iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 **Issue:** VIII **Month of publication:** August 2025

DOI: https://doi.org/10.22214/ijraset.2025.73941

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue VIII Aug 2025- Available at www.ijraset.com

Seismic and Wind Load Comparative Analysis of Overhead Intake Water Tanks with Unfilled, Half Filled and Completely Filled Condition in Earthquake III to V-Zone

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Abstract: ***Safe and pure water is most important elements for human being to prolong healthy life. Reinforced cement concrete overhead water tanks are largely used to offer safe drinking water. There are several water supplying systems having in developing countries, like India, where population is increasing on daily basis, that's why there is necessary to construct large amount of water tanks. Previous designs of water tank completed by working stress method given in IS: 3370 1965. From past records we can say that, many of reinforced concrete elevated water tanks were severely damaged or collapsed during the earthquakes and cyclones all over the world. Generally, these are happening because of the failure of supporting system which states that the supporting system of the elevated tanks has more serious significance than the other structural parts of tanks. Mostly the damages observed due to the seismic events and cyclonic events. This happens might be because of the lack of knowledge regarding the proper behaviour of supporting system of the tank against dynamic effect and also due to inappropriate geometrical selection of staging patterns. In order to require proper head of water, its generally require to construct elevated water tank, generally these types of water tank is used for storing water for fulfil daily needs. For storing water R.C.C. structure is most favourable structures amongst others structure.***

Elevated Water Tanks is widely used for storage large amount of water for supply system and its play vital role in seismic areas. Water Tanks may be flaw because of scarcity of water or problem with the peoples to suppress the flames during seismic movement. The seismic movement is responsible for different failure such as ground surface failure and deficiency of support to the stages. The aim of this Research work is Response spectrum analysis, seismic analysis of overhead Intze Water Tanks with unfilled, half filled and completely filled condition in earthquake 3rd to 5th Zone. This whole analysis is done by STAAD Pro V8i SS6. The seismic zones of Zone-III, Zone-IV, Zone-V and the equivalent lateral load characteristics have been taken from IS 1893 (PART 1)-2002 & draft code IS 1893 (Part 2) and IS 875 (PART 3) - 1987. For this different condition of water tank. It has Intze shape. Water Tank having 1800000 litres holding capacity and supported on RCC frame stages height 20 m & 30 m under seismic movement loads provide according to code section 2 of IS 1893:2002.

Keywords: Overhead Intze Tank, rectangular Tank, lateral displacement, Water Tank, base shear, IS: 3370 1965, STAAD Pro V8i, 1893 (PART 1)-2002, Response Spectrum Method.

I. INTRODUCTION

The phrase "water tank" describes a building that is used to store liquids. Water is very vital for people and is even necessary for human life, hence innovations have been produced for preservation of water in various forms. This tank was created about 80th years back and is now well-built, cost-effective, and efficient item for both commercially and residential use. Additionally, it is an essential component of the water supply system and is frequently used to store and process a wide range of liquid-like materials, including water and petroleum products. The architecture of a water tank and the requirement for water in that specific location are both factors that affect how much water is distributed. Water tanks are therefore crucial for industrial structures and public services. Natural calamities including earthquake activity, tropical storms, and others are raging across the Indian continent. These natural calamities, in particular seismic movement, are defined as sudden earth trembling. Typically, earthquakes occur in weaker areas and can destroy entire communities as well as hurt the populace. Seismic movement in that area is defined as seismic movement frequency at a specified site over a specific period of time. Examples of natural disasters that causes destruction. Seismic analysis as per IS 1893 (Part I). The water storage reservoir is most commonly used structure for the provision of clean drinking water, manufacturing facilities, fire suppression systems, swimming pools, and waste sedimentation. For safety concern during seismic movement is alarming. The failure of such type of structure may pressurize public as well as shortage of water or a fire during seismic movement. Generally, Water, liquid fuel, petroleum oil, and related liquids are stored in storage tanks. Underground storage tanks and high reservoirs is 2 kind of fluid depot tanks. These are mounted on R.C.C., steel structure, stonework foundation. The reservoir is in 27 m elevation. These types of structure don't have enough strength, but shall be free from any vent. The motive of analysis is to know the behavior of this in seismic zone and modelling done by Staad Pro V8i SS6 software according to IS code.

II. ELEVATED WATER TANK, AND EARTHQUAKE INFLUENCE

In major places, individual supply frameworks of businesses and mechanical homes—raised tanks crucial component—increase supply planning. A raised water tank should have reinforced and durability features, and leakage issues should be prevented by using proper building techniques. However, generally speaking, these structures designed to. Due to the large mass at highest point of the slender supporting structure, have a configuration that makes them especially defenseless against Lateral like seismic. Therefore, it is crucial to determine how important these powers are for a given region.

Therefore, elevated tanks are Due to the large absolute mass aggregated at the highest point of the slender supporting structure, these constructions have a configuration that makes them especially defenseless against Lateral powers like seismic tremor and wind powers. Therefore, it is crucial to determine how important these powers are for a given region.

Water supply is essential for suppressing flames that can occur during seismic shocks, which cause significant damage and fatalities. Therefore, elevated tanks are According to historical events, several types of damage to tanks have occurred, including: fractures in ground-supported RC tanks, for a variety of reasons, including faulty structural configuration design, material, reinforcement, wind forces, subpar craftsmanship, seismic stresses, etc. Tanks may suffer from numerous components.

Every creation on Earth has its origin in water. 72% of the planet's surface is made up of water, of which 96% is in the oceans, 3% is in ice glaciers, and only 1% is pure enough to drink. So, while it is necessary to meet the need for water, it is not necessary to store water. One method to store water is in water tanks. Water tanks are buildings that store water, meeting the needs of public, industry, and irrigation systems.

A. Position and shape are used to categorize water tanks

S. No.	Position-based classification	Shape-based classification
01.	Underground tanks	Rectangular
02.	Surface level water tanks	Square
03.	Overhead tanks Circular	Intz, Spherical bottom, Domed bottom, Coned bottom

III. LITERATURE REVIEW

Ramazan LIVAOGLU & Adem DOGANGUN (2006) have investigated, the ground effects on the behaviour of tanks. Eventually, in this study shown that the ground types are defined in EC-8 gave lesser results than the consistent one in TEC-06. Also, it is seen from the results that for a lot of ground types the supporting system of tanks doesn't gave the satisfactory performance. The following conclusions are done.

The seismic forces were analysed of an elevated water tank consisting eight ground types defined in EC-8 and TEC-06. The results of a displacement along with the height according to the ground types are compared. The minimum displacement and Maximum displacement the A class as 0.16 and the Z4 class as 0.48 m at 21 m height level and at the same level.

Comparative analysis of base responses such base shears and predicted overturning moments for examined elevated tanks. It's interesting to note that the ratios increased at intervals of 5%–25% between the similar soil types indicated by TEC-06 and EC-8, such as between A and Z1 or D and Z4, etc. This demonstrates that comparable definitions established for various codes provide varied results and further demonstrates that the ground types stated in TEC-06 may produce a larger reaction than the others by about 25%. According to the analysis' findings, Z2 ground types produce a 26% better reaction to axial stresses than Z1 ground types. Despite the nearly identical qualities of the consistent ground types described by several codes, only one defined in TEC-06 has produced nearly greater outcomes.

F. Omidinasab & H Shakib (2008) have researched, on sample of R.C. tanks, with 900 m³ under different- differen 7 earthquakes record have been considered and the responses of tanks including tank displacement, sloshing displacement, base shear, overturning moment have been evaluated and then after the results compared and distinguished.

A FEM model is used for this system. The Intze tank is protected by a frame framework, with circumferential beams connecting the columns at heights of 7, 14, and 20 metres above ground. It does, however, consist of the tank's elastic Supporting Structure, which includes beams and columns on a truncated cone. The expected capacities of the structural elements have been evaluated and the criteria of approval of the members of the structure including control parameters by force and variation are studied.

Dr. Suchita Hirde, Ms. Asmita Bajare & Dr. Manoj Hedaoo (2011) seismic effect on the tank has been investigated for different seismic zones in India for different ht. or capacities of the tanks for various soil conditions. The effect of heights of the tank, in the earthquake prone area or soil conditions on earthquake forces have been presented in this paper by using analysis of 240 models for various parameters.

Ayazhussain M Jabar & H S Patel (2012) have investigated the behaviour of the supporting device and its suitability software. For the various tank filling situations, two separate supporting member like radial. The GSDMA guidelines divide the water mass into two categories: were measured and compared. The findings revealed that the structure's responses are heavely depending on characteristics of the earthquake.

For the sake of research. A RCC tank with 1000 m3 storage capacity is used, with a Using SAP2000 structural software, a FEM used for modelling water tank structure. The max. from four earthquake records. The substitute staging patterns in this study the vital response emerges. This may be because of hydrodynamic pressures of the container in the half-full case are higher than in the full tank case. It may also happen as a result of the frequency contented of earthquake records accumulating. Earthquake with high seismic frequency.

Chirag N. Patel & H. S. Patel (2012) The motive of this investigates the efficacy of tank supporting systems under various conditions. The research focuses on the significant changes in seismic activity of elevated tanks, In General, when earthquake occurs the major failures harms the supporting systems. It is also important to identify the suitable and modified water tank with staging pattern for the best performances at the time of earthquake. Moreover, arrangements is also essential to take in practice. Eventually the study discloses the importance of supporting member that is to be required to withstand against the damages and failures of the tanks during earthquake.

Ibrahim et al. (2001) with a focus on cylindrical and rectangular tanks, covering both linear and nonlinear studies.

Karamanos et al. (2006) and Patkas and Karamanos (2007) under earthquake excitation, developing mathematical modelling for measuring linear sloshing effects in the dynamical response of horizontal cylindrical and spherical liquid containers

IV. LOADS ACTING TO TANKS

A. *Dead Loads*

The dead loads includes wt. of concrete of side wall, foundations, Top dome, columns, Ring beams, Bracings,slab etc. And wt. of the tank is equivalent to the product of the sp. Wt. of material and volume of the concrete for the tank. Idyllically, the specific weight of concrete is considered as 25kN/m3 for calculation purposes. Though the actual specific weight depends upon compaction of concrete, water-cement ratio, and unit wt. of the aggregate used.

B. Imposed Loads

An imposed load of 0.75kN/m² is taken on domes top as no entrance is provided on roof apart from the maintenance of the tank (IS: 875 part-2 1987). If any assessment gallery is arranged for all around the tank, the similar imposed load (0.75kN/m²) will be considered with the dead load for the same.

C. Water loads

The water pressure intend to every time acts normal to the surface. The vertical water pressure would performance on Bottom dome and conical slab of the tank. The water pressure intensity (p) on the bottom dome and conical slab is expressed as

$p = \gamma w\ h$

Where, γw = Sp.wt. of water (10 kN/m3)

The water pressure intensity on the side wall fluctuates linearly with the depth of the water (h), and it acts it is zero at the top and maximum at walls bottom.

D. Wind Forces

Wind is air in motion relation to the surface of earth. its exposed to precisely high winds in specific duration and acts majorly on supporting system compared to the container. Its evaluated as per the IS: 875 (part 3) subjected on wind pressure zones or terrains and aspects as per geometrical properties of the tank. Intensity of wind and acquaintance are applied in the directions as obligatory. Design Wind Speed (Vz) - To derive design wind velocity at any height,basic wind speed (Vb) for any site could be calculate out of Fig. 1 and updated to including various effects: Terrain roughness, structure size and height, and local topography.

It can be stated numerically as follows:

k1 x k2 x k3 x Vb = Vz

Where

k1 denotes the probability factor

k2 = factor of ht. and construction size, terrain

k3 refers to the topographical factor.

Vb = D.W.S. in m/s at any ht. z

NOTE: It shall be regarded constant up to a height of 10 metres above mean ground level.

Risk Coefficient (k1 Factor) - Based on 50 years, Figure 1 depicts the B.W.S. for Category 2 at 10 metres above G.L. 1 no. table represent the suggested life duration which is assume in designing and complying kl factors of structures class for design purposes. Except as noted in Table 1, an area vb with a mean return time of 50 years will be utilised for design.

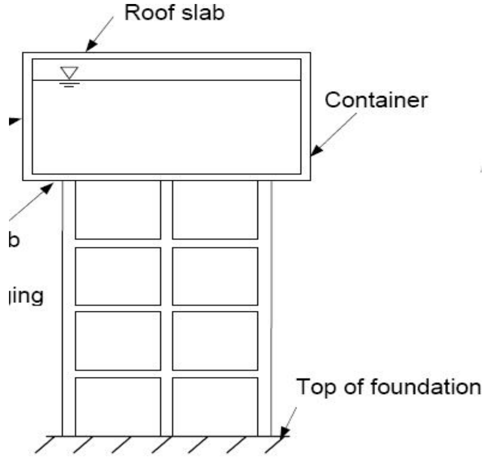
V. SEISMIC ANALYSIS PROCEDURE

A. General

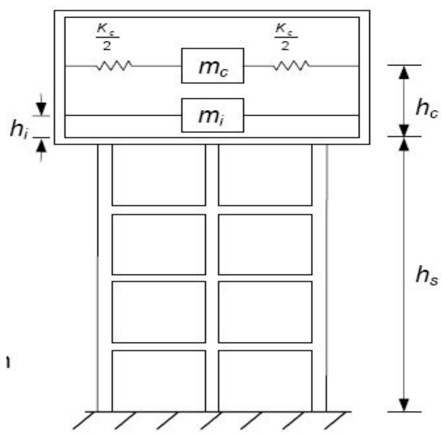
Hydrostatic pressure- It define as if tank contains liquid, and this liquid exerting impulsive and convective pressure on wall and base of the tank. To account for the influence of hydrodynamic pressure, it take idealised by a two-mass model that incorporates the effect of wall of tank. The flexibility and geometry of the tank are factors to consider. Two mass models are used to estimate these hydrodynamic forces.

B. Two Mass Model

This is given by Housner (1963) its one of the accurate methods which includes international codes and Draft code for IS 1893 (Part-II). The dynamic motion produced inside the liquid or fluid of the tank could be divided into 2 parts impulsive and convective. If tank contains fluid with free surface which is subjected to horizontal seismic ground motion, the tank's wall or fluid (water) exposed to the horizontal acceleration. The bottom section of tank liquid behaves as a mass which is hardly attached to wall of the tank. The impulsive liquid mass accelerates and puts impulsive pressure on tank's wall, causing the tank to swirl around in the upper region. Convective liquid mass, uses convective pressure which affects base or wall of the tank. In filling condition tanks, a two-mass model is used to describe these two masses in order to keep the influence their hydrodynamic pressure out of the study.



(a) Elevated tank



(b) Spring mass model

VI. LATERAL STIFFNESS OF STAGING

The horizontal force that must be exerted at the C.G. to generate a constant unit horizontal displacement. The C.G. is used as the C.G. of an unfilled container in this investigation.

The staging is modelled by F.E. software, is given in Fig. no.3.6. As a result, the container part is stiff, and rigid linking from staging top to C.G. of the tank is anticipated. The horizontal displacement of the C.G. obtained from this study owing to a random 10 kN force. Hence, lateral stiffness of staging, *Ks* = 10 / Displacement.

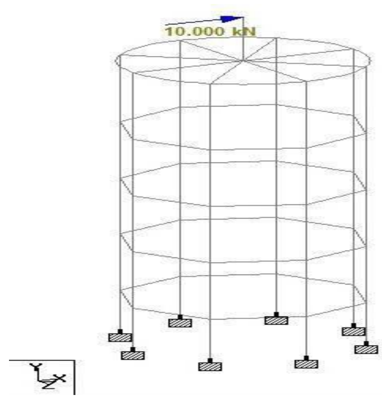


Figure Staad model of staging

VII. TIME PERIODS

The following formulas were used to calculate time periods for Convective and impulsive modes. Duration of the Impulsive mode, Ti in seconds, is calculated as follows:

$$T_i = 2\pi\sqrt{\frac{m_i + m_s}{K_s}}$$

Where
Ks denotes the staging's lateral stiffness.
mi = liquid's impulsive masses
ms = container masses plus 1/3rd staging masses,
The Convective mode's time period, Tc in seconds,

$$T_c = 2\pi\sqrt{\frac{m_c}{K_c}}$$

where
mc = Convective masses fluid.
Kc = Convective mode of spring stiffness

VIII. DESIGN HORIZONTAL SEISMIC COEFFICIENT

The following expression is use to determine the horizontal seismic coefficient, Ah. The (Ah)i (Ah)c will be analysed independently.

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

Here,
Z = Zone factor
I = Importance factor
Sa/g = Average response acceleration coefficient
R = Response reduction factor

IX. BASE SHEAR

In rashness state Vi immediately above the staging's base shear is provided by and B.S. in convective mode, *Vc* is

$$V_i = (A_h)_i (m_i + m_s) g$$
$$V_c = (A_h)_c m_c g$$

In this formula
(Ah)i is the impulsive mode of designing horizontally seismic coefficient
(Ah) g = Gravitational acceleration,
c = Designing seismic horizontally coefficient for convective mode.
mi = liquid's impulsive mass,
ms = container's mass plus 1/3rd staging mass
mc = liquid's convective mass, and
V is calculated by combine effect of convective and impulsive modes.

X. BASE MOMENT

For impulsive mode, the base instant, Mi, at stage base is provided by

$$M_i^* = (A_h)_i \left[m_i (h_i^* + h_s) + m_s h_{cg} \right] g$$

and base moment in convective mode, *Mc* is

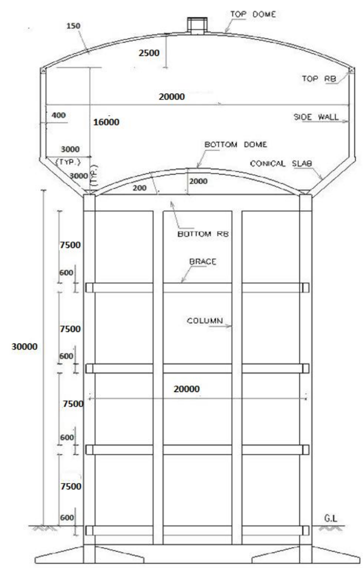
$$M_c^{*} = (A_h)_c \, m_c \left(h_c^{*} + h_s\right) g$$

$$M^{*} = \sqrt{M_i^{*2} + M_c^{*2}}$$

wherever hs is the staging structurally ht., which is measure from staging top and footing to the tank wall bottom, hcg is ht. of empty container's centre of gravity, which is measure from footing top and tank walls bottom. The total moment is calculated by adding the moments in both the modes using Squaring of Sums of Squaring method, as shown below.

XI. HYDRODYNAMIC PRESSURE

Here walls of the tank are subjected to lateral hydrodynamically pressure by laterally base excitation, while base is subjecting to liquid pressure in vertical direction Hi is ht. of tank wall bottom where the consequent of impulsive pressure on wall is placed in the two-mass model of tank. Hi*from tank wall bottom indicates the ht. at which complete impulsive pressure act. If the influence pressure of base is ignored, the mi, liquid mass will act at the hi ht., while if the base effect is taken into account, mi will act at hi*. Hi and hi* heights are explained. Similarly, hc is the ht. where complete convective pressure acts at bottom of tank and whereas hc* is the ht. where complete convective pressure of walls and tank base is positioned. Figure: 3.7c and 3.7d shows the heights hc and hc*.



XII. RESULTS

1) Lateral Stiffness of stagings (Zone-III: 20m Ht.)

Staging prototype	Lateral Displacement of staging in (mm)	Stiffness of Staging (Ks)in kN/m
Basically bracing	0.38	26315.79
Radially bracing	0.29	35087.72

2) Seismic parameters: Impulsive mode (Zone-III: 20m Ht.)

Staging pattern	Time Periods (Ti)	Sa/g value (Hard soil)	Horizontal Seismic coefficient (Ah)i
Basic bracing	2.116	0.473	0.0226
Radial bracing	1.958	0.511	0.0245

3) Seismic parameters: Convective mode (Zone-III: 20m Ht.)

Staging pattern	Time Periods (Tc)	Sa/g value (Hard soil)	Horizontal Seismic coefficient (Ah)c
Basic bracing	4.00	0.250	0.012
Radial bracing	4.00	0.250	0.012

4) B.S. (IIIrd: 20m Ht.)

Staging prototype	(Vi)	(Vc)	$V = Sqrt(Vi^2+Vc^2)$
Basically bracing	530.14	95.35	538.64
Radially bracing	602.34	89.254	608.916

5) Base Moment (Zone-III: 20m Ht.)

Staging prototype	(Mi)	(Mc)	(M) $M= Sqrt(M_i^2+M_c^2)$ kN-m
Basic bracing	12112.325	2024.908	12280.418
Radial bracing	10546.51	2024.908	10739.139

6) Roof Displacement (Zone-III: 20m Ht.)

Staging pattern	**Roof Displacements in mm**		
	Tank Empty condition	**Half circumstance**	**Filled circumstance**
Basically	39.298	31.437	32.345
Radial bracing	34.942	27.953	28.726

7) Base Shear and Base Moment

Staging Pattern	B.S. (kN)			B.M.(kN-m)		
	Empty	Halfed	Filled	Empty	Halfed	Filled
Basic bracing	183.16	146.53	123.69	353.01	282.41	279.13
Radial bracing	172.69	138.18	136.05	321.77	257.43	254.05

8) Roof Displacements

Staging pattern	Roof Displacements in mm		
	Empty circumstance	halfed filled circumstance	Filled circumstances
Basic bracing	53.37	42.69	42.12
Radial bracing	45.02	35.99	35.6

9) Comparison of Roof Displacements, Base Shears, Base Moments for Different staging patterns in Zone IIIrd, IVth & Vth for Staging Height of 20 m

Tank condition	Staging Patterns	Roof displacements in mm		
		Zone - III	Zone - IV	Zone - V
Empty	Basic Bracing	39.29	58.92	88.36
	Radial Bracing	34.94	52.40	78.59
	Concentric Column	21.62	32.42	48.63
Half Full	Basic Bracing	31.43	47.13	70.68
	Radial Bracing	27.95	41.92	62.87
	Concentric Column	17.29	25.94	38.90
Full	Basic Bracing	32.34	48.04	71.59
	Radial Bracing	28.72	42.69	63.64
	Concentric Column	17.29	25.94	38.90

10) Base Shear summary for Seismic Load

Staging Patterns	B.S. in kN		
	IIIrd	IVth	Vth
Basic Bracing	550.89	826.34	1239.51
Radial Bracing	639.86	959.79	1439.69
Concentric Columns	799.96	1199.93	1799.90

11) Base Moment summary for Seismic Load

Staging Patterns	B.M. in kN-m		
	IIIrd	IVth	Vth
Basic Bracing	12649.33	18974	28461
Radial Bracing	14715.67	22073.51	33110.27
Concentric Columns	17443.03	26164.54	39246.81

12) Comparison of Roof Displacements, Base Shears, Base Moments for Different staging patterns in Zone IIIrd, IVth & Vth for Staging Height of 30 m

Tank condition	Staging Patterns	Roof Displacements in mm	
		Zone III & IV	Zone - V
Empty	Basic Bracing	53.37	85.88
	Radial Bracing	45.02	59.88
	Concentric Columns	24.7	24.7
Half Full	Basic Bracing	42.69	68.71
	Radial Bracing	35.99	58.73
	Concentric Columns	19.76	19.77
Full	Basic Bracing	42.12	58.41
	Radial Bracing	35.64	57.95
	Concentric Columns	19.76	19.77

13) Base Shear summary for Wind Load

Tank condition	Staging Patterns	B.S. in kN	
		III & IV	V
Empty	Basic Bracing	183.16	285.43
	Radial Bracing	172.69	267.86
	Concentric Columns	107.8	107.8
Half Full	Basic Bracing	146.53	228.35
	Radial Bracing	138.18	214.32
	Concentric Columns	86.236	86.23
Full	Basic Bracing	123.69	200.91
	Radial Bracing	136.05	210.51
	Concentric Columns	86.236	86.23

14) Base Moment summary for Wind Load

Tank condition	Staging Patterns	B.M. in kN	
		III & IV	V
Empty	Basic Bracing	353.01	549.56
	Radial Bracing	321.77	500.62
	Concentric Columns	206.28	206.28
Half Full	Basic Bracing	282.41	439.65
	Radial Bracing	257.47	400.59
	Concentric Columns	168.02	165.02
Full	Basic Bracing	279.13	386.99
	Radial Bracing	254.05	394.06
	Concentric Columns	168.02	165.02

XIII. CONCLUSION

In this presentation, the seismic behavior of tanks has significantly changed, along with concerned responses approximating base moment, stiffness, displacement, B.S., etc. Supported systems using for proper adjustments. The study's conclusion highlights the importance of using the right supporting configuration to prevent elevated water tanks from suffering severe damage or collapse during an earthquake.

The main excitation factor for reactions like the O.M., roof displacement, and B.S.F., earthquake properties in different zones are compared and equated.

1) In the first case study of the IIIrd zone, a storage tank with a 20-meter staging height, basically bracing (Ks= 26315.79kN/m) is either more suited than radial bracing (Ks= 35087.72kN/m) in this instance.
2) The roof displacement for the Basically (70mm) and Radially (62mm) are greater than limitation value (54mm) in Vth zone for similar Case study-1 liquid storing tank with a 20-meter staging height.
3) In Case Studies 1 and 2, storing tank with a height of 20 and 30 meters, respectively, the Radially, B.S. and Base moments are comparably bigger than those of Basically bracing, have jeopardize staging parts' reinforcing plan.
4) After altering the diameters of the bracing beams in Vth for similar Case Study-2 storing with ht. Of staging, it was found that the minimum staging stiffness (Ks) value needed to keep roof displacements within acceptable bounds was 11013kN/m.

XIV. ACKNOWLEDGMENT

The preferred spelling of the word “acknowledgment” in American English is without an “e” after the “g.” Use the singular heading even if you have many acknowledgments.

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