



International Journal of Innovative Research in Science Engineering and Technology (IJIRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)



Impact Factor: 9.935

Volume 15, Issue 5, May 2026

Seismic and Wind Load Analysis of Elevated Intze Water Tank using ETABS

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ABSTRACT: Elevated water tanks are essential structures for municipal and industrial water supply systems. Among different tank configurations, the Intze water tank is widely preferred because of its structural efficiency and economical use of materials. However, these tanks are highly vulnerable to seismic and wind forces due to their elevated center of gravity and complex geometry. This study investigates the structural behavior of an elevated reinforced concrete Intze water tank subjected to seismic and wind loads using ETABS software. The tank was modeled according to Indian Standard codes including IS 1893 (Part 2):2014, IS 875, IS 456:2000, and IS 3370. Response Spectrum Analysis was carried out for seismic loading, while wind analysis was performed as per IS 875 Part III. Various load combinations involving dead load, live load, water load, wind load, and earthquake load were considered. Parameters such as lateral displacement, story drift, base shear, overturning moment, and modal characteristics were evaluated. Results indicated that seismic forces govern the design response compared to wind loads. Maximum lateral displacement obtained was within permissible limits, confirming the structural adequacy and stability of the staging system. The study highlights the importance of dynamic analysis in ensuring safe and economical design of elevated Intze water tanks in seismic-prone regions.

KEYWORDS: Intze Water Tank, ETABS, Seismic Analysis, Wind Analysis, Response Spectrum, Elevated Water Tank, Story Drift, Base Shear.

I. INTRODUCTION

Water tanks are critical infrastructure components used for water storage and distribution. Elevated water tanks ensure sufficient hydraulic pressure and uninterrupted water supply during emergencies such as earthquakes and fire hazards. Among different configurations, the Intze water tank is recognized for its economical and structurally efficient design. The Intze tank consists of a cylindrical wall, spherical dome, conical bottom slab, and ring beams. The conical bottom effectively reduces bending moments and transfers hydrostatic loads efficiently. However, due to the elevated staging system and large mass of stored water, the structure becomes highly sensitive to seismic and wind forces.

Past earthquake failures have shown that elevated water tanks are vulnerable to staging collapse, excessive drift, and cracking at shell junctions. Therefore, accurate structural analysis considering dynamic loading is essential. Modern finite element software such as ETABS enables detailed evaluation of tank behavior under lateral loads.

The objective of this study is to analyze the seismic and wind response of an elevated Intze water tank using ETABS and evaluate its structural performance under different load combinations.

II. LITERATURE REVIEW

Several researchers have studied the seismic and wind behavior of elevated water tanks.

Severn et al. (2023) investigated Fluid-Structure Interaction (FSI) effects and reported that neglecting FSI may underestimate base shear and overturning moment by nearly 40%. Livaoglu and Dogangun (2022) emphasized the

importance of staging flexibility in seismic response. Panchal and Jangid (2024) studied wind-induced pressures and identified localized buckling regions in Intze tanks.

Ghaedi et al. (2023) performed fragility analysis under near-fault earthquakes and concluded that seismic demands increase significantly under pulse-type ground motions. Zhang and Liu (2025) showed that base isolation systems can reduce seismic base shear by nearly 70%.

Previous studies consistently indicate that:

- Seismic loading governs design of elevated tanks.
- Staging is the most vulnerable component.
- Fluid-Structure Interaction significantly affects dynamic response.
- Advanced finite element analysis improves prediction accuracy.

III. METHODOLOGY

The methodology adopted in this study includes:

1. Literature review and code study.
2. Modeling of elevated Intze water tank in ETABS.
3. Definition of material properties and section dimensions.
4. Application of gravity, seismic, wind, and water loads.
5. Response spectrum analysis.
6. Evaluation of displacement, drift, base shear, and modal response.
7. Interpretation of results and conclusions.

IV. MODELING OF INTZE WATER TANK

4.1 Geometrical Details

The Intze water tank was modeled as a reinforced concrete elevated structure. Major dimensions are summarized below:

Component	Dimensions
Cylindrical Wall Diameter	5.0 m
Cylindrical Wall Height	3.5 m
Conical Bottom Height	2.5 m
Staging Height	15 m
Top Dome Thickness	150 mm
Bottom Slab Thickness	250 mm
Column Size	500 mm × 600 mm
Bracing Size	300 mm × 300 mm

4.2 Material Properties

	Property
Concrete Grade	M30
Reinforcement Steel	Fe500
Density of Concrete	25 kN/m ³
Steel Density	7850 kg/m ³

4.3 Loading Details

Seismic Parameters

- Zone Factor (Z) = 0.24
- Importance Factor (I) = 1.5
- Response Reduction Factor (R) = 3.0

- Soil Type = Medium Soil
- Wind Parameters
- Basic Wind Speed = 45 m/s
 - Terrain Category = 2

V. LOAD COMBINATIONS

The following major load combinations were considered:

- 1.5(DL + LL)
- 1.2(DL + LL + EQX)
- 1.2(DL + LL + EQY)
- 1.2(DL + LL + WLX)
- 1.2(DL + LL + WLY)
- 1.2(DL + LL + WATER + EQX)
- 0.9DL ± 1.5EQ

These combinations were applied according to IS 1893 and IS 875 provisions.

VI. RESULTS AND DISCUSSION

6.1 Seismic Response

The maximum seismic displacement in the X-direction was observed at the top story with a value of 1.606 mm. The structure showed negligible displacement in the Y-direction due to high stiffness.

6.2 Wind Response

Under wind loading, the maximum displacement was 1.291 mm in the X-direction. Wind effects were comparatively lower than seismic effects.

6.3 Combined Load Response

For the critical load combination 1.2(DL + LL + WL + EQY), the maximum displacement obtained was 2.599 mm at Story 6. This indicates that combined loading produces higher structural demand compared to individual loads.

Comparative Maximum Displacements

Load Case	Maximum Displacement
Seismic Load	1.606 mm
Wind Load	1.291 mm
DL + LL + WL + EQX	2.281 mm
DL + LL + WL + EQY	2.599 mm

The displacement values remained well within permissible limits, confirming structural safety.

VII. MODAL ANALYSIS

Modal analysis was performed to evaluate the dynamic characteristics of the structure.

Mode	Time Period (sec)	Dominant Direction
1	1.24	Y Translation
2	1.23	X Translation
3	0.91	Torsional
4	0.42	X Translation
5	0.41	Y Translation

The cumulative mass participation exceeded 90% in both horizontal directions, satisfying IS 1893 requirements.

VIII. BASE SHEAR AND DRIFT ANALYSIS

8.1 Base Shear

Load Case	Base Shear X (kN)
Seismic Load	238.4
Wind Load	186.3

Seismic base shear was approximately 27% higher than wind base shear, indicating that earthquake forces govern the design.

8.2 Story Drift

The maximum story drift ratio obtained was 0.00017, which is much lower than the permissible limit of 0.004 specified by IS 1893.

IX. CONCLUSIONS

The following conclusions are drawn from the present study:

1. The elevated Intze water tank showed satisfactory performance under seismic and wind loading conditions.
2. Seismic forces governed the design response compared to wind forces.
3. Maximum lateral displacement and story drift values remained within permissible limits specified by IS codes.
4. The staging system provided adequate stiffness and stability against lateral loads.
5. Combined loading conditions produced greater displacements than individual load cases.
6. Modal analysis confirmed acceptable dynamic behavior with sufficient mass participation.
7. ETABS proved to be an effective tool for accurate analysis and evaluation of elevated water tanks.

The study confirms that properly designed Intze water tanks can safely resist seismic and wind forces while maintaining structural stability and serviceability.

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