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Comparative Study of Seismic Analysis of Existing Elevated Reinforced Concrete Intze Water Tank Supported on Frame Staging

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Abstract: *As known from the very past experiences, elevated water tanks were collapsed or heavily damaged during earth quakes all over the world. These unusual events showed that the supporting system of the elevated tanks has more critical importance than the other structural types of tanks. The main aim of this project is to understand the seismic behavior of the elevated water tank and comparison of various seismic analysis parameters of the elevated reinforced concrete water tank with consideration and modeling of impulsive and convective water masses inside the container in Two Mass Model as per IS: 1893(part 2)-2002. The behavior of elevated water tanks with frame staging pattern is analyzed using from the codes IS 1893 (part 1): 2002 and IS 1893 (part 2): 2002. It can be observed from the analysis that elevated water tank with frame type of staging can perform better by following IS: 1893 (part 2): 2002 because, IS 1893 (part 1): 2002 is only for buildings and is not suitable for liquid retaining structures. The Base Shear and Overturning moments obtained from the code IS 1893 (part 1):2002 are greater than the values obtained from the code IS 1893 (part 2): 2002, this is due to the consideration of single degree of freedom in earlier code. Then finally concluded that in the earlier code the reinforcement is heavy, this will leads to uneconomical and it is considered as one of the disadvantage. From the recent code the base shear and overturning moment is less from that the reinforcement is reduced. It is very necessary to design and analyze the water tank as economical as possible. Finally the results have been presented in the form of graphs and tables.*

Keywords: *Elevated RC INTZE water tank, Design, Analysis, Comparative study.*

1. INTRODUCTION

The word "Water Tank" is generally referred as unmistakable liquid holding structure. It has been produced around 80 years prior and perceived also outlined, effective and temperate unit for business and private use. Raised water storage tanks components to search for quality and toughness, and of course spillages can be maintained a strategic distance from by recognizing great development hones. Be that as it may, as a general rule these structures don't frequently keep going the length of they are intended for. When all is said in done, water holding structures misery has been watched early even in 9 to 10 years of administration life because of a few issues identified with basic viewpoints and over accentuation of seismic examination in quake inclined regions. Amid the past seismic tremors, the water tanks have been endured with differing level of harms, which include: Buckling of ground upheld thin tanks (Malhotra, 1997), break of steel tank shell at the area of joints with channels, breakdown of supporting tower of hoisted tanks (Manos and clough,1983, Rai, 2002), splits in the ground bolstered RC tanks, and so forth.

2. ELEVATED WATER TANK

Water is day by day essential requirement for each human life. A raised Reinforced Concrete roundabout tank is a water stockpiling holder built with the end goal of holding water supply at certain tallness to pressurize the water circulation framework. Numerous new thoughts and developments have been made for the capacity of water and other fluid materials in distinctive structures and molds. There are distinctive routes for the capacity of fluid, for example, underground tanks, ground bolstered tanks, lifted tanks and so on. Fluid stockpiling tanks are utilized widely by districts and commercial ventures for capacity of water, inflammable fluids and different chemicals. In this way water tanks are essential for open utility and for modern structures.

Indian sub-landmass is exceptionally defenseless against characteristic debacles like quakes, drafts, surges, violent winds and so on. Greater part of states or union domains are inclined to one or numerous calamities. These regular catastrophes are bringing on numerous setbacks and countless property misfortune consistently. Seismic tremors involve ahead of everyone else in powerlessness. Henceforth, it is important to figure out how to live with these occasions. As per seismic code IS: 1893(Part I):2002, more than 60% of India is inclined to tremors. After a seismic tremor, property misfortune can be recuperated to some degree nonetheless, the life misfortune can't. The fundamental explanation behind life misfortune is breakdown of structures. It is said that quake itself never slaughters individuals; it is seriously built structures that execute. Subsequently it is vital to break down the structure legitimately for seismic tremor impacts.

3. INDIAN CODE PROVISIONS

Systems for the seismic examination of capacity tanks are for the most part taking into account the Housner, (1963) multi segments spring/mass relationship. The relationship permits the mind boggling dynamic conduct of a tank and its substance to be considered in disentangled structure. The central methods of reaction incorporate a brief period incautious mode, with a time of around 0.5 seconds or less, and various longer period convective (sloshing) modes with periods up to a few seconds. For most tanks, it is the rash mode, which commands the stacking on the tank divider. The primary convective mode is generally a great deal less huge than the rash mode, and the higher request convective modes can be disregarded.

Tanks upheld on adaptable establishments, through unbending base mats, experience base interpretation and shaking, bringing about longer rash periods and by and large more noteworthy successful damping. These progressions may influence the incautious reaction fundamentally. The convective (or sloshing) reaction is basically harsh to both the tank divider and the establishment adaptability because of its long stretch of wavering. With the end goal of this investigation hoisted tanks is considered as a solitary level of flexibility with their mass gathered at their focal point of gravity. Seismic investigation of hoisted water tanks are did in light of the rules given in IS1893-part2. IITK-GSDMA has proposed certain extra rules for seismic investigation and outline of fluid storage tanks. The present study considers IS 1893 (part 1): 2002 and procurements alongside IS 1893 (part 2): 2002 rules for examining the raised water tanks.

4. SEISMIC ANALYSIS OF 800KL CAPACITY ELSR AS PER IS 1893 (PART 1) 2002:

Water towers are top-heavy structures; the entire system could be approximated as a single degree of freedom without much loss of accuracy.

Certain fraction of weight (usually 1/3rd) of columns and braces may be assumed to be added to the weight at top and the columns may be treated as weightless springs to facilitate the calculations. (Is 1893)

From the design,

I.L + D.L of superstructure = 11769.85kN

Water load only = 8026.80kN

D.L of staging only = (62.60 + 23.63) x 18 = 1552.14Kn (column and braces)

D.L of container portion:

= (11769.85 – 8026.80 – 115.57 – 156.51) = 3470.97kN

(i) Tank empty condition:

Equivalent weight @ C.G W_e

= 3470.97 + (1552.14/3)

c) Base shear

i) For tank empty condition,

W_s= 3988.35kN

V_b = 0.066 x 3988.35 = 263.23kN

ii) For tank full condition,

W_s=11915.15kN

V_b = 0.066 x 11915.15 = 786.40kN

Hence full tank condition is critical

Base shear at bottom most bay per each column = 786.48/18 = 43.68kN

Height of C.G of container from top of foundation = 15.70 + 6.35 /4 = 17.275m

Base moment due to seismic loading = 786.40 x 17.275 = 13585.06kN-m

(ii) Tank full condition:

Equivalent weight, W_f

= 3988.35 + 8026.80

= 11915.15kN

h = Height of the structure = 24.30m

For water towers, I = 1.50

Response Reduction Factor, R = 3.0

For Zone III, Vijayawada, Z = 0.16

Assuming damping @ 5%, the acceleration coefficient for a fundamental natural period of 0.84sec, from fig.2 of IS 1893

a) Fundamental time period

$T = 0.075 \times 24.30^{0.75} = 0.821\text{sec}$

b) Design horizontal seismic coefficient

As per IS 1893 (part 1), 2002

For medium soils, S_a/g = 1.65

$\therefore A_h = \frac{0.16 \times 1.50}{2 \times 3} \times 1.65 = 0.066$

5. Seismic Analysis Of 800KL Capacity ELSR As Per IS 1893 (Part 2) 2002:

The sectional details of Elevated water tank are shown below. Capacity of tank= 800 kilolitre and supported on R.C. frame staging of 18 columns with horizontal bracing.

i) Preliminary data:

Details of sizes of various components and geometry are shown below

Table1. *Sizes of various components*

S. No	Component	Size (mm)
1	Top Dome	100 Thick
2	Top Ring Beam	400 x 300
3	Cylindrical Wall	200 Thick
4	Bottom Ring Beam	600 x 550
5	Circular Ring Beam	400 x 850
6	Bottom Dome	200 Thick
7	Conical Dome	200 Thick
8	Braces	300 x 600
9	Columns	400 x 400

ii) Weight calculations:

Table2. *Weight of various components*

S. No	Components	Calculations	Weight(kN)
1	Top Dome	Radius of Dome, $r_1 = [15.32/2]^2 + 2.2^2/2 \times 2.2 = 14.44$m $2 \times \pi \times 14.44 \times 2.22 \times (0.1 \times 25)$	503.547
2	Top Ring Beam	$\pi \times (15.2 + 0.4) \times 0.4 \times 0.3 \times 25$	147.026
3	Cylindrical Wall	$\pi \times 15.4 \times 0.2 \times 3.55 \times 25$	858.754
4	Bottom Ring Beam	$\pi \times (15.2 + 0.6) \times 0.6 \times 0.55 \times 25$	409.506
5	Circular Ring Beam	$\pi \times 10.86 \times 0.4 \times 0.85 \times 25$	290.000
6	Bottom Dome	Radius of Dome, $r_2 = (10.86/2)^2 + 1.55^2/2 \times 1.55 = 10.29$ $2 \times \pi \times 10.29 \times 1.55 \times 0.2 \times 25$	501.068
7	Conical Dome	Length of Cone, $L_c = \sqrt{(1.77^2 + 1.6^2)} = 2.38$m $\pi \times (15.4 + 10.86)/2 \times 2.38 \times 0.2 \times 25$	490.864
8	Braces	$1.96 \times 0.3 \times 0.6 \times 4 \times 12 \times 25$	423.36
9	Columns	$0.4^2 \times 16.05 \times 18 \times 25$	1155.6

Weight of Water:

$= [\pi/4 \times 15.2^2 \times 3 + \pi/12 \times 1.55 \times (15.2^2+10.86^2+15.2 \times 10.86) - \pi/3 \times 2.2^2(3 \times 7.95 - 2.2)]\ 9.81$

= 6310.184 kN

Weight of staging:

= weight of columns + braces

= 423.36 + 1155.6

= 1578.96kN

Weight of empty container= 503.547+147.026+858.754+409.506+290+501.068+490.864

= 3200.765kN

Hence, w = weight of container + 1/3 rd weight of staging

W= 3200.765+1578.96/3 = 3727.085kN

iii) Center of gravity of empty container:

Components of empty container are Top Dome, Top Ring Beam, Cylindrical Wall, Bottom Ring Beam, Bottom Dome, Conical Dome and Circular Ring Beam. Height of center of gravity (C.G) of empty container from top of Circular Ring Beam will be

=[503.547x7.35+147.026x5.15+858.754x3.55+409.506x1.875290x0.425+501.068x2.3+490.864x1.6] /3200.765

=3.152m

Hence, height of C.G of empty container from top of footing will be

h_{cg} = 16.43+3.152

=19.582m

iv) Lateral stiffness of staging:

Lateral stiffness of staging is defined as the force required to be applied at the C.G of tank so as to get a corresponding unit deflection.

Modulus of elasticity for M_{30} concrete is obtained as

$E = 27386$ MPa$= 27.386 \times 10^6$kN/m^2

Stiffness of column in each bay $k_c = 12EI/l^3$

I=moment of inertia $=2.133 \times 10^{-3}$ m^4

l = length of the staging = 15m

k_c=207.695kN/m

k_s= 3738.51kN/m

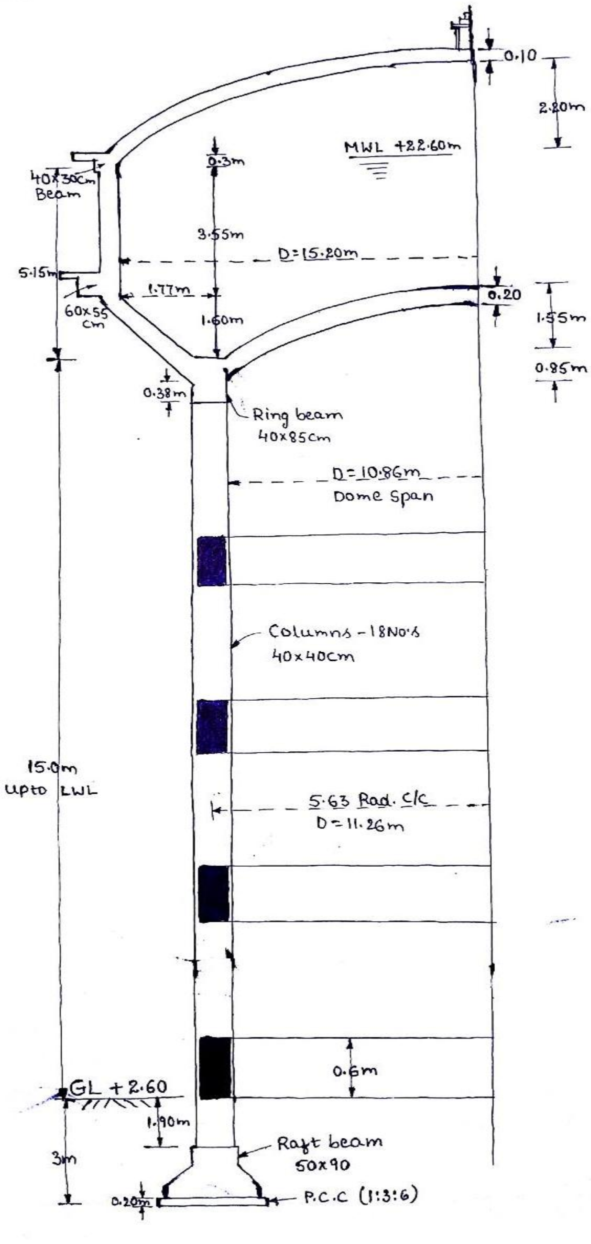


Fig1. *Section of elevated intze water tank*

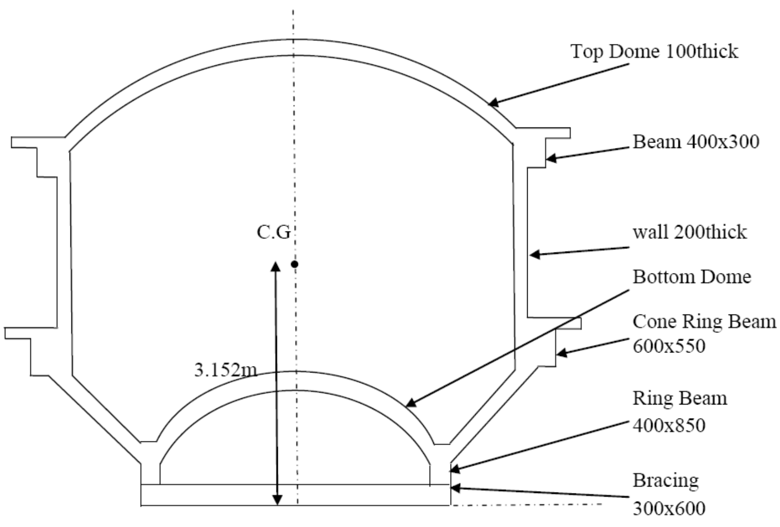


Fig2. *Container parameters in frame staging tank*

v) Parameter of spring mass modal:

A) Tank full condition

Total weight of water = 800k.lit or 7848000N

Hence, mass of water: m = 800 x 10^3kg

Volume of water = 7848/9.81 = 800m^3

Inner diameter of the tank, D = 15.2m

For obtaining parameters of Spring Mass Model, an equivalent circular container of same volume and diameter equal to diameter of tank at top level of liquid will be considered.

Let ‘h’ be the height of the equivalent circular cylinder,

$h = 800/ (\pi\ (15.2/2)^2)$

= 4.408m

Hence for, h/D = 4.408/15.2 = 0.29

$m_i/m = 0.36$; $m_i = 288000$kg

$m_c/m = 0.64$; $m_c = 512000$kg

$h_i/h = 0.375$; $h_i = 1.653$m

$h_i*/h = 1.375$; $h_i* = 6.061$m

$h_c /h = 0.55$; $h_c = 2.424$m

$h_c*/h = 1.3$; $h_c* = 5.73$m

Here the sum of impulsive and convective mass is 800000kg which compares well with the total mass.

m_s = (3200.765 + 1578.96) x 1000/9.81

= 379927.115kg

Lateral stiffness of staging;

k_s= 3738.51kN/m

1. Time period:

a) Time period of impulsive mode,

$T_i = 2\pi \sqrt{\{(288000+379927.115)/(3738.51 \times 10^3)\}}$

= 2.655sec

b) Time period of convective mode,

$T_c = 3.6\sqrt{15.2/9.81}$ = 4.481sec= 4sec

2. Design horizontal seismic coefficient:

a) Design seismic horizontal coefficient for impulsive mode

$(A_h)_i = Z/2 \times I/R \times (Sa/g)_i$

I=1.5 (table1 of IS: 1893 (part2):2002)

Z = 0.16 (Zone III)

For T_i = 2.655sec, site is medium soil and damping is 5%

(Sa/g) = 0.6 [IS: 1893 (part 1):2002, fig 2]

R = 1.8 (table 2 of IS: 1893 (part 2):2002);

$(A_h)_i$= 0.16/2 x 1.5/1.8(0.6)= 0.04

b) Design horizontal seismic coefficient for convective mode

T_c = 4sec

Site is medium soil and damping is 0.5%

Hence $(S_a/g)_c$ =1.36/4 = 0.34

Multiplying factor of 1.36 is used to obtain Sa/g values for 0.5% damping from that for 5% damping

R = 1.5, (table 7 of IS: 1893 (part 1):2002);

$(A_h)_c$= 0.16/2 x 1.5/1.8 (0.34) = 0.0226

3. Base shear:

a) Base shear at the bottom of staging in impulsive mode

V_i = 0.04x (288000 + 379927.115) x 9.81

= 262.094kN

b) Base shear at the bottom of the staging in convective mode

V_c = 0.0226 (512000) x 9.81

= 113.513kN

c) Total base shear at the bottom of staging

V= V_i + V_c= 262.094 + 113.513

= 375.607kN

4. Base moment:

a) Overturning moment at the base of staging in impulsive mode

M_i^* = 0.04 [288000 (6.061 + 16.43) + 379927.115 x 19.582] 9.81

= 5461.086kN-m

b) Overturning moment at the base of staging, in convective mode

M_i^* = 0.0226 x 512000 [5.73 + 16.43] 9.81

= 2515.458kN-m

c) Total base moment, M = M_i^* + M_c^*

= 5461.086 + 2515.458

= 7976.544kN-m

5. Hydrodynamic pressure:

Impulsive hydrodynamic pressure

a) Impulsive hydrodynamic pressure on wall; maximum pressure will occur at ϕ=0, cosϕ=1

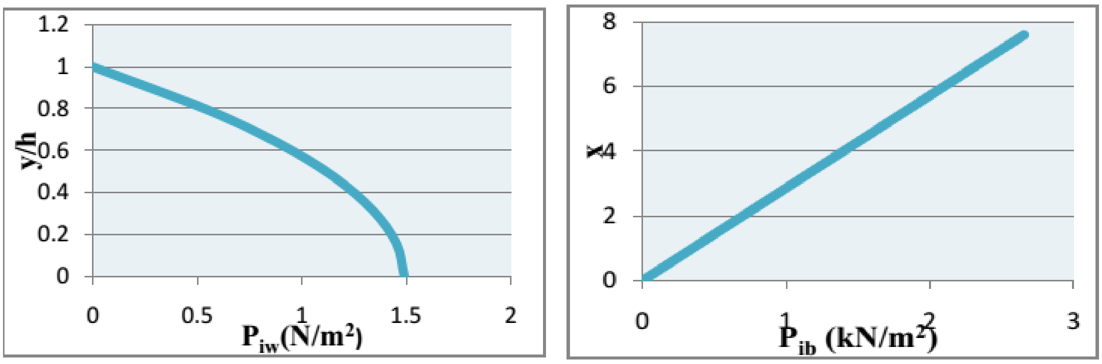
$P_{iw}(y)$ = 0.861 (0.4) 1 x 9.81 x 4.408 x 1

= 1.490kN/m^2

b) Impulsive hydrodynamic pressure on Base Slab

P_{ib}**=** 0.866(0.04) 1 x 9.81x 4.408 [(sin h (0.866) 2.5/4.408)/(cos h (0.866))3/4.408]

= 2.653kN/m^2



(1) (2)

Fig3. *Impulsive hydrodynamic pressure on the Wall (1) and Base Slab (2)*

Convective hydrodynamic pressure:

a) Convective hydrodynamic pressure on the wall

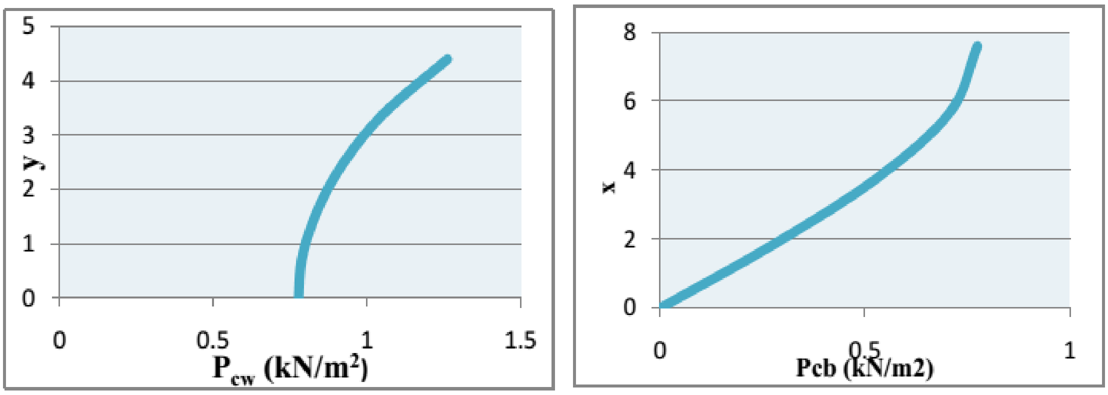
$P_{cw}(y) = 0.346 \times 0.0226 \times 9.81 \times 15.2 [1\text{-}1/3 (1)^2] 1$

$= 0.777 kN/m^2$

b) Convective hydrodynamic pressure on Base Slab

$P_{cb} = 0.229 \times 0.0226 \times 1 \times 9.81 \times 15.2$

$= 0.774 kN/m^2$



(1) (2)

Fig4. *Convective hydrodynamic pressure on the Wall (1) and Base slab (2)*

6. Pressure due to wall inertia

Pressure on wall, due to its inertia,

$P_{ww} = 0.04 (0.2) \times 25$

$= 0.2 kN/m^2$

This pressure is uniformly distributed along the wall height

7. Pressure due to vertical excitation

This period of vertical mode of vibration is recommended as 0.3sec for 5%damping, then Sa/g value is 2.5. for this time period, damping and medium soil site condition

$Z = 0.16$

$I=1.5,$

$R=1.8$

$A_v=2/3[0.16/2 \times 1.5/1.8 \times 2.5]$

$= 0.111$

At the base of the wall i.e, y=0

P_v= 0.111(1 x 9.81 x 4.408 (1-0/4.408))

= 4.804kN/m^2

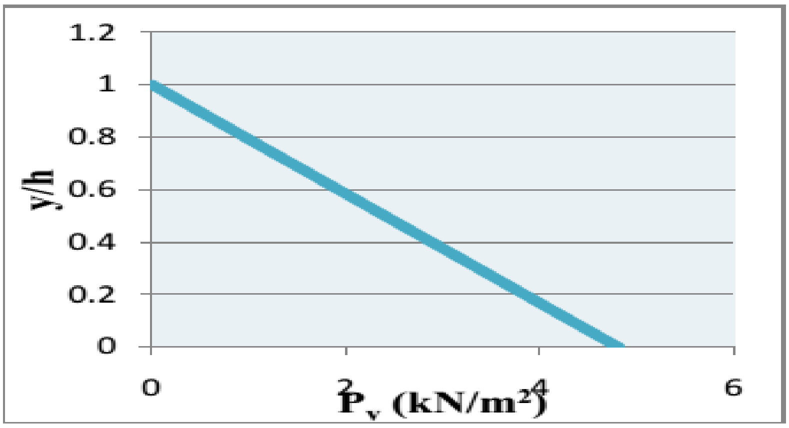


Fig5. *Pressure due to vertical excitation*

6. Maximum hydrodynamic pressure at the base of wall

P = √ [(14.903 + 2 + 7.773)^2+ (4.804)^2]

= 25.139kN/m^2

7. Sloshing wave height

d_{max} = 0.0226 x 15.2/2

= 0.1717m

Height of sloshing wave should be less than free board of 0.3m

B) Tank empty condition

For empty condition, tank will be considered as single degree of freedom system.

m_s = mass of empty container + 1/3rdmass of staging

m_s= 379927.115kg

Stiffness of staging, k_s = 3738.51kN/m

1. Time period:

Time period of impulsive mode

T_i= 2π√(379927.115/(3738.51 x 10^3))

= 2.002sec

Empty tank will not have convective mode of vibration

2. Deign horizontal seismic coefficient

Design horizontal seismic coefficient for impulsive mode

$(A_h)_i$= Z/2 x I/R x (S_a/g)

I = 1.5

For T_i= 2.134sec, site has medium soil and damping is 5%

$(Sa/g)_i$= 0.7

R = 1.8 (table 2 of IS: 1893 (part 2):2002);

$(A_h)_i$= 0.16/2 x 1.5/1.8 x (0.5)

= 0.033

iii. Base shear

Total base shear at the bottom of staging in impulsive mode

V= (0.033) 379927.115 x 9.81 = 122.993kN

iv. Base moment

Total base moment,

M* = 0.033 x 379927.115 x 19.582 x 9.81

= 2408.464kN-m

Since total base shear and base moment in tank full condition are more than base shear and base moment in tank empty condition design will be governed by tank full condition

6. RESULTS

Comparison of different seismic analysis parameters of Intze tank supported on frame staging is shown in below tables. In that tables all parameters from the codes IS 1893 (part 1): 2002 and IS 1893 (part 2): 2002 for the frame staging are summarized.

Table1. *Comparison of various parameters*

Sl. No	Identification	IS 1893 (PART 1): 2002	IS 1893 (PART 2): 2002
1	Brace beam flexibility	-	Neglected
2	Lateral stiffness of staging	-	3738.51kN/m
3	Time period		
	Impulsive	-	
	a) Tank empty (T_i)	-	2.002sec
	b) Tank full (T_i)	-	2.655sec
	Convective mode		
	Tank full(T_c)	0.821sec	4sec
4	Design horizontal seismic coefficient		
	Impulsive mode		
	a) Tank empty $(A_h)_i$		
	b) Tank full $(A_h)_i$	-	0.033
	convective mode	-	0.4
	a) Tank full $(A_h)_c$	0.066	0.226
5	Base shear(V)		
	a) Tank empty	263.23kN	122.993kN
	b) Tank full	786.40kN	3756.079kN
6	Overturning moment(M)		
	a) Tank empty	-	2408.464kN-m
	b) Tank full	13585.06kN	79765.445kN-m

Table2. *Comparison of Base Shear from two codes*

CONDITION	BASE SHEAR	
	IS 1893 (PART 1):2002	IS 1893 (PART 2):2002
Tank empty	263.23kN	122.993kN
Tank full	786.40kN	375.607kN

Table3. *Comparison of overturning moment from two codes*

CONDITION	OVERTURNING MOMENT	
	IS 1893 (PART 1):2002	IS 1893 (PART 2):2002
Tank empty	-	2408.464kN-m
Tank full	13585.06kN-m	7976.544kN-m

7. CONCLUSIONS

Seismic analysis and performance of existing elevated RC Intze water tank has been presented in this study for frame type of staging pattern. Most of the damages observed during the earthquakes arise from the causes like unsuitable design of supporting system, mistakes on selecting supporting system. Therefore supporting structural elements of elevated water tanks are extremely vulnerable under lateral forces due to an earthquake. The behavior of elevated water tanks with frame staging pattern is analyzed using from the codes IS 1893 (part 1): 2002 and IS 1893 (part 2): 2002. It can be observed from the analysis that elevated water tank with frame type of staging can perform better by following IS: 1893 (part 2): 2002 because, IS 1893 (part 1): 2002 is only for buildings and is not suitable for liquid retaining structures and the analysis parameters are compared due to the following characteristics:

- It can be observed from the earlier code IS 1893 (part 1): 2002 can follow only the single degree of freedom and from the later code IS 1893 (part 2): 2002 can follow the Two Mass Modal.
- For elevated tanks, the two degree of freedom idealization of tank should be used for analysis initial use of single degree of freedom idealization of tank, as the effect of convective hydrodynamic pressure should be included in the analysis of the tanks.
- Bracing beam flexibility is explicitly included in the calculation of lateral stiffness of tank staging in IS:1893(part 2) 2002 which is not included in IS:1893 (part 1): 2002
- The distribution of impulsive and convective hydrodynamic pressure is represented graphically for convenience in analysis, the hydrodynamic pressure also is higher in two mass modal when compared to lumped mass modal.
- Effect of vertical ground acceleration on hydrodynamic pressure is also considered while analysis the tank by two mass modal.
- All documents suggest consideration of convective and impulsive components in seismic analysis of tanks
- The Base Shear and Overturning moments obtained from the code IS 1893 (part 1):2002 are greater than the values obtained from the code IS 1893 (part 2): 2002, this is due to the consideration of single degree of freedom in earlier code.
- Then finally concluded that in the earlier code the reinforcement is heavy, this will leads to uneconomical and it is considered as one of the disadvantage. From the recent code the base shear and overturning moment is less from that the reinforcement is reduced. It is very necessary to design and analyze the water tank as economical as possible.

REFERENCES

[1] BIS Draft code on IS: 1893-part 2, "Criteria for Earthquake Resistant Design of Structure, Liquid Retaining Tanks Elevated and Ground Supported (fifth revision of IS: 1893)", Workshop on Revision of IS Codes on LRS.

[2] IS: 1893-1984 "Criteria for Earthquake Resistant Design of Structures"

[3] IS: 1893(2002) "Criteria for Earthquake Resistant Design of Structures"

[4] IITK-GSDMA guidelines for seismic design of liquid storage tanks.

[5] Beheshtian.N, Omidinasab. F and Shakib.H, "Seismic Response Evaluation of the RC Elevated Water Tank with Fluid-Structure Interaction", KSCE Journal of Civil Engineering (2012).

[6] Chirag N. Patel and H. S. Patel, "Supporting systems for reinforced concrete elevated water tanks: A state of the art", Patel et al, International Journal of Advanced Engineering Research and Studies (2012)

[7] Dutta, S.C., Jain, S.K. and Murty, C.V.R., (2000). "Assessing the Seismic torsional Vulnerability of Elevated Tanks with RC Frame Type staging", Soil Dynamics and Earthquake Engineering.

[8] Housner, G. W., (1963), "The Dynamic Behavior of Water", Bulletin of the Seismological Society of American.

[9] Manish N. Gandhi, Prof.A.Rajan, "Necessity of Dynamic Analysis of Elevated Water Storage Structure Using Different Bracing in Staging", International Journal of Research in Advent Technology, Vol.2, No.2, February 2014.

[10] Rai, D. C., (2003), "Performance of Elevated Tanks in Mw 7.7 Bhuj Earthquake", Indian Acad. Sci. (Earth Planet. Sci.), Elevated Tanks in Mw 7.7 Bhuj Earthquake", Indian Acad. Sci. (Earth Planet. Sci.), 067X Volume 1, Issue 1 (May 2012), PP 22-30.

[11] Soheil Soroushnia, Sh.Tavousi Tafreshi, F. Omidinasab, N. Beheshtian, Sajad Soroushnia, "Seismic Performancof RC Elevated Water Tanks with Frame Staging and Exhibition Damage Pattern", The Twelfth East Asia-Pacific Conference on Structural Engineering and Construction (2011).

[12] SuchitaHirde Dr., Ms. AsmitaBajare, Dr. ManojHedaoo, "Seismic performance of elevated water tanks", International Journal of Advanced Engineering Research and Studies (2011).

[13] Ajagbe, W.O.1, Adedokun2, S.I. and Oyesile W.B.1 "Comparative Study on the Design of Elevated Rectangular and Circular Concrete Water Tanks", International Journal of Engineering Research and Development ISSN: 2278

[14] Ranjit Singh Lodhi, Dr. Abhay Sharma, Dr. VivekGarg, Design of Intze Tank in Perspective of Revision of IS: 3370 International Journal of Scientific Engineering and Technology (ISSN : 2277-1581) Volume No.3 Issue No.9, pp : 1193-1197 1 Sep 2014.

[15] Krishna Rao M.V1, Rathish Kumar. P2, Divya Dhatri. K3, seismic analysis of overhead circular water tanks – a comparative study, IJRET: International Journal of Research in Engineering and Technology eISSN: 2319-1163 | pISSN: 2321-7308.

[16] F. Omidinasab and H. Shakib, seismic vulnerability of elevated water tanks using performance based-design, the 14thWorld Conference on Earthquake Engineering October 12-17, 2008, Beijing, China.

[17] Mangulkar Madhuri.N,Gaikwad Madhukar V, review on seismic analysis of elevated water tank, international journal of civil engineering and technology (IJCIET) ISSN 0976 – 6308 (Print) ISSN 0976 – 6316(Online)Volume 4, Issue 2, March - April (2013), pp. 288-294.

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