International Journal of Scientific & Engineering Research, Volume 4, Issue 11, November-2013 1551
ISSN 2229-5518

Dynamic analysis of circular water tank and study of relevant codal provision

Harshal Nikhade, Ajay Dandge, Anshul Nikhade

Abstract— Seismic force on water tank is calculated by IS 1893-1984 code. The new draft code is widely circulated but it is not yet adopted. The procedures defined in these codes vary to large extent. There are many parameters common in both the codes while the draft codes needs calculations of horizontal shear force, shear moment, sloshing wave height, time period etc. in impulsive & convective modes in addition to other parameters. In this paper provisions of existing codes are compared with the draft code. Some of the findings of the comparison are also presented. The draft code considers various parameters like convective and impulsive loadings, it is found to be covering many facets related to seismic loading.

Index Terms — Convective, Impulsive, Sloshing effect, Base shear, Seimic Coefficient, Response spectrum

———————————— ◆ ————————————

1 Introduction

IN order to Study the design of elevated circular water tank the staging system seismic force calculation 3 tanks of 1000m3,2000m3,3000m3 capacity where design as per provision of IS 3370(Draft codes) two different configuration i,e, cylindrical and Intz type were chosen. manual design for both configuration were carried out for 1000m3 capacity .Excel sheet were prepared for design procedure ,design output were checked with hand calculation .there after design were carried out 2000 ,3000 cum capacity
Staging for all the tanks were design with provision of IS 11682
Excel Sheet were developed for calculation of IS 1893-1984 and 1893-partII (draft code).
All result were tabulated and graph were plotted among various parameter .Total number of graphs plotted 26. Wherever significant relationship among different parameter were found the equation of those trend lines Where verified with the observed parametric values

2.Study of IS Codes

2.1 IS 1893-1984 "Criteria for Earthquake Resistance Design of Structure".

Clause 5.2.1 The elevated water tank is idealized as single degree of freedom system with their mass concentrated at their centre of gravity.

Prof.H.R.Nikhade,Deparmen of C.E.,Yashwanrao chavan collage of engineering,RTMNU,M.H.08180946956,
E-mail:harshal.nikhade@rediffmail.com
Prof.A.L.Dandge,Deparmen of C.E.,Yashwanrao chavan collage of engineering,RTMNU,M.H.09850358057,
E-mail: ajayldandge@gmail.com
Prof.A.R.Nikhade,Deparmen of C.E.,G.H.Raisoni Academy of engineering technology,RTMNU,M.H.09764442530,
E-mail:anshul.nikh@rediffmail.com

lause 5.2.2 Damping is considered as 2% of creiticalk for free steel structure and 5% for concrete structure.
Clause 5.2.3 Time period in second can be calculated as

$$T = 2\prod\sqrt{(\Delta/g)}$$

Were, Δ = Static horizontal deflection at the top of the tank under static

horizontal force equal to Weight W acting at C.G. of tank.
g = acceleration due to gravity.

Clause 5.2.4 When empty: the weight W used in the design shall consist of dead load of the tank and 1/3 the weight of the staging

When Full : The weight of content is to be added to the weight under empty condition using period T & appropriate the spectral acceleration shall be read off from avg. Acceleration spectra. The design horizontal seismic Coefficient 'αh' shall be calculated.

$$\alpha_h = \beta I F_o \frac{S_a}{g}$$

β = Coefficient depending upon soil foundation system
I = Factor depending upon importance of structure
Fo = seismic zone factor for average acceleration spectra
Sa/g = avg. acceleration coefficient for appropriate natural period & damping of the structure.

Seismic Zone	I	II	III	IV	V
Seimic Coefficient	0.01	0.02	0.03	0.04	0.05
Response spectrum	0.05	0.10	0.20	0.25	0.40

Table 02 Values of Seismic Coeff. for Different Zones

TABLE 3 VALUES OF β FOR DIFFERENT SOIL-FOUNDATION SYSTEMS

(*Clause* 3.4.3)

Sl No.	Type of Soil Mainly Constituting the Foundation	Values of β for: Piles Passing Through Any Soil, but Resting on Soil Type I	Piles Not Covered Under Col 3	Raft Foundations	Combined or Isolated RCC Footings with Tie Beams	Isolated RCC Footings Without Tie Beams or Unreinforced Strip Foundations	Well Foundations
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Type I Rock or hard soils	1·0	—	1·0	1·0	1·0	1·0
ii)	Type II Medium soils	1·0	1·0	1·0	1·0	1·2	1·2
iii)	Type III Soft soils	1·0	1·2	1·0	1·2	1·5	1·5

NOTE — The value of β for dams shall be taken as 1·0.

TABLE 4 VALUES OF IMPORTANCE FACTOR, *I*

(*Clauses* 3.4.2.3 *and* 3.4.4)

Sl No.	Structure	Value of Importance Factor, *I* (*see* Note)
(1)	(2)	(3)
i)	Dams (all types)	3·0
ii)	Containers of inflammable or poisonous gases or liquids	2·0
iii)	Important service and community structures, such as hospitals; water towers and tanks; schools; important bridges; important power houses; monumental structures; emergency buildings like telephone exchange and fire bridge; large assembly structures like cinemas, assembly halls and subway stations	1·5
iv)	All others	1·0

NOTE — The values of importance factor, *I* given in this table are for guidance. A designer may choose suitable values depending on the importance based on economy, strategy and other considerations.

Sa/*g*= Average acceleration coefficient as from fig 2 for appropriate natural period and damping of the structure.

Clause 5.2.6 The lateral force shal be taken as = $\alpha_h \times W$. This force shall be assumed to be applied at the CG of tank horizontally in the plane in which the structure is assume to associate for purpose carring out the lateral load analysis.

2.2 IS 1893(Part 1) : 2002 "Criteria for Earthquake Resistance Design of Structure".

Part 1(General Provision of buildings)

Fifth Revision

The following are the major and important modifications made in fifth revision:

a) The last revision is further divided into five parts,
   PART 1:- General provisions and buildings
   PART 2:- Liquid retaining tanks – Elevated and ground supported
   PART 3:- Bridges and retaining walls
   PART 4:- Industrial structures including stack line structures
   PART 5:- Dams and embankment
b) The seismic zone map is revised with only four zones instead of five. Zone I has been merged to Zone II.
c) The values of seismic zone factors have been changed.
d) Three types of founding strata that is rock, hard soil, medium soil and soft soil.
e) Expressions for estimating fundamental natural period T have been changed.
f) The soil foundation system factor is dropped. Instead the clause is introduced to restrict use of foundations unguarded to differential settlements in severe seismic zone.
g) Torsional eccentricity values have been revised.
h) Model combination rule in dynamic analysis of buildings has been revised.

Other clauses have been redrafted where necessary for more effective implementation.

Table 2: Zone Factor,

Seismic Zone	II	III	IV	V
Seismic	Low	Moderate	Severe	Very
Z	0.10	0.16	0.24	0.36

Table 6: Values of Importance Factor,

S. N.	Structure	I
1	Important service and	

Table 7. Response Reduction Factor, R, for Building Systems

Sr.no	Lateral Load Resisting System	R
1	Building Frame System	3.0
2	Ordinary RC moment-resisting frame	5.0
3	(OMRF)	
	Special RC moment-resisting frame	4.0
	(SMRF)	5.0
4	Steel frame with	5.0
	a) Concentric braces	
5	b) Eccentric braces	
	Steel moment resisting frame	1.5
	Building with Shear Walls	2.5
	Load bearing masonary wall buildings	3.0
	a) Unreinforced	
6	b) Reinforced with horizontal RC	3.0
7	bands	4.0
	c) Reinforced with horizontal RC	
8	bands and vertical bars at corners of	3.0
9	rooms and jambs of openings.	4.0
10	Ordinary reinforced concrete shear walls	4.5
11	Ductile shear walls	5.0
	Building with Dual Systems	
	Ordinary shear wall with OMRF	
	Ordinary shear wall with SMRF	
	Ductile shear wall with OMRF	
	Ductile shear wall with SMRF	

Sa/*g*= Average response acceleration coefficient for rock and soil sites as given by fig 2 and table 3 based on appropriate natural periods and damping.

2.3 IS 11682: 1985 "Criteria for Design of RCC Staging for Overhead Water Tanks"

Clause 2.6.1 Braces For staging of height above foundation greater than 6 m, the columns shall be rigidly connected by horizontal braces suitably spaced vertically at distance not exceeding 6 m. Bending moment in

ISSN 2229-5518

horizontal braces due to horizontal loads shall be calculated when horizontal forces act in a critical direction. The moments in braces shall be the sum of moments in the upper and lower columns at the joint resolved in the direction of horizontal braces. Moment and shears arising from local vertical load, if any, should be accounted for the design.

2.4 IS 4326: 1993 "Code of practice for Earthquake Resistant Design and Construction of Buildings''.

Importance factor, I

1. Tanks used for storing drinking water, non-volatile material, low inflammable petrochemicals etc. and intended for emergency services such as fire fighting services. Tanks of post earthquake importance. (I= 1.5)
2. All other tanks with no risk to life and with negligible consequences to environment, society and economy. (I= 1.0)

Response reduction factor, R

Tank supported on RC frame

a) Frame not conforming to ductile detailing, i.e., ordinary moment resisting frame (OMRF) : (R= 1.8)
b) Frame conforming to ductile detailing, i.e., special moment resisting frame (SMRF): (R= 2.5)

3.0 Analysis of Water Tank

In order to Study the design of elevated circular water tank the seismic force calculated of 3 tanks of 1000m^3,2000m^3,3000m^3 capacity, where design as per provision of IS 3370(Draft codes) of two different configuration i,e, cylindrical and Intz type were chosen. manual design for both configuration were carried out for 1000m3 capacity .Excel sheet were prepared for design procedure ,design output were checked with hand calculation .there after design were carried out 2000 ,3000 cum capacity Excel Sheet were developed for calculation of IS 1893-1984 and 1893-partII (draft code). Following are Excel sheet for Seismic Analysis of Water tank for Intz and Cylindrical Of 1000 m3.

3.1 Result & Discussion

3.1.1 For Circular Water Tank

The following correlations are drafted from analyses data

		Total Shear tank full		Total Shear tank empty	
Capa city		Draft Code	Existing Code	Draft Code	Existing Code
1000	Draft Code	515.34	848.86	296.63	306.58
1000	Draft Code	920.55	1358.18	474.61	490.54
1000	Draft Code	1380.83	2037.27	711.92	735.81
1000	Draft Code	2071.25	3055.91	1067.88	1103.71
2000	Draft Code	927.23	1533.64	630.23	719.81
2000	Draft Code	1483.57	2453.83	1008.38	1151.7
2000	Draft Code	2225.36	3680.75	1512.57	1727.55
2000	Draft Code	3338.04	5521.12	2268.86	2591.72
3000	Draft Code	1181.43	2062.35	903.63	1039.2
3000	Draft Code	1890.29	3299.76	1445.81	1662.73
3000	Draft Code	2976.24	4949.65	2168.72	2494.09
3000	Draft Code	4253.17	7861.21	3253.09	3594.43

Table 01: Comparison of Base Shear Draft Code Vs 1984 Code(Tank Full)

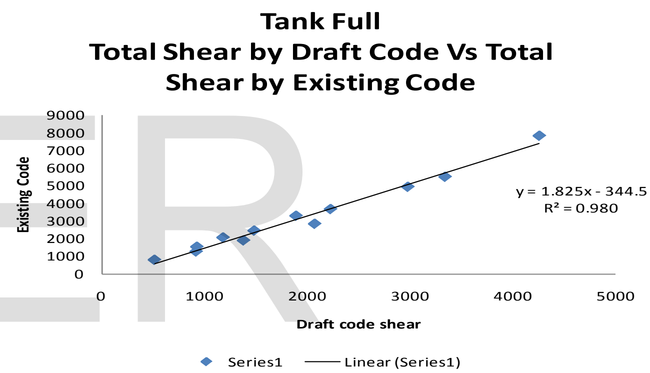


Fig. 01 Comparison of Base Shear by Draft Code Vs 1984 Code

.		Total Shear tank full		Total Shear tank empty	
Capac ity		Draft Code	Existing Code	Draft Code	Existing Code
1000	Draft Code	515.34	848.86	296.63	306.58
1000	Draft Code	920.55	1358.18	474.61	490.54
1000	Draft Code	1380.83	2037.27	711.92	735.81
1000	Draft Code	2071.25	3055.91	1067.88	1103.71
2000	Draft Code	927.23	1533.64	630.23	719.81
2000	Draft Code	1483.57	2453.83	1008.38	1151.7
2000	Draft Code	2225.36	3680.75	1512.57	1727.55
2000	Draft Code	3338.04	5521.12	2268.86	2591.72
3000	Draft Code	1181.43	2062.35	903.63	1039.2

3000	Draft Code	1890.29	3299.76	1445.81	1662.73
3000	Draft Code	2976.24	4949.65	2168.72	2494.09
3000	Draft Code	4253.17	7861.21	3253.09	3594.43

Table 02.Comparison of Base Shear Draft Code Vs Existing Code (Tank Empty)

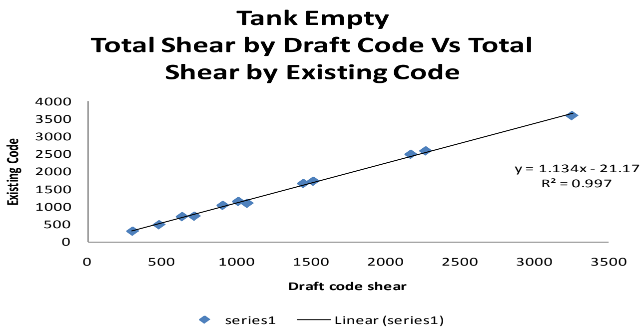


Fig.02 Comparison of Base Shear Draft Code Vs Existing Code (Tank Empty Condition)

3.2.2 For Intz Type Water Tank

The following correlations are drafted from analyses data

			Total Shear		Total Shear(tank empty)	
Zone	Capacity		Draft Code	Existing Code	Draft Code	Existing Code
2	1000	Draft Code	932.13	1199.05	490.325	686.45
3	1000	Draft Code	1491.4	1918.48	784.52	1255.23
4	1000	Draft Code	2237.11	3139.33	1176.78	1882.25
5	1000	Draft Code	3355.66	4709	1765.17	2608.99
2	2000	Draft Code	2009.76	2637.05	1215.61	1886.03
3	2000	Draft Code	3359.62	4219.28	1944.98	3017.64
4	2000	Draft Code	5039.43	6328.92	2917.47	4526.47
5	2000	Draft Code	7559.15	9493.38	4376.21	6789.71
2	3000	Draft Code	2301.99	2764.63	1717.8	2054.27
3	3000	Draft Code	3683.18	4423.42	2748.48	3386.83
4	3000	Draft Code	5524.77	6635.13	4122.72	4930.24
5	3000	Draft Code	8287.16	9952.69	6184.08	7395.37

Table 03: Comparison of Base Shear Draft Code Vs 1984 Code(Tank Full)

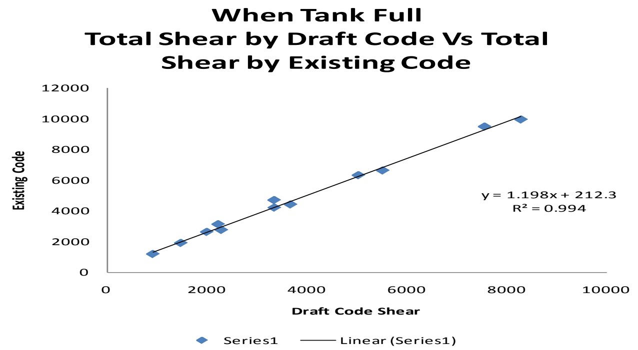
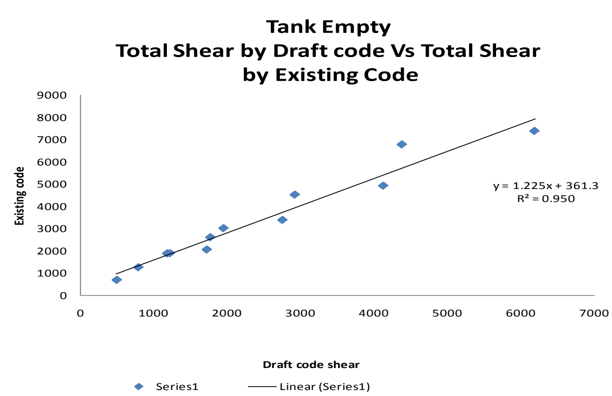


Fig. 03 Comparison of Base Shear by Draft Code Vs 1984 Code

			Total Shear		Total Shear	
Zone	Capacity		Draft Code	Existing Code	Draft Code	Existing Code
2	1000	Draft Code	932.13	1199.05	490.325	686.45
3	1000	Draft Code	1491.4	1918.48	784.52	1255.23
4	1000	Draft Code	2237.11	3139.33	1176.78	1882.25
5	1000	Draft Code	3355.66	4709	1765.17	2608.99
2	2000	Draft Code	2009.76	2637.05	1215.61	1886.03
3	2000	Draft Code	3359.62	4219.28	1944.98	3017.64
4	2000	Draft Code	5039.43	6328.92	2917.47	4526.47
5	2000	Draft Code	7559.15	9493.38	4376.21	6789.71
2	3000	Draft Code	2301.99	2764.63	1717.8	2054.27
3	3000	Draft Code	3683.18	4423.42	2748.48	3386.83
4	3000	Draft Code	5524.77	6635.13	4122.72	4930.24
5	3000	Draft Code	8287.16	9952.69	6184.08	7395.37

Table 04: Comparison of Base Shear Draft Code Vs 1984 Code(Tank Empty)



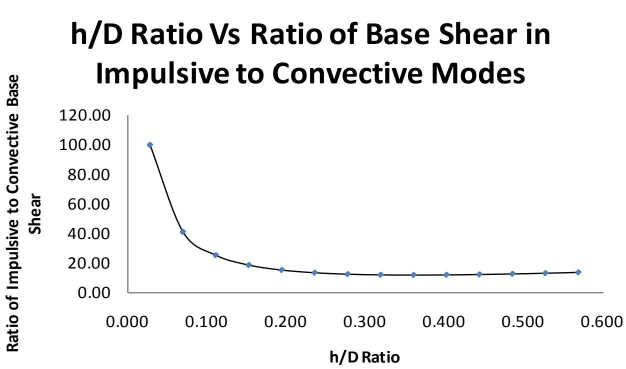
ISSN 2229-5518

Fig. 04 Comparison of Base Shear by Draft Code Vs 1984 Code

3.3.3 Based on above graphs following mathematic al modes are developed:

Model	Variables	Equation	R^2 value
Model 1	Total Base shear by Draft code Vs Total Base shear by existing code(cylindrical when tank is full)	Y=1.825x-344.5	0.98
Model 2	Total Base shear by Draft code Vs Total Base shear by existing code(cylindrical when tank is full)	Y=1.134x-21.17	0.997
Model 3	Total Base shear by Draft code Vs Total Base shear by existing code(Intz type when tank is full)	Y=1.198x+212.3	0.994
Model 4	Total Base shear by Draft code Vs Total Base shear by existing code(Intz type when tank is full)	Y=1.225x+361.3	0.95

3.4.4 Results of h/D Ratio Analysis plotted graphically



7.0 Conclusions

The following conclusions may be drawn from the study.

- Horizontal Seismic coefficient in Impulsive and Convective mode is to found more in 1000 m^3 as compared to 2000 m^3 and 3000m^3 tank.
- Total base Shear in Convective and Impulsive mode found to be more in 2000m^3,3000m^3
- Sloshing wave height in all seismic zone almost same
- Time Period in case of Convective mode is found to be varying between 4 sec to17sec.For medium soil condition Sa/g is calculated using formula 1.36/T , resulting in very low values of Sa/g. For buildings there is limitation on time period on 4 sec as per 1893-2002 part II However these limitations are removed from code for tank. The excessive lower values of Sa/g result in very lower value of base shear in convective mode which need reconsideration.
- An attempt was also made to find effect of water level on the base shear calculation by Impulsive and Convective mode. It was observed that very low h/d ratio (where h stands for height of water) the ratio of base shear in Impulsive mode to convective mode is very high. From h/d ratio of 0.3,this become almost constant to around 12 to 14
- Good relationships have also been found between h/d ratio Vs Base Shear in both Impulsive and convective mode.

4.0 References

1. Netaji Babal"SEISMIC ANALYSIS OF ELEVATED SERVICE RESERVOIR"
2. Durgesh C. Rai1" Review of Code Design Forces for Shaft Supports of Elevated Water Tanks "
3. Sudhir K. Jain and Sajjan Sameer U., A Review of Requirement in Indian Codes for A Seismic Design of Elevated Water Tanks.
4. O. R. Jaiswal et.al.,Review of Code Provisions on Design Seismic Forces for Liquid Storage Tanks, IITK-GSDMA –EQ03-V1.0
5. Durgesh C Rai et.al., Review of Code Provisions on Seismic Analysis of Liquid Storage Tanks, IITK-GSDMA-EQ04-V1.0
6. Advanced Reinforced Concrete Design(IS 456-2000) N.KRISHNA RAJU.
7. IS 1893(Part1)2002, criteria for earthquake resistance design
8. IS 3370(PartI,II,III,IV,)Code of practice for liquid storage tank
9. 25. Durgesh C. Rai,Performance of elevated tanks in Mw 7.7 Bhuj earthquake of January 26th, 2001.
10. ACI 350.3, 2001, "Seismic design of liquid containing concrete structures", American Concrete
11. J A Munshi et.al., Seismic Design of Liquid-Containing Concrete Structures as per ACI

ISSN 2229-5518
Standard 350.3, Pacific Conference on Earthquake Engineering (2003)

12. Praveen K Malhotra et.al., *Simple Procedure for Seismic Analysis of Liquid Storage Tanks*, Structural Engineering International (3/2000)