

ANALYTICAL APPROACH ON HIGH-RISE STRUCTURE UNDER P-DELTA AND RESPONSE SPECTRUM ANALYSIS USING ETABS SOFTWARE.

Gagan Kumar R
Department of civil engineering,
Visvesvaraya Technological University (VTU),
Belagavi, Karnataka
gagankumar93804@gmail.com

Dr. Virendra Kumara K N
Department of civil engineering,
Visvesvaraya Technological University (VTU),
Belagavi, Karnataka
virendrakumara80@gmail.com

Abstract: Recent urban growth has led to an increase in tall buildings that are highly affected by wind and earthquake forces. To ensure their safety, detailed structural analysis is essential. This study examines the seismic behavior of a reinforced concrete multi-storey building with shear walls. The model is created in ETABS using appropriate material properties and loading conditions based on Indian codes. Dynamic response is evaluated through response spectrum analysis. Special attention is given to P-Delta effects, which introduce additional moments due to lateral displacement. Key parameters such as storey displacement, drift, base shear, and time period are analyzed. Results show that including P-Delta effects increases displacement and drift values. Shear walls significantly enhance stiffness and reduce excessive lateral movement. Overall, combining dynamic analysis with second-order effects provides a more realistic assessment for safe structural design.

Keywords: *Shear Wall System, P-Delta Effect, Response Spectrum Analysis, High-Rise Buildings, Seismic Analysis, Structural Stability, Storey Drift, Lateral Loads, ETABS, Reinforced Concrete Structures.*

I. INTRODUCTION

High-rise buildings require specialized analysis due to their sensitivity to lateral forces such as wind and earthquakes. Unlike low-rise structures, their design is governed mainly by horizontal loads rather than gravity loads. P-Delta analysis accounts for additional moments caused by axial loads acting on laterally displaced members. This second-order effect increases stresses and deformations, making it essential for tall structures. Response spectrum analysis is used to evaluate structural response under seismic loading in an efficient manner. It estimates peak responses without performing detailed time-history analysis. Various structural systems such as rigid frames, braced frames, shear walls, and outrigger systems improve lateral resistance. Among these, shear wall systems are widely used due to their high stiffness and effectiveness. Shear walls act as vertical cantilevers, resisting lateral loads while also

supporting gravity loads. Overall, combining dynamic analysis with shear wall systems ensures safe, stable, and efficient high-rise design.

P-Delta analysis is essential in high-rise structures as it captures additional moments caused by axial loads acting on displaced members. These second-order effects increase internal forces and must be considered for safe design. As building height increases, P-Delta effects lead to greater storey displacement and inter-storey drift. They also reduce structural stiffness, which may lead to instability or buckling under heavy loads. Response spectrum analysis is a dynamic method used to evaluate structural response under seismic forces. It effectively captures the influence of multiple vibration modes in tall and irregular buildings. This method provides reliable peak responses without requiring detailed time-history analysis. Combining P-Delta with response spectrum analysis ensures both geometric nonlinearity and dynamic effects are considered. This leads to higher and more realistic estimates of forces, displacements, and overall behavior. Ultimately, the combined approach improves accuracy, stability assessment, and safety in high-rise structural design.

II. PROBLEM STATEMENT

Rapid urbanization has increased the need for high-rise buildings, making lateral stability a major design concern. As building height increases, wind and earthquake forces significantly influence structural behavior. Ensuring adequate stiffness and strength is essential for safety and serviceability. Shear wall systems are widely used due to their ability to resist lateral loads effectively. They provide high in-plane stiffness and help control excessive displacement and drift. Accurate modelling of such systems is critical for reliable structural performance. Neglecting P-Delta effects can lead to underestimation of forces and displacements. Similarly, ignoring response spectrum analysis fails to capture true dynamic behavior under seismic loads. This may result in incorrect evaluation of base shear, drift, and member forces. Therefore, including both analyses is necessary for safe, realistic, and efficient high-rise design.

The rapid expansion of urban areas has increased the demand for taller buildings, bringing lateral stability into focus. As structures rise in height, they become more vulnerable to horizontal forces such as wind and earthquakes. To maintain safety and proper functioning, sufficient stiffness and load-carrying capacity are required. Shear wall systems are frequently used because they efficiently counteract these lateral effects. They contribute significantly to structural rigidity and help minimize unwanted movement between floors. Reliable performance depends on careful and accurate analytical modelling of these systems. If second-order effects like P-Delta are ignored, the resulting forces and displacements may be underestimated. Similarly, excluding dynamic analysis methods can overlook important vibration characteristics during earthquakes. This may lead to errors in estimating key response parameters such as drift and base shear. Therefore, incorporating both advanced analysis methods is essential for achieving safe and dependable high-rise designs.

III. METHODOLOGY

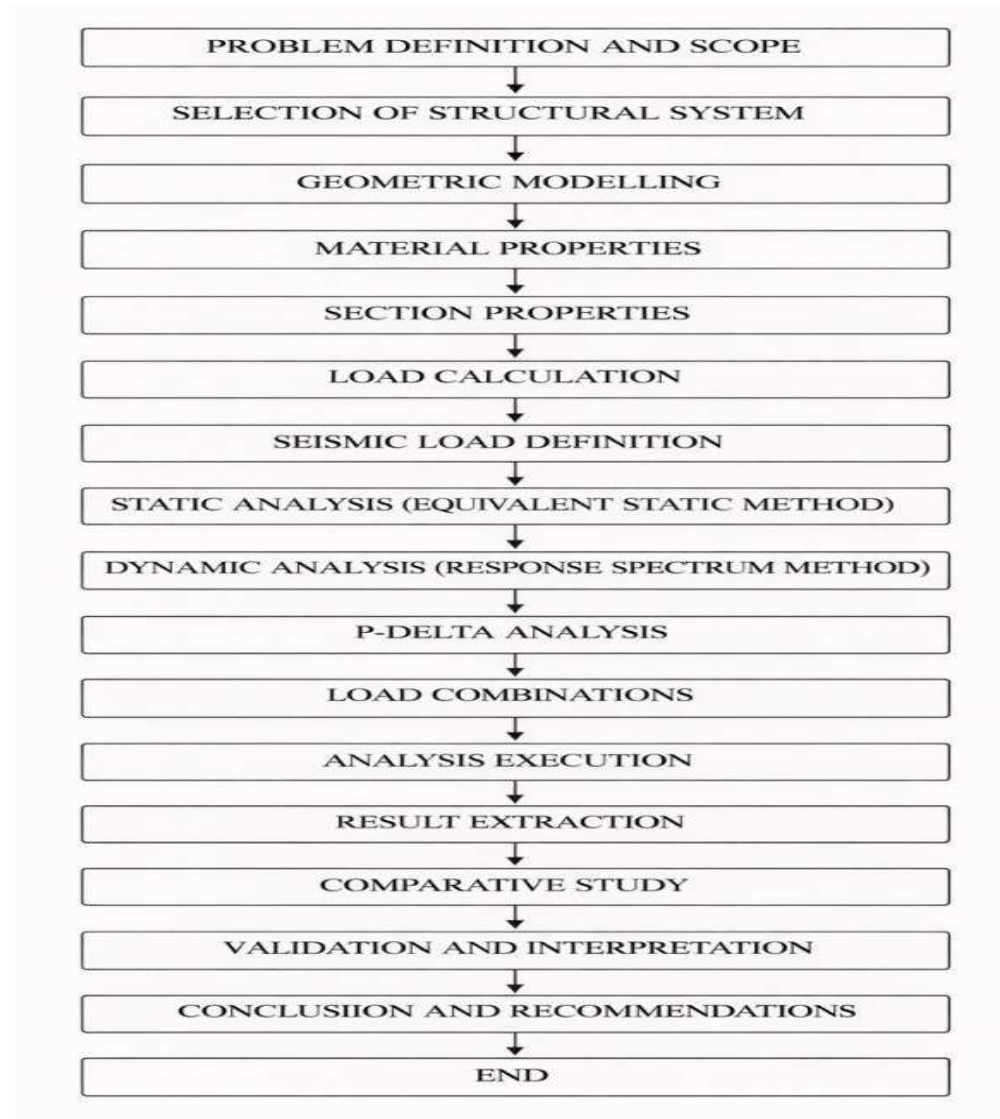


Fig 1. Flow Chart

A. **Lateral Load Analysis of High-Rise Structures**

The behavior of high-rise buildings is largely controlled by their response to lateral forces such as wind and earthquakes. As structures become taller, these forces play a dominant role in design considerations. Maintaining sufficient stiffness is essential to control displacement and ensure user comfort. In this study, a tall building with a shear wall system is analyzed for lateral load effects. The structural model is developed in ETABS and evaluated under both static and dynamic conditions. Seismic forces are assessed using the equivalent static approach and response spectrum method. The dynamic method captures key

properties like natural period and mode shapes. Second-order effects are included to account for additional forces caused by deformation. Important results such as storey drift, displacement, and base shear are examined. The study highlights that combining these methods leads to a more accurate and dependable structural design.

B. Equivalent static analysis of Building

Equivalent Static Method is used to determine seismic forces acting on a structure by converting earthquake effects into equivalent static loads. As per IS 1893 (Part 1): 2016, the design base shear is calculated as:

$$V_b = A_h \times W$$

Where, V_b = Design base shear, A_h = Design horizontal seismic coefficient, W = Total seismic weight of the building.

The horizontal seismic coefficient is given by: $A_h = (Z/2) \times (I/R) \times (S_a/g)$

Where, Z = Zone factor, I = Importance factor, R = Response reduction factor, S_a/g = Average response acceleration coefficient.

The approximate fundamental natural period for RC frame building is:

$$T_a = 0.075 h^{0.75}$$

Where, h = Height of the building in meters.

The base shear is distributed along the height of building using:

$$Q_i = V_b \times (W_i h_i / \sum W_i h_i)$$

Where, Q_i = Lateral force at floor i , W_i = Seismic weight of floor i , h_i = Height of floor i from base, n = Number of storeys.

C. Dynamic Response Spectrum Analysis

The response spectrum method is a dynamic analysis technique used to evaluate seismic behavior in tall structures. It estimates peak structural responses such as displacement, drift, and base shear under earthquake loading. This method considers multiple vibration modes, providing a more realistic analysis than static approaches. The structural model, including shear walls, is analyzed using ETABS as per IS 1893 (Part 1): 2016. Shear walls enhance lateral stiffness and help control excessive movement during seismic events. Modal analysis is carried out to determine natural periods, mode shapes, and mass participation. Each vibration mode contributes differently to the overall structural response. These modal responses are combined using methods like SRSS and CQC. The CQC method is preferred for structures with closely spaced natural frequencies. Overall, this approach ensures accurate prediction of seismic performance and supports safe structural design.

D. Wind Analysis

The design wind speed at height z is determined using:

$V_z = V_b \times k_1 \times k_2 \times k_3 \times k_4$ where V_b is the basic wind speed, k_1 is the risk coefficient factor, k_2 is the terrain, height and structure size factor, k_3 is the topography factor, and k_4 is the importance factor for cyclonic region.

For Bengaluru, the basic wind speed is taken as 33 m/s. Since a design life of 100 years is considered, the risk coefficient factor k_1 is taken as 1.05. Terrain Category 4 is adopted and the structure is classified as Class C. For normal flat ground condition, the topography factor k_3 is taken as 1.0 and the importance factor k_4 is taken as 1.0.

Thus, wind load input parameters for present study are: Location : Bengaluru

Basic Wind Speed (V_b) = 33 m/s Risk Coefficient Factor

(k_1) = 1.05 Terrain Category = 4

Structure Class = C Topography Factor (k_3) = 1.0

Importance Factor (k_4) = 1.0

E. Modeling

The structural model of a regular multi-storey reinforced concrete building was created using ETABS 19 software. The building has a uniform configuration in plan and elevation, ensuring consistent mass and stiffness distribution. Key elements such as beams, columns, slabs, and shear walls were defined with appropriate properties. Loads including dead, live, wind, and seismic were applied as per relevant standards, with floor diaphragms ensuring proper force transfer. The analysis provided results like displacement, drift, and base shear, helping assess overall structural performance and safety.

F. Building Modelling and Loading Data

1) Building Data

Type of Structure – Reinforced Concrete Shear Wall Structural System

Plan Configuration – Rectangular

Number of Storeys – Basement + Ground + 11 Upper Floors+ Head rooms

Height of Each Floor – 3.5 m Total Height of Building –
49.5 m

Building Type – Residential Apartment

The building considered in this study is a reinforced concrete residential structure designed using a shear wall structural system with a rectangular plan configuration. The structure consists of one basement level, ground floor, and eleven upper storeys, forming a multi-storey residential apartment. Each storey is modelled with a uniform floor-to-floor height of 3.5 m, giving an overall structural height of 49.5 m measured from foundation level to roof level.

2) Material Properties

Grade of concrete for shear wall happening in

- basement floor , ground floor, and first floor,second floor. M40
- third floor, fourth floor,fifth floor,sixth floor. M35
- seventh floor, eighth floor, ninth floor, tenth floor M30
- eleventh floor and head room. M25
- grade of concrete for all other structural members M25

- grade of steel f_y -500

3) **Material Property Design Data Section**

- beams sections -200x300, 200x450, 200x600, 200x750, 200x900, 300x450, 300x600, 300x900
- slab sections – 125mm,150mm,175mm,200mm.
- wall sections – 200mm,300mm,350mm,400mm.

4) **Gravity Load**

[1] Dead loads(self weight)

[2] Live loads

For lobby -4 Kn/sqm For corridor -4Kn/sqm

For hall – 3Kn/sqm For room – 2Kn/sqm For
toilets.- 2Kn/sqm

For terrace accessible – 1.5Kn/sqm For terrace
inaccessible – 0.75Kn/sqm

[3] Super imposed dead load floor finish loads –
1.2Kn/sqm wall loads

5) **Earthquake inputs as per IS 1893 (Part 1):2016 Location of building** – Moderate intensity zone2(bengaluru) Soil type – type2
Importance factor -1 Response reduction factor -3

6) **Wind load input as per IS 875:2015**

Wind speed V_b = 33 m/s Terrain Category = 3
Structure Class = c

Risk Coefficient = 1 Topography Factor = 1

7) **Load Combination**

Type	Design Load Combinations
Gravity Analysis	1.5 (Dead Load + Live Load)
Equivalent Static Analysis (Seismic)	1.2 (Dead Load + Live Load + EQX)
	1.2 (Dead Load + Live Load - EQX)
	1.2 (Dead Load + Live Load + EQY)
	1.2 (Dead Load + Live Load - EQY)
	1.5 (Dead Load + EQX)
	1.5 (Dead Load - EQX)
	1.5 (Dead Load + EQY)
	1.5 (Dead Load - EQY)
	0.9 (Dead Load + EQX)
	0.9 (Dead Load - EQX)

Type	Design Load Combinations
	0.9 (Dead Load + EQY)
	0.9 (Dead Load - EQY)
Response Spectrum Analysis	1.2 (Dead Load + Live Load + SPECX)
	1.2 (Dead Load + Live Load - SPECX)
	1.2 (Dead Load + Live Load + SPECY)
	1.2 (Dead Load + Live Load - SPECY)
	1.5 (Dead Load + SPECX)
	1.5 (Dead Load - SPECX)
	1.5 (Dead Load + SPECY)
	1.5 (Dead Load - SPECY)
	0.9 (Dead Load + SPECX)
	0.9 (Dead Load - SPECX)
	0.9 (Dead Load + SPECY)
	0.9 (Dead Load - SPECY)
Wind Analysis	1.2 (Dead Load + Live Load + WINDX)
	1.2 (Dead Load + Live Load - WINDX)
	1.2 (Dead Load + Live Load + WINDY)
	1.2 (Dead Load + Live Load - WINDY)
	1.5 (Dead Load + WINDX)
	1.5 (Dead Load - WINDX)
	1.5 (Dead Load + WINDY)
	1.5 (Dead Load - WINDY)
	0.9 (Dead Load + WINDX)
	0.9 (Dead Load - WINDX)
	0.9 (Dead Load + WINDY)
	0.9 (Dead Load - WINDY)

G. Procedure for Modeling and Analysis

- [1] Model Initialization
- [2] Preparation of template and defining grid and story heights
- [3] Defining required material properties
- [4] Defining required section properties frames ,slab/floors and shear wall
- [5] Preparing framing layout
- [6] Defining and Assigning floor diaphragms
- [7] Defining and Assigning pier labels for all shear walls
- [8] Defining P-delta load case
- [9] Defining load patterns

[10] Defining load cases

[11] Defining load combinations and analyzing structure

IV. RESULT AND DISCUSSION

A. Story Displacement (Considering P-delta)

1) Story Displacement under Gravity Loads (Dead, Live & SIDL)

Under dead load, displacement increases gradually from 0 mm at the base to about **4.94 mm (X)** and **≈3.0 mm (Y)** at the top storey.

For live load, the maximum displacement is lower, around

3.06 mm (X) and **≈1.6 mm (Y)**.

Under superimposed dead load (SIDL), higher values are observed, reaching **≈6.29 mm (X)** and **≈4.8 mm (Y)**.

In all cases, displacement is higher in the X-direction, indicating lower stiffness compared to Y-direction.

Lower storeys show minimal movement due to strong base restraint.

The smooth variation confirms uniform stiffness distribution. Overall, displacements remain within acceptable serviceability limits.

2) Story Displacement under Earthquake Loads (EQX & EQY)

Earthquake loading produces significantly larger displacements compared to gravity loads.

For EQX, the maximum displacement reaches **≈193.74 mm (X)** and about **40 mm (Y)**.

For EQY, the peak displacement is **≈195.36 mm (Y)** and **≈30–**

35 mm (X).

Displacement increases steadily from base to top, with maximum at upper storeys.

Higher values in the loading direction indicate directional flexibility.

The displacement curve remains smooth without irregularities. Shear walls effectively control excessive seismic deformation.

3) Story Displacement under Wind Loads (WINDX & WINDY)

Wind load causes moderate displacement compared to seismic effects.

For WINDX, maximum displacement is about **17.84 mm (X)**

and **≈5–6 mm (Y)**.

For WINDY, it reaches **≈28.41 mm (Y)** and **≈5–6 mm (X)**. Displacement increases gradually with height due to lateral wind pressure.

Lower storeys remain stiff with minimal deformation.

The response is smooth, indicating no stiffness irregularity. Results are within permissible limits, confirming safe performance.

4) *Story Displacement under Response Spectrum Analysis*

Dynamic analysis shows higher displacement due to combined modal effects.

For Spectrum-X, maximum displacement is about **180.49 mm**

(X) and **≈130–140 mm (Y)**.

For Spectrum-Y, values reach **≈194.38 mm (Y)** and **≈150–160 mm (X)**.

Displacement increases steadily with building height.

Higher response is observed in the primary vibration direction. The smooth profile indicates uniform mass and stiffness distribution.

Results confirm adequate seismic performance of the structure.

1) *Modal Analysis (Fundamental Mode Shape)*

Modal analysis shows maximum displacement at the top storey.

Values reach about **20.80 mm (Y)** and **≈15–16 mm (X)**. Displacement increases gradually from base to top.

Higher flexibility is observed in the Y-direction.

The pattern represents typical fundamental mode behavior. No sudden variation indicates structural uniformity.

The system shows stable and controlled dynamic response.

B. *Story Drift (with p-delta)*

1) *Story Drift under Gravity Loads (Dead, Live & SIDL)*

Under dead load, the maximum drift is very small, about **0.000296**

(X) and **≈0.00016–0.00017 (Y)**.

For live load, peak drift occurs at lower storey with values around **0.00048 (X)** and **0.00054 (Y)**.

Under SIDL, drift slightly increases to **≈0.000614 (X)** and **≈0.00028– 0.00030 (Y)**.

Drift values increase gradually with height due to cumulative deformation.

All values are extremely low since these loads are primarily vertical. Smooth variation indicates no stiffness irregularity. All results are well within IS 1893 permissible limits, confirming good stiffness.

2) *Story Drift under Earthquake Loads (EQX & EQY)*

Seismic loading produces the highest drift values in the structure.

For EQX, maximum drift is about **0.005954 (X)** at mid-height (Storey 7).

For EQY, it reaches **0.006168 (Y)** at Storey 7.

Drift increases up to mid-height and then reduces towards the top.

Values exceed the codal limit of **0.004h**, indicating need for design improvement.

Higher drift occurs in the direction of applied load.

Despite this, the overall drift pattern remains smooth and stable.

3) *Story Drift under Wind Loads (WINDX & WINDY)* Wind loads produce moderate drift compared to seismic effects.

For WINDX, maximum drift is ≈ 0.00057 (X) and ≈ 0.00018 –0.00020 (Y).

For WINDY, it is ≈ 0.000953 (Y) and ≈ 0.00018 –0.00020 (X).

Peak drift occurs around mid-height (Storey 4–6).

Lower storeys show negligible drift due to higher stiffness. All values are within permissible serviceability limits.

The structure shows stable and controlled behavior under wind loading.

4) *Story Drift under Response Spectrum Analysis* Dynamic analysis shows higher drift due to combined modal effects.

For Spectrum-X, maximum drift is ≈ 0.005994 (X) and ≈ 0.0042 –0.0045 (Y).

For Spectrum-Y, it reaches ≈ 0.006407 (Y) and ≈ 0.0045 –0.0048 (X).

Maximum drift occurs at mid-height (Storey 6–7).

Values slightly exceed codal limits, suggesting need for stiffness enhancement.

Drift variation is smooth, indicating uniform mass and stiffness distribution.

Shear walls significantly improve seismic resistance.

1) *Modal Analysis (Fundamental Mode Drift)*

Modal analysis shows maximum drift at mid-height (around Storey 6).

Values are about 0.000691 (Y) and ≈ 0.00048 – 0.00050 (X). Drift increases from base to mid-height and then decreases towards top.

This represents typical fundamental mode behavior. Lower levels show negligible drift due to high stiffness.

Values are very small compared to codal limits. The structure exhibits stable and controlled dynamic performance.

C. *Story Shear (With P-Delta)*

1) *Story Shear under Gravity Loads (Dead, Live & SIDL)* Under dead load, storey shear values are nearly zero, with maximum around 5.17×10^{-8} kN.

For live load, the values remain negligible at about 4.01×10^{-8}

kN.

Similarly, SIDL produces very small shear values of approximately 5.79×10^{-8} kN.

These minimal values occur because gravity loads act vertically and do not induce lateral forces.

Shear remains almost constant from base to top.

The structural system efficiently transfers loads directly to the foundation.

This confirms stable behavior under vertical loading conditions.

2) *Story Shear under Earthquake Loads (EQX & EQY)* Seismic loads generate significant lateral shear forces in the structure.

For EQX, maximum base shear is approximately **8003 kN**. For EQY, it reaches about **6767 kN** at the base level.

Shear values decrease gradually from base to top due to mass participation.

Higher values occur in the direction of applied seismic force. The smooth variation indicates uniform stiffness distribution. Shear walls effectively transfer seismic forces to the foundation.

3) *Story Shear under Response Spectrum Analysis* Dynamic analysis produces similar but slightly refined shear values.

For Spectrum-X, base shear is about **7999.62 kN**. For Spectrum-Y, it is approximately **6767.47 kN**. Shear decreases progressively from base to top.

This reflects realistic seismic force distribution considering multiple modes.

Higher values occur in the primary vibration direction.

The system shows efficient load transfer and improved seismic performance.

4) *Story Shear under Wind Loads (WINDX & WINDY)* Wind loads generate moderate shear compared to seismic loads.

For WINDX, maximum base shear is around **992.06 kN**. For WINDY, it increases to about **1396.45 kN**.

Shear decreases gradually from base to top due to load distribution.

Higher values appear in the direction of wind action.

The structure shows smooth variation without irregularities. Shear walls provide adequate resistance to wind forces.

1) *Modal Analysis (Storey Shear Behavior)*

Modal analysis shows variation of shear due to vibration modes.

Maximum modal shear is about **270.99 kN**.

Values vary along height with both positive and negative directions.

This reflects the oscillatory nature of structural response. Lower values compared to seismic loads are expected.

The pattern indicates proper mass and stiffness distribution. The structure shows stable dynamic characteristics.

D. *Story Displacement (Without P-Delta)*

1) *Story Displacement under Gravity Loads (Dead, Live & SIDL)*

Under dead load, maximum displacement is about **4.67 mm**

(X) and **≈2.50 mm (Y)** at the top storey.

For live load, values reduce to **≈2.89 mm (X)** and **≈1.50 mm**

(Y).

Under SIDL, displacement increases slightly to **≈5.91 mm (X)**

and **≈4.80 mm (Y)**

Displacement gradually increases from base to top in all cases. Higher values in X-direction indicate relatively lower stiffness.

The smooth curve shows uniform stiffness distribution. Overall, displacement remains within safe and acceptable limits.

2) Story Displacement under Earthquake Loads (EQX & EQY)

Seismic loads produce significantly higher displacement compared to gravity loads.

For EQX, maximum displacement is **≈178.91 mm (X)** and **≈40 mm (Y)**.

For EQY, it reaches **≈177.84 mm (Y)** and **≈20 mm (X)**. Displacement increases continuously from base to top. Higher values occur in the direction of applied seismic force. The smooth variation indicates proper stiffness and load transfer. Shear walls effectively control excessive lateral movement.

3) Story Displacement under Wind Loads (WINDX & WINDY)

Wind loads cause moderate displacement compared to seismic effects.

For WINDX, maximum displacement is **≈16.41 mm (X)** and **≈5.50 mm (Y)**.

For WINDY, it is **≈25.79 mm (Y)** and **≈3.50 mm (X)**. Displacement increases gradually with height. Higher values occur in the direction of wind action. The smooth pattern indicates no stiffness irregularity. Results confirm adequate structural stability under wind loads.

1) Story Displacement under Response Spectrum Analysis

Dynamic analysis shows high displacement due to seismic effects.

For Spectrum-X, maximum displacement is **≈167.49 mm (X)**

and **≈120 mm (Y)**.

For Spectrum-Y, it reaches **≈174.98 mm (Y)** and **≈135 mm (X)**.

Displacement increases steadily from base to top. Higher response occurs in dominant vibration direction.

The smooth curve indicates uniform stiffness distribution. Shear walls improve seismic performance effectively.

2) Modal Analysis (Fundamental Mode Shape)

Modal analysis shows maximum displacement at the top storey. Values are about **≈20.88 mm (Y)** and **≈15.20 mm (X)**. Displacement increases gradually along the height.

Higher flexibility is observed in Y-direction.

The pattern represents typical fundamental mode behaviour. No irregularities indicate uniform mass and stiffness distribution.

The structure exhibits stable dynamic characteristics.

E. Story Drift (Without P-Delta)

1) *Story Drift under Gravity Loads (Dead, Live & SIDL)* Under dead load, maximum drift is about **0.000296**, occurring near upper storeys. For live load, the peak drift is slightly higher at **≈0.000529**, mainly at lower levels. Under SIDL, drift increases to **≈0.000613** due to additional permanent loads.

Drift values are very small as these loads act primarily in vertical direction.

Slightly higher drift is observed in X-direction, indicating minor stiffness variation.

The smooth variation confirms uniform stiffness distribution. All values are well within permissible limits, ensuring good serviceability.

2) *Story Drift under Earthquake Loads (EQX & EQY)* Seismic loads produce significantly higher drift compared to gravity loads.

For EQX, maximum drift is **≈0.005455 (X)** at mid-height. For EQY, it reaches **≈0.005554 (Y)** at intermediate storeys. Drift increases from base to mid-height and reduces towards the top.

Higher drift occurs in the direction of applied seismic force. The smooth curve indicates no stiffness irregularity. Shear walls effectively control deformation and improve stability.

3) *Story Drift under Wind Loads (WINDX & WINDY)* Wind loads produce moderate drift compared to seismic effects.

For WINDX, maximum drift is **≈0.00052 (X)**. For WINDY, increases to **≈0.000853 (Y)**. Peak drift occurs at intermediate storeys. Lower storeys show negligible drift due to higher stiffness. The variation is smooth, indicating stable structural response.

All values are within allowable limits, ensuring safe performance.

1) *Story Drift under Response Spectrum Analysis* Dynamic analysis shows higher drift due to seismic effects. For Spectrum-X, maximum drift is **≈0.005524 (X)**.

For Spectrum-Y, it is **≈0.005683 (Y)**.

Maximum drift occurs at mid-height of the structure. Values are higher than static loads due to modal effects. Smooth variation indicates proper stiffness distribution.

The structure shows stable behavior under dynamic loading.

2) *Modal Analysis (Fundamental Mode Drift)*

Modal analysis shows maximum drift at intermediate storeys. Values are about **≈0.000686 (Y)** and lower in X-direction.

Drift increases from base to mid-height and then decreases. This represents typical fundamental mode behaviour.

No sudden changes indicate uniform mass and stiffness distribution.

Values are very small compared to seismic drift.

The structure exhibits stable dynamic characteristics.

F. Story Shear (Without P-Delta)

1) *Story Shear under Gravity Loads (Dead, Live & SIDL)* Under dead load, storey shear is almost zero, with a maximum of $\approx 1.13 \times 10^{-8}$ kN. For live load, it remains negligible at $\approx 6.32 \times 10^{-9}$ kN.

Under SIDL, the value is slightly higher but still very small at $\approx 2.54 \times 10^{-8}$ kN.

These minimal values occur because all these loads act vertically.

No significant lateral force is generated across storeys. The graph remains nearly constant throughout the height.

This confirms stable behavior under gravity loading conditions.

2) *Story Shear under Earthquake Loads (EQX & EQY)*

Seismic loads generate significant lateral shear forces. For EQX, maximum base shear is about **≈ 8003 kN**. For EQY, it is approximately **≈ 6767 kN** at the base. Shear values decrease gradually from base to top.

Higher shear occurs in the direction of applied seismic load. The smooth curve indicates proper stiffness distribution.

Shear walls efficiently transfer forces to the foundation.

3) *Story Shear under Response Spectrum Analysis* Dynamic analysis provides realistic seismic shear distribution. For Spectrum-X, base shear is about **≈ 8005 kN**. For Spectrum-Y, it is around **≈ 6767 kN**.

Shear reduces progressively with building height.

Higher values are observed in the primary vibration direction. The variation pattern is smooth and consistent.

This confirms efficient seismic load transfer.

4) *Story Shear under Wind Loads (WINDX & WINDY)*

Wind loads produce moderate lateral shear.

For WINDX, base shear is approximately **≈ 992 kN**. For WINDY, it increases to **≈ 1396 kN**.

Shear decreases gradually from base to top.

Higher values occur in the direction of wind loading. The structure shows stable and smooth variation.

Shear walls provide adequate resistance to wind forces.

1) *Modal Analysis (Storey Shear Behavior)*

Modal analysis shows inertia-based shear distribution. Maximum shear is about **≈ 299.83 kN (Y)** and **≈ 161.77 kN (X)**.

Shear increases from top to base in fundamental mode. Values are lower compared to seismic load cases.

The variation reflects vibration characteristics of the structure. Smooth pattern indicates uniform mass and stiffness.

The structure exhibits stable dynamic behavior.

G. Base Shear

The comparison of base shear values obtained from ETABS analysis with and without P-Delta effect shows that the influence of P-Delta on base shear is negligible for the present shear wall building. The equivalent static seismic load cases EQX and EQY give exactly the same base shear values in both analyses, while the response spectrum cases show only marginal variation. This confirms that the P-Delta effect does not significantly alter the total lateral force transferred to the base. However, it remains important in evaluating second- order effects such as additional displacement, drift, and moment amplification in high-rise structures.

H. Over all Comparison of Storey Shear Plots (With P- Delta vs Without P-Delta) for Shear Wall Structure

The comparison of storey shear results obtained from ETABS analysis, considering both with and without P-Delta effects, shows that the structural response of the shear wall system remains consistent under different loading conditions. The study includes gravity loads, wind loads, seismic loads, response spectrum cases, and modal analysis.

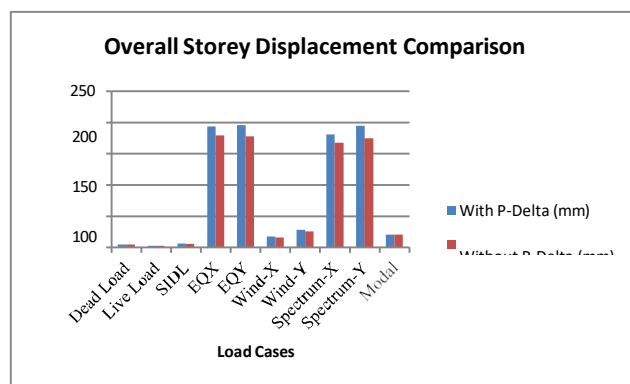
In all cases, the maximum storey shear is observed at the base level and decreases progressively towards the top, which reflects the typical response of multi-storey structures under lateral loading. The comparison indicates that the variation between P-Delta and non P-Delta results is minimal, as the shear values in both cases are nearly identical and the graphical trends closely match.

Seismic loading conditions produce significantly higher storey shear compared to wind loads, indicating that earthquake forces govern the design for the given structure. Wind-induced shear forces are comparatively smaller, and the influence of P- Delta effects on these values is negligible.

Modal analysis shows only slight differences due to second- order effects, suggesting a minor reduction in stiffness. However, the overall structural behavior remains stable, and no irregularities or weak storey conditions are observed along the building height.

The inclusion of shear walls enhances the lateral stiffness of the structure, reducing the impact of P-Delta effects on storey shear. While these effects have limited influence on shear forces, they are more relevant in evaluating displacement and drift.

In conclusion, the structure demonstrates reliable performance under all loading conditions. The consideration of P-Delta effects improves analysis accuracy but does not significantly alter storey shear results. The building satisfies stability and safety requirements as per relevant design standards



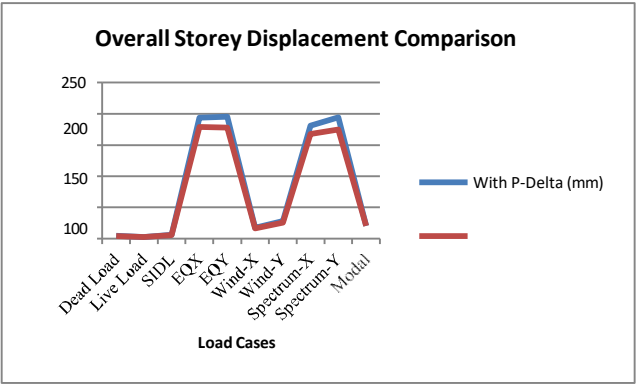


Fig. 2 Overall Storey Displacement Comparison

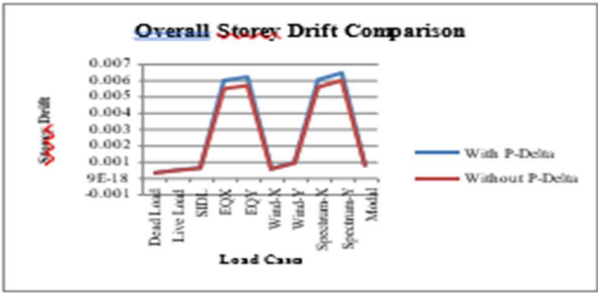
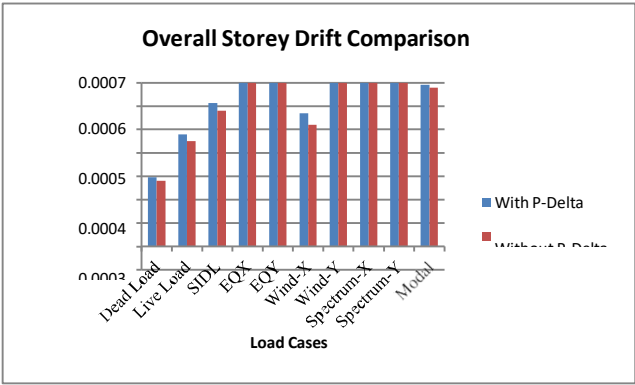


Fig. 3 Overall Storey Drift Comparison

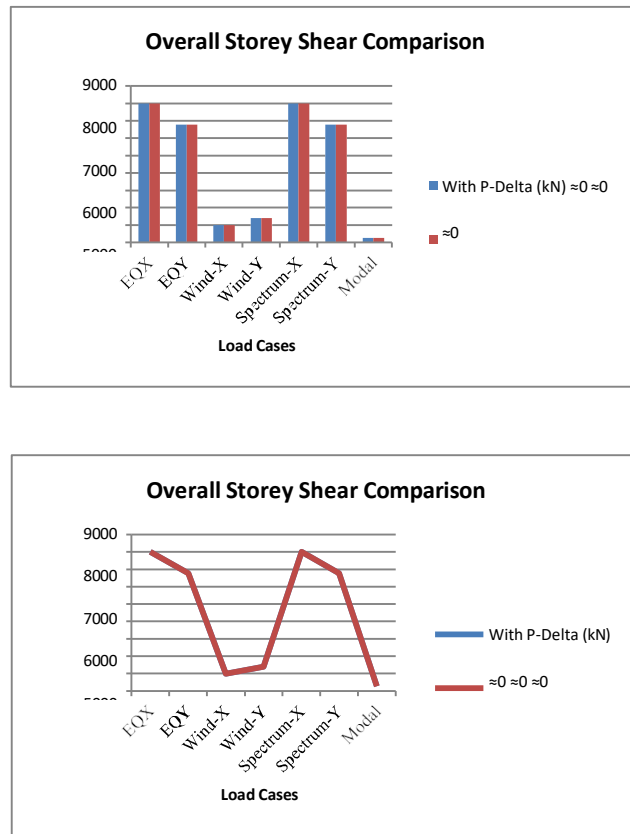


Fig. 4 Overall Storey Shear Comparison

V. CONCLUSION

- The analysis shows that storey shear is highest at the base and reduces gradually towards the top, reflecting expected structural behavior under lateral loads.
- Comparison between cases with and without P-Delta effect reveals only minor differences in shear values.
- The similarity in graph patterns indicates that overall stiffness is not significantly affected by second-order effects.
- Seismic load cases generate much higher shear compared to gravity loads, making them the governing factor in design.
- Results from response spectrum analysis closely match those from the equivalent static method, confirming consistency.
- Maximum base shear is around 8000 kN in X-direction and 6767 kN

in Y-direction, indicating higher demand along X.

- Wind loads produce comparatively lower shear forces than seismic loads.
- The influence of P-Delta effect on wind-induced shear is negligible.
- Modal analysis shows only slight variation due to second- order effects, indicating stable dynamic response.
- The shear distribution along the height is smooth, showing uniform stiffness throughout the structure.
- No abrupt changes in shear values are observed, confirming absence of soft storey behavior.
- Shear walls significantly enhance lateral stiffness and reduce sensitivity to P-Delta effects.
- Differences in base shear between the two cases are minimal, showing that P-Delta mainly affects displacement rather than shear.
- The structure demonstrates efficient load transfer from top to foundation under all loading conditions.
- Overall, the building satisfies safety and performance requirements, and inclusion of P-Delta improves analytical accuracy without major impact on shear values.

REFERENCES

- [1] Regina Gaiotti and Bryan Stafford Smith, "P-Delta Analysis of Building Structures", Journal of Structural Engineering, Vol.115, Issue 4, pp.755-770, 1989.
- [2] E. L. Wilson and A. Habibullah, "Static and Dynamic Analysis of Multi-Story Buildings Including P-Delta Effects", Computers and Structures Inc., Berkeley, California, USA.
- [3] Brian R. Wood, "Column Design by P-Delta Method", Journal of Structural Engineering, ASCE, 1990.
- [4] Pushparaj J. Dhawale, G. N. Narule and M. S. Engineer, "Analysis of High Rise Buildings", International Journal of Civil Engineering Research, 2015.
- [5] Christoph Adam, Luis F. Ibarra and Helmut Krawinkler, "Evaluation of P-Delta Effects in Multi-Degree-of-Freedom Structures Using Equivalent Single-Degree-of-Freedom Systems", Earthquake Engineering and Structural Dynamics, 2015.
- [6] C. G. Konapure and P. V. Dhanshetti, "Effect of P-Delta Action on Multistory Buildings", International Journal of Engineering Research and Applications, 2016.
- [7] Ajay Kumar Gupta, "Response Spectrum Method in Seismic Analysis and

- Design of Structures”, Journal of Earthquake Engineering, 1990.
- [8] Yuki Terazawa and Toru Takeuchi, “Generalized Response Spectrum Analysis for Structures with Dampers”, Earthquake Spectra, Vol.34, Issue 3, pp.1459-1479, 2018.
 - [9] Michalis Fragiadakis, “Response Spectrum Analysis of Structures Subjected to Seismic Actions”, Journal of Structural Engineering, 2010.
 - [10] Donato Cancellara and Fabio De Angelis, “Dynamic Assessment of Base Isolation Systems for Irregular in Plan Structures: Response Spectrum Analysis vs Nonlinear Analysis”, Composite Structures, Vol.215, pp.98-115, 2019.
 - [11] Sigmund A. Freeman, “Response Spectra as a Useful Design and Analysis Tool for Practicing Structural Engineering”, ISET Journal of Earthquake Technology, Vol.44, Issue 1, pp.25-37, 2007.
 - [12] Roberto Villaverde, “Simplified Response-Spectrum Seismic Analysis of Nonlinear Structures”, Journal of Engineering Mechanics, Vol.122, Issue 3, pp.282-285, 1996.
 - [13] N. R. Chandak, “Response Spectrum Analysis of Reinforced Concrete Buildings”, Journal of Institution of Engineers (India): Series A, Vol.93, Issue 2, pp.121-128, 2012.
 - [14] Zhidong Gao, Mi Zhao, Xiuli Du and Xu Zhao, “Seismic Soil-Structure Interaction Analysis of Structure with Shallow Foundation Using Response Spectrum Method”, Bulletin of Earthquake Engineering, Vol.18, Issue 8, pp.3517-3543, 2020.
 - [15] A. Ravi Kumar, K. Sundar Kumar and Badipati Anup, “Analysis and Design of Shear Wall for an Earthquake Resistant Building Using ETABS”, International Journal for Innovative Research in Science and Technology, Vol.4, Issue 5, pp.73-79, 2017.
 - [16] Rachkonda Divya and K. Murali, “Comparative Analysis of Behaviour of Horizontal and Vertical Irregular Buildings with and without Using Shear Walls by ETABS Software”, Materials Today: Proceedings, Vol.52, pp.1821-1830, 2022.
 - [17] M. Pavani, G. Nagesh Kumar and Dr. Sandeep Pingale, “Shear Wall Analysis and Design Optimization in Case of High Rise Buildings Using ETABS”, International Journal of Scientific and Engineering Research, Vol.6, Issue 1, pp.546-559, 2015.
 - [18] B. Vamshi Krishna, A. V. Prasanna Kumar and E. Rakesh Reddy, “Shear Wall Analysis and Design Optimization in Case of High Rise Buildings Using ETABS”, Solid State Technology, Vol.63, Issue 2, 2020.
 - [19] V. Singh and G. Tanwar, “Importance of Shear Wall in Multistory Building with Seismic Analysis using ETABS”, International Journal of Science Technology and Management, Vol.8, Issue 2, 2021.
 - [20] Kamalroop Kaur and Balwinder Singh, “Seismic Analysis of Symmetric and Asymmetric Structure with and without Shear Wall using ETABS Software”, IOP Conference Series: Earth and Environmental Science, Vol.889, 012043, 2021.
 - [21] Jaimin Dodiya, Mayank Devani, Akash Dobariya, Mehul Bhuva and Kamalsinh Padhiar, “Analysis of Multistory Building with Shear Wall using ETABS Software”, International Research Journal of Engineering and Technology (IRJET), Vol.5, Issue 02, 2018.
 - [22] V. B. P. Ravishankar and Vishwanath B. Patil, “Comparative Study of Seismic Performance of a Building with and without P-Delta Effect using Response Spectrum Analysis”, International Journal for Scientific Research and Development, Vol.5, Issue 09, 2017.

Gagan Kumar R holds a bachelor's degree in civil engineering from Visvesvaraya Technological University (VTU), Belagavi, Master's degree in Structural Engineering from VTU (final semester), Belagavi. His current research interests are analysis of high-rise structures, and behavior of structures in different modes.

e-mail id: gagankumar93804@gmail.com
Ph: no. 7975846992

Dr. Virendra Kumara K.N. holds a bachelor's degree in civil engineering from Visvesvaraya Technological University (VTU), Belagavi, Master's degree in Structural Engineering from VTU, Belagavi. Ph.D in Fibre Reinforced Concrete in the year 2019 from VTU, Belagavi. He is Head and Professor in the Department of Civil Engineering, Vijaya Vittala Institute of Technology, Bangalore. His current research interests are fiber reinforced concrete, concrete production with industrial by products and alternative building materials.

e-mail id: virendrakumara80@gmail.com
Ph: no. 9164347804