Seismic Analysis of Overhead Water Tank Using Indian, American and British Codal Provisions

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Abstract – *Reinforced cement concrete overhead water tanks are very important structures. They are considered as main lifeline elements during and after earthquakes. An overhead water tank behaves like an inverted pendulum, which consist of huge water mass at the top of a slender staging. This is most critical consideration for the failure of the tank during earthquakes. Basically, supporting system, so called staging is formed by a group of columns and horizontal braces provided at intermediate levels to reduce the effective length of the column. In this study seismic behaviour of RCC overhead tanks in seismic zone (iii), was carried out by performing dynamic response spectrum analysis using FEM base software (ETABS) as per IS 1893: 2002.Analysis was carried out for elevated RCC tank for empty & full tank condition under different codal provisions. The responses include base shear, base moments and Compared among the three standards, ACI proves to be more economical. In terms of economic value, the codal provisions are queued as ACI, IS and BS. All the three codes follow working stress method and results in higher stability.*

Key Words: **Overhead water tank, seismic zone (iii), Indian, American and British Standards, ETABS 16.2.1**

1. INTRODUCTION

A water tank is utilized to store water to hold over the day by day necessity. In the development of solid structure for the capacity of water and different fluids the impenetrability of cement is generally fundamental .The porousness of any uniform and completely compacted cement of given blend extents is for the most part subject to water concrete proportion .The expansion in water concrete proportion brings about increment in the penetrability .The reduction in water concrete proportion will along these lines be alluring to diminish the penetrability, yet especially decreased water concrete proportion may cause compaction challenges and end up being destructive too. Plan of fluid holding structure must be founded on the shirking of breaking in the solid having respect to its rigidity. Splits can be forestalled by staying away from the utilization of thick timber covering which forestall the simple getaway of warmth of hydration from the solid mass. The danger of splitting can likewise be limited by lessening the restrictions on free development or withdrawal of the structure. Planning, Analysis and Design of an RCC Overhead Water Tank to located at Tambaram, Chennai. Design and comparison of overhead RCC water tank using Indian, American and British Standards, Optimization of overhead water tank for the fixed capacity

1.1 OBJECTIVE

- To plan an RCC overhead water tank for a capacity of 2,50,000 liters.
- To analyze the water tank using E-tabs software.
- To analysis the overhead RCC water tank based on Indian, American and British standard code books

2. LITERATURE REVIEW

- Pavan S. Ekbote and Dr. Jagadish G. Kori (2013), overhead water tanks were collapsed during earth termor. Due to the liquid structure interactions, the seismic behaviour of elevated water tanks has the characteristics of intricate phenomena. The main aim of this study is to understand the behaviour of supporting system (or staging) which is more effective under different response spectrum method with SAP 2000 software. In this paper, diverse supporting frameworks, for example, cross and outspread propping were examined.

- R.V.R.K. Prasad and Akshaya B. Kamdi (2012),Capacity raised water tanks are utilized to store water. BIS has drawn out the overhauled rendition of IS 3370 (section 1&2) after quite a while from its 1965 form in year 2009. This updated code is chiefly drafted for the fluid stockpiling tank. In this amendment significant is that breaking point state technique is consolidated in the water tank structure. This paper gives to sum things up, the hypothesis behind the plan of roundabout water tank utilizing WSM and LSM. Structure of water tanks by LSM is generally conservative as the amount of material required is less when contrasted with WSM. Water tank is the most significant compartment to store water in this manner, Crack width estimation of water tank is additionally vital.

- Hasan Jasim Mohammed (2011), studied application of optimization method to the structural design of concrete rectangular and circular water tanks, considering the total cost of the tank as an objective function with the properties of the tank that are tank capacity, width and length of tank in rectangular, water depth in circular, unit weight of water and tank slab thickness, as design variables.
- Merlecha S.K. (2002) studied on "Analysis of Water tank on Sloping ground". The author analyzed water tanks on level as well as on upward slope. Four column staging is used for two heights of staging one of which 4 is 9m high and another is 12m high. 6 models for each staging height are studied for different level differences. For 9m height staging interval is kept 3m and for 12m height staging interval is kept 4m. Earthquake forces are calculated as per I.S 1893-1984 and the models are analyzed. Forces for different components like base beam, column and bracing beam is studied for all 12 models.

3. METHODOLOGY

- Planning of RCC overhead water tank: Calculating the required amount of water was used at particular area and planning the required size of the water tank.
- Analysis of overhead water tank: The modal of the water tank was analysed using professional software name E-Tabs according to the different codal provisions.
- Results discussion.

4. RESULTS AND DISCUSSION

- **Planning**

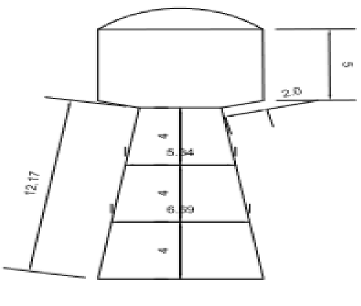


Fig: 1 Section of water tank

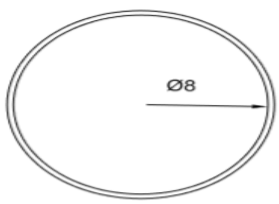


Fig:2 Diameter of water tank

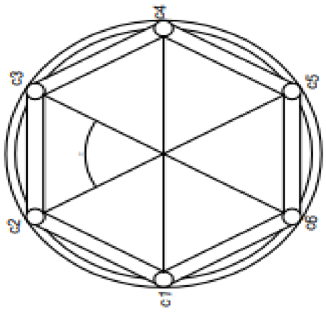
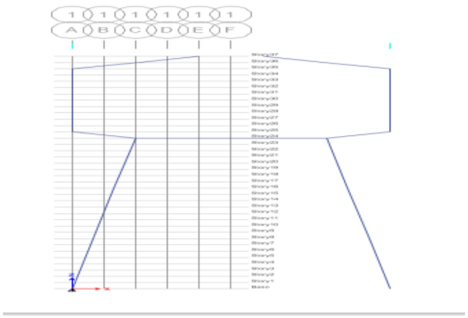
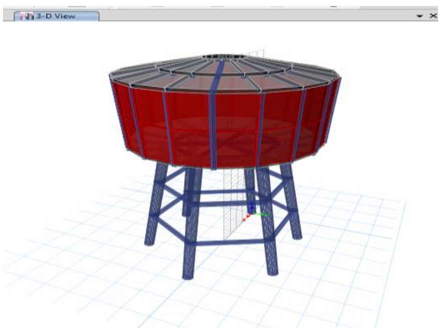


Fig: 3 Tank water bottom ring beam

Modal of RCC overhead water tank



(a)



(b)

Seismic analysis results

Design spectrum

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

Zone factor

According to IS: 1893(part 1):2002 the Chennai was given as zone iii so

Zone factor = 0.16

Importance factor (I)

According to the IS: 1893(part 1):2002 for water tank comes under the others so

I = 1.0

Response reduction factor

R(ORDINARY RC MOMENT RESISTING FRAME (OMRF)

R = 3

Soil conditions

As per the geometric details delhi comes under hard and rocky soil so

$$\frac{s_a}{g} = \begin{cases} 1 + 1.5T & 0.00 \leq T \leq 0.10 \\ 2.50 & 0.10 \leq T \leq 0.40 \\ \frac{1}{T} & 0.40 \leq T \leq 4 \end{cases}$$

Fundamental natural period (Rc frame)

T_a = $0.075h^{0.75}$

= $0.075(18.5)^{0.75}$

= 0.669 sec

$\frac{s_a}{g} = \frac{1}{T}$

= $\frac{1}{0.669}$

= 1.494 = 1.5 sec

$A_h = \frac{zis_a}{2Rg}$

= $\frac{0.16}{2 \times 3} \times 1.5$

= 0.04

Seismic weight

Empty tank weight = volume × density

= (2πr) × l × d × t

= 26.156 × 5.5 × 0.163

= 23.44 × 2500

= 58600 kg

= 574.66 kn

Weight of water = 2,80,000 lit

= 2,80,000 kg

= 2745.862 kn

Weight of full tank= 58600 + 2,80,000

= 3,38,600 kg

= 3320.531 kn

Weight of doom = 17.199 × 2500

= 23361.9 kg

= 229.10 kn

Bottom ring beam = 0.75 × 2500

= 1875 kg

= 18.397 kn

Top ring beam = (1.5 × 0.3 × 0.2) × 2500

= 3750 kg

= 36.774 kn

Bottom slab = 1.2 × 2500

= 3000 kg

= 29.419 kn

Column = 46.8 × 2500

= 117000 kg

= 1147.378 kn

Beam at 4 m from GL= 2.01 × 2500

= 5025 kg

= 49.278 kn

Beam at 8 m from GL= 1.59 × 2500

= 3975 kg

= 38.981 kn

Total empty tank weigh = 2124053 kn

Total full tank weight = 4870.40 kn

Base shear

Empty tank = $V_B = A_h$ × W

= 0.04 × 2124.53 KN

= 84.98 KN

Full tank = $V_B = A_h \times W$

= 0.04 × 5062.40 KN

= 194.816 KN

- **Distribution of Design Forces**

Story	W_i	H_i	${H_i}^2$	$W_i{H_i}^2$	$\frac{W_i{H_i}^2}{\sum W_i{H_i}^2}$	$V_B \frac{W_i{H_i}^2}{\sum W_i{H_i}^2}$
1	888.88	12	144	1,27,998.72	0.1712	14.548
2	1810.28	18.5	342.25	6,19,568.33	0.8287	70.42
				7,47,567.05		

Fig:4 Distribution of Design Force on empty tank

Story	W_i	H_i	${H_i}^2$	$W_i{H_i}^2$	$\frac{W_i{H_i}^2}{\sum W_i{H_i}^2}$	$V_B \frac{W_i{H_i}^2}{\sum W_i{H_i}^2}$
1	3634.75	12	144	5,23,404	0.2611	50.8514
2	4556.15	18.5	342.25	15,59,342.33	0.7388	143.4420
				20,82,746.33		

Fig:5 Distribution of Design Force on Full Tank

Load Case/Combo	**FX**	**FY**	**FZ**	**MX**	**MY**	**MZ**	**X**	**Y**	**Z**
	kN	kN	kN	kN-m	kN-m	kN-m	m	m	m
Dead	1316.672	54.832	3035.3119	0	0	0	0	0	0
Live	42894.848	1786.752	98874.336	0	0	0	0	0	0
Seismic	1154.976	48.098	2661.9739	0	0	0	0	0	0
Wind	1154.976	48.098	2661.9739	0	0	0	0	0	0
AutoSeq Max	0.0023	0	0.0282	0	0	0	0	0	0
AutoSeq Min	0	-0.0046	0	0	0	0	0	0	0
Comb1	67588.9088	2815.3318	155795.0736	0	0	0	0	0	0

Fig:6 Base reaction (IS CODE)

Load Case/Combo	**FX**	**FY**	**FZ**	**MX**	**MY**	**MZ**	**X**	**Y**	**Z**
	kN	kN	kN	kN-m	kN-m	kN-m	m	m	m
Dead	1153.056	217.691	4246.0419	0	0	0	0	0	0
Live	37955.072	7166.656	139746.784	0	0	0	0	0	0
Seismic	1009.968	190.7175	3718.7639	0	0	0	0	0	0
Wind	1009.968	190.7175	3718.7639	0	0	0	0	0	0
AutoSeq Max	0	0	0.0084	0	0	0	0	0	0

AutoSeq Min	-0.0008	-0.0036	0	0	0	0	0	0	0
Comb1	59773.5744	11286.4049	220081.2701	0	0	0	0	0	0

Fig:7 Base reaction (BS CODE)

Load Case/Combo	FX	FY	FZ	MX	MY	MZ	X	Y	Z
	Kn	kN	kN	kN-m	kN-m	kN-m	m	m	m
Dead	800.264	35.88	2518.9774	0	0	0	0	0	0
Live	27449.088	1230.976	86410.4	0	0	0	0	0	0
Seismic	696.872	31.26	2193.6654	0	0	0	0	0	0
Wind	696.872	31.26	2193.6654	0	0	0	0	0	0
AutoSeq Max	0	0.0025	0.0024	0	0	0	0	0	0
AutoSeq Min	-0.0008	0	0	0	0	0	0	0	0
Comb1	43139.2436	1934.616	135802.9222	0	0	0	0	0	0

Fig:8 Base reaction (ACI CODE)

Story	Joint Label	Load Case/Combo	FX	FY	FZ	MX	MY	MZ
			kN	kN	kN	kN-m	kN-m	kN-m
Base	2	Dead	1316.6701	54.832	3035.3579	0	0	0
Base	2	Live	42894.647	1786.7368	98878.411	0	0	0
Base	2	Seismic	1154.9819	48.0982	2662.2897	0	0	0
Base	2	Wind	1154.9819	48.0982	2662.2897	0	0	0
Base	2	AutoSeq Max	0.0023	0	0.0282	0	0	0
Base	2	Comb1	67588.6139	2815.3094	155801.7127	0	0	0

Fig:9 Joint reaction (IS CODE)

Story	Joint Label	Load Case/Combo	FX	FY	FZ	MX	MY	MZ
			kN	kN	kN	kN-m	kN-m	kN-m
Base	2	Dead	1153.0272	217.6906	4245.9157	0	0	0
Base	2	Live	37954.3175	7166.6469	139744.5269	0	0	0
Base	2	Seismic	1009.9891	190.7169	3718.8304	0	0	0
Base	2	Wind	1009.9891	190.7169	3718.8304	0	0	0
Base	2	AutoSeq Max	0	0	0.0084	0	0	0
Base	2	AutoSeq Min	-0.0008	-0.0036	0	0	0	0
Base	2	Comb1	59772.4411	11286.3898	220077.839	0	0	0

Fig:10 Joint reaction (BS CODE)

Story	Joint Label	Load Case/Combo	FX	FY	FZ	MX	MY	MZ
			kN	kN	kN	kN-m	kN-m	kN-m
Base	2	Dead	800.2531	35.8822	2518.9585	0	0	0
Base	2	Live	27450.241	1230.9844	86412.3974	0	0	0
Base	2	Seismic	696.8637	31.2616	2193.7373	0	0	0
Base	2	Wind	696.8637	31.2616	2193.7373	0	0	0
Base	2	AutoSeq Max	0	0.0025	0.0024	0	0	0
Base	2	AutoSeq Min	-0.0008	0	0	0	0	0
Base	2	Comb1	43140.9481	1934.6336	135806.0043	0	0	0

Fig:11 Joint reaction (ACI CODE)

Story	Joint Label	Load Case/Combo	FX	FY	FZ	MX	MY	MZ
			kN	kN	kN	kN-m	kN-m	kN-m
Base	2	Dead	1316.6701	54.832	3035.3579	0	0	0
Base	2	Live	42894.647	1786.7368	98878.411	0	0	0
Base	2	Seismic	1154.9819	48.0982	2662.2897	0	0	0
Base	2	Wind	1154.9819	48.0982	2662.2897	0	0	0
Base	2	AutoSeq Max	0.0023	0	0.0282	0	0	0
Base	2	AutoSeq Min	0	-0.0046	0	0	0	0
Base	2	Comb1	67588.6139	2815.3094	155801.7127	0	0	0

Fig:12 Design reaction (IS CODE)

Story	Joint Label	Load Case/Combo	FX	FY	FZ	MX	MY	MZ
			kN	kN	kN	kN-m	kN-m	kN-m
Base	2	Dead	1153.0272	217.6906	4245.9157	0	0	0
Base	2	Live	37954.3175	7166.6469	139744.5269	0	0	0
Base	2	Seismic	1009.9891	190.7169	3718.8304	0	0	0

Base	2	Wind	1009.9891	190.7169	3718.8304	0	0	0
Base	2	AutoSeq Max	0	0	0.0084	0	0	0
Base	2	AutoSeq Min	-0.0008	-0.0036	0	0	0	0
Base	2	Comb1	59772.441 1	11286.389 8	220077.839	0	0	0

Fig:13 Design reaction (BS CODE)

Story	Joint Label	Unique Name	Load Case/Combo	FX	FY	FZ	MX	MY	MZ
				kN	kN	kN	kN-m	kN-m	kN-m
Base	2	155	Dead	800.2531	35.8822	2518.9585	0	0	0
Base	2	155	Live	27450.241	1230.9844	86412.3974	0	0	0
Base	2	155	Seismic	696.8637	31.2616	2193.7373	0	0	0
Base	2	155	Wind	696.8637	31.2616	2193.7373	0	0	0
Base	2	155	AutoSeq Max	0	0.0025	0.0024	0	0	0
Base	2	155	AutoSeq Min	-0.0008	0	0	0	0	0
Base	2	155	Comb1	43140.9481	1934.6336	135806.0043	0	0	0

Fig:14 Design reaction (ACI CODE)

Code	Max story drift	STORY
INDIAN	1352627584	15 -19
BRITISH	12862824876	15 - 19
AMERICAN	887408233	15 - 19

Fig:15 Max story drift

Code	Max story displacement	STORY
INDIAN	2.62E+13	30 - 33
BRITISH	2.32E+13	30 - 33
AMERICAN	1.91E+13	30 - 33

Fig:16 Max story displacement

Code	Max Over turning moment	STORY
INDIAN	504.371802	22 - 28
BRITISH	936.406261	22 - 26
AMERICAN	285.973793	22 - 26

Fig:17 Max Overturning moment

Code	Max bending moment	Element no
INDIAN	-2627.6004 kn-m	D3
BRITISH	-1388.1836 KN-M	D3
AMERICAN	-1203.4703 KN-M	D3

Fig:18 Max bending moment

Code	Max shear force	Element no
INDIAN	491.9200 KN	D18
BRITISH	375.136	D18
AMERICAN	239.008	D18

Fig :19 Max shear force

Code	Max axial force	Element no
INDIAN	-2609.3560 KN	D3
BRITISH	-3980.5921	D3
AMERICAN	-22911.1027	D3

Fig:20 Max axial force

5. CONCLUSIONS

- Compared among the three standards, ACI proves to be more economical
- In terms of economic value, the codal provisions are queued as ACI, IS and BS.
  All the three codes follow working stress method and results in higher stability

Future Scope:

The analysis and design of overhead RCC water tanks was based on Indian, American and British standards. The project results clearly explain about the economical design and help to understand the variations in the design procedures. This shall be further expanded to study about the other universal codes compared with Indian standards. The further expansion of this studies will help understand the economical design consideration of RCC overhead water tanks compared to the Indian standards

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