INDIAN JOURNAL OF SCIENCE AND TECHNOLOGY

RESEARCH ARTICLE

OPEN ACCESS

Received: 06-01-2023

Accepted: 08-06-2023

Published: 11-07-2023

Citation: Jayaprakash PO, Reddy BD, Babu MM, Lessly SH (2023) Design and Modelling of Intze Water Tanks in Seismic Zones by Using M40 Grade Concrete. Indian Journal of Science and Technology 16(26): 2016-2023. https://doi.org/10.17485/IJST/v16i27.46

* **Corresponding author**.

jayaprakasholiver@gmail.com

Funding: None

Competing Interests: None

Published By Indian Society for Education and Environment (iSee)

ISSN
Print: 0974-6846
Electronic: 0974-5645

Design and Modelling of Intze Water Tanks in Seismic Zones by Using M40 Grade Concrete

P Oliver Jayaprakash[1]*, B Damodhara Reddy[2], M Mohan Babu[3], S Herald Lessly[4]

1 Professor, Department of Civil Engineering, Sri Venkateswara College of Engineering and Technology, Andra Pradesh, India
2 Professor & Head, Department of Civil Engineering, Sri Venkateswara College of Engineering and Technology (Autonomous), RVS Nagar, Chittoor, Andra Pradesh, India
3 Principal, Sri Venkateswara College of Engineering and Technology (Autonomous), RVS Nagar, Chittoor, Andra Pradesh, India
4 Assistant Professor, Department of Civil Engineering, Mepco Schlenk Engineering College (Autonomous), Sivakasi, 626005, India

Abstract

Objectives: To provide an efficient analysis and design for Intze water tank that is secure and safe. An reinforced concrete building (intze water tank) with a 0° to 10° ground slope is modelled using STAAD PRO analysis. Based on IS 1893(Part-I):2002 code the seismic weight is evaluated. To achieve best results, the proposed techniques compared with the existing approaches. **Methods:** In the current investigation, different Seismic Zones i.e. Zone-II, Zone-III, Zone-IV, & Zone-V is performed by Response Spectrum Method. Tremor investigation is directed utilizing the Equivalent Lateral Force Method (static technique) or Dynamic Strength Analysis. M40 grade concrete is employed for structural components. **Findings:** Utilizing the proposed work, an efficient design of Intze water tank is carried out. The proposed technique attains the lateral displacement (4.687mm), base moment (16231 KN/m), base shear (878 KN) and time period of vibration (0.7266s).the suggested methods achieves better performance, when compared to the conventional methods. **Novelty:** Elevated water tanks become a necessary component of daily life. Yet, numerous elevated water tanks have been harmed by the natural disasters, which affect the structure. The majority of studies only takes into account the impact of wind on a structure, ignoring seismic impact. Therefore, proposed method consider three structure classes, by using the Indian standard code of IS 1893(Part-I):2002 for seismic zones. The occurrence of damages, violation of safety measures and reduced strength are accurately addressed by the suggested approach. Comparison is carried out with existing work in which the proposed work generates enhanced outputs related to base shear, displacement and vibration period.

Keywords: Intze Water Tank; STAAD PRO; Equivalent Lateral Force; Response Spectrum; Seismic Zone

1 Introduction

The water tanks designed in many different shapes and sizes. Water is stored using a variety of methods, such as elevated, ground supported and supported water tanks with a range of forms, including circular, rectangular and intze. Elevated water tanks become a need for day to day existence in such situations. Yet, numerous elevated water tanks have been harmed by earthquake induced vibrations [1,2].

Therefore, the intze water tank is proposed in this study, which is free from damage and ensures safety for the structure. Intze water tanks are constructed to minimize project costs since the lower dome resists horizontal thrust, whereas circular tanks are more difficult to construct. In previous work, the tanks are constructed in compliance with IS: 3370, a standard for the construction of concrete structures used to hold liquids. It is found that, during extreme shaking, minor damage occurs affecting the operation of the tank [3]. In [4,5] the majority of studies just takes wind's influence into account, ignoring a structure's seismic impact. Therefore, it is essential to concentrate on seismic safety in lifeline structures in order to consider alternative supporting systems that are secure during earthquakes and can sustain higher design stresses. As a result, several earthquake zones are analysed for intze water tank design. In [6] the intze water tank designed with IS: 1893 is studied and is analyzed by response spectrum method. However, it fails to meet the safety conditions. Therefore, in this research the intze water tank is designed with IS 1893(Part-l):2002, which gives the proper safety conditions. Different staging heights in distinct wind effects are used to examine the reinforced concrete Intze water tank. When shaft type supporting is utilized, the displacement reduces to a certain percentage. However, the shear and moment measured at base are lower when tank is at full capacity [7]. In [8,9], the tank designed is analyzed with the aid of SAP 2000 software. A code based procedure is also conducted with various load combinations for better evaluation. Moreover, when compared to the tank considering the earthquake force design, this tank exhibits reduced strength and the model is affected by beam to column connections [10]. So, the ETBAS software is proposed to analyze the structure, which is the good alternative solution for SAP2000.

The Intze water tank is effectively analysed and designed in this study, ensuring safety and preventing damage. The proposed approach takes three structural classes into consideration and applies the Indian Standard Code of IS 1893(Part-l):2002 for seismic zones. Using STAAD PRO analysis, a Reinforced Concrete structure (intze water tank) with a ground slope ranging from 0° to 10° is modelled. Based on IS 1893(Part-l):2002 code the seismic weight is evaluated. Based on the calculation of the structure's vibration modes, Response Spectrum method is used to predict the maximum response of a structure to complicated time history excitations such as earthquake ground motions and it is used to conduct several seismic zones, such as Zone-II, Zone-III, Zone-IV and Zone-V. Tremor investigation is directed by utilizing the Equivalent Lateral Force Method (static technique) or Dynamic Strength Analysis. The investigation of the structure outlines are completed by utilizing the ETABS program. The proposed technique attains the lateral displacement (4.687mm), base moment (16231 KN/m), base shear (878 KN) and time period of vibration (0.7266s).the suggested methods achieves better performance, when compared to the conventional methods. As a result, the occurrence of damages, violation of safety measures and reduced strength are accurately addressed by the suggested approach. Then the Comparison is carried out with existing work, when compared to other techniques, the proposed approach generates enhanced outputs related to base shear, displacement and vibration period.

2 Methodology

The proposed method consider three structure classes of soils like rock, medium and soft by using the Indian standard code of IS 1893(Part-l):2002 for seismic zones. As a result, violations of safety precautions and decreased strength are not addressed by the prior works and the majority of research only takes into account the wind effect while ignoring seismic effect on structure and likelihood of damages. Using STAAD PRO software, a Reinforced Concrete structure (intze water tank) with a ground slope ranging from 0° to 10° is modeled and studied. The Response Spectrum Method is utilized for understanding and the outcomes are contrasted. The Equivalent Lateral Force Method is used to represent the twist coming about because of the vertical inconsistency of the structure. By adopting the lateral force method with dynamic analysis, the proposed work prevents damages and fulfills the safety measures.

2.1 Design aspects

When a structure is disturbed by an earthquake, it vibrates. The tremor settles on the whole three commonly opposite bearings, the two flat headings (longitudinal and cross over removal) and the vertical course (revolution). This movement permits the framework to vibrate or shake taking all things together along with three bearings considering the essential shaking heading level. Owing to the innate assurance component utilized in the development prerequisites, most structures in general will be adequately obtained from vertical shaking. Vertical quickening can likewise be tended in frameworks of wide range, where the plan strength is kept up for the general security investigation of the constructions. Many techniques are accessible for the seismic tremor investigation of structures which are discussed below.

2.1.1 Lateral Force Method

This strategy for discovering sidelong powers is regularly alluded as the static technique or the practically equivalent static technique or the seismic coefficient strategy. The static methodology is the least demanding and requires less computational work and depends on the recipes in the code of training. On the whole considering the techniques for investigation of multi-story structures suggested in the code, the construction is viewed as a circumspect gadget with merged mass at floor level, remembering the heaviness of sections and dividers for each storey and ought to be spread equally over the floors above and underneath the storey. Furthermore, it is additionally lumped along with the satisfactory measure of burden demanded on this floor.

a) Base Shear

The base shear V_b is calculated using the formula given below specified in IS 1893(part-l): 2002:

$$V_B = A_h W \tag{1}$$

Where, design horizontal acceleration spectrum value A_h in the relevant vibration direction is calculated using the fundamental natural period T and seismic weight of building is given by W.

$$A_h = \frac{ZIS_a}{2Rg} \tag{2}$$

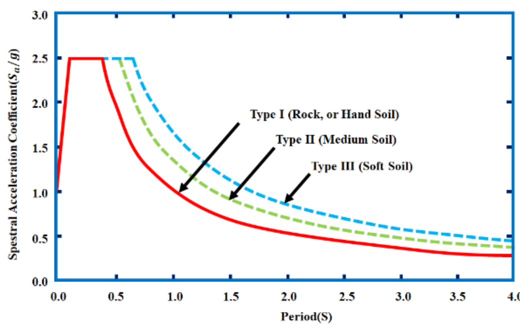

Fig 1. Design spectrums for 5 % damping as per Indian Standards

According to Table 2, 6 and 7 of IS: 1893, I is an importance factor, Z is a zone factor,R is response reduction factor and S_a/g is an average response acceleration coefficient as per Indian standard IS l893 (Part-l): 2002 as given by Figure 1 and it is based on appropriate natural periods and damping of the structures.

b) Seismic Weight

In addition to basic volume of pushed load, seismic load of each level is a most severe dead burden. The final one is the bit of the heaps forced that are necessary to be needed to be added to the design at the hour of the tremor. This incorporates the heaviness of perpetual and versatile allotments, lasting hardware, part of the live burden and so on. According to IS 1893(Part-l):2002, Table 1 depicts the percentage of induced load to be taken into account while calculating seismic weight

Table 1. Percentage of imposed load to be taken into account when calculating seismic weight

Imposed uniformity distributed loads (KN/m^2)	**Percentage of imposed load**
Up to and including 3.0	25
Above 3.0	50

c) Time Period

The determined key regular term of vibration T_a in a moment or two, of a snapshot of protection from outline development without block infill boards, can be estimated utilizing the accompanying empiric equation.

$$T_a = 0.085h0.85 \text{ for steel frame building} \tag{4}$$

As per IS 1893: 2002 in provision 7.7.1, the plan base shear was along these lines acquired from Eq. 1. It will be partitioned around the stature of the structure as follows:

$$Q_i = V_B \frac{W_i h_i^2}{\sum_{j=1}^{n} W_i h_i^2} \tag{5}$$

Where, the design lateral force, seismic weight and height at the floor i is given by Q_i, $W_i$and h_i respectively and the number of stores in the building is given by n.

2.1.2 Dynamic Analysis

The seismic power and its conveyance at various levels around the height of a structure, as well as in the various parallel loads that are impervious to the component for the accompanying structures, will be calculated using dynamic inquiry.

a) Time history technique

The utilization of this methodology will be on a compelling ground based premise and will be completed as per the concurred ideas of elements. In this cycle, the numerical model of the structure is dependent upon the quickening of the quake records that mirror the anticipated seismic tremor at the base of the establishment.

b) Response range strategy

The term continuum in designing passes on the feeling that the response of structures with a wide assortment of periods is summarized in a solitary chart. This methodology will be done utilizing the plan range characterized in the code or by the site explicit plan range for the construction arranged at the task site.

2.2 Modeling and Analysis

2.2.1 Material Properties

Material properties of cement incorporate thickness, unit weight, modulus of flexibility and proportion of Poisson, modulus of shear and coefficient of warm extension. The modulus of versatility of built up concrete as characterized in IS 456:2000 will be determined by

$$E_C = 5000\sqrt{f_{CK}} \tag{6}$$

Where f_{CK} is the compressive strength of cement at 28 days in MPa.

2.2.2 Loads

The live load, imposed load and earthquake loads are included as per IS: 875 part I and part II respectively. The cumulative load at the base of the structure would be barely above the foundation.

$$W = \sum_{i=1} W_i + W_0 \tag{7}$$

Where, W_0 is the weight of elements in the ground storey, depth of foundation below ground is 2 m and type of soil is given by Type II, Medium as per IS: 1893.

3 Result and Discussion

3.1 ETABS

The demonstrating and the investigation of the structure outlines were completed utilizing business programming ETABS. The significant highlights of this design are as per the following:

3.2 Depiction of Intze water tank

The Water tank chosen for analysis is the multipurpose water tank. It is situated in the earthquake zone V on the site of the Rock and Rough earth. M40 type of concrete was used for all structural components. It is presumed that the stage diaphragms are stiff. Seismic loads are assumed to be working in a horizontal direction in one of the two major directions and not in a vertical direction since they are not considered to be important. The step by step process in designing water tank is shown in Figures 2, 3, 4, 5, 6 and 7.

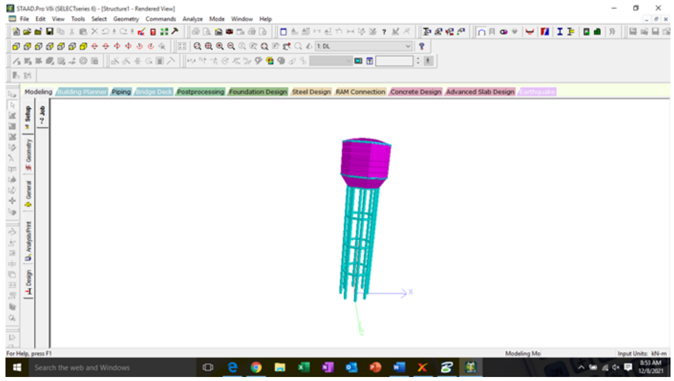

Fig 2. Design of water tank

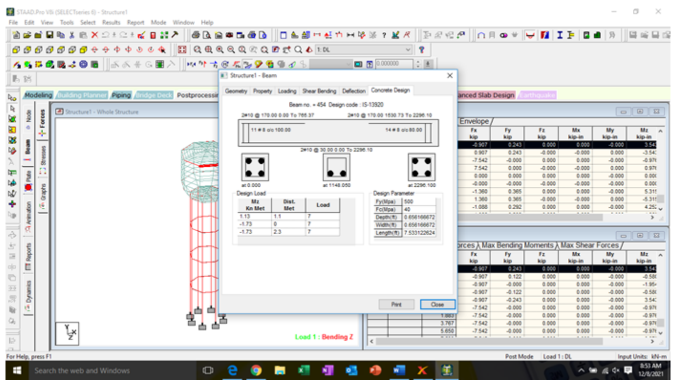

Fig 3. Design of water tank

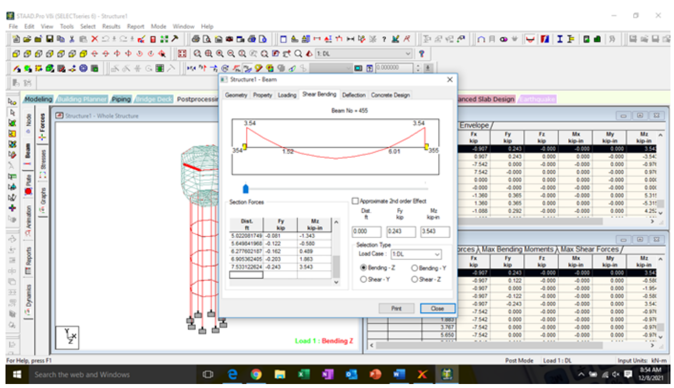

Fig 4. Design of water tank

Using STAAD PRO, a Reinforced Concrete structure (intze water tank) with a ground slope ranging from 0° to 10° is modeled, studied. As a water tank with a slope between 0° and 10°, the 3-D Views and elevations of the structure are seen in the figures above.

Thus, by utilizing STAAD PRO, the multipurpose water tank is designed successfully. By adopting the lateral force method with dynamic analysis, the proposed work prevents damages and fulfills the safety measures. Added to this, the proposed modelling analysis of materials and loads increases the strength of the designed tank.

Table 2 compares the planned work to previous work in terms of variables such lateral displacement, base moment, base shear and vibration time, which gives the better outcomes for the proposed method like lateral displacement, base moment and base shear when compared to the exiting approaches. Figure 8 shows the comparison for empty, half-filled and full states.

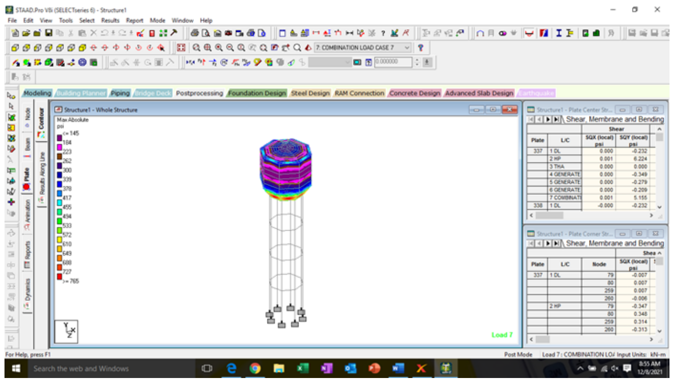

Fig 5. Design of water tank

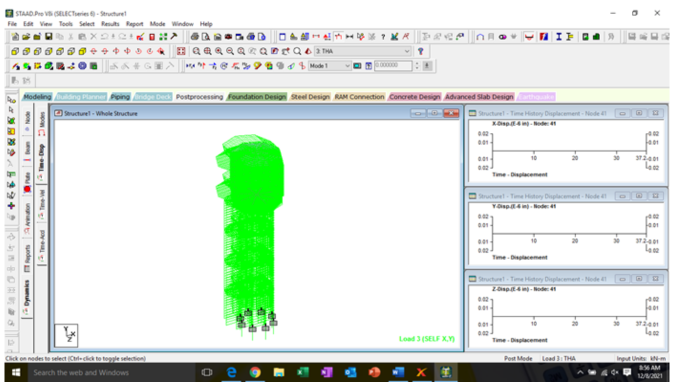

Fig 6. Design of water tank

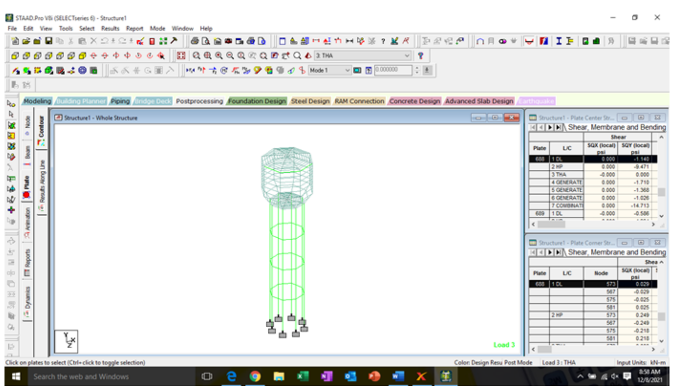

Fig 7. Design of water tank

Table 2. Comparison of proposed work with existing work

Intze Tank	Methodology in [11]	Proposed method
Lateral displacement (mm)	4.687	4.247
Base moment (kN.m)	16231.63	16345.21
Base shear (kN)	869.48	878.5
Time period of vibration (s)	0.7395	0.7266

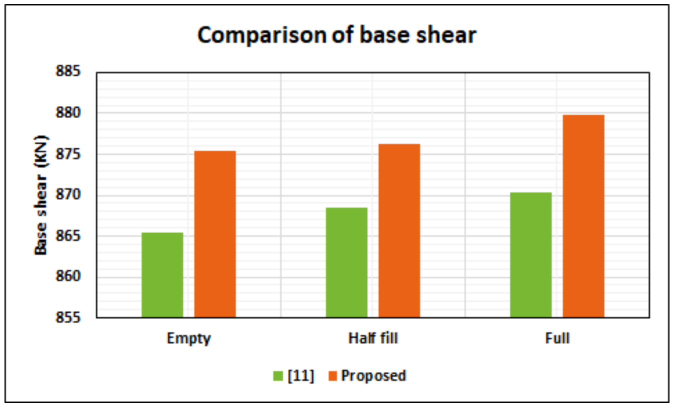

Fig 8. Comparison of base shear of proposed work with the conventional method

On comparing, the proposed method achieves 875KN for empty state, 876 for Half fill state and 879.9KN for full state, which exhibits more improved outputs indicating efficient analysis when compared to the conventional approaches.

4 Conclusion

Elevated water tanks become a necessary component of daily life. Yet, numerous elevated water tanks has been harmed by the natural disasters, which affect the structure. The majority of studies just takes wind's influence into account, ignoring structure's seismic impact. In order to account for seismic zones, suggested method uses Indian Standard Code of IS 1893(Part-l):2002, which takes into account three structural classes. The Response Spectrum Method is used in current inquiry to perform several Seismic Zones, including Zone-II, Zone-III, Zone-IV and Zone-V. Tremor investigation is directed utilizing the Equivalent Lateral Force Method (static technique) or Dynamic Strength Analysis. M40 grade concrete is employed for structural components. By adopting the lateral force method with dynamic analysis, the proposed work prevents damages and fulfills the safety measures. Thus, the proposed modelling analysis of materials and loads increases the strength of the designed tank. The suggested technique attains the lateral displacement (4.687mm), base moment (16231 KN/m), base shear (878 KN) and time period of vibration (0.7266s. As a result, the occurrence of damages, violation of safety measures and reduced strength are accurately addressed by the suggested approach. Comparison is carried out with existing work, from that the proposed work generates enhanced outputs related to base shear, displacement and vibration period.

References

1) Sengar G, Rajpoot A. Design Analysis and Comparsion of Over Head Water Tank for Different Wind Speed and Seismic Zones as Per Indian Standard Codes. 2022. Available from: https://ijrpr.com/uploads/V3ISSUE9/IJRPR7066.pdf.
2) Workeluel N, Saha P, Matiyas S, Mohanty T. A comparative study on analysis and design of R. C. C elevated water tank using different country codes. *Materials Today: Proceedings*. 2023;11(5). Available from: https://www.ijraset.com/best-journal/comparative-study-of-intze-type-of-water-tank-for-different-bracing-pattern-under-wind-and-seismic-load.
3) Jadhav JC, Magarpatil HR. Seismic Analysis of Reinforced Beam-Column Connection for Intze Water Tank. 2020. Available from: https://jespublication.com/upload/2020-110764.pdf.
4) Patil KS. A Study on Wind Analysis of Elevated INTZE Tank Using Different Arrangements of Bracing System. *International Journal of Creative Research Thoughts*. 2022;10(5):2320–2882. Available from: https://ijcrt.org/papers/IJCRT2205449.pdf.
5) Devi G, Chaitra R, M D. Analysis and design of elevated water tank for different seismic zones. *International Journal of Research in Engineering and Science (IJRES)*. 2021;9(8):54–67. Available from: https://www.ijres.org/papers/Volume-9/Issue-8/Series-5/H09085467.pdf.
6) Nidhi BA. Study of Intze Water Tank in Different Seismic Zones as per IS: 1893(Part 2). *Journal of Civil Engineering and Environmental Technology*. 2020;7(2):191–195. Available from: https://www.krishisanskriti.org/vol_image/07Oct202012101721%20%20%20Nidhi1%20%20%20%201%20%20%20191-195.pdf.
7) Yadav R. Analysis of Reinforced Concrete Intze Water Tank with Different Staging Heights in Different Seismic Zones. *International Journal of Recent Technology and Engineering (IJRTE)*. 2020;8. Available from: https://www.ijrte.org/wp-content/uploads/papers/v8i6s/F10370386S20.pdf.
8) Nidhi BA. Study of Intze Tank with Different Horizontal Bracing Patterns. 2020. Available from: http://www.ijniet.org/wp-content/uploads/2020/07/13.pdf.
9) Yadav D, Mishra V. Elevated Water Tank Design and Seismic Study in Various Zones. *International Research Journal of Engineering and Technology (IRJET)*. 2021;08(10):588–595. Available from: https://www.irjet.net/archives/V8/i10/IRJET-V8I1095.pdf.
10) Ansari MS, Mishra N, Netula O. Study on Seismic Analysis of Intze Water Tank with Four Types of Staging Configuration. *Journal of Huazhong University of Science and Technology*. 2021;50(6):1–10. Available from: https://www.researchgate.net/publication/353117540.

11) Bansode PA, Datye VP. Seismic analysis of elevated water tank with different staging configuration. 2018. Available from: https://www.researchgate.net/publication/328381311.