Seismic Study of Circular Elevated Water Tank compression with Using Is Code and Euro Code

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Abstract Water tanks, particularly elevated ones, are critical structures that are essential for maintaining their intended functionality, even in the event of earthquakes. Consequently, there has been a growing interest among researchers in investigating the seismic performance of these tanks. While a considerable amount of research has been conducted on ground tanks, only a limited number of studies have focused on elevated tanks, and even fewer have specifically examined reinforced concrete elevated tanks. In this research, a reinforced concrete elevated water tank of 35 m^3 capacity has been analysed on ETABS software, and the earthquake analysis is also carried out on ETABS software. During earthquake analysis of the model on ETABS software, it is first analysed as per Indian standard code IS 1893:2014 (Part 2), and then again as per European standard. During analysis, base moment, base shear, lateral force, story drift, story displacement, and axial force are analysed by Indian standard and Euro code, and then the results are compared. The result of the analysis showed a rise in storey drift, storey displacement, and lateral forces with an increasing zone factor for all soil types. The seismic response as per the European standard is similar to the response of the structure as per the Indian standard code. As per European standards, in soil type D, the seismic response values are higher as compared with type B and type C soils in both spectrum zones.

Keywords: Base moment and ETABS, Storey drift, Storey displacement, Base shear, elevated water tank.

1. Introduction

Various types of reinforced concrete water tanks are used to meet the daily water needs in industries, campuses, hotels, localities, towns, cities, and fire departments. Because water is crucial in everyday life, proper storage of water is essential. A substantial water storage unit called an elevated tank is made to keep water at a particular elevation and maintain a constant pressure in the water distribution system. Flammable liquids and various chemicals are also stored in liquid storage tanks. Industrial liquid tanks may contain highly toxic and flammable substances, making it crucial to prevent any leakage during an earthquake. In addition to hydrostatic forces, According to the code, it is necessary to take into account the hydrodynamic forces exerted by fluids on the tank wall during the analysis. The spring-mass model is used to evaluate the hydrodynamic forces on tanks. The water tanks are highly vulnerable to lateral loads that occur during earthquakes because these loads are concentrated at the top. During the earthquake, the water tanks were destroyed due to a lack of understanding of the supporting structure. The support system must be strong enough to withstand the lateral forces caused by earthquakes in the ground. The goal of this project is to analyze and construct a water tank in various seismic zones and soil conditions. Circular water tanks are used for capacities of up to 750,000 liters. They are usually provided with a dome as a top cover. The rise of a spherical dome may be kept as 1/7th of its diameter. All overhead water tanks require a top slab cover and staging for support. When a top slab is present, the top edge of the tank can be considered hinged. With the exception of the base slab, walls are always monolithic. Walls can be thought of as having fixed edges at the bottom and hinged edges at the top.

2. Objective

The objective of this research is the study of elevated circular water tank under seismic load.

1. To study the analysis and design of an elevated water tank.
2. To examine the principles and recommendations outlined in IS 3370 (Part 2)-2009 and IS 456:2016 regarding the design of structures that retain liquids.
3. To gain knowledge of the design principles for the secure and economical design of water tanks.
4. To compare the various parameters, such as storey displacement, storey drift, base moment, and base shear, obtained from the design codes of the Indian Standard and Euro Code for water tanks. Additionally, we will study the seismic behavior of both tanks.

3. Methodology

Circular elevated tank have different components such as: -

• Bottom Ring Beam
• Base Slab
• Top Ring Beam
• Top dome
• Tank wall

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Top dome is spherical shaped structure which is situated above top ring beam. As per the code used in the design of the tank, a live load of 1.5 kN/m is considered. Finishing load may also be added to get total acting per unit area of surface. Meridional force is a force acting in longitudinal direction at dome which is maximum at support. It is tension force and is also known as meridional thrust. Top dome is also subjected to hoop tension which acts in circumferential direction. The thickness of top dome varies between 75mm to 100m. Let us consider the capacity of the elevated water tank =35000 litters. Assume M-30 grade concrete and Fe-415 grade of steel to be used. The water tank has flat bottom and supported on the ring beam.

4. Modeling

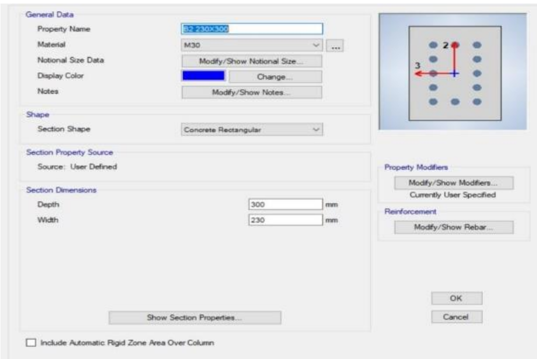
The ETABS software is utilized for the purpose of modeling an elevated water tank. Definition of material properties and areal components has been performed. Analysis and plan of the beam and column sections are also performed in ETABS programming.

4.1 Material definition

The materials used in construction of water tank are concrete of M30 grade and steel of fe- 415 grade.

4.2 Frame section definition

There are total three beams in the water tank. First beam is top ring beam of size 230mm×300mm. The second beam is bottom ring beam and third is bracing beams both having size of 300mm×600mm. There are total six columns provided, all having size of 400mm×400mm.



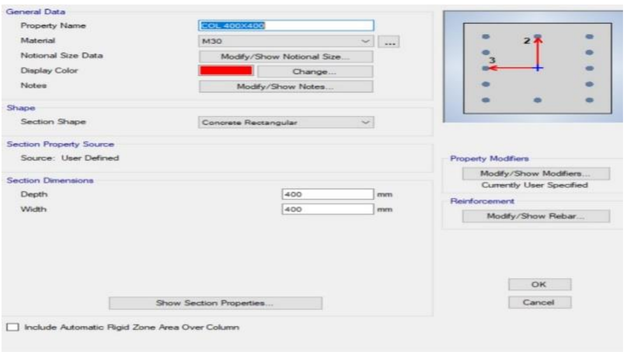


Fig. 4.1 Top ring beam definitions

Fig.4.2-Bottom ring beam and bracing definitions

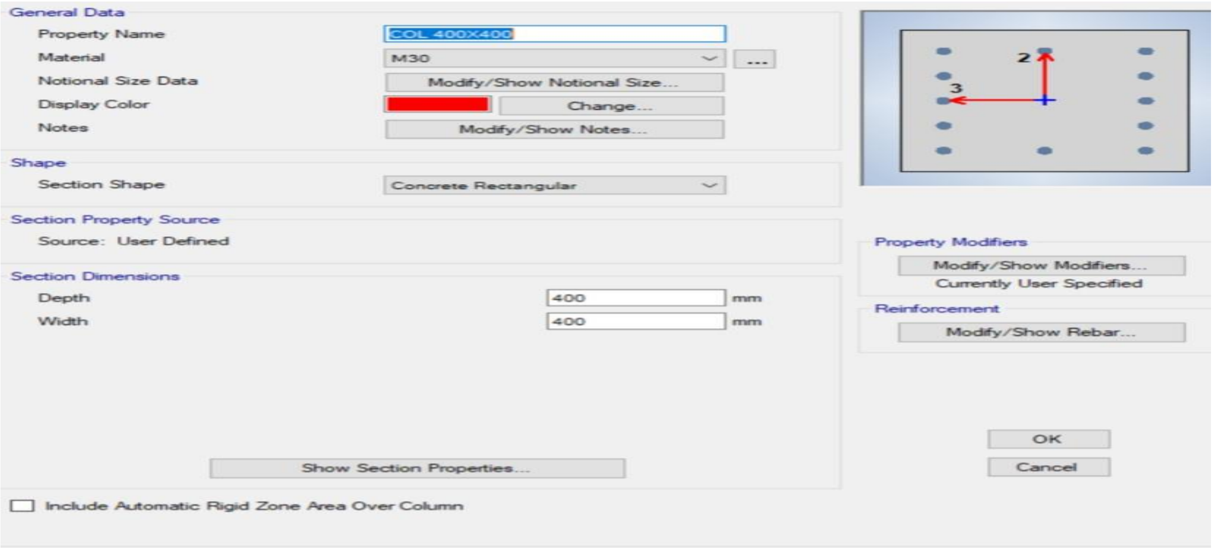


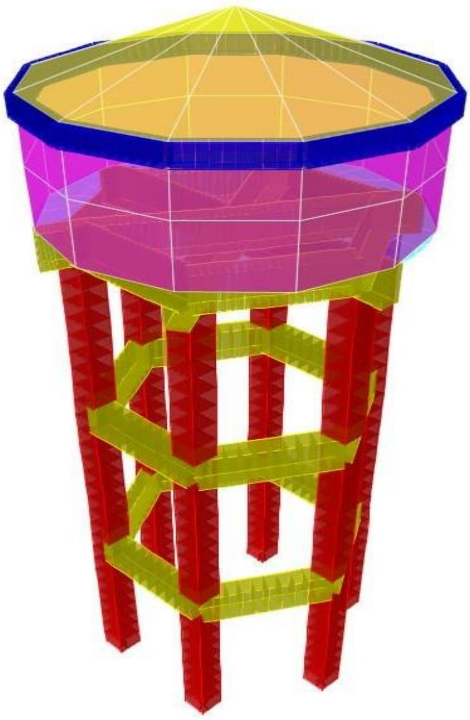
Fig.4.3 Column definition

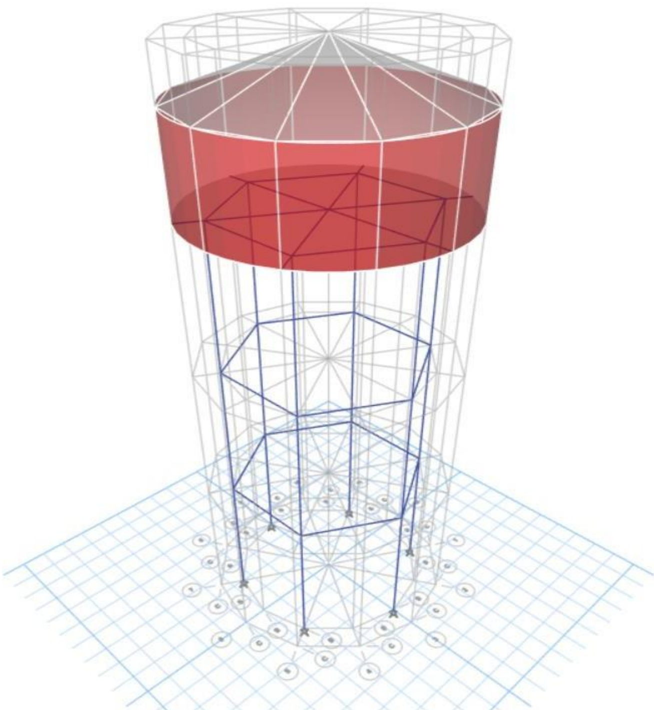
5. Load combinations

a) Dead load of water tank

b) Live load of 4 KN/m^{2}as per IS 3370(Part 2):2009.

c) Earthquake load as per IS 1893(Part 1):2016 and euro code 8





6. Seismic Analysis of Tank

After modelling on ETABS software the final parameters of the elevated circular watertank is as follows:-

Table 6.1 Component Description of Tank

Name of the Component	Size (mm)
Tank Capacity	35 cubic meters
Size of Column	300mm × 300mm
Bottom Ring Beam dimension	600mm × 300mm
Bracing dimension	600mm × 300mm
Top Ring Beam dimension	300mm × 230mm
Thickness Side wall	230 mm
Top dome	150 mm
Number of columns	6

Calculation of weights of different component of water tank.

Table 6.2 Weight of different component of tank

Component	Calculations	Weight
Top dome	$[\pi \times 2.73^2 \times 0.15 \times 25]$	87.81 KN
Wall	$[\pi \times 5.23 \times 2 \times 0.23 \times 25]$	188.95 KN
Top ring beam	$[\pi \times 5.23 \times 0.23 \times (0.3-0.23) \times 25]$	6.613 KN
Bottom slab	$[\pi \times 2.73^2 \times 0.30 \times 25]$	175.605 KN
Bottom ring beam	$[\pi \times 5.23 \times 0.3 \times (0.6-0.23) \times 25]$	46 KN
Columns	[π /4 × 0.4^2 × 10 × 6 × 25]	188.49 KN
Bracing	$0.6 \times 0.3 \times 2 \times 6 \times 25 \times 2$	108 KN
Water	$\pi \times 2.52 \times 3 \times 9.81$	577.858 KN

7. Result

7.1 Base Moment

The base moment is calculated as per IS 1893:2016 which is mentioned above. The moment calculated by software are mentioned in below table.

Table 7.1.1 Base moment as per Indian standard

Soil Type	Base Moment in Zone III(KN-m)	Base Moment in Zone IV (KN-m)
I	429.5847	644.355
II	601.4009	859.0811
III	730.2631	1091.1859

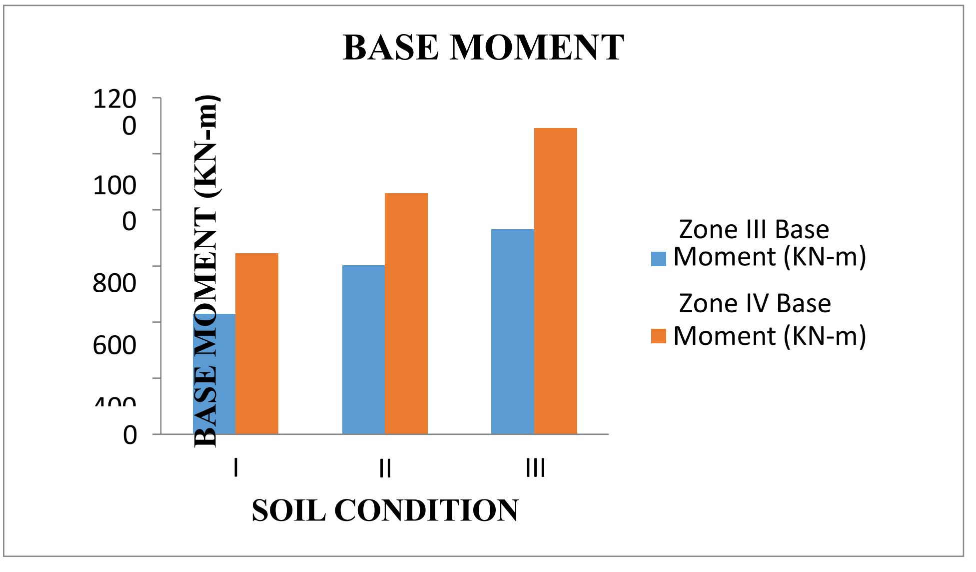


Fig. 7.1.1 Base moment as per Indian standard code

The magnitude of the base moment experiences an increase as the transition is made from Zone III to Zone IV. Furthermore, the value of the soil condition exhibits an upward trend as it transitions from hard soil to moderate soil to soft soil. This trend culminates in the attainment of its highest value within the soft soil of Zone IV.

Table 7.1.2 Base moment as per European code

Soil Type	Base Moment InSpectrum Zone I(Kn-M)	Base Moment InSpectrum Zone II(Kn-m)
B	910.67	687.3009
C	1159.8	816.1712
D	1331.62	945.033

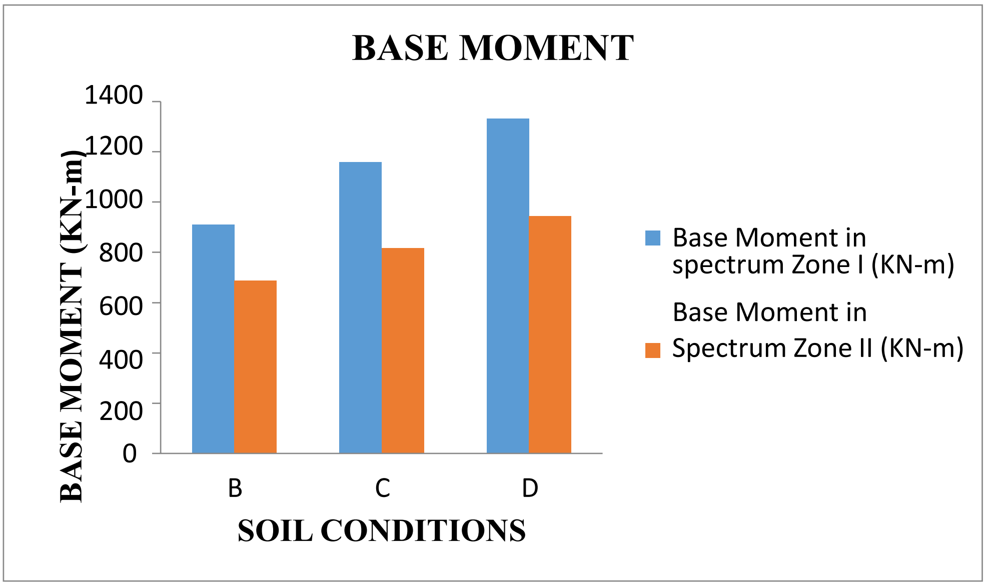


Figure 7.1.2 Base moment as per European standard code

As per European standard also the values in spectrum zone I is more as compared to spectrum zone II. Figure 7.1.2 In water tank developed according to the Euro code, it has been demonstrated that the maximum base moment for B, C, and D soils is higher in water tanks designed in the type I spectrum zone.

7.2 Base Shear

Table 7.2.1 Base shear per Indian standard

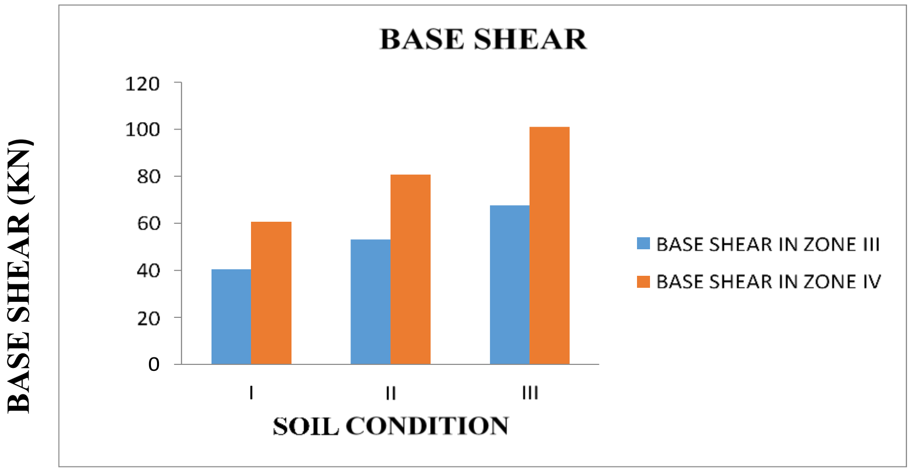


Fig. 7.2.1 Base Shear as per Indian standard code

Table 7.2.2 Base Shear as per European code

Soil Type	Base Shear(Kn)InSpectrum Zone I	Base Shear(Kn) In Spectrum Zone II
B	85.66	64.655
C	109.1	76.779
D	125.269	88.9007

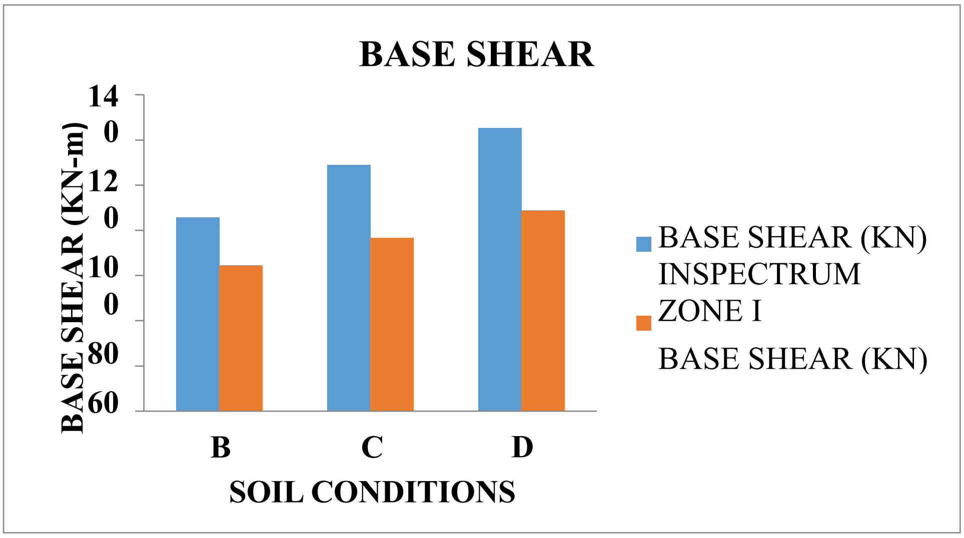


Fig. 7.2.2 Base Shear as per euro code

The base shear is reduced when a water tank is situated in a type II spectrum zone when built in accordance with European Standard Code. Figure 7.2.2 further illustrates that in both spectrum zones, type-D soil exhibited the maximum base shear in comparison to types B and C of soil.

7.3 Storey Displacements

According to the European code, the maximum storey displacement is H/250.

(Where H is the distance from the ground to the top of the water tank).

Table 7.3.1 Story displacement as per Indian code

Soil Type	Max. StoryDisplacement (Mm) In Zone III	Max. StoryDisplacement (Mm) In Zone IV
I	5.003	7.504
II	7.004	10.005
III	8.505	12.688

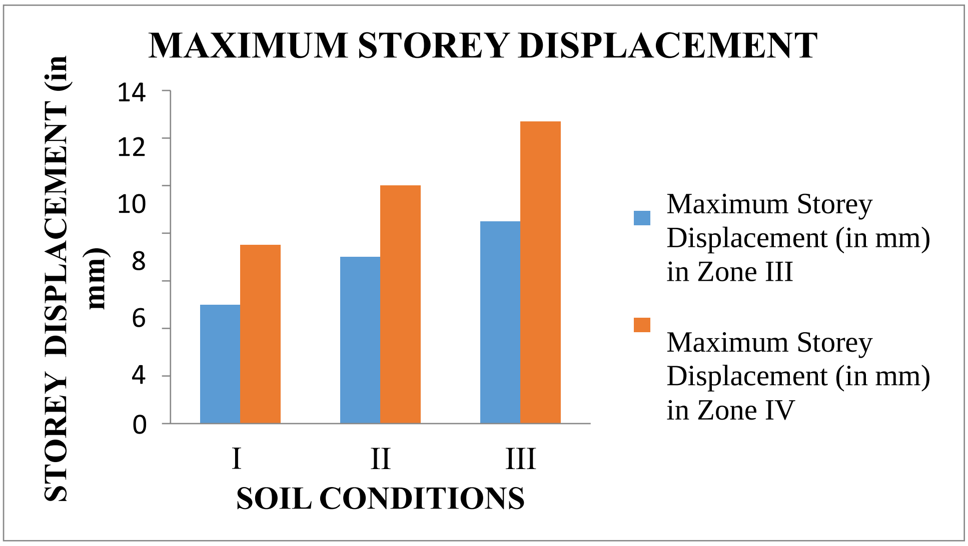


Fig. 7.3.1 Storey displacement as per IS code

In the context of a water tank, the highest magnitude of storey displacement is observed at the uppermost storey, and this displacement progressively increases as one moves from zone III to zone IV. Furthermore, the displacement magnitude is found to escalate when transitioning from hard to medium to soft soil types

Table 7.3.2 Storey Displacement by Euro code

Soil Type	Max. Storey Displacement In Spectrum Type I	Max. Storey Displacement In Spectrum Type II
B	10.606	8.004
C	13.507	9.505
D	15.508	11.006

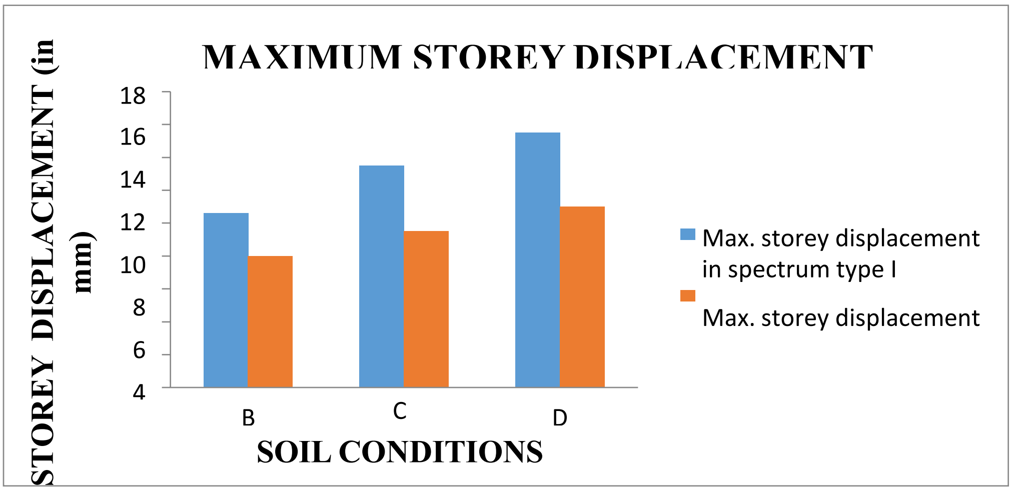


Fig. 7.3.2 Storey displacements as per Euro code

In accordance with European codal regulations, the highest degree of displacement within a building is observed in the uppermost tank's upper levels. Additionally, Figure 7.3.2 shows that in both circumstances, type-D soil exhibits a higher displacement than type-B and type-C soils.

7.4 Storey Drift

According to the provisions outlined in the building code, the maximum permissible magnitude of story drift is 0.004 times the height of the story being evaluated.

Table 7.4.1 Story drift by IS code

Soil Type	Maximum Storey Drift in Zone III	Max Storey Drift in Zone IV
1	0.000941	0.001261

2	0.001177	0.001681
3	0.001429	0.00213

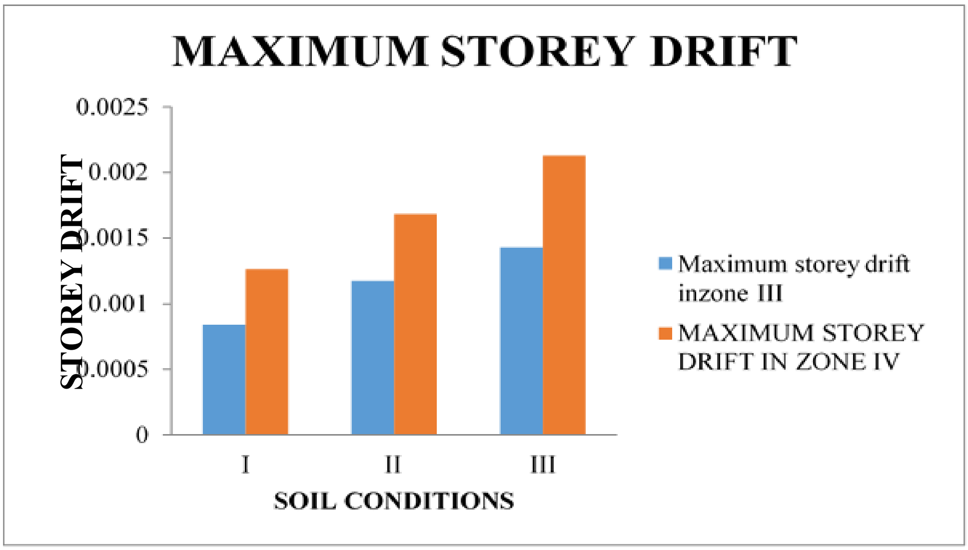


Fig. 7.4.1 Storey drift as per IS code

In both seismic zones III and IV, it has been observed that the maximum storey drift value occurs in soft soil. The increase in drift value can be attributed to variations in soil conditions within these zones.

Table 7.4.2 Storey drift by Euro code

Soil Type	Max. Storey Drift In Spectrum Type I	Max. Storey Drift is Spectrum Type II
B	0.001782	0.001345
C	0.00227	0.001597
D	0.002606	0.00185

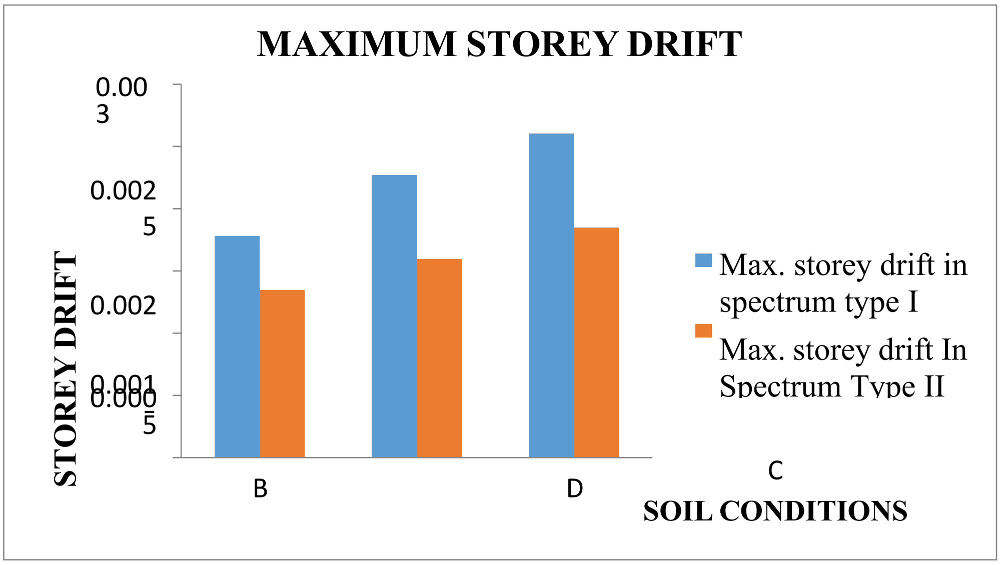


Figure 7.4.2 Storey drift as per Euro code

When compared to IS design, the amount of storey drift is larger in the context of European standard design. The value of drift progressively rises as the soil conditions transition from hard to moderate to soft. The storey drift in both spectrum zones comes in soil type D.

8. Conclusions

In this research investigation, an examination was carried out on a raised circular water tank utilizing ETAB software to conduct a seismic analysis. The analysis took into account various seismic zones and soil conditionsBased on the information provided in the tables and figures, we can draw several conclusions regarding the seismic behaviour of base moment, base shear, storey displacement, and storey drift.

I. According to both Indian and European codes, the maximum base moment is found to be highest in soft soil or type-D soil as per the European code. Additionally it can be noted that water tanks built in accordance with the Comparing water tanks built to the Indian standard code to those built to the Euro code reveals larger maximum base moments for type B, type C, and type D soils.

II. Based on the analysis of the base shear data, it can be inferred that the maximum base shear occurs in soft soil conditions. Furthermore, when adhering to the Indian standard code for water tank design, the base shear is comparatively lower than when following the European standard code.

III. In both Indian and European building codes, the highest degree of displacement within a building is observed in the uppermost storey of water tanks. Additionally, it can be deduced that Type III soils exhibit greater displacement comparable to both Type I and Type II soils scenarios, across various seismic zones.

IV. It is noted that the storey drift value in the context of European standard design is significantly larger than that in Indian standard design. The magnitude of drift tends to escalate as the soil transitions from hard to medium to soft. This increase in drift values amounts to an approximate growth of 62%.

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