Analysis and Design of Elevated Intez Water Tank based on Normal Frame Staging Subjected to Seismic Loading by Using Staad Pro Software

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Abstract: ***Water is as important commodity as food and air for the existence of life. All plants and animals must have water to survive. If there was no water there would be no life on earth. As water is very precious and due to the scarcity of drinking water in day-to-day life one has to take care of every drop. Anelevated Intez water tank is used to store water for fire protection and potable drinking water within a designated area or community over the daily requirement. Elevated Intez tanks allow the natural force of gravity to produce consistent water pressure throughout the system. Elevated Intez water tanks are one of the most important structures in earthquake high regions. In major cities and also in rural areas elevated or overhead water tanks forms an integral part of water supply scheme. Based on the intended application and needs of the distribution area, Elevated Intez water tanks can be engineered using a broad range of shapes, sizes, and materials. Elevated Intez water tank is the most effective storing facility used for domestic or even industrial purpose. The design should be based on the worst possible combination of loads, moments and shears arising from vertical loads and horizontal loads acting in any direction when the tank is full as well as empty. These structures have large mass concentrated at the top of slender supporting structure hence these structures are especially vulnerable to horizontal forces due to earthquake. In this research by performing the seismic analysis of Intez elevated tank, what is deflection shape due to hydrostatic pressure then stresses, are analysed. Elevated Intez water tanks that are inadequately analyzed and designed have suffered extensive damage during past earthquakes record. Hence it is important to check the severity of these earthquake forces for particular region. In this paper presents the study of seismic performance of the elevated Intez water tanks for high intensity seismic zones of India for various sections. Cracks can be prevented by avoiding the use of thick timber shuttering which prevent the easy escape of heat of hydration from the concrete mass. Elevated Intez tank consist of a container at the top, supported on a staging to transfer the load of the container to the foundation. Container consists of 'a domical roof, cylindrical vertical wall, a conical dome and a bottom dome. The staging consists of a frame work of columns and braces or a thin circular shaft. Generally, a column-brace system is preferred as staging for elevated Intez tank. By considering all the requirements which are essential for economical construction, in this research by performing the seismic analysis of elevated Intez tank is designed for population of around 5,926 people. The effect of height of water tank in earthquake zones and section of tank on earthquake forces have been presented with the help of STAAD PRO software***

Keywords: Types of tanks, Elevated Intez water tank, Tank Capacity, Hydrostatic pressure, Analysis, Design criteria as per IS code

1. Introduction

Intez elevated water tanks are used extensively by municipalities and industries for water supply, firefighting automatic systems, inflammable liquids and chemicals plant. Thus, Water tanks plays a vital role for public utility as well as industrial structure having basic purpose to secure constant water supply from longer or shorter distance with sufficient static head to the desired location under the effect of gravitational force. With the rapid increase of human population, demand for drinking water has increased by many fields. Also due to shortage of electricity at many places in India and around the developing nations, it is not possible to supply water through pumps at peak hours. In such situations elevated water tanks become an important part of life. India is highly vulnerable to natural disasters like earthquake, draughts, floods, cyclones etc. Majority of Indian states and union territories are prone to one or multiple disasters. These natural calamities are causing many causalities and huge natural property loss every year. According to seismic code IS 1893(Part-1):2002, more than 60% of India is prone to earthquakes. The main reason for life loss is collapse of structures It is said that natural calamities itself never kills people; it is badly constructed structure that kill or damaged property. Hence it is important to analyze the structure properly for different natural calamities like earthquake, cyclones, floods and typhoons etc. Past experiences revealed that elevated water tanks were heavily damaged or collapsed during earthquakes and this might be due to the lack of knowledge about the proper behaviour of supporting system of the tank against dynamic effect and also due to improper geometrical selection of staging patterns. Lateral force is more in tank full condition when compared to tank empty condition and hence tank full case is considered for seismic analysis. Generally, no cracks are allowed to take place in any part of the structure of Liquid Retaining R-C.C. tanks and they are made water tight by using richer mix(not less than M30 grade) of concrete. In addition, sometimes water proofing materials also are used to make tanks water tight. The risk of cracking can also be minimized by reducing the restraints on free expansion or contraction of the structure. The main reason for life loss is collapse of structures. It is said that natural calamities itself never kills people; it is badly constructed structure that kill. Hence it is important to analyse the structure properly for different natural calamities like earthquake, cyclones, floods and typhoons etc. The main reason for life loss during region. Since the Intez elevated tanks are frequently used in seismically active regions also, their seismic behaviour of has to be investigated in detail by using STAAD PRO software.

2. Literature Review

i. Zone factor Z: (IS: 1893. Clause.6.4.2.)
Earthquake severity has been classified into zones on the basis of maximum ground acceleration based on past earthquake data. India has been divided into four seismic zones (page 5 of IS 1893 (Part–1):2002) for the Maximum Considered Earthquake (MCE) and service life of the structure in a zone. The map is based on expected intensity of ground shaking but does not consider the frequency of occurrence. In seismic zone map, zone-I and zone -II of the contemporary map have been merged and assigned the level of zone-II. Zone II has lowest danger or risk while Zone - V has highest hazards.

ii. IS: 875 (Part 1) – 1987 for Dead Loads: Indian Standard Code of Practice for Design Loads (Other Than Earthquake) For Buildings and Structures, all permanent constructions of the structure form the dead loads. The dead load comprises of the weights of walls, partitions floor finishes, false ceilings false floors and the other permanent constructions in the buildings. The dead load loads may be calculated from the dimensions of various members and their unit weights. The unit weights of plain concrete and reinforced concrete made with sand and gravel or crushed natural stone aggregate may be taken as 24 kN/m^3 and 25kN/m^3respectively.

iii. IS: 875 (Part 2) - 1987 for Imposed Loads, Indian Standard Code of Practice for Design Loads (Other Than Earthquake), For Buildings and Structures, imposed load is produced by the intended use or occupancy of a building including the weight of movable partitions, distributed and concentrated loads, load due to impact and vibration and dust loads. Imposed loads do not include loads due to wind, seismic activity, snow, and loads imposed due to temperature changes to which the structure will be subjected to, creep and shrinkage of the structure, the differential settlements to which the structure may undergo.

iv. IS:1893(Part-1)-2002: Indian Standard Criteria for Earthquake Resistant Design of Structures, (Part 1-General Provisions and Buildings), It deals with assessment of seismic loads on various structures and earthquake resistant design of buildings. Its basic provisions are applicable to buildings; elevated structures; industrial and stack like structures; bridges; concrete masonry and earth dams; embankments and retaining walls and other structures. Temporary elements such as scaffolding, temporary excavations need not be designed for earthquake forces.

v. IS 456 -2000: Indian standard code of practice for plain and reinforced concrete (fourth revision), Bureau of Indian Standards. This standard deals with the general structural use of plain and reinforced concrete. For the purpose of this standard, plain concrete structures are those where reinforcement, if provided is ignored for the determination of strength of the structures.

vi. IS: 875 (Part 5) – 1987 for Load Combinations: Indian Standard Code of Practice for Design Loads (Other Than Earthquake) For Buildings and Structures, the various loads should be combined in accordance with the stipulations in the relevant design codes. In the absence of such recommendations, the following loading combinations, whichever combination produces the most unfavorable effect in the building, foundation or wind, earthquake, imposed and snow loads is not likely. All members are designed for the critical forces.

vii. IS: 3370 (part 1&2) is given in the paper. Elevated tank is used to store water for supplying it to the consumer. BIS has revised the version of IS: 3370 (part 1&2). After an elongated time from its 1965 version in year 2009. The code is drafted for the water tank. Limit state method is included in this new version. This paper gives the brief study on the design of Intez water tank using limit state method. This edition adopts limit state method with these additions. Cracking width of limit state design is limited and second addition is it limits the stresses in steel so that concrete does not reaches in over stressed zone. IS: 3370 (Part 2) 2009. Grade of concrete is taken as M30, as minimum grade of concrete for RCC structures is M30 as per IS: 3370 (Part1) 2009. As per discussion above, the water tank was designed by the following two design methods.

1) Limit state design method with crack width calculations and check in accordance IS: 3370 (2009).
2) Limit state design method deemed to satisfy (limiting steel stresses in accordance IS: 3370 (2009).

viii. IS 11682-1985- Layout of Elevated Tanks: Generally, the shape and size of elevated concrete tanks for economical design depends upon the functional requirements such as:

a) Maximum depth for water.
b) Height of staging;
c) Allowable bearing capacity of foundation strata and type of foundation suitable;
d) Capacity of tank; and
e) Other site conditions.

Classification and Layout of Elevated Tanks - Based on the capacities of the tank, the possible classification for types of elevated tanks may be as followed for general guidance.

1) For tank up to 50 m^3capacity may be square or circular in shape and supported on staging three or four columns.
2) Tanks of capacity above 50 $m^3$and up to 200 m^3rnay be square or circular in plan and supported on minimum four columns.
3) For capacity above 200 m^3 and up to 800 m^3 the tank may be square, rectangular, circular or intez type tank.

The number of columns to be adopted shall be decided based on the column spacing which normally lies between 3.6 and 4.5 m.

For circular, intez or conical tanks, a shaft supporting structures may be provided. Different shapes of water towers with certain arrangements of bottom construction are shown in Fig. 1 to 4 ofIS 11682 -1985. Besides the general shapes given in IS 11682 -1985 Cl. 6.1.1 to 6.1.4, tanks of unusual shapes, such as spherical, conical or multicell may also be adopted depending upon the discretion of the designer.

ix. Design Lateral Force:
The design lateral force shall first be computed for the building as a whole. This design lateral force shall then be distributed to the various floor levels. The overall design seismic force thus obtained at each floor level shall then be distributed to individual lateral load resisting elements depending on the floor diaphragm action.

x. Design Seismic Base Shear:
The total design lateral force or design seismic base shear (V_B) along any principal direction shall be determined by the following expression:

$$V_B = A_h W$$

Where, A_h= horizontal acceleration spectrum using the fundamental natural period in the considered direction of vibration.

$$A_h = \frac{\frac{Z}{2}\frac{S_a}{g}}{\frac{R}{I}}$$

where, z = Zone factor
I - Importance factors
R - Response reduction factor
Sa/g = Average acceleration response coefficient for approximate, natural period of vibration $T_a$to be determined.
W = seismic weight of all the floors of building

The seismic coefficient method does not need theoretical concepts of structural dynamics and modal analysis.

xi. Fundamental Natural Period:
The approximate fundamental natural period of vibration (T_a), in seconds, of a moment resisting frame building without brick in the panels may be estimated by the following empirical expression:
$T_a = 0.075\, h^{0.75}$ for RC frame building
$T_a = 0.085\, h^{0.75}$ for steel frame building
Where, H = Height of building, in m.

This excludes the basement story's, where basement walls are connected with the ground floor deck or fitted between the building columns. But it includes the basement stores, when they are not so connected. The approximate fundamental natural period of vibration (T), in seconds, of all other buildings, including moment-resisting frame buildings with brick lintel panels, may be estimated by the empirical Expression:

$$T_a = \frac{0.09}{\sqrt{d}}$$

Where, h = Height of building in m, and d = Base dimension of the building at the plinth level, in m, along the considered direction of the lateral force.

xii. Distribution of Design Force:
Vertical Distribution of Base Shear to Different Floor Level. The design base shear (V_b) shall be distributed along theheight of the building as per the following expression:

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

Where, Q_i = Design lateral force at floor i,

3. Types of Water Tanks

There are several types of water tank according to the shape, position with respect to ground level etc. From the position point of view and placement of tank, water tanks are divided into three classes. Those are,

a) Tanks resting on ground
b) Underground tanks
c) Overhead water tanks
d) From state of tank, water tanks might be named types. These are,
   - Circular tanks
   - Conical or channel formed tanks
   - Rectangular tanks
   - Intez tanks
   - circular tank with conical bottom
   - Spherical Tanks

4. Water Quantity Estimation:

The quantity of water required for municipal uses for which the water supply scheme has to be designed requires following data: Water consumption rate (Per Capita Demand in liters per day per head) Population to be served.

Quantity=Per demand x Population

Table 1: Water Consumption for Various Purposes

Sl No	Types of Consumption	Normal Range (lit/capita/day)	Average	%
1	Domestic Consumption	65 -300	160	35
2	Industrial and Commercial Demand	45 -450	135	30
3	Public including Fire Demand Uses	20 - 90	45	10
4	Losses and Waste	45 - 150	62	25

5. Water Consumption Rate

It is very difficult to precisely assess the quantity of water demanded by the public, since there are many variable factors affecting water consumption. The various types of water demand, which a city may have, may be broken into following class

6. Water Requirements for drinking and domestic use: National Building Code 2016, BIS

The value of water supply given as 150 to 200 liter per head per day may be reduced to 135 liter per head per day for houses for Medium Income Group (MIG) and Lowe Income Groups (LIG) and Economically Weaker Section of Society (EWS), depending upon prevailing conditions and availability of water. Out of the 150 to 200 liter per head per day, 45 liter per head per day may be taken for flushing requirements and the remaining quantity for other domestic purposes.

Quantity=Per demand x Population

= 135 x 5,926x 0.001 = 800.01m^3 or say 800m^3

7. Structural Elements of Elevated Intez Tank

The various structural elements of an elevated INTZE type water tank comprises of the following:

1. Top spherical dome
2. Top ring beam
3. Circular side walls
4. Bottom ring beam
5. Conical dome
6. Bottom spherical dome
7. Bottom circular girder
8. Tower with columns and braces
9. Foundations

1) ***Top Spherical Dome:*** The dome at top is usually 100 mm to150 mm thick with reinforcement along the meridians and latitudes. The rise is usually l/5th of the span.
2) ***Top Ring Beam:*** The ring beam is necessary to resist the horizontal component of the thrust of the dome. The ring beam will be designed for the hoop tension induced.
3) ***Cylindrical Side Walls:*** This has to be designed for hoop tension caused due to horizontal water pressure.
4) ***Bottom Ring Beam:*** This ring beam is provided to resist the horizontal component of the reaction of the conical wall on the cylindrical wall. The ring beam will be designed for the induced hoop tension.
5) ***Conical Dome:*** This will be designed for hoop tension due to water pressure. The slab will also be designed as a slab spanning between the ring beams at top and the ring girder at bottom.
6) ***Bottom Spherical Dome:*** The floor may be circular or domed. This slab is supported on the ring girder.
7) ***Bottom Circular Girder:*** This will be designed to support the tank and its contents. The girder will be supported on columns and should be designed for resulting bending moment and Torsion.
8) ***Columns:*** These are to be designed for the total load transferred to them. The columns will be braced at intervals and have to be designed for wind pressure or seismic loads whichever govern.
9) ***Foundations:*** A combined footing is usually provided for all supporting columns. When this is done it is usual to make the foundation consisting of a ring girder and a circular slab.
10) **Problem on Elevated Intez Tank**

Design an elevated INTZE type water tank of 800m^3 supported onan elevated tower comprising of 12 columns. The base of the tank is 16 m above ground level. Adopt M-30 grade concrete and Fe-415 grade tor steel. The design of the tank should confirm to the stresses specified in IS:3370-1965 and IS:456-2000

11) **Dimensions of Intez Tank**

D = Inside diameter of tank

Assuming the average depth 0.75 D

a. Volume $= \frac{\pi}{4}D^2 \text{ x } 0.75 \text{ D}$

b. Rise of top dome $= \frac{D}{6} = h_1$

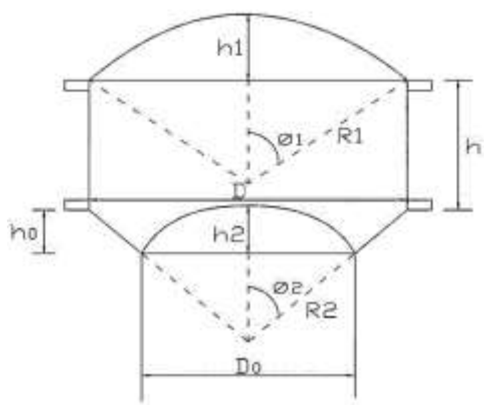
c. Rise of bottom dome $= \frac{D}{8} = h_2$

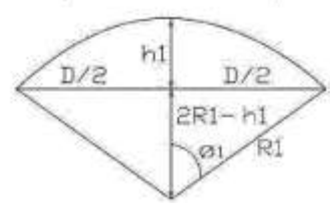
d. Depth of conical dome $= \frac{D}{6} = h_0$

e. Diameter of ring beam $B_2 = D_0 = \frac{5}{8} D$

f. Exact volume of Intez tank

$$V = \frac{\pi}{4}D^2 h + \frac{\pi}{12}h_0\left[D^2 + {D_0}^2 + DD_0\right] - \frac{\pi}{3}{h_2}^2(3R_2 - h_2)$$





$$h_1(2R_1 - h_1) = \left(\frac{D}{2}\right)^2$$

Find R_1, $\sin \emptyset_1$, $\cos \emptyset_1$

Similarly, R_2, $\sin \emptyset_2$, $\cos \emptyset_2$

$$\sin \emptyset_1 = \left[\frac{\frac{D}{2}}{R_1}\right], \sin \emptyset_2 = \left[\frac{\frac{D}{2}}{R_2}\right]$$

8. Design and Analysis of Elevated Intez Water Tank

The RC Elevated Intez water container of 800m^3 capacity has inner diameter of 12 m and height of 7 m (including freeboard of 0.3 m). It is supported on RC staging consisting of 12 columns. Staging columns have isolated rectangular footings at a depth of 2m from ground level. Tank is located on medium soil in seismic zone III, and IV. Grade of staging concrete and steel are M 30 and Fe415, respectively. Density of concrete is 25 kN/m^3. Analyzed the tank for seismic loads. The tank is analysed for full water filled condition, and tank in empty condition. Considered Zone III, and IV (as per IS 1893 -1984 and IS 1893:2002) for analysis.

9. Modelling and Analysis

For the analysis of elevated Intez type water tank following dimensions are considered which arein table 2, 3 below. The maximum value of forces and moments obtained from STAAD Pro gives the maximum load to which the tank is subjected and thus critical. The check for critical members from STAAD Pro also reveals that the tank is stable for maximum forces and moments. Analysis of the structure means to determination of the internal forces like axial compression bending moment, shear force etc. in the component member for which the member is to be designed under the action of given external load and various effect of earthquake. From the study of the elevated Intez type water tank, main objective is to know deflected shape, stresses and B.M. for the same.

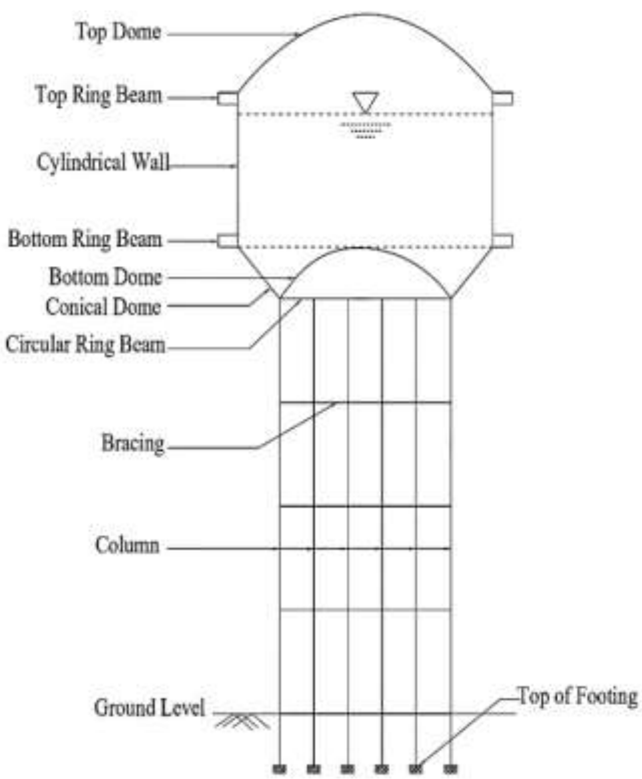


Figure 1: Elevation of Intex Water Tank

10. Equivalent Static Analysis

All design against seismic loads must consider the dynamic nature of the load. However, for simple regular structures, analysis by equivalent linear static methods is often sufficient. This is permitted in most codes of practice for regular, low- to medium-rise structures It begins with an estimation of base shear load and its distribution on each story calculated by using formulas given in the code. Equivalent static analysis can therefore work well for low to medium-rise structures without significant coupled lateral-torsional modes, in which only the first mode in each direction is considered. Tall buildings (over, say, 75 m), where second and higher modes can be important, or buildings with torsional effects, are much less suitable for the method, and require more complex methods to be used in these circumstances.

11. Methodology

The design base shear is computed by STAAD for building structures as per IS: 1893 (Part 1) 2002.

$$V_B = A_h . W$$

Where, $A_h = \frac{Z}{2}\frac{I}{R}\frac{S_a}{g}$

Table 2: Intez tank Parameters and Description

Parameters	Dimensions/ Description
Height of the tank	25.7 m
Top Diameter of Tank (D)	12 m
Rise of top dome (h1)	2 m
Rise of bottom dome (h2)	1.5 m
Depth of conical dome (h0)	2 m
Diameter of ring beam (D0)	8 m
Straight Height (linear)	16 m
Circular ring beam (m)	1.1 x 0.68
Middle ring beam (m)	1.1 x 0.68
Top ring beam (m)	0.3 x 0.3
Number of columns	12 Nos
Height of Cylindrical Wall (h)	5 m
Thickness of Cylindrical Wall	200 mm
Thickness of top dome	100 mm
Thickness of conical dome	200 mm
Thickness of bottom dome	200 mm
Depth of foundation	2 m below GL
Safe bearing Capacity	250 kN/m^2

Table 3: Intez tank Parameters and Description

Seismic Zone	III	IV
Column Type: Circular (m)	0.58	0.68
Bracings (m)	0.35x 0.48	0.45x 0.58

Table 4: Staircase parameters and description

Seismic Zone	III	IV
Column Type: Rectangular (m)	0.23x 0.30	0.23x 0.30
Beams (m)	0.23x 0.30	0.23x 0.30
Thickness of plate (mm)	150	150

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Table 5: Seismic Constants which are considered for calculation

S. No	Constant	Zone III	Zone IV	Remarks
1	Z	0.16	0.24	Structures considered in Zone III and IV
2	I	1.5	1.5	Importance Factor
3	R	5	5	Response Reduction Factor

STAAD utilizes the following procedure to generate the lateral seismic loads:

1) We provide seismic zone coefficient and desired 1893 specs through the DEFINE 1893 LOAD command.
2) The program calculates the structure period, T_a.
3) The program calculates S_a/g utilizing T_a.
4) The program calculates V_B from the above equation. W is obtained from masstable data entered viaSELFWEIGHT, JOINT WEIGHT(S), MEMBER WEIGHT(S), and/or REFERENCE LOAD we provide through the DEFINE1893 LOAD command.
5) The total lateral seismic load (base shear) is then distributed by the program among different levels of the structure per the IS: 1893(part -1) 2002 procedures

Table 6: Nodes, Elements, Plates

STRUCTURE TYPE		SPACE FRAME	
Number of Nodes	529	Highest Node	565
Number of Elements	231	Highest Beam	648
Number of Plates	413	Highest Plate	649

Table 7: Number of basic and combination load cases

Type	*L/C*	*Name*
Primary	1	EQ+X
Primary	2	EQ-X
Primary	3	EQ+Z
Primary	4	EQ-Z
Primary	5	Dead Load
Primary	6	Live Load
Primary	7	Hydrostatic Load
Combination	8	1.5 (DL+LL+HL)
Combination	9	1.2 (DL+LL+HL+EQX)
Combination	10	1.2 (DL+LL+HL-EQX)
Combination	11	1.2 (DL+LL+HL+EQZ)
Combination	12	1.2 (DL+LL+HL-EQZ)
Combination	13	1.5 (DL+EQX)
Combination	14	1.5 (DL-EQX)
Combination	15	1.5 (DL+EQZ)
Combination	16	1.5 (DL-EQX)
Combination	17	0.9 DL + 1.5 EQX
Combination	18	0.9 DL-1.5 EQX
Combination	19	0.9 DL + 1.5 EQZ
Combination	20	0.9 DL - 1.5 EQZ

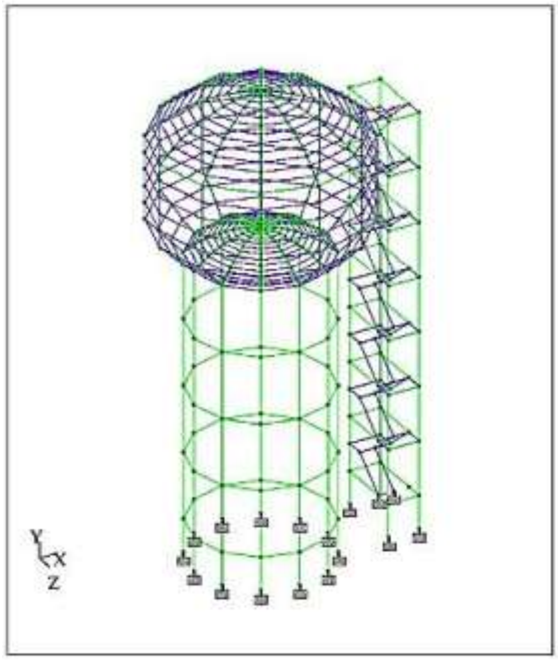


Figure 2: Proposed Model for Elevated Intez Water Tank

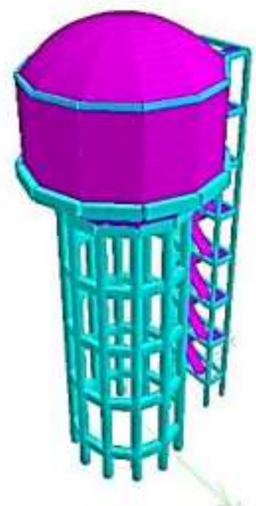
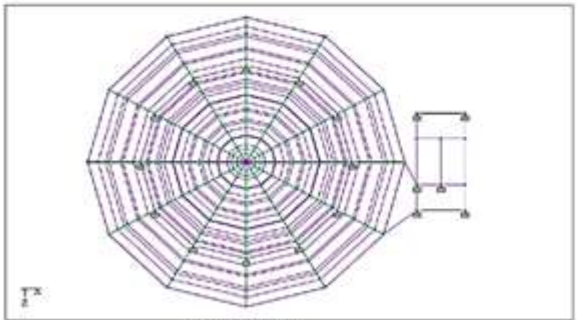


Figure 3: 3D Rendered View

Figure 4: Earthquake +X direction

Figure 5: Earthquake +Z direction



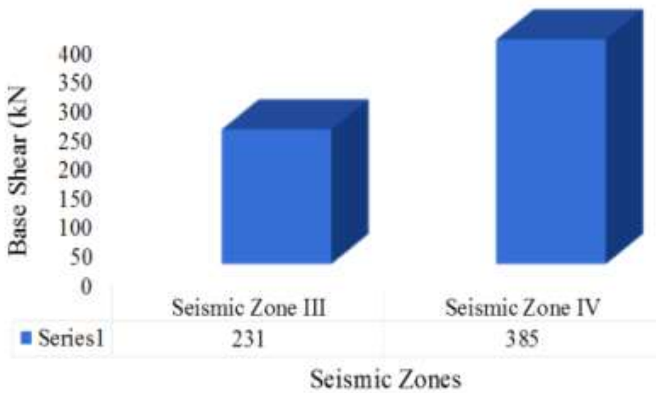
Normal Staging

Fig 6. Staging arrangement

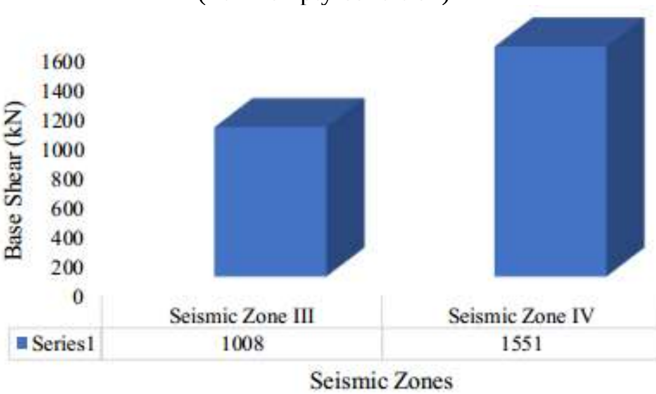
12. Analysis and Results

Table 8: Base Shear (kN)

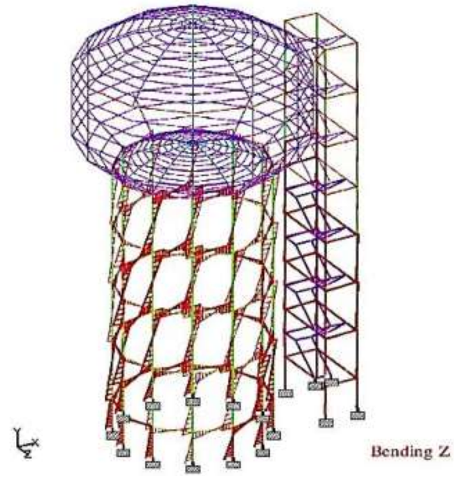
S. No	Condition	h/d ratio	No. Columns	Base Shear (kN)	
				Seismic Zone III	Seismic Zone IV
1	Think empty	0.558	12	231	385
2	Tank with water full	0.558	12	1008	1551



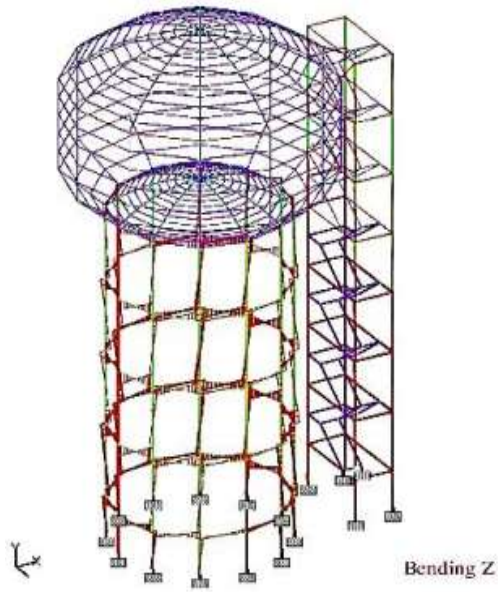
Graph 1: Seismic Zones Vs Base Shear (kN)
(Tank empty condition)



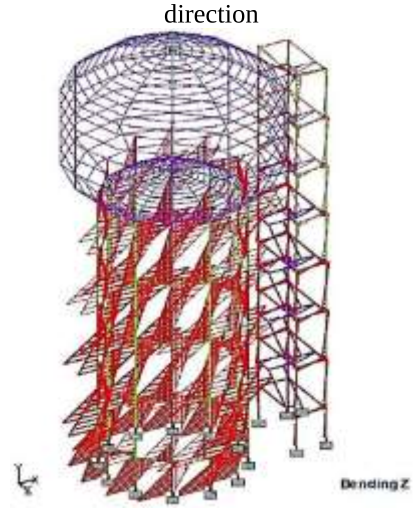
Graph 2: Seismic Zones Vs Base Shear (kN)
(Tank with Water Full Condition)



(Tank empty condition in Seismic Zone III)
Figure 7: Maximum Bending Moment Diagram in EQ+X-direction)

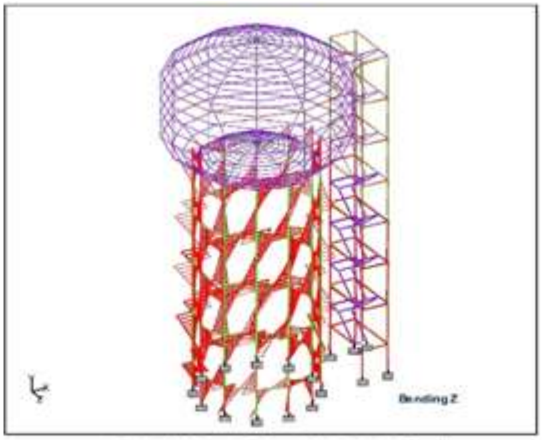


(Tank empty condition in Seismic Zone III)
Figure 8: Maximum Bending Moment Diagram in EQ +Z-direction



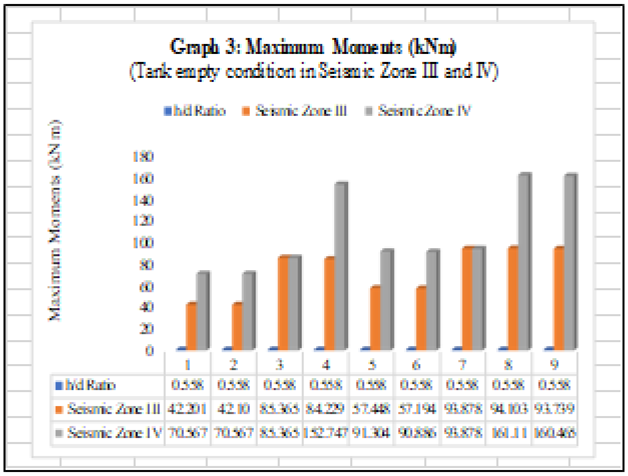
(Tank with full water filled condition in Seismic Zone III)

Figure 9: Maximum Bending Moment Diagram in EQ +X-direction

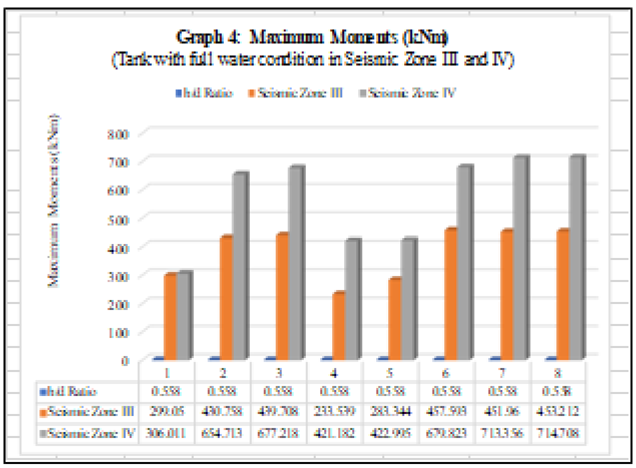


(Tank with full water filled condition in Seismic Zone III)

Fig 10. Maximum Bending Moment Diagram in EQ +Z-direction



	1	2	3	4	5	6	7	8	9
h/d Ratio	0.558	0.558	0.558	0.558	0.558	0.558	0.558	0.558	0.558
Seismic Zone III	42.201	42.10	85.365	84.229	57.448	57.194	93.878	94.103	93.739
Seismic Zone IV	70.567	70.567	85.365	152.747	91.304	90.886	93.878	161.11	160.465



	1	2	3	4	5	6	7	8
h/d Ratio	0.558	0.558	0.558	0.558	0.558	0.558	0.558	0.558
Seismic Zone III	299.05	430.758	439.708	233.539	283.344	457.933	451.96	453.212
Seismic Zone IV	306.011	654.713	677.218	421.182	422.905	670.823	713.356	714.708

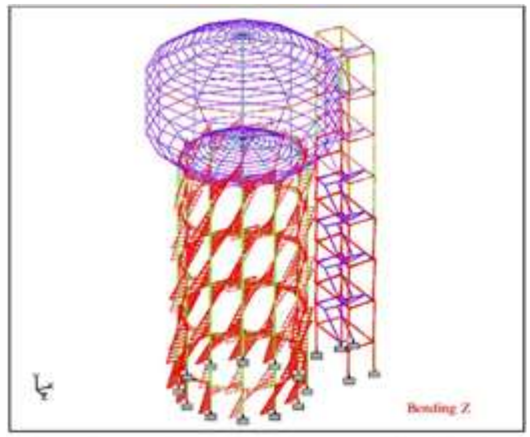


Fig 11. Maximum Bending Moment Diagram in EQ + X direction
(Tank empty condition in Seismic Zone IV)

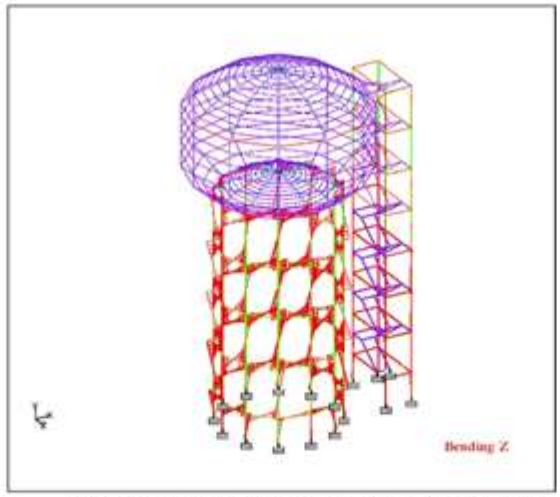


Fig 12. Maximum Bending Moment Diagram in EQ + Z direction
(Tank empty condition in Seismic Zone IV)

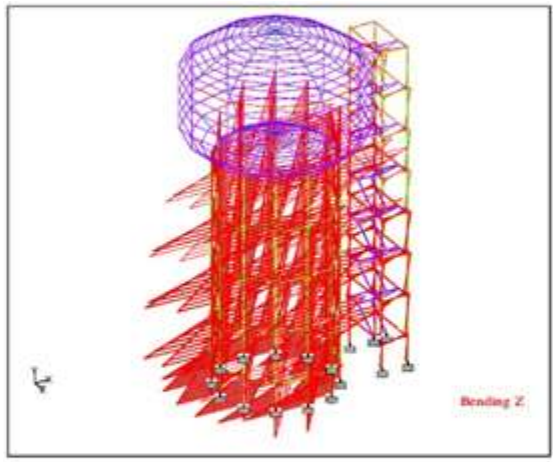


Fig 13. Maximum Bending Moment Diagram in EQ + X direction
(Tank with full water condition in Seismic Zone IV)

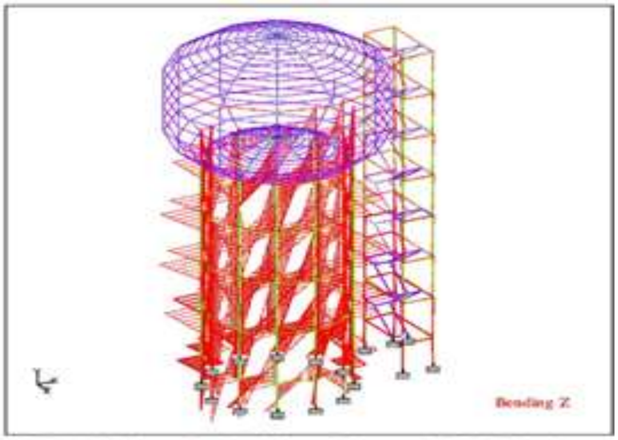
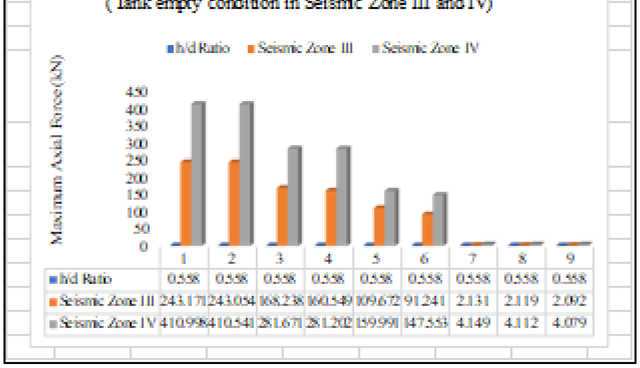
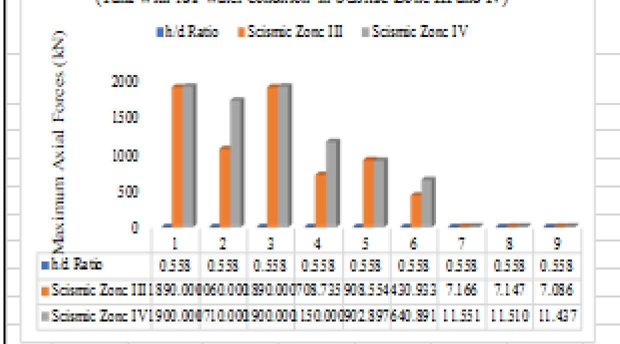


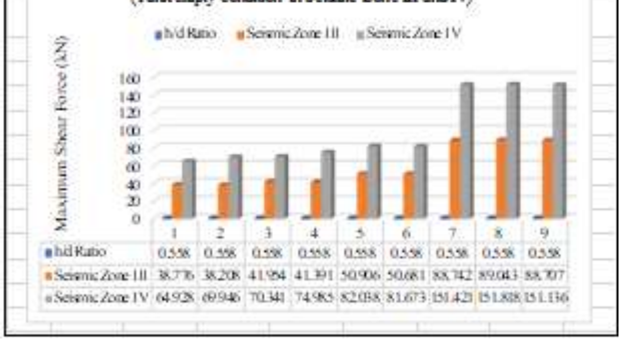
Fig 14. Maximum Bending Moment Diagram in EQ + Z direction (Tank with full water condition in Seismic Zone IV)



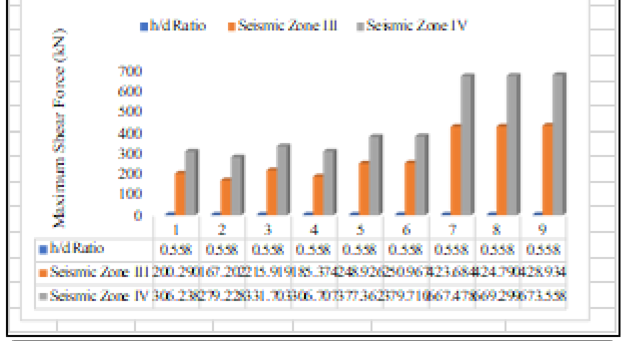
Graph 5: Maximum Axial Forces (kN)
(Tank empty condition in Seismic Zone III and IV)



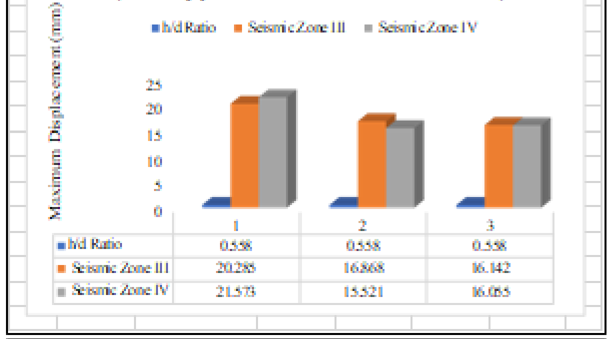
Graph 6 : Maximum Axial Forces (kN)
(Tank with full water condition in Seismic Zone III and IV)



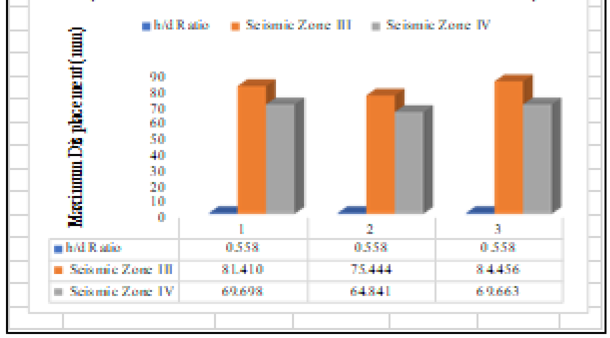
Graph 7: Maximum Shear Forces (kN)
(Tank empty condition in Seismic Zone III and IV)



Graph 8: Maximum Shear Force (kN)
(Tank with full water condition in Seismic Zone III and IV)



Graph 9: Maximum Displacement (mm)
(Tank empty condition in Seismic Zone III and IV)

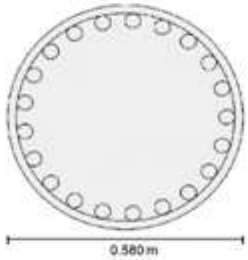


Graph 10: Maximum Displacement (mm)
(Tank with full water condition in Seismic Zone III and IV)

STAAD.Pro Concrete Design

Column No. 79

Design Code: IS-456-2000



Design Load

Load	15
Location	End 1
Pu (Kns)	-22.290001
Mz (Kns-Mt)	0.500000
My (Kns-Mt)	439.709991

Design Results

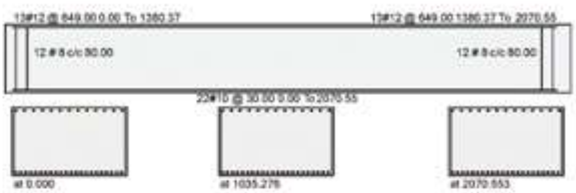
Fy (Mpa)	415
Fc (Mpa)	30
As Reqd(mm²)	6552.000000
As (%)	2.497000
Bar Size	20
Bar No	21

Fig 15. Reinforcement details of column No: 79
(Tank with full water condition in Seismic Zone III)

STAAD.Pro Concrete Design

Beam No. 57 (Circular Ring Beam)

Design Code: IS-456-2000



Design Load

Mz (Kn Met)	Dist.at	Load
281.989990	0.000000	13
-186.929993	0.000000	2
-233.539993	2.100000	13

Design Parameter

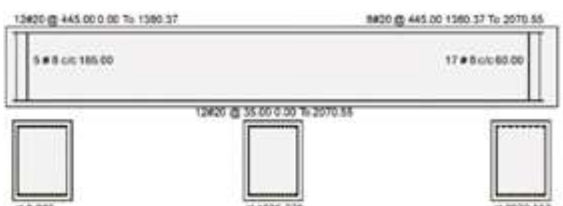
Fy (Mpa)	415.000000
Fc (Mpa)	30.000000
Depth(m)	0.680000
Width(m)	1.100000
Length(m)	2.070553

Fig 16. Reinforcement details of beam No 57
(Tank with full water in Seismic Zone III)

STAAD.Pro Concrete Design

Beam No. 27 (Bracing)

Design Code: IS-456-2000



Design Load

Mz(Kn Met)	Dist.at	Load
434.929993	2.100000	17
-453.209991	0.000000	18
-290.019989	2.100000	2

Design Parameter

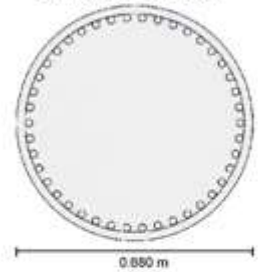
Fy(Mpa)	415.000000
Fc(Mpa)	30.000000
Depth(m)	0.480000
Width(m)	0.350000
Length(m)	2.070553

Fig 17. Reinforcement details of beam No: 27
(Tank with full water condition in Seismic Zone III)

STAAD.Pro Concrete Design

Column No.79

Design Code: IS-456-2000



Design Load

Load	15
Location	End 1
Pu (Kns)	-19.290001
Mz (Kns-Mt)	0.600000
My (Kns-Mt)	677.219971

Design Results

Fy (Mpa)	415
Fc (Mpa)	30
As Reqd(mm²)	8426.000000
As (%)	2.325000
Bar Size	16
Bar No	42

Fig 18. Reinforcement details of column No.79
(Tank with full water condition in Seismic Zone IV)

STAAD.Pro Concrete Design

Beam No. 57

Design Code: IS-456-2000

Design Load

Mz(Kn Met)	Dist.at	Load
421.179993	0.000000	13
-279.679993	0.000000	2
-380.339996	2.100000	13

Design Parameter

Fy(Mpa)	415.000000
Fc(Mpa)	30.000000
Depth(m)	0.680000
Width(m)	1.100000
Length(m)	2.070553

Fig 19. Reinforcement details of beam No.57
(Tank with full water condition in Seismic Zone IV)

STAAD.Pro Concrete Design

Beam No. 27

Design Code: IS-456-2000

Design Load

Mz (Kn Met)	Dist.at	Load
680.039998	2.100000	17
-714.710022	0.000000	18
-453.589995	2.100000	2

Design Parameter

Fy (Mpa)	415.000000
Fc (Mpa)	30.000000
Depth(m)	0.580000
Width(m)	0.450000
Length(m)	2.070553

Fig 20. Reinforcement details of beam No.27
(Tank with full water condition in Seismic Zone IV)

TIE REINFORCEMENT: Provide 8 mm dia. circular ties @ 300 mm c/c for column No 79 in Seismic Zone III, as shown in fig 15.

TIE REINFORCEMENT: Provide 8 mm dia. circular ties @ 255 mm c/c for column No. 79 in Seismic Zone IV as shown in fig 18.

13. Result and Discussion

In this research work, using normal staging arrangements, twelve number of columns, and h/d ratio 0.558, following conclusions were drawn, and these are illustrated as:

Base Shear

From graph 1, it is observed that the tank empty condition and the base shear is high in seismic zone IV, compare to, another for tank empty condition in seismic zone III. Similarly, from graph 2, it is observed that the tank with full water condition and the base shear is high in seismic zone IV, compare to, another for tank with full water condition in seismic zone III.

Maximum Moments

From graph 3, it is observed that the maximum value of moments is high for the tank empty condition in seismic zone IV, compare to another for the tank empty condition in seismic zone III. Similarly, from graph 4,it is observed that the maximum value of moments is high for the tank with full water condition in seismic zone IV, compare to another for the tank with full water condition in seismic zone III.

Maximum Axial Force

From graph 5, it is observed that the maximum value of axial forces is high for the tank empty condition in seismic zone IV, compare to, another for the tank empty condition in seismic zone III. Similarly, from graph 6, it is observed that the maximum value of axial forces is high for the tank with full water condition in seismic zone IV, compare to another for the tank with full water condition in seismic zone III.

Maximum Shear Force

From graph 7, it is observed that the maximum value of shear forces is high for the tank empty condition in seismic zone IV, compare to another for the tank empty condition in seismic zone III. Similarly, from graph 8,it is observed that the maximum value of shear forces is high for the tank with full water condition in seismic zone IV, compare to another for the tank with full water condition in seismic zone III.

Maximum Displacements

From graph 9, it is observed that the maximum value of displacements is high for the tank empty condition in seismic zone III, compare to another for the tank empty condition in seismic zone IV. Similarly, from graph 10, it is observed that the maximum value of displacements is high for the tank with full water condition in seismic zone III, compare to another for tank with full water condition in seismic zone IV.

14. Conclusion

It is observed that the Limit State Design of Reinforced Concrete Elevated Intez water tank by using STAAD PRO Software. The moments are high for the tank with full water condition in seismic Zone IV, compare to another for tank with full water condition in seismic zone III. The reinforcement which is provided in the elevated Intez water structure can be reduced because the moments obtained in the analysis are high. The basic need of any structure is to design as economical as possible reinforcement in a structure plays an important key role in the elevated Intez water tank and it should not be over reinforced.

References

[1] IS 3370-2 (2009) Code of Practice Concrete structures for the storage of liquids, Part 2 Reinforced concrete,Bureau of Indian Standards, New Delhi.

[2] IS 3370-4 (1967) Code of practice for concrete structures for the storage of liquids, Bureau of Indian Standards, New Delhi.

[3] IS 1893-1984 Criteria for Earthquake Resistant Design of Structures, Bureau of Indian Standards, New Delhi.

[4] IS: 1893 (Part-1) - 2002: Indian Standard Criteria for Earthquake Resistant Design of Structures, (Part 1- General Provisions and Buildings) Bureau of Indian Standards, New Delhi.

[5] IS 11682: Criteria for design of RCC staging for overhead water tanks. Bureau of Indian Standards, New Delhi.

[6] Draft IS: 1893 (Part-II liquid Retaining Tanks) Criteria for Earthquake Resistant Design of Structures, Bureau of Indian standards, New Delhi, India.

[7] IS: 875 (Part 1) – 1987For Dead Loads **-** Code of Practice for Design Loads (Other Than Earthquake) For Buildings and Structures, Bureau of Indian Standards, New Delhi.

[8] IS: 875 (Part 2) - 1987 for Imposed Loads - Code of Practice for Design Loads (Other Than Earthquake), For Buildings and Structures, Bureau of Indian Standards, New Delhi.

[9] IS 456 -2000 - Code of practice for plain and reinforced concrete (fourth revision), Bureau of Indian Standards. New Delhi.

[10] IS: 875 (Part 5) – 1987 for Load Combinations: Indian Standard Code of Practice for Design Loads (Other Than Earthquake). Bureau of Indian Standards. New Delhi.

[11] IITK-GSDMA Guidelines for Seismic Design of Liquid Storage Tanks Provisions with commentary and explanatory examples.

[12] S. Ramamrutham, Design of Reinforced Concrete Structures. 17th Edition. 2016.

[13] U. Ranga Raju, B. Dead name. Effect of Staging Height on the Seismic Performance of RC Elevated Water Tank. 2015. http://www.ijirset.

[14] P. B. Murnal, S. K. Jangave1. Structural Assessment of Circular Overhead Water Tank Based onFrame Staging Subjected to Seismic Loading. 2014. www.ijetae.com.

[15] A. M. Kalani S. A. Salpekar (1978), ―A comparative study of different methods of analysis for staging of elevatedwater tanks, Indian Concrete Journal, July August – 1978, Pg. No.210-216.

[16] S. S. Quadri, R. M. Sawant - Seismic Analysis of RC Elevated Water Tank Using Different Staging Pattern,

IJSEA (2016), Vol 3 issue 1Pg. No 1 - 22 @Journals Publication 2016.www.journalspublications.com

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Indian Scenario of Water Resources - An Overview, Integrated Water Management and Major Issues related to Indian Waters " inISSN:2321-7758, Vol.6., Issue.5, 2018 Sept-Oct., PP 64-70, International Journal of Engineering Research by Venkata Raju Badanapuri.

“On Overview of Integrated theory of Irrigation efficiency and Uniformity and Crop Water Use Efficiency Indian Waters "InISSN:2321-7758, Vol.6., Issue.6, 2018 Nov-Dec., PP 11-26, International Journal of Engineering Research by Venkata Raju Badanapuri.

Water Resources Scenario in India its Requirement, Water Degradation and Pollution, Water Resources Management -in ISSN:2348-6848, Volume 05 Issue 23December2018, PP 672-696, International Journal of Research by Venkata Raju Badanapuri.

Seismic Forces and Stability Analysis of Gravity Dam - in ISSN 2319 -7064, Volume 08 Issue 06 June2019, PP 2021- 2030, International Journal of Science and Research (IJSR)by Venkata Raju Badanapuri.

Design Principles that are involved in the design of Flow over an Ogee Crest Spillway in ISSN2319 -7064Volume 08 Issue 08August 2019, PP 245- 254, International Journal of Science andResearch (IJSR)by Venkata Raju Badanapuri.

Static and Dynamic Analysis of Multistoried Building in Seismic Zone-III, in ISSN 2319 -7064Volume 10 Issue 02February 2021, PP 86- 96, International Journal of Science and Research (IJSR) by Venkata Raju Badanapuri.