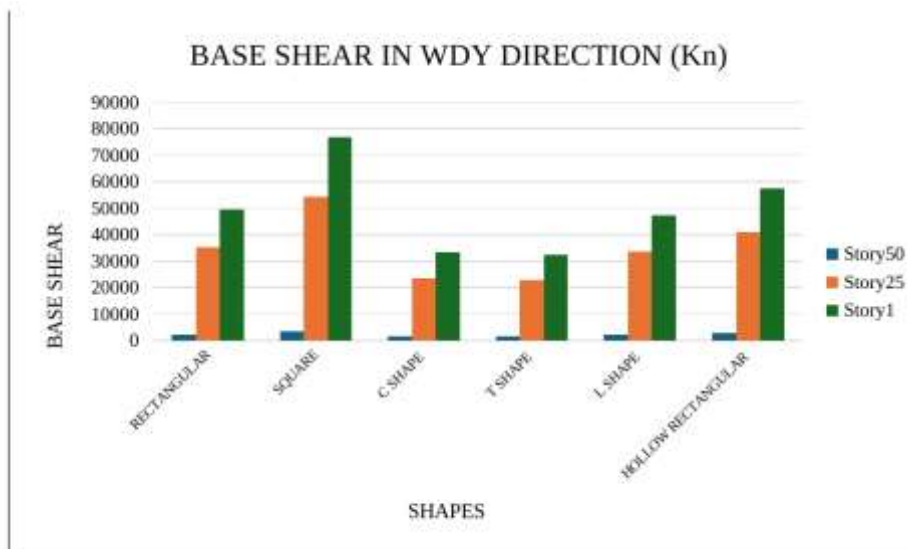


Figure 11. Original report Graph 4.6: storey shear in the WDY direction.

Figure 11 reproduces the WDY storey-shear graph from the report and shows an even stronger force concentration in the square configuration. Its Story 1 value reaches 76,663.95 kN, followed by the hollow-rectangular model at 57,509.13 kN. The rectangular and L-shaped buildings record 49,677.16 kN and 47,272.52 kN, while the C-shaped and T-shaped cases reach 33,321.67 kN and 32,440.05 kN. The square shear is approximately 136.32% greater than the T-shaped value. This ranking is nearly opposite to the WDY roof-displacement ranking, where the T-shaped model is highest and the square model is lowest. The paired results clearly demonstrate stiffness-controlled load attraction. Story 25 values show that the square building already carries 54,286.28 kN, confirming that its higher base demand is accumulated throughout the height rather than generated at one level. The foundation and lower-storey system for the square and hollow-rectangular models must therefore resist higher shear and overturning even though their deformation performance is comparatively favourable.

Table 5. Storey shear at Story 50 / Story 25 / Story 1.

Model	WDX shear (kN)	WDY shear (kN)
Rectangular	2,254.87 / 34,897.86 / 49,288.30	2,237.78 / 35,172.72 / 49,677.16
Square	2,959.20 / 46,212.38 / 65,261.86	3,476.21 / 54,286.28 / 76,663.95
C-shape	1,649.41 / 25,621.04 / 36,214.61	1,564.93 / 23,534.13 / 33,321.67
T-shape	1,338.25 / 20,016.05 / 28,394.97	1,484.82 / 22,947.35 / 32,440.05
L-shape	2,432.93 / 34,394.81 / 48,227.50	2,410.00 / 33,666.92 / 47,272.52
Hollow rectangular	2,852.57 / 40,739.69 / 57,134.23	2,838.19 / 41,072.48 / 57,509.13

Table 5 provides the exact values represented by the two shear graphs. The progression from Story 50 to Story 25 and Story 1 is smooth for every model, supporting the expected accumulation of wind force toward the base. The square configuration is the largest at all selected levels and in both directions. Its Story 25 WDY shear of 54,286.28 kN is already greater than the final Story 1 shear of the rectangular, C-shaped, T-shaped and L-shaped models. The hollow-rectangular configuration consistently ranks second, suggesting that its perimeter arrangement provides substantial stiffness and attracts high force. The T-shaped model remains the lowest-force case, but this does not indicate superior behaviour because it also develops the longest period and the maximum WDY displacement. The rectangular and L-shaped values are closely grouped, while the C-shaped model remains below them. These results demonstrate why force and deformation must be assessed together. Final equilibrium checks should reconcile the Story 1 reactions with the total applied wind loads and should also verify base overturning moment and torsional reaction.

5.6 Modal Time Period

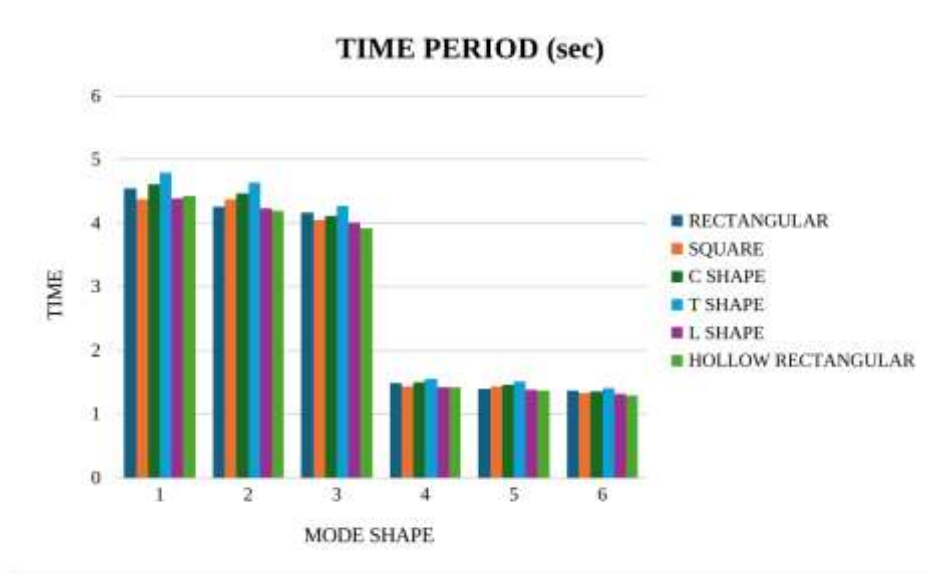


Figure 12. Original report Graph 4.7: modal time period for Modes 1–6

Figure 12 reproduces the report time-period graph for the first six modes. The first three modal periods are much larger than Modes 4–6 and therefore represent the dominant global translational and torsional behaviour. The T-shaped configuration has the longest first-mode period, 4.797 s, followed by the C-shaped model at 4.615 s and the rectangular model at 4.542 s. The hollow-rectangular, L-shaped and square models record 4.426 s, 4.390 s and 4.372 s. The T-shaped first period is approximately 9.72% longer than the square value, consistent with its lower shear attraction and higher WDY displacement. By Mode 4 the periods reduce to approximately 1.421–1.548 s, and by Mode 6 they lie between 1.288 and 1.405 s. Closely spaced values among the first three modes may indicate coupled X translation, Y translation and torsion. The mode-shape plots and cumulative mass participation should therefore be reviewed before labelling any mode as purely directional. Longer periods also indicate greater sensitivity to dynamic wind excitation and occupant comfort.

Table 6. Reported modal time periods in seconds.

Mode	Rect.	Square	C	T	L	Hollow
1	4.542	4.372	4.615	4.797	4.390	4.426
2	4.251	4.372	4.472	4.630	4.233	4.187
3	4.170	4.042	4.119	4.276	4.004	3.912
4	1.488	1.438	1.503	1.548	1.421	1.428
5	1.401	1.438	1.464	1.508	1.380	1.366
6	1.374	1.334	1.358	1.405	1.316	1.288

Table 6 confirms that the T-shaped model is the most flexible configuration across all six reported modes. Its first three periods are 4.797, 4.630 and 4.276 s, each exceeding the corresponding square values. The square and L-shaped models have the shortest first-mode periods, consistent with their low roof displacement. The C-shaped and rectangular buildings occupy an intermediate range. The second period of the square model is reported equal to the first period, while Mode 5 is reported equal to Mode 4. Such repeated values can occur when two orthogonal modes have very similar stiffness, but the associated mode shapes and participating mass should be checked before accepting this interpretation. The sharp reduction between Modes 3 and 4 indicates a transition from dominant global modes to higher-order response. For wind-serviceability assessment, the first three modes deserve the greatest attention because they control sway, torsion and acceleration. The reported periods should be used with an appropriate damping assumption and dynamic wind procedure where required by the code.

5.7 Reported Modal Frequency

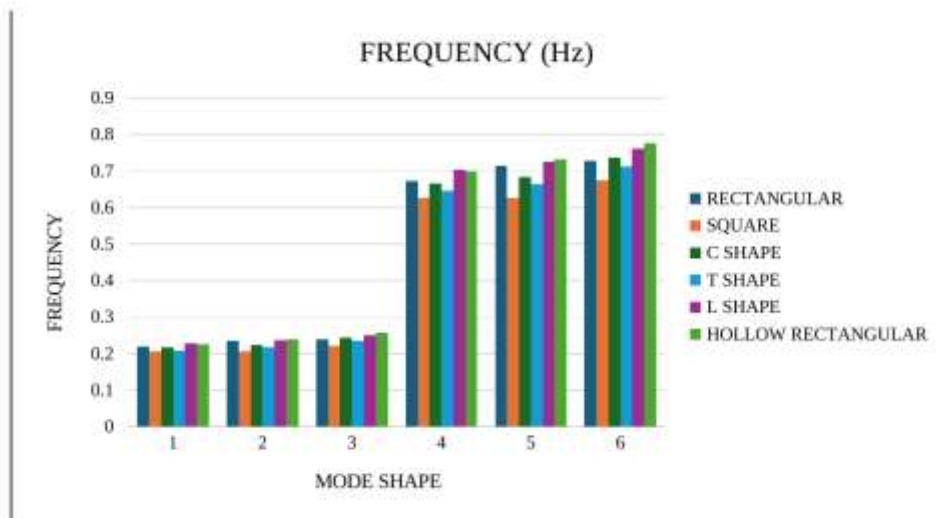


Figure 13. Original report Graph 4.8: reported modal frequency for Modes 1–6

Figure 13 reproduces the frequency graph exactly as it appears in the source report. For most configurations, frequency increases from approximately 0.21–0.26 Hz in the first three modes to approximately 0.63–0.78 Hz in Modes 4–6, which is consistent with the inverse relationship between period and frequency. The T-shaped model generally has the lowest frequency because it has the longest periods, while the L-shaped and hollow-rectangular models reach the highest sixth-mode values of 0.760 and 0.776 Hz. A quality-control issue is visible in the square series. The reported first frequency is 0.2061 Hz, whereas the reciprocal of the reported 4.372 s period is approximately 0.2287 Hz. Similar differences continue in later modes. The paper retains the original values rather than silently replacing them, because traceability to the report is required. However, the square frequency series should be re-exported directly from ETABS before it is used for resonance, acceleration or occupant-comfort calculations. The other model series agree much more closely with the reciprocal check.

Table 7. Source-reported modal frequencies in hertz.

Mode	Rect.	Square	C	T	L	Hollow
1	0.220	0.2061	0.217	0.208	0.228	0.226
2	0.235	0.2061	0.224	0.216	0.236	0.239
3	0.240	0.2223	0.243	0.234	0.250	0.256
4	0.672	0.6255	0.666	0.646	0.704	0.700
5	0.714	0.6255	0.683	0.663	0.725	0.732
6	0.728	0.6750	0.737	0.712	0.760	0.776

Table 7 preserves the dissertation frequency data and allows a direct quality-control comparison with Table 6. The rectangular, C-shaped, T-shaped, L-shaped and hollow-rectangular values are generally consistent with $f = 1/T$ to the displayed precision. The square values are not. For example, Mode 1 should be approximately 0.229 Hz from the reported period, but the table gives 0.2061 Hz. Mode 4 should be approximately 0.695 Hz from 1.438 s, while the table reports 0.6255 Hz. Because the discrepancy is systematic rather than random, it may reflect a frequency column copied from a different model or analysis case. The original numbers are retained to avoid altering source data, but they should be treated as provisional. This observation does not change the displacement, drift or shear ranking, because those results are extracted independently. It does affect any resonance or acceleration conclusion involving the square model. Re-exporting the ETABS modal table and checking analysis-case labels, units and mode ordering are therefore essential before final submission.

5.8 Integrated Performance Assessment

Table 8. Overall performance ranking based on combined response.

Rank	Model	Governing evidence	Engineering assessment
1	Square	Lowest roof displacement in WDX and WDY; shortest T1	Best balanced deformation control; highest base-force demand
2	L-shape	Roof displacement close to square; low maximum drift	Favourable global response; torsion and re-entrant corner require checking
3	Hollow rectangular	Low maximum drift; moderate displacement; high shear	Efficient perimeter response; diaphragm flexibility around opening must be verified
4	Rectangular	Highest WDX displacement and highest WDY drift	Regular but strongly direction-sensitive because of aspect ratio
5	C-shape	High WDY displacement and drift	Open side and re-entrant corners increase directional and torsional sensitivity
6	T-shape	Highest WDY displacement; longest T1; lowest shear	Most flexible overall; requires stiffness, torsion and comfort control

Table 8 ranks the configurations using the combined evidence rather than a single numerical output. The square model is placed first because it controls roof displacement in both directions and has the shortest first-mode period. Its high base shear is not treated as poor performance; it is the force consequence of greater stiffness and must be addressed through member and foundation design. The L-shaped model ranks second because its global displacement is close to the square case and its maximum drift is comparatively low. The ranking remains conditional on acceptable edge movement, torsion and forces at the re-entrant corner. The hollow-rectangular model ranks third because it distributes drift effectively, although the central opening requires diaphragm and collector checks and the model attracts high shear. The rectangular building is regular but suffers from aspect-ratio sensitivity. The C-shaped and T-shaped models occupy the final positions because their open or projecting geometries produce high directional displacement, longer periods or larger drift. The ranking is a comparative design guide, not a substitute for code checks or wind-tunnel testing. The response trends agree with contemporary research showing that plan geometry and aerodynamic modification directly affect wind forces and motion [2], [4]–[10]. For the C- and T-shaped buildings, practical improvement measures include a more centrally positioned core, additional shear walls, increased perimeter-frame stiffness, outriggers, damping devices or aerodynamic corner treatment. The L-shaped and hollow-rectangular configurations should be analysed with semi-rigid diaphragms to verify local in-plane response. For all models, wind-tunnel or validated CFD analysis is recommended where height, flexibility, surrounding-building interference or occupant-comfort criteria exceed the limitations of code-based equivalent static loading [1], [3], [14]–[18].

6. CONCLUSION

The revised paper uses the actual ETABS model images and all eight result graphs from the uploaded dissertation. The controlled comparison demonstrates that plan geometry has a decisive influence on deformation, force attraction and dynamic behaviour. The square configuration provides the best balanced wind response, with the lowest roof displacement of 291.770 mm in WDX and 269.754 mm in WDY and a first-mode period of 4.372 s. The T-shaped model is the most flexible, reaching 391.607 mm in WDY and a first period of 4.797 s. The rectangular model governs WDX roof displacement and WDY maximum drift, showing that a regular plan can remain direction-sensitive when its aspect ratio is large. The square model attracts the largest Story 1 shear, equal to 65,261.86 kN in WDX and 76,663.95 kN in WDY, while the T-shaped model attracts the lowest. This inverse displacement–shear relationship confirms that lower base force does not automatically indicate superior performance. The L-shaped and hollow-rectangular models have comparatively low maximum drift, but their re-entrant corners and openings require torsional, diaphragm and collector-force verification. The C-shaped model combines high WDY displacement and drift and therefore requires improved stiffness distribution. For final design, the study recommends verification of the exact wind speed and exposure factors, re-export of the square-model frequency data, evaluation of cumulative modal mass participation, edge drift, torsional rotation, P-Delta sensitivity and base overturning moment. Advanced wind-tunnel or CFD loading, semi-rigid

diaphragm modelling, neighbouring-building interference and acceleration-based occupant-comfort assessment should be included in future work. These measures will convert the comparative ETABS study into a complete performance-based wind design framework.

REFERENCES

- [1] M. Jafari and A. Alipour, "Methodologies to mitigate wind-induced vibration of tall buildings: A state-of-the-art review," *Journal of Building Engineering*, vol. 33, Art. no. 101582, 2021, doi: 10.1016/j.jobbe.2020.101582.
- [2] F. Alkhatib, N. Kasim, W. I. Goh, N. Shafiq, M. Amran, E. V. Kotov, and M. A. Albaom, "Computational aerodynamic optimization of wind-sensitive irregular tall buildings," *Buildings*, vol. 12, no. 7, Art. no. 939, 2022, doi: 10.3390/buildings12070939.
- [3] S. P. Hareendran, A. Alipour, B. Shafei, and P. Sarkar, "Performance-based wind design of tall buildings considering the nonlinearity in building response," *Journal of Structural Engineering*, vol. 148, no. 9, 2022, doi: 10.1061/(ASCE)ST.1943-541X.0003312.
- [4] N.-T. Yu, W. Li, Y.-G. Zheng, and W.-B. Yuan, "Wind-induced aerodynamic effects on set-back tall buildings using LES," *Buildings*, vol. 14, no. 5, Art. no. 1252, 2024, doi: 10.3390/buildings14051252.
- [5] S. Shanthi, R. Vidjeapriya, and K. P. Jaya, "Influence of across-wind on rectangular tall buildings," *Buildings*, vol. 14, no. 12, Art. no. 3902, 2024, doi: 10.3390/buildings14123902.
- [6] R. K. Meena, R. Raj, S. Anbukumar, M. I. Khan, and J. Khatib, "Fluid dynamic assessment of tall buildings with a variety of complicated geometries," *Buildings*, vol. 14, no. 12, Art. no. 4081, 2024, doi: 10.3390/buildings14124081.
- [7] H. Guo, Y. Liu, and Y. He, "Iterative investigation of wind environments influenced by bulge-part geometries of typical T-form high-rise buildings using parametric modelling, CFD and IAs analysis," *Sustainability*, vol. 16, no. 8, Art. no. 3354, 2024, doi: 10.3390/su16083354.
- [8] A. H. H. Al-Masoodi et al., "Aerodynamic optimization for corner modification of octagonal-shape tall buildings using computational approach," *Journal of Building Engineering*, vol. 76, Art. no. 107017, 2023, doi: 10.1016/j.jobbe.2023.107017.
- [9] P. Sanyal and S. K. Dalui, "Forecasting of aerodynamic coefficients of tri-axially symmetrical Y-plan shaped tall building based on CFD data-trained ANN," *Journal of Building Engineering*, vol. 47, Art. no. 103889, 2022, doi: 10.1016/j.jobbe.2021.103889.
- [10] V. Guzmán-Solís, A. Pozos-Estrada, and R. Rodríguez Gómez, "Experimental study of wind-induced shear, bending, and torsional loads on rectangular tall buildings," *Advances in Structural Engineering*, vol. 23, 2020, doi: 10.1177/1369433220927280.
- [11] P. Mazarakou and A. Papalou, "Effect of structural forms on wind-induced response of tall buildings," *Eng*, vol. 6, no. 6, Art. no. 131, 2025, doi: 10.3390/eng6060131.
- [12] G. Angelucci et al., "Parametric analysis of outrigger systems in high-rise buildings with regular, tilted and twisted geometries," *Applied Sciences*, vol. 15, no. 10, Art. no. 5643, 2025, doi: 10.3390/app15105643.
- [13] X. Chen et al., "Improving the wind-induced human comfort of the Beijing Olympic Tower by a double-stage pendulum tuned mass damper," *The Structural Design of Tall and Special Buildings*, vol. 29, 2020, doi: 10.1002/tal.1704.
- [14] Y. Zhao et al., "Wind-induced nonlinear behavior of tall buildings, high-rise structures and long-span systems: A review," *Buildings*, vol. 13, no. 8, Art. no. 2033, 2023, doi: 10.3390/buildings13082033.
- [15] Y. Li et al., "Integrated aerodynamic, structural and thermal performance of the Shanghai Tower," *Sustainability*, vol. 16, no. 10, Art. no. 4146, 2024, doi: 10.3390/su16104146.
- [16] B. G. Kavyashree et al., "Evolution of outrigger structural system: A state-of-the-art review," *Arabian Journal for Science and Engineering*, 2021, doi: 10.1007/s13369-021-06074-9.
- [17] W. Alhaddad et al., "Optimum topology and size design of outrigger and belt-truss systems for high-rise buildings," *Advances in Civil Engineering*, Art. no. 2589735, 2020, doi: 10.1155/2020/2589735.
- [18] H. S. Kim et al., "Optimization of outrigger placement in tall buildings," *Journal of Building Engineering*, vol. 31, Art. no. 101379, 2020, doi: 10.1016/j.jobbe.2020.101379.
- [19] S. Y. Jeong et al., "Performance-based wind design using synthetic time-history wind loads," *Journal of Structural Engineering*, vol. 147, 2021, doi: 10.1061/(ASCE)ST.1943-541X.0003077.

- [20] H. Pang et al., “Influence of wind direction on the inelastic responses of a base-isolated square-section high-rise building,” *Buildings*, vol. 12, no. 8, Art. no. 1208, 2022.
- [21] A. Giaralis and F. Petrini, “Wind-induced vibration mitigation in tall buildings using the tuned mass-damper-inerter,” *Journal of Structural Engineering*, vol. 143, no. 9, 2017, doi: 10.1061/(ASCE)ST.1943-541X.0001863.
- [22] C. M. Alexander, “Reduction of wind loads on rectangular tall buildings with different taper ratios,” *Journal of Building Engineering*, vol. 50, Art. no. 103588, 2022, doi: 10.1016/j.jobbe.2021.103588.
- [23] M. Premrov and V. Žegarac Leskovic, “Contemporary structural systems for multi-storey timber and hybrid buildings,” *Buildings*, vol. 13, no. 7, Art. no. 1820, 2023, doi: 10.3390/buildings13071820.
- [24] P. S. Patil and K. K. Sangle, “Seismic behaviour of outrigger braced systems in high-rise 2-D steel buildings,” *Structures*, vol. 8, pp. 1–16, 2016, doi: 10.1016/j.istruc.2016.07.005.
- [25] M. A. Haque, A. Ray, A. R. Chakraborty, M. M. Elias, and I. M. Alam, “Seismic performance analysis of RCC multi-storied buildings with plan irregularity,” *American Journal of Civil Engineering*, vol. 4, no. 3, pp. 68–73, 2016, doi: 10.11648/j.ajce.20160403.11.
- [26] Bureau of Indian Standards, IS 875 (Part 3): 2015, Design Loads (Other Than Earthquake) for Buildings and Structures—Part 3: Wind Loads. New Delhi, India, 2015.
- [27] Bureau of Indian Standards, IS 456: 2000, Plain and Reinforced Concrete—Code of Practice. New Delhi, India, 2000.
- [28] Bureau of Indian Standards, IS 1893 (Part 1): 2016, Criteria for Earthquake Resistant Design of Structures—General Provisions and Buildings. New Delhi, India, 2016.
- [29] Bureau of Indian Standards, IS 16700: 2017, Criteria for Structural Safety of Tall Concrete Buildings. New Delhi, India, 2017.
- [30] Computers and Structures, Inc., ETABS Integrated Building Design Software: Analysis Reference Manual. Berkeley, CA, USA, 2024.