



IJRASET

International Journal For Research in
Applied Science and Engineering Technology



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 12 **Issue:** V **Month of publication:** May 2024

DOI: <https://doi.org/10.22214/ijraset.2024.62564>

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Optimization of Staging Height of RCC Overhead Water Tank in High Seismic Zones Using P-Delta Analysis

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Abstract: This study investigates the P-delta effect, which is a secondary effect or a geometric non-linear effect in the analysis of a circular overhead water tank with a capacity of 100 KL using STAAD software in high seismic zones, i.e., Zone IV & Zone V with a focus on optimization of staging height and to quantify the effect of P-Delta. Initially, a linear static analysis was performed without considering the P-Delta effect to determine the shear forces, bending moments and lateral displacements due to all possible loads including seismic and wind loads acting on RCC overhead water tanks. Subsequently, the P-Delta effect has been considered to assess the structural behaviour of the RCC overhead water tank with varying staging heights. To optimize the staging height, the maximum lateral displacement has been considered as the governing criteria. Based on the analysis, the optimum staging heights can be observed at 30 m. and 33 m. in Seismic Zone V and Zone IV respectively.

Keywords: P-Delta effect, Optimization, Staging Height, Over Head Water Tank, Seismic Analysis

I. INTRODUCTION

Rapid urban growth and population growth requires the development of a reliable water supply, especially in earthquake-prone regions where the risk of damage from earthquakes is high. An important part of this system is reinforced concrete (RCC) waterworks, which must be designed to withstand seismic forces while ensuring proper water distribution. The water distribution area will increase as the above water tank's staging height rises.

The P-Delta effect plays a crucial role in the analysis of structures when they encounter with lateral forces. When a tall structure or structural component is subjected to lateral forces or significant lateral displacement, it leads to additional moments, and/or axial force distribution at the base of the structure. In the P-Delta analysis initially structural response under the imposed loads, conduct a linear static analysis without considering the P-Delta effect, later that The P-Delta effect is to be taken into account in this analysis either geometric nonlinear analysis or iterative process or both.

In this study to assess and quantify the structural performance parameters like axial force, shear force, bending moment of the overhead water tank with and without P-Delta effect in accordance with IS codal provisions, subsequently to optimize the staging height of the 100 KL circular RCC overhead water tank in high seismic zones.

II. NUMERICAL MODELLING

A circular flat bottom RC overhead water tank has modelled in Bentley Staad pro software. The columns, brace/tie beams and ring beams are considered as beam elements and tank walls, top and bottom slabs are considered as plate elements with the following input parameters

Table I - Input Parameters for tank Model

| S No. | Parameter | Value |
|-------|------------------|--|
| 1 | Tank Type | Flat bottom circular RCC Overhead tank |
| 2 | Capacity of tank | 100 KL |
| 3 | Dia. of Tank | 6.5 m |
| 4 | Height of tank | 3.5 m |
| 5. | Free board | 0.3 m |
| 6 | Dead storage | 0.2 m |
| 7 | No. of columns | 6 No.s |

| | | |
|----|--|------------------------------------|
| 8 | Centre to centre Spacing between Bracing/Tie Beams | 3.0 m |
| 9 | Columns with fixed supports at base | 450 X 450 mm |
| 10 | Clear cover | for columns 40mm & for beams 30 mm |
| 11 | Thickness of tank roof | 150 mm |
| 12 | Thickness of tank side walls and bottom floor slab | 250 mm |
| 13 | Walk way around the tank | 1m. Wide and 125 mm thick |
| 14 | Ring beam | 300 X 600 mm |
| 15 | Tie beam/ Brace beam | 400 X 450 mm |
| 16 | Grade of Concrete | M 30 |
| 17 | Grade of Steel | Fe 415 |
| 18 | Staging Height | From 9 m onwards |

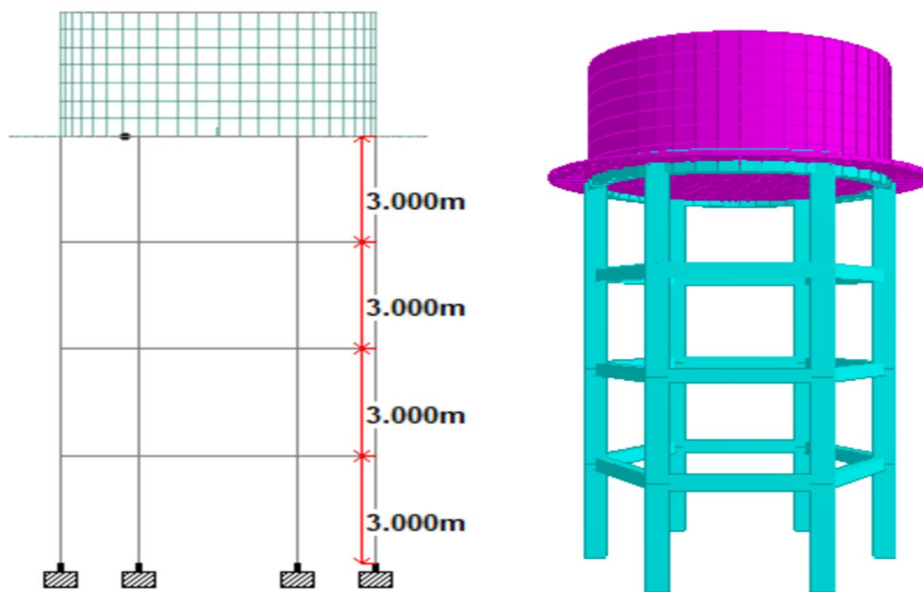


Fig 1. Model of a Circular Flat Bottom Overhead Tank

III. LOAD CONSIDERATIONS

The following loads are considered for the analysis of the overhead water tank

- 1) *Dead Load*: Self-weight of the all-structural elements.
- 2) *Live Load*: 2 KN/m² on the roof for maintenance.
- 3) *Seismic Loads*: In High seismic zones (IV & V), the overhead circular water tank was first given the seismic load; in accordance with IS 1893-2016, the appropriate zone factors are 0.24 & 0.36 respectively and the importance factor is 1.5. considering that the structure has a Special Moment Resisting Frame (SMRF) and is to be erected on Type I (Hard) soil, 5.0 was chosen as the reduction factor with a damping ratio of 5 %. The seismic load was applied in all four directions (+X, -X, +Z, and -Z) using these values.

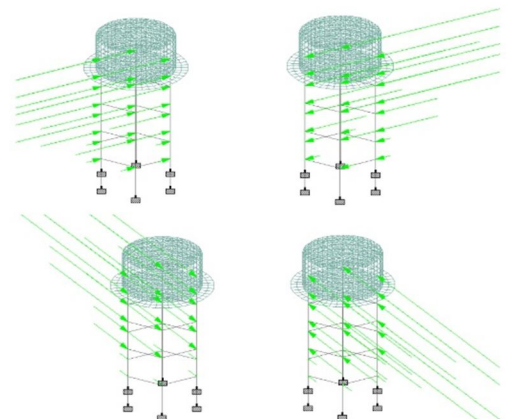


Fig 2. Seismic Loading on a tank

4) *Wind Loads:*

As per IS 875 Part III; The Basic Wind Speed (V_b) 50 m/sec for Bhuj & 47 m/sec for Ambala, Risk Coefficient k_1 , Topography factor k_3 , importance factor cyclonic region k_4 are taken as 1 and Terrain, Height and structure factor k_2 (Terrain I)

$$\text{Design wind speed } V_z = V_b \cdot k_1 \cdot k_2 \cdot k_3 \cdot k_4$$

$$\text{Design wind pressure at Z height } P_z = 0.6 V_z^2$$

$$\text{Design wind pressure } P_d = K_d \times K_a \times K_c \times P_z$$

$$\text{wind directionality factor } K_d = 1$$

$$\text{Area averaging factor } K_a = 0.9 \text{ \&}$$

$$\text{Combination factor } K_c = 0.9$$



Fig 3. Wind loads acting on a tank

5) *Water pressure on tank walls:*

The circumstances were taken into account when analyzing the tank structure in both full and empty states.

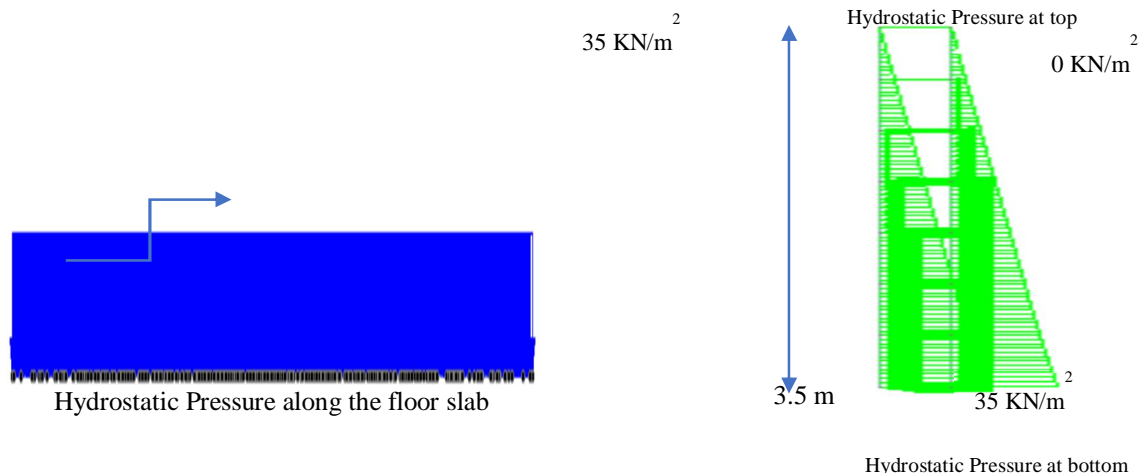


Fig 4 Hydrostatic Pressure on tank walls and floor slab under tank full condition

6) *Load combinations:*

The Load combinations are taken from IS 456:2000 & IS 875-Part V

1.5 (DL+LL)

• *Earthquake Load Combinations*

1.5 (DL+WATER LOAD ± EQ Load)

0.9(DL+WATER LOAD) ±1.5 EQ Load

1.2 (DL+LL+WATER LOAD ± EQ Load)

1.0 (DL+WATER LOAD ± EQ Load)

1.0 (DL+LL+WATER LOAD ± EQ Load)

• *Wind Load Combinations*

1.5 (DL+WATER LOAD ± WIND Load)

0.9(DL+WATER LOAD) ± 1.5 WIND Load

1.2 (DL+LL+WATER LOAD ± WIND Load)

1.0 (DL+WATER LOAD±WIND Load)

1.0 (DL+LL+WATER LOAD±WIND Load)

IV. RESULTS AND DISCUSSIONS

A 100 KL circular overhead water tank has been created and analysed in Staad Pro with tank empty and full conditions and drawn the following results with and without the P-Delta effect in high seismic zones.

As a result, the maximum lateral displacement in Seismic Zone V exceeding the allowable limit at a staging height of 33 meters, Therefore, the structural performance parameters are analysed and compared and quantified the P-Delta effect from a staging height of 27m in Zone V & IV.

A. Axial Force (Fx):

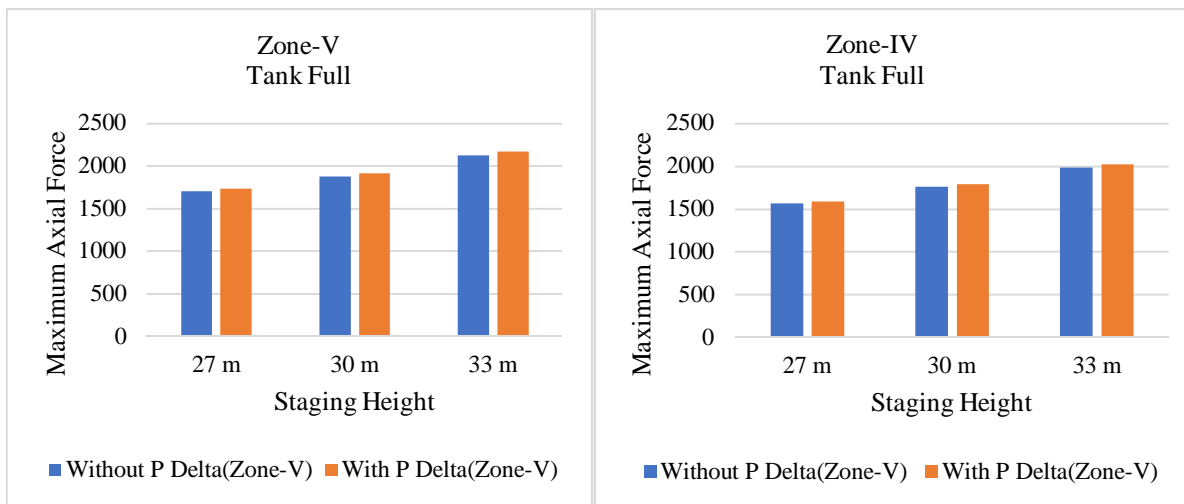
From the analysis the maximum axial force is developed at the base of the structure with a critical load combination of 1.5 (DL+WATER LOAD+WIND ±X) in tank full condition and 1.5(DL+WIND±X) in empty condition. The maximum axial force increases with staging height and shifts from seismic zone IV to zone V, as the following table makes evident.

Table II - Maximum axial force (Fx) in tank full condition

| STAGING HEIGHT (m) | TANK FULL | | | | | |
|--------------------|--------------------------|--------------|-----------------|-----------------|--------------|-----------------|
| | MAXIMUM AXIAL FORCE (KN) | | | | | |
| | ZONE V | | | ZONE IV | | |
| | WITHOUT P DELTA | WITH P DELTA | % OF DIFFERENCE | WITHOUT P DELTA | WITH P DELTA | % OF DIFFERENCE |
| 27 | 1703.38 | 1731.042 | 1.60 | 1567.282 | 1590.46 | 1.46 |
| 30 | 1879.925 | 1914.893 | 1.83 | 1758.016 | 1788.545 | 1.71 |
| 33 | 2124.103 | 2168.335 | 2.04 | 1987.637 | 2026.697 | 1.93 |

Table III - Maximum axial force (Fx) in tank empty condition

| STAGING HEIGHT (m) | TANK EMPTY | | | | | |
|--------------------|--------------------------|--------------|-----------------|-----------------|--------------|-----------------|
| | MAXIMUM AXIAL FORCE (KN) | | | | | |
| | ZONE V | | | ZONE IV | | |
| | WITHOUT P DELTA | WITH P DELTA | % OF DIFFERENCE | WITHOUT P DELTA | WITH P DELTA | % OF DIFFERENCE |
| 27 | 1413.854 | 1429.775 | 1.11 | 1277.756 | 1291.36 | 1.05 |
| 30 | 1590.399 | 1610.912 | 1.27 | 1468.399 | 1486.637 | 1.23 |
| 33 | 1834.59 | 1861.952 | 1.47 | 1698.123 | 1722.854 | 1.44 |



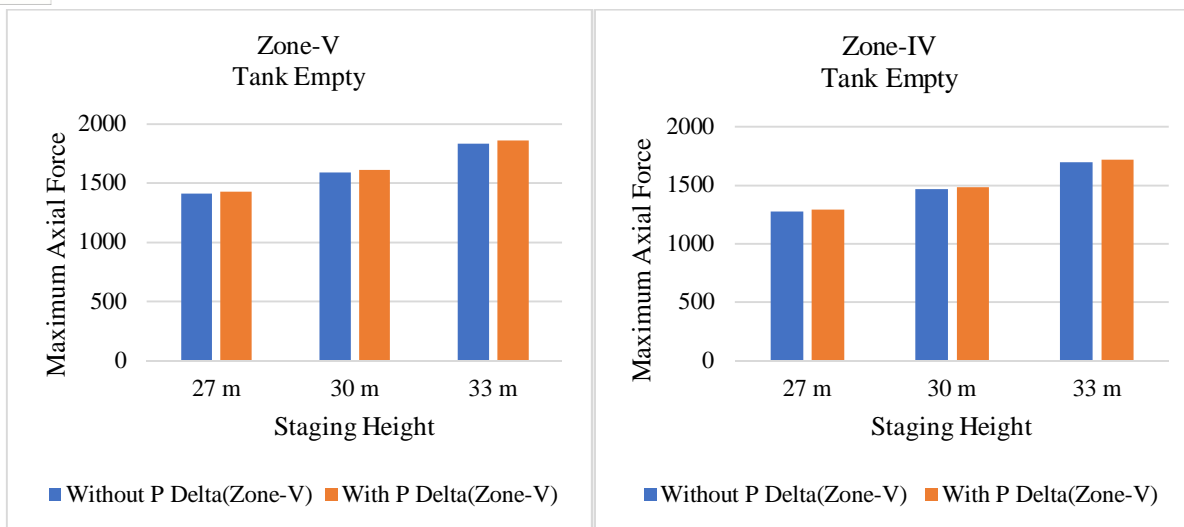


Fig 5. Maximum axial force in tank full and empty condition (Zone V & IV)

In Figure 5, the maximum axial force for a certain staging height for a given zone is shown to have an average increment of **1.8%** in tank full condition and **1.3%** in tank empty condition which takes the P-Delta effect into account.

B. Maximum Shear Force (Fy):

From the analysis the maximum Shear force increases with staging height and shifts from seismic zone IV to zone V, as the following table makes evident. The maximum shear force developed at 30 m & 33 m staging height under a critical load combination of 1.5 (DL+WATER LOAD+ WIND ±X).

Table IV - Maximum Shear force (Fy) in tank full condition

| STAGING HEIGHT (m) | TANK FULL | | | | | |
|--------------------|--------------------------|--------------|-----------------|-----------------|--------------|-----------------|
| | MAXIMUM SHEAR FORCE (KN) | | | | | |
| | ZONE V | | | ZONE IV | | |
| | WITHOUT P DELTA | WITH P DELTA | % OF DIFFERENCE | WITHOUT P DELTA | WITH P DELTA | % OF DIFFERENCE |
| 27 | 159.537 | 161.091 | 0.965 | 138.204 | 139.242 | 0.75 |
| 30 | 161.723 | 167.095 | 3.215 | 142.885 | 147.587 | 3.19 |
| 33 | 179.356 | 185.511 | 3.318 | 159.453 | 164.885 | 3.29 |

Table V - Maximum Shear force (Fy) in tank Empty condition

| STAGING HEIGHT (m) | TANK EMPTY | | | | | |
|--------------------|--------------------------|--------------|-----------------|-----------------|--------------|-----------------|
| | MAXIMUM SHEAR FORCE (KN) | | | | | |
| | ZONE V | | | ZONE IV | | |
| | WITHOUT P DELTA | WITH P DELTA | % OF DIFFERENCE | WITHOUT P DELTA | WITH P DELTA | % OF DIFFERENCE |
| 27 | 150.321 | 153.192 | 1.87 | 129.243 | 131.726 | 1.88 |
| 30 | 161.722 | 165.115 | 2.05 | 142.868 | 145.905 | 2.08 |
| 33 | 179.356 | 183.48 | 2.25 | 159.453 | 163.182 | 2.29 |

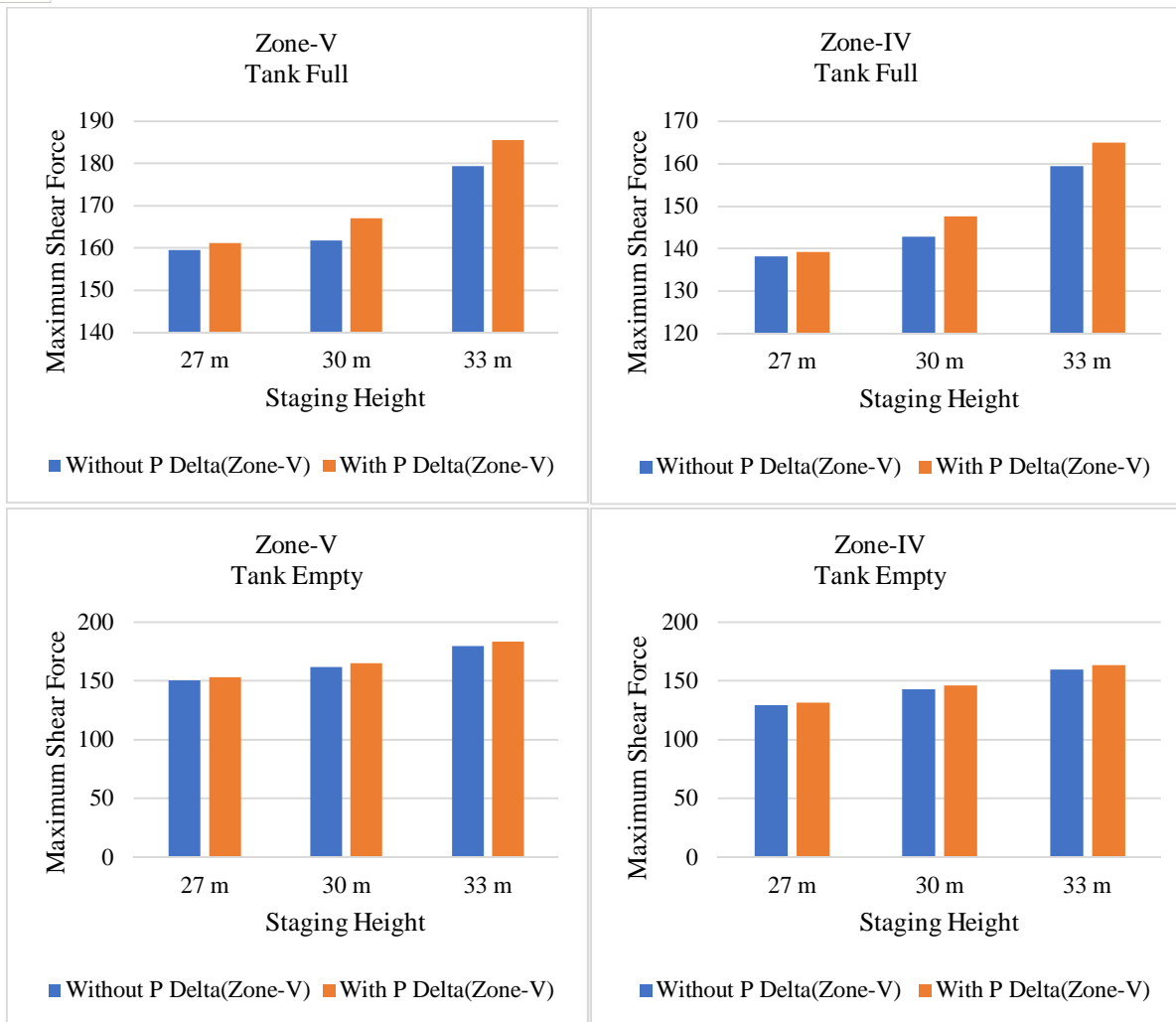


Fig 6. Maximum Shear force in tank full and empty condition (Zone V & IV)

In Figure 6, the maximum shear force for a certain staging height for a given zone is shown to have an average increment of 2.5% in tank full condition and 2.05% in tank empty condition which takes the P-Delta effect into account

C. Maximum Bending Moment:

From the analysis the maximum bending moment increases with staging height and shifts from seismic zone IV to zone V, as the following table makes evident. The maximum bending moment developed under a critical load combination of 1.5 (DL+WATER LOAD+ WIND ±X).

Table VI - Maximum Bending Moment - tank full condition

| STAGING HEIGHT (m) | TANK FULL | | | | | |
|--------------------|-------------------------------|--------------|-----------------|-----------------|--------------|-----------------|
| | MAXIMUM BENDING MOMENT (KN-m) | | | | | |
| | ZONE V | | | ZONE IV | | |
| | WITHOUT P DELTA | WITH P DELTA | % OF DIFFERENCE | WITHOUT P DELTA | WITH P DELTA | % OF DIFFERENCE |
| 27 | 232.711 | 240.273 | 3.15 | 198.46 | 204.873 | 3.13 |
| 30 | 251.237 | 259.932 | 3.35 | 220.625 | 228.24 | 3.34 |
| 33 | 279.891 | 289.849 | 3.44 | 247.549 | 256.341 | 3.43 |

Table VII - Maximum Bending Moment - tank empty condition

| STAGING HEIGHT (m) | TANK EMPTY | | | | | |
|--------------------|-------------------------------|--------------|-----------------|-----------------|--------------|-----------------|
| | MAXIMUM BENDING MOMENT (KN-m) | | | | | |
| | ZONE V | | | ZONE IV | | |
| | WITHOUT P DELTA | WITH P DELTA | % OF DIFFERENCE | WITHOUT P DELTA | WITH P DELTA | % OF DIFFERENCE |
| 27 | 232.71 | 237.349 | 1.95 | 198.458 | 202.474 | 1.98 |
| 30 | 251.236 | 256.717 | 2.14 | 220.599 | 225.507 | 2.18 |
| 33 | 279.891 | 286.547 | 2.32 | 247.55 | 253.572 | 2.37 |

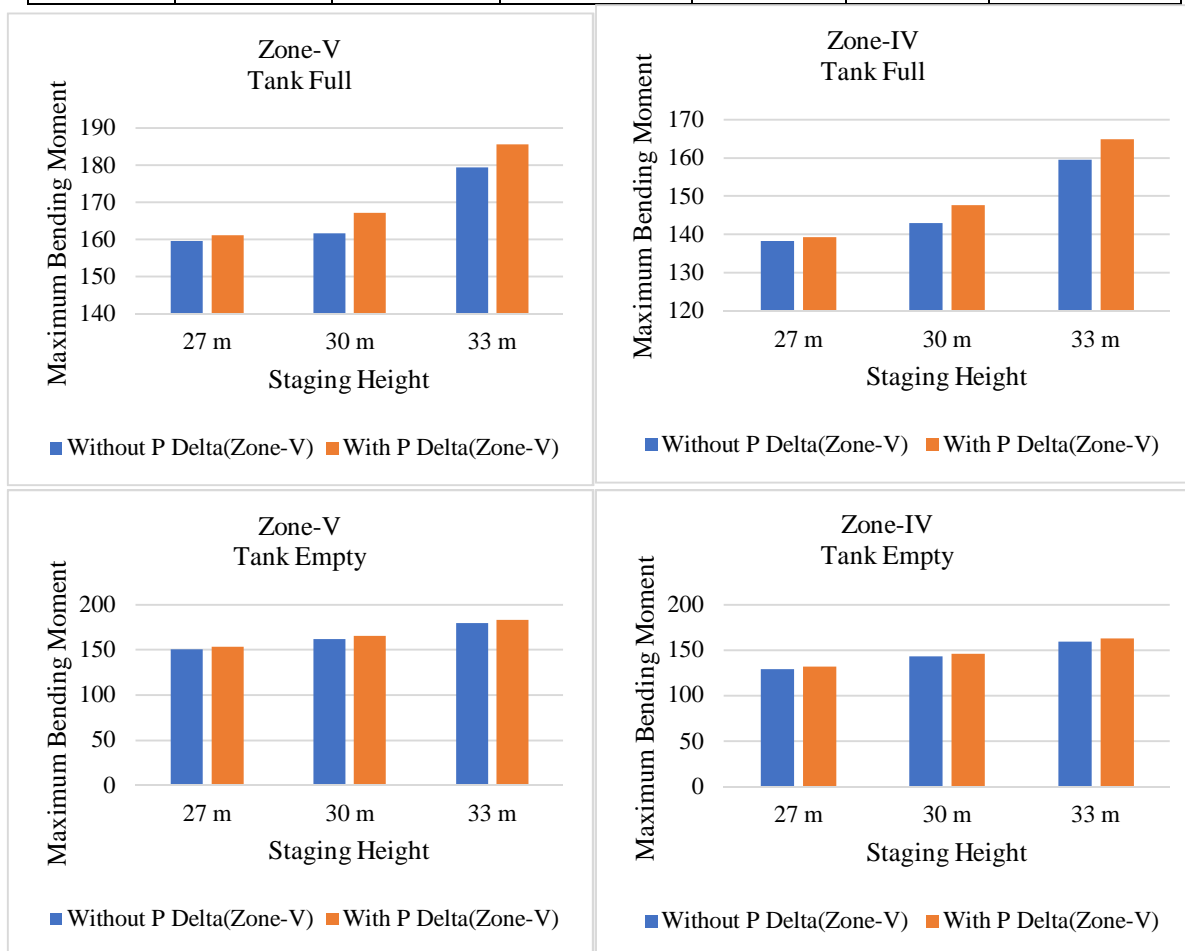


Fig 7. Maximum Bending Moment in tank full and empty condition (Zone V & IV)

In Figure 7, the maximum Bending Moment for a certain staging height for a given zone is shown to have an average increment of **3.3%** in tank full condition and **2.15%** in tank empty condition which takes the P-Delta effect into account

D. Base Shear:

The base shear value depends on the seismic weight of the structure, zone factor, Importance factor, Response reduction factor and natural time period. In zone V gets the maximum base shear values when compares with the Zone IV at common staging height. The variation of base shear values considering the P-Delta effect is shown below

Table VIII - Maximum Bending Moment - tank full condition

| STAGING HEIGHT (m) | TANK FULL | | | | | |
|--------------------|-----------------|---------|-----------------|------------|---------|-----------------|
| | BASE SHEAR (KN) | | | | | |
| | TANK FULL | | | TANK EMPTY | | |
| | ZONE V | ZONE IV | % OF DIFFERENCE | ZONE V | ZONE IV | % OF DIFFERENCE |
| 27 | 188.52 | 122.95 | 34.78 | 129.78 | 86.45 | 33.54 |
| 30 | 184.43 | 120.74 | 34.53 | 129.68 | 86.52 | 33.28 |
| 33 | 181.11 | 118.93 | 34.33 | 129.77 | 86.67 | 33.21 |

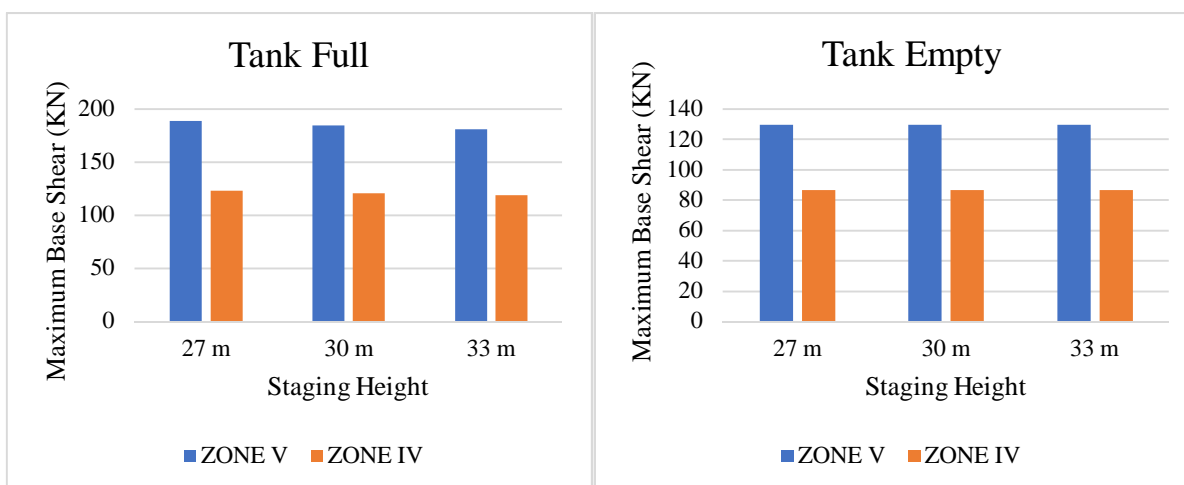


Fig 7. Maximum Base Shear in tank full and empty condition in both Zone V & IV

E. Quantity of concrete & Reinforcement in the staging without considering the tank walls:

1) Quantity of Concrete

The amount of concrete needed for the staging of an overhead water tank is displayed in the following table at different staging heights without taking the tank walls into account. It is noted that the amount of concrete remains the same at common staging heights regardless of whether the P-Delta effect is taken into account or not.

Table IX - Quantity of concrete at varying staging heights

| STAGING HEIGHT (m) | 9 | 12 | 15 | 18 | 21 | 24 | 27 | 30 |
|--|------|------|------|------|------|------|------|------|
| Quantity of Concrete (m ³) | 21.6 | 28.8 | 35.9 | 43.1 | 50.2 | 57.4 | 64.6 | 71.7 |

The Total Quantity of Reinforcement in the staging in KN

The amount of reinforcement needed for the staging of an overhead water tank is displayed in the following table at different staging heights without taking the tank walls into account. It is observed that, whether the P Delta effect is taken into account, the amount of reinforcement is increasing at common staging height.

Table X - Quantity of Reinforcement at varying staging heights in Zone V

| STAGING HEIGHT (m) | 9 | 12 | 15 | 18 | 21 | 24 | 27 | 30 |
|--------------------|--------|--------|--------|--------|--------|--------|--------|--------|
| WITHOUT | 17.736 | 22.502 | 26.727 | 30.941 | 38.164 | 45.708 | 55.799 | 63.865 |

| | | | | | | | | |
|--------------|--------|--------|------|--------|--------|-------|--------|--------|
| P DELTA | | | | | | | | |
| WITH P DELTA | 19.832 | 24.707 | 29.8 | 35.755 | 41.641 | 49.37 | 60.619 | 67.867 |

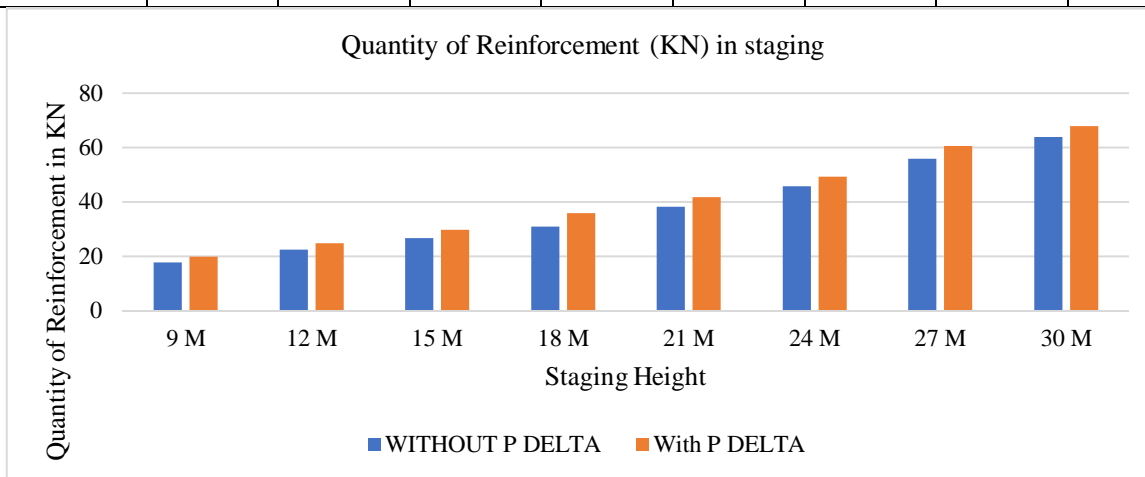


Fig 10. Quantity of Reinforcement in the staging in Zone V at different staging heights

F. Maximum lateral displacement:

The permissible maximum lateral displacement is considered from clause 20.5 of IS 456-2000 (the lateral sway at the top should not exceed H/500) [1].

In P Delta analysis the maximum permissible displacement (Hs/500) is considered from “C4.13.5- P-Delta effect: of IITK-GSDMA Guidelines for Seismic Design of Liquid storage tanks” [9]

Table XI - Maximum lateral displacement at top in Zone V – Tank full condition

| STAGIN G HEIGHT (m) | TANK FULL (ZONE V) | | | | |
|---------------------|-------------------------------------|----------------------|-------------------|-----------------------------------|-----------------|
| | MAXIMUM LATERAL DISPLACEMENT AT TOP | | | | |
| | CRITICAL LOAD COMBINATION | WITHOUT P DELTA (mm) | WITH P DELTA (mm) | PERMISSIBLE DISPLACEMENT (Hs/500) | % OF DIFFERENCE |
| 9 | 1.0 (DL+LL+WATER LOAD+ EQ +X) | 11.311 | 11.455 | 18 mm | 1.26 |
| 12 | 1.0 (DL+LL+WATER LOAD+ EQ +X) | 15.447 | 15.633 | 24 mm | 1.19 |
| 15 | 1.0 (DL+LL+WATER LOAD+ EQ +X) | 19.559 | 19.866 | 30 mm | 1.55 |
| 18 | 1.0 (DL+LL+WATER LOAD+ EQ +X) | 23.812 | 24.223 | 36 mm | 1.70 |
| 21 | 1.0 (DL+LL+WATER LOAD+ EQ +X) | 28.319 | 28.842 | 42 mm | 1.81 |
| 24 | 1.0 (DL+LL+WATER LOAD+WIND +X) | 33.253 | 33.947 | 48 mm | 2.04 |
| 27 | 1.0 (DL+LL+WATER LOAD+WIND +X) | 45.892 | 46.932 | 54 mm | 2.22 |
| 30 | 1.0 (DL+LL+WATER LOAD+WIND +X) | 55.776 | 57.151 | 60 mm | 2.41 |
| 33 | 1.0 (DL+LL+WATER LOAD+WIND +X) | 70.556 | 72.399 | 66 mm | 2.55 |

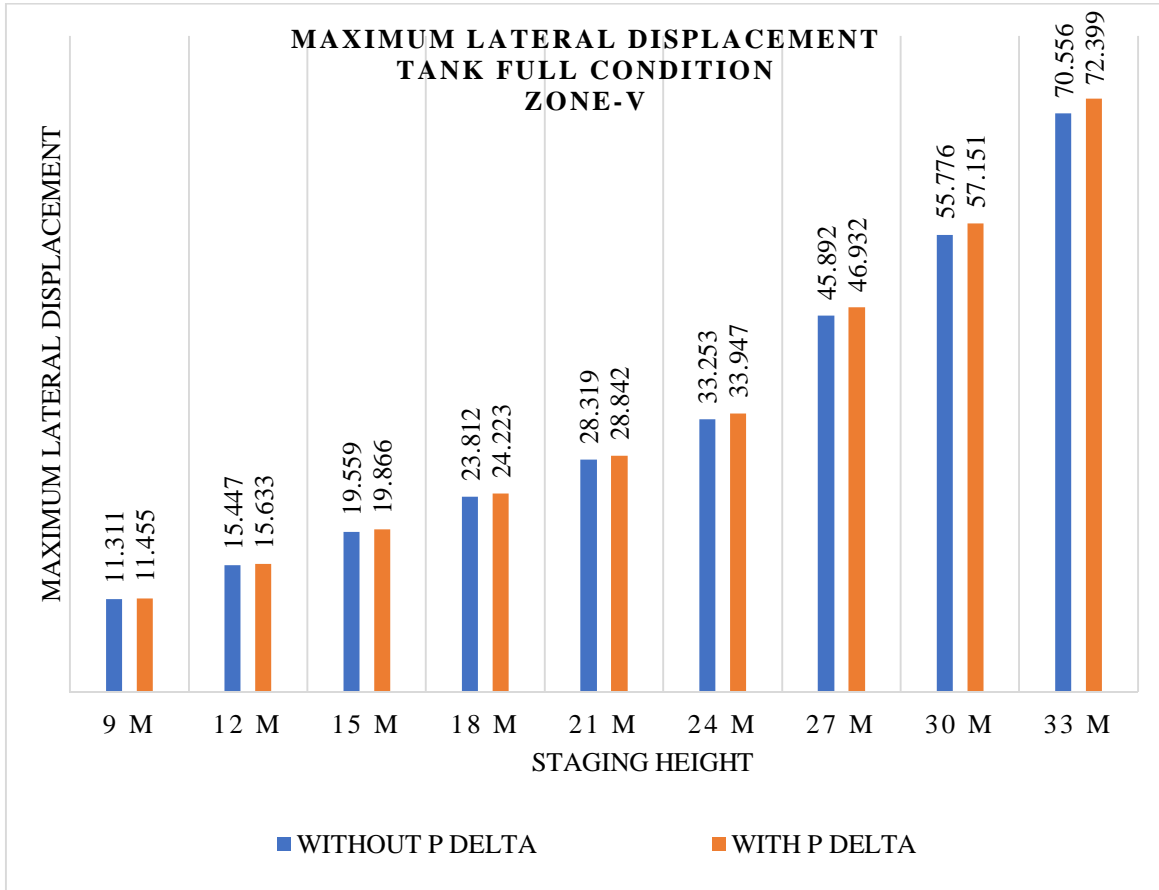


Fig 11. The maximum lateral displacement (mm) at top in Zone V at different staging heights

From Table XI The earthquake load is the predominant force up to 21 meters of staging height; after that, the wind load is the predominant for determining the maximum lateral displacement and it is clearly observed that the P-Delta effect has a greater impact as the staging height increases

Table XII - Maximum lateral displacement at top in Zone V – Tank empty condition

| STAGING HEIGHT (m) | TANK EMPTY (ZONE V) | | | | |
|--------------------|-------------------------------------|----------------------|-------------------|-----------------------------------|-----------------|
| | MAXIMUM LATERAL DISPLACEMENT AT TOP | | | | |
| | CRITICAL LOAD COMBINATION | WITHOUT P DELTA (mm) | WITH P DELTA (mm) | PERMISSIBLE DISPLACEMENT (Hs/500) | % OF DIFFERENCE |
| 9 | 1.0 (DL+LL+ EQ+X) | 6.28 | 6.317 | 18 mm | 0.59 |
| 12 | 1.0 (DL+LL+ EQ+X) | 8.965 | 9.029 | 24 mm | 0.71 |
| 15 | 1.0 (DL+LL+ EQ+X) | 11.78 | 11.876 | 30 mm | 0.81 |
| 18 | 1.0 (DL+LL+ WIND+X) | 17.23 | 17.397 | 36 mm | 0.96 |
| 21 | 1.0 (DL+LL+WIND +X) | 24.262 | 24.523 | 42 mm | 1.06 |
| 24 | 1.0 (DL+LL+WIND +X) | 33.254 | 33.652 | 48 mm | 1.18 |
| 27 | 1.0 (DL+LL+WIND +X) | 45.892 | 46.5 | 54 mm | 1.31 |
| 30 | 1.0 (DL+LL+WIND +X) | 55.777 | 56.594 | 60 mm | 1.44 |
| 33 | 1.0 (DL+LL+WIND +X) | 70.557 | 71.697 | 66 mm | 1.59 |

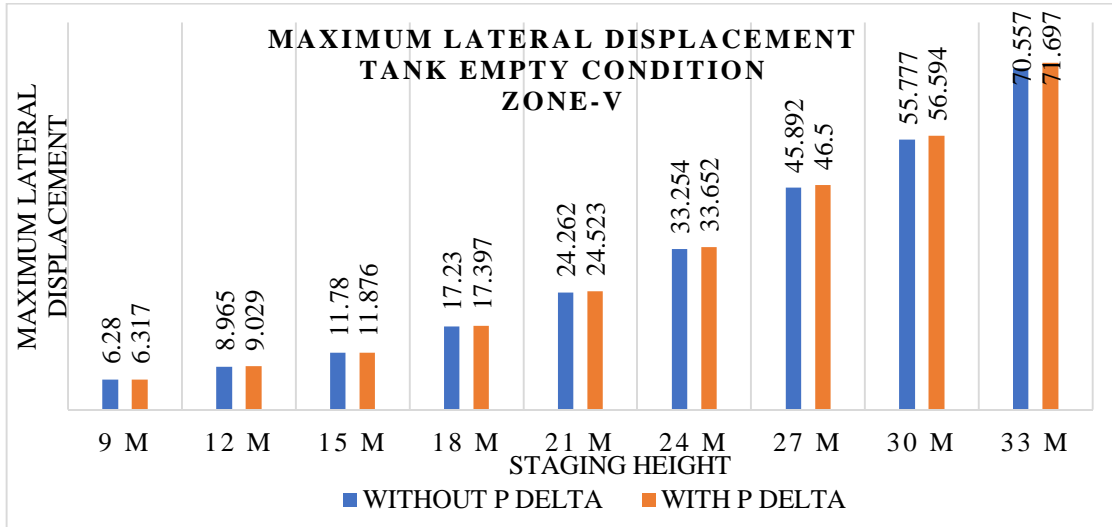


Fig 12. The maximum lateral displacement (mm) at top in Zone V at different staging heights

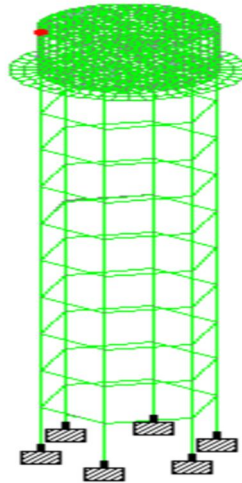


Fig 13. The maximum lateral displacement showing at top of the overhead water tank

Table XIII - Maximum lateral displacement at top in Zone IV – Tank full condition

| STAGING HEIGHT (m) | TANK FULL (ZONE IV) | | | | |
|--------------------|-------------------------------------|----------------------|-------------------|-----------------------------------|-----------------|
| | MAXIMUM LATERAL DISPLACEMENT AT TOP | | | | |
| | CRITICAL LOAD COMBINATION | WITHOUT P DELTA (mm) | WITH P DELTA (mm) | PERMISSIBLE DISPLACEMENT (Hs/500) | % OF DIFFERENCE |
| 27 | 1.0 (DL+LL+WATER LOAD+WIND +X) | 38.446 | 39.318 | 54 mm | 2.22 |
| 30 | 1.0 (DL+LL+WATER LOAD+WIND +X) | 48.728 | 49.93 | 60 mm | 2.41 |
| 33 | 1.0 (DL+LL+WATER LOAD+WIND +X) | 62.331 | 63.959 | 66 mm | 2.55 |
| 36 | 1.0 (DL+LL+WATER LOAD+WIND +X) | 77.832 | 80.1 | 72 mm | 2.83 |

Table XIV - Maximum lateral displacement at top in Zone IV – Tank empty condition

| STAGING HEIGHT (m) | TANK EMPTY (ZONE IV) | | | | |
|--------------------|-------------------------------------|----------------------|-------------------|-----------------------------------|-----------------|
| | MAXIMUM LATERAL DISPLACEMENT AT TOP | | | | |
| | CRITICAL LOAD COMBINATION | WITHOUT P DELTA (mm) | WITH P DELTA (mm) | PERMISSIBLE DISPLACEMENT (Hs/500) | % OF DIFFERENCE |
| 27 | 1.0 (DL+LL+WIND +X) | 38.447 | 38.963 | 54 mm | 1.32 |
| 30 | 1.0 (DL+LL+WIND +X) | 48.729 | 49.454 | 60 mm | 1.47 |
| 33 | 1.0 (DL+LL+WIND +X) | 62.332 | 63.356 | 66 mm | 1.62 |
| 36 | 1.0 (DL+LL+WIND +X) | 77.833 | 79.242 | 72 mm | 1.78 |

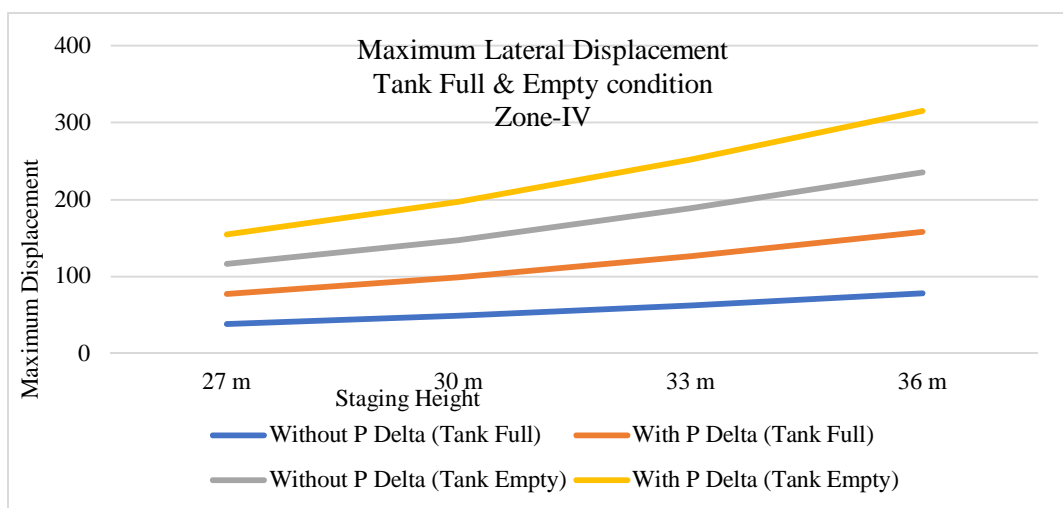


Fig 14. The maximum lateral displacement in Zone IV

From table XI & table XII, the maximum lateral displacement exceeds the permissible displacement at a staging height of 33 m in Zone V both tank full and empty conditions. Subsequently, From table XIII & table XIV, the maximum lateral displacement exceeds the permissible displacement at a staging height of 36 m in Zone IV both tank full and empty conditions.

V. DISCUSSIONS

- 1) The P Delta effect has a greater impact from the corresponding parameters, such as displacements, axial shear, shear force, and bending moment, as the staging height increases.
- 2) The earthquake load is the predominant force up to 21 meters of staging height; after that, the wind load is the predominant for determining the maximum lateral displacement.
- 3) Moving from Seismic Zone IV to Seismic Zone V for a common staging height result in increases in displacement, shear force, and bending moments.
- 4) As a result, the maximum lateral displacement in Seismic Zone V exceeding the allowable limit at a staging height of 33 meters, hence the analysis in Zone IV is performed from a staging height of 27 meters.

VI. CONCLUSION

The following conclusions have been shown after the analysis of a circular overhead water tank in high seismic zones i.e., Zone IV & V with the aforementioned parametric study as outlined below:

- 1) The maximum axial force for a certain staging height for a given zone is shown to have an average increment of 1.8% in tank full condition and 1.3% in tank empty condition which takes the P-Delta effect into account.

- 2) The maximum shear force for a certain staging height for a given zone is shown to have an average increment of 2.5% in tank full condition and 2.05% in tank empty condition which takes the P-Delta effect into account.
- 3) The maximum Bending Moment for a certain staging height for a given zone is shown to have an average increment of 3.3% in tank full condition and 2.15% in tank empty condition which takes the P-Delta effect into account.
- 4) The optimum staging height of 30m. has been arrived in seismic zone V by considering the exceedance of maximum lateral displacement i.e., $H_s/500$ for the cases with & without P-Delta and tank full & empty conditions.
- 5) The optimum staging height of 33m. has been arrived in seismic zone IV by considering the exceedance of maximum lateral displacement i.e., $H_s/500$ for the cases with & without P-Delta and tank full & empty conditions.

VII. FUTURE SCOPE

The current investigations can be extended by considering the following parameters

- 1) The tank's storage capacity can be increased in various soil conditions, more research can be done.
- 2) In this study, only simple bracing was performed; additionally, because the type of bracing varies, the outcomes may also vary.
- 3) Since the current study focused on seismic zones IV and V, additional seismic zones might be taken into consideration as well, which could lead to more generalised outcomes.

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