ISSN: 0974-5823 Vol. 7 No. 1 January, 2022

International Journal of Mechanical Engineering

Comparison of Elevated Water Tank Designs in Different Seismic Zones

Dasari Tirupathi [a], Kota Srinivasu [b]
a Research Scholar, Acharya Nagarjuna University, Guntur*
b NRI Engineering College, Guntur.*

Abstract

Water is stored in elevated tanks as part of the public water system. The collapse of these water tanks may result in major hazards for people owing to a lack of water or trouble controlling a fire during an earthquake. According to draft code Part II of IS 1893:2002, twelve raised circular, and H-intake water tanks with a capacity of 2Lakhs liters each are considered in this study. With the help of STAAD Pro V8i, a response spectrum analysis of elevated circular and H-shaped water intake tanks in seismic zones II and V is performed. All results obtained compared for base shear axial force and lateral displacements. Comparison between two water tanks the analysis showing that there is a deviation in H-tank and negligible variation in rectangular tank.

Keywords:Elevated circular water tank, Elevated H- intake water tank, Response spectrum analysis.

1.0 Introduction

Water is a daily necessity for every human being. As a result of its design, this sort of tank is used to pressurize the water circulation system by holding water at a predetermined height. Innovative concepts and technological improvements have been made in the field of water and other fluid materials' capacity in a number of different structures and models.[1] There are distinct approaches for fluid capacity, such as underground tanks, ground tanks, elevated tanks, etc. Earth quakes, breezes, flows, violent winds, and other representative calamities are causing a lot of trouble in the Indian subcontinent, especially. Unfortunate events tend to strike large areas of states and unions, whether they be states or unions. Numerous setbacks and property losses are a result of these regular tragedies. Seismic tremors put everyone else in a position of powerlessness before they even begin to occur. As per seismic code IS: 1893(Part I):2002, more than 60% of India is inclined to tremors. After a seismic tremor, property damage can be repaired to a certain extent, however life-threatening damages can't. Water, oil, petroleum, acid and even gases are stored in massive volumes. There is also a requirement for containers or tanks. A variety of materials have been used to construct these structures including masonry, steel, reinforced concrete, and pre stressed concrete. For lesser capacities, masonry and steel tanks are employed. Despite their considerable cost, steel water storage tanks are considered insignificant. Reinforced concrete tanks are particularly popular because, in additional to their simple construction and design, they are economical, monolithic in character, and can be made leak resistant. Liquid-retaining Richer concrete is used in the RCC tanks to provide water tightness. When it comes to making tanks watertight, many different types of waterproofing materials are used.

1.2 Scope of the study

It was used in this study to model the water tank utilizing STADD Pro V8i's finite element modeling software system. The effect of several imaging techniques in tanks was investigated. For this, seismic analyses were performed for entire water level and partial water level conditions. The present study also includes an analytical analysis of the seismic reaction of an elevated water tank using the Frequency Response approach, which takes into account the convective mode of earthquake data. Similarly, the study produced peak displacement and base shear results, which were compared.

2.0 Literature Review

In this section, we review a few published studies on the seismic performance parameters of reinforced concrete (RC) water tanks. Basing their assessment on seismic codes of other regions and findings of numerous investigations, Jain and Sajjad [1] discovered that the seismic design force in IS 1893- 1984 is very low due to the lack of a sufficient performance factor that must be in the range of 3.0-4.5.

Nitesh Singh,et al Water tanks are designed to withstand dead load + live load, wind load, and seismic loads, according to IS rules of procedure. Tanks are often planned for wind forces and not even examined for earthquake loads, believing that they will be safe under seismic forces after they are designed for wind forces. However, this is not always the case. A water tank with an H-shaped inlet is studied for Indian circumstances. Due to the fact that wind flows relative to the surface of the earth and exerts loads on structures standing on the ground, the wind's effect on elevated structures is quite important**.**

Rupachandra et al In industries, liquid storage facilities are used to hold chemicals, oil products, and water for public water distribution networks, among other things. The behavior of cylindrical liquid storage tanks under seismic stresses has been examined according to the IS 1893:2002 draft code part II. Software (STAAD-PRO) based on finite element modeling (FEM) that calculates earthquake-induced forces on tank systems.

Sonali M. Maidankar R.C.C. raised water tanks were severely damaged or collapsed as a result of a few earthquakes disaster in India. According to experts, the tank's support system failed due to an earthquake and a poorly constructed staging area.

A.D.V.S. Uma Maheswari, et al As we know from the past, several reinforced concrete elevated water tanks were severely damaged or collapsed during earthquakes all around the world. As a result of general findings, the collapse of the raised tank's supporting system is more critical than the other structural sections of the tank.

Prashant Bansode Structures such as reinforced concrete elevated water tanks are extremely valuable. During and after earthquakes, they are regarded to be essential lifelines. Like an inverted pendulum, an elevated water tank is composed of an enormous water mass perched on the topmost stage in its design. For the tank to fail during an earthquake, this is the most important factor to keep in mind.

Nanjunda, et al A contribution to the total water tank was subjected to dynamic forces in the present study, which focused on its reactivity. Large water masses at the top of a narrow staging are the most important factor in determining whether an overhead water tank will fail after an earthquake.

M. Sai Ramya et al System's lifeline is its elevated water tanks, which are its most significant structures. As a result of earthquakes, elevated water tanks have been damaged and collapsed in the past. Lack of suitable support systems for the water tank and incorrect staging are responsible for the damage.

Ranjit Singh Lodhi,et al Every creation comes from the water. Water is essential to daily living. As a home or industrial storage facility, the overhead liquid storage tank is the most efficient. Water tanks can be classified as overhead, on ground, or under, according on where they are located in the structure.

3.0 Research Methodology

As part of the technique, IS 1893-2002 (Part 1) and IS 1893-2002 (Part 2) draft codes are used to pick the kind of water tank, fix the component dimensions, and perform a linear dynamic analysis (Response Spectrum Method of Analysis) on the selected water tank. In this case, we are looking at circular and H-shaped raised water tanks with a capacity of 2 litres, mounted on a 12m-high RCC frame with six columns and horizontal bracing at 4 categories. The elevated water tanks are located in Zone II and Zone V on medium soil. For this study, concrete grade M30 and steel grade Fe-415 are taken into consideration. Staad Pro V8i was used to evaluate these models using Response Spectrum Analysis.

Table-1:ParametersofElevatedCircularTank

Particulars	ValuesorDimensions
TheThicknessofTopDome	100mm
RiseofTopDome	1.4m
Top Dome Radius at Base	8.0 m
SizeofTopRingBeam	250mmx250mm
DiameterofCylindricalWall	8.0 m
HeightoftheCylindrical wall	4m
Dimensions and thickness of the cylindrical walls	150mm
ThicknessofBottomSlab	175mm
SizeofBottomRingGirder	350mmx350mm
No.ofColumns	6nos.
No.ofBracingLevels.	3m,6m,9m,12m
The distance between intermediate Braces	3.0 m
SizeofBracing	0.350mx0.450m
TheSizeofColumns	0.375mx0.375m

3.1 3D Rendering View of Tanks:

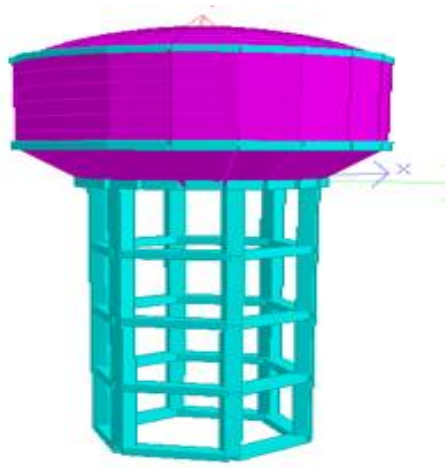

Figure1:.3DmodelofElevatedCircularTank **Figure 2**.3DmodelofElevatedHH- intakeTank

Table2:ParametersofElevatedH- intakeTank

Particulars	**ValuesorDimensions**
TheThicknessofTopDome	100mm
RiseofTopDome(h1)	1.4m
SizeofTopRingBeam	250mmx250mm
DiameterofCylindricalWall	8m
HeightoftheCylindrical wall	3.6m
ThicknessofCylindricalWall	150mm
SizeofMiddleRingBeam	350mmx350mm
HeightofConicalDome	1.6m
diameter of the conical dome on the average	6.45m
ThicknessofConicalDome	200mm
RiseofBottomDome	0.9m
RadiusofBottomDome	3.75m
ThicknessofBottomDome	175mm
SizeofBottomRingGirder	375mmx750mm
No.ofColumns	6nos.
No.ofBracingLevels.	3m,6m,9m,12m
Distance betweenintermediateBraces	3m
SizeofBracing	0.350mx0.450m
TheSizeofColumns	0.375mx0.375m

3.2 Seismic loads:

An earthquake response spectrum analysis is based on factors such as zone factor, significance factor, response reduction factor, and response reduction factor, among others. Seismic zones II and V are defined by IS Code 1893:2002 as having zone factors of 0.10 and 036, respectively. Tanks used to hold drinking water, non-volatile materials, low-inflammable petrochemicals, etc., are assigned a factor of 1.5. The type of frame utilized affects the response reduction factor. Moment-resisting response is thought to be reduced by 1.8 for frames that are not ductile designed. It is utilized in zone II. It is utilized in zone V for frames that have ductile detailing, which means they have an unique moment-resistance response reduction of 2.5.

4.0 Results and discussions

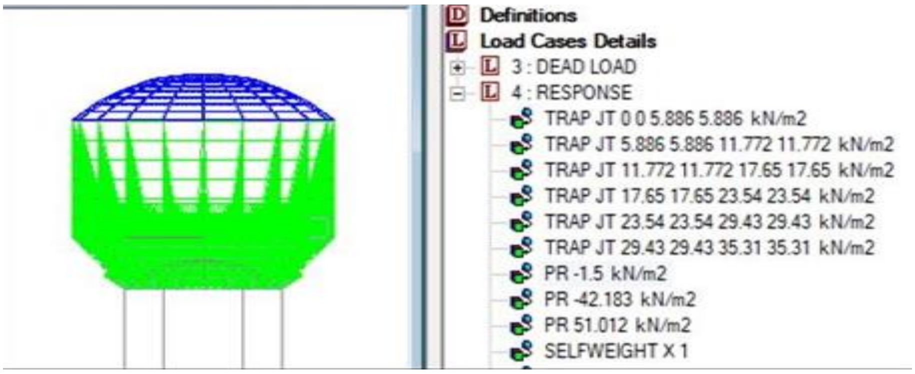

Figure.3 WaterLoadforFullTankforHH- intakeTank

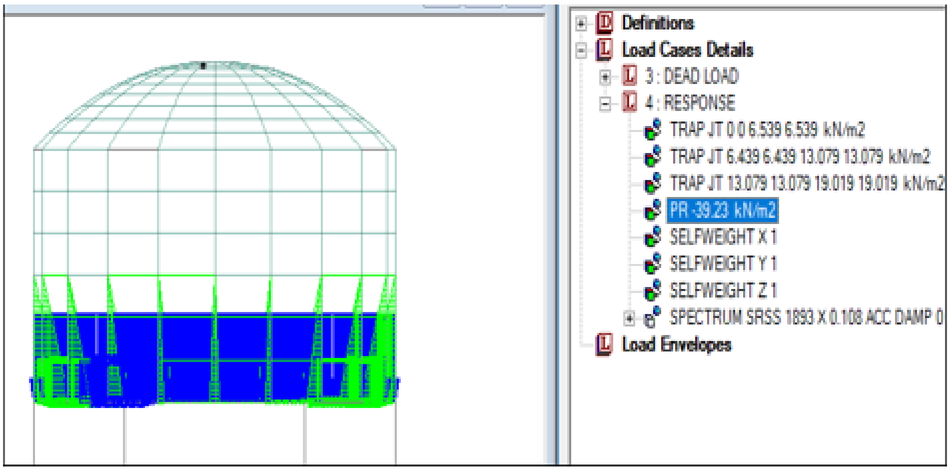

Figure 4: Water Load for Half Tank for Circular Tank

Specific factors of elevated water tanks are studied to find their maximum responses. Included in these reactions are base shear force, nodal displacement, and period of time. The seismic parameters of elevated water tanks are evaluated by analyzing the reaction spectra of full, half-filled, and empty water tanks. As section of the study, the seismic zones II and V will be considered.

Base Shear (in KN): Response spectrum analysis in the Stad.pro software is used to calculate base shear values for circular and H-intake models.

Table 3: Base Shear Values for Zone V

BaseShearValues forZone– V,		
Waterlevelsintank	CircularTank	H- intakeTank
	Fx(inKN)	Fx(inKN)
Empty TankLevel	193.66	208.65
HalfTankLevel	207.32	288.38
FullTankLevel	307.21	323.68

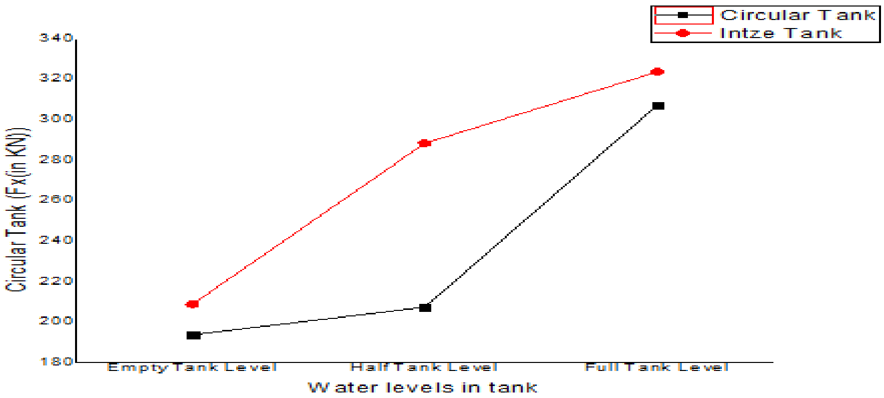

Figure 5:BaseshearvaluesforcirculartankandH- intake tankinzoneV

Table: 4 Base Shear Values for Zone II

BaseShearValues forZone– II,		
Waterlevelsintank	CircularTank	H-intakeTank
	Fx(inKN)	Fx (inKN)
Empty TankLevel	75.31	81.15
HalfTankLevel	81.13	112.17
FullTankLevel	98.14	125.88

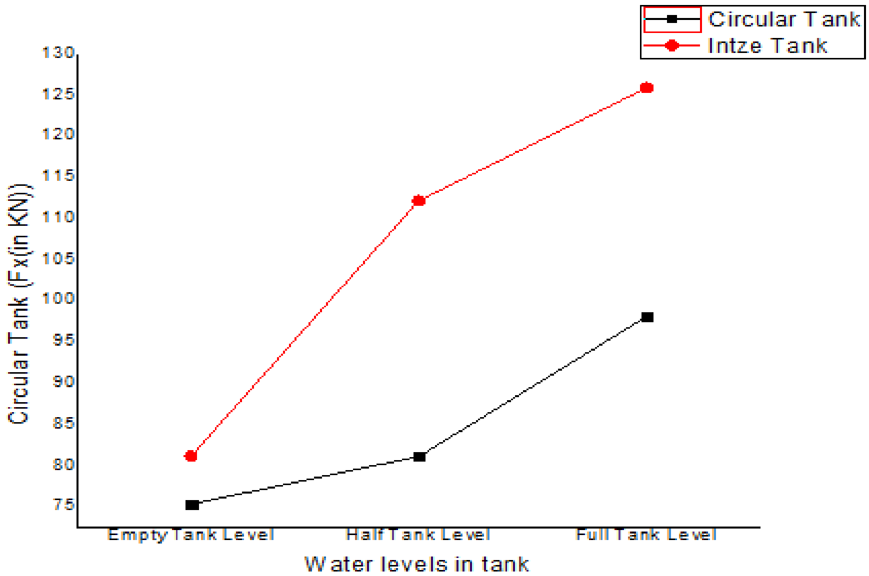

Figure 6:BaseshearvaluesforcirculartankandH- intaketankinzoneII

NodalDisplacement:

For circular and H-intake models at various water levels, response spectrum analysis from the staad.pro software under seismic zones II and V produces displacement data.

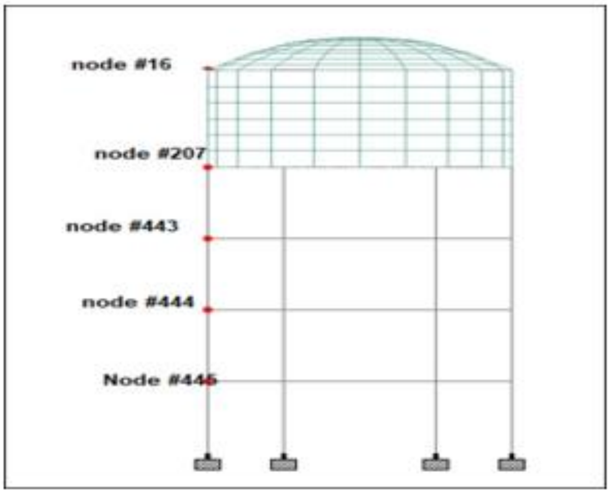

Figure 7.Nodesnumbersincirculartank

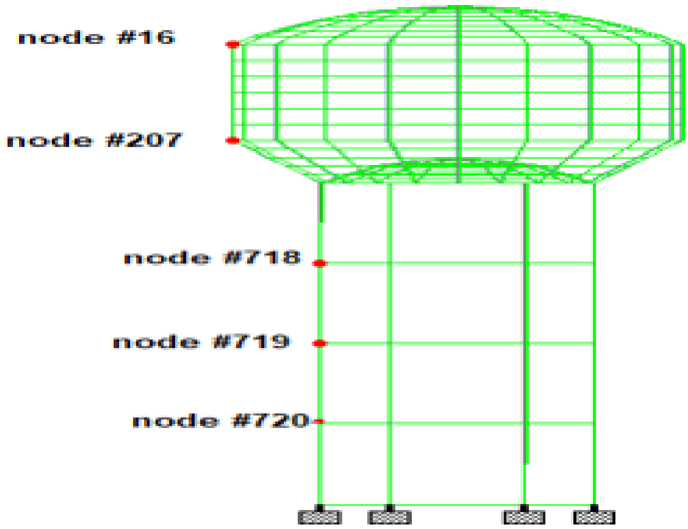

Figure 8: Nodes numbers in Intake tank

Table5:DisplacementsincirculartankinzoneV

SeismicZone-V			
ResponseSpectrumAnalysisofElevatedCircularTank			
NodeNumbers	ElevatedCircularTank Displacementsinmm		
	full	half	empty
445	7.41	7.379	7.365
444	19.55	19.34	19.25
443	34.36	33.58	33.2
207	58.25	55.99	54.90
16	59.26	56.94	55.87

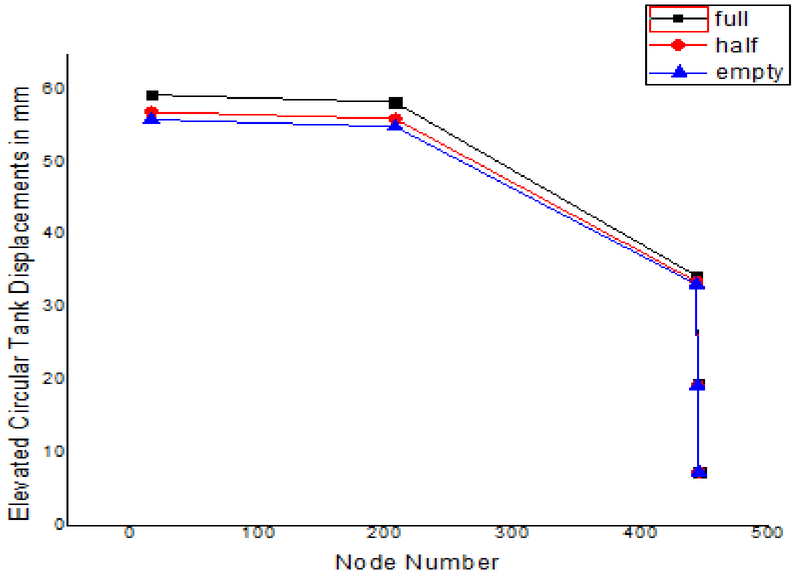

Figure 9: ResponseSpectrumAnalysisofElevatedcircular tank displacement in mm

Table6:DisplacementsincirculartankinzoneII

SeismicZone-II			
ResponseSpectrumAnalysisofElevatedCircularTank			
NodeNumbers	Displacementsinmm		
	full	half	empty
445.0	2.85	2.84	2.841
444.0	7.54	7.46	7.429
443.0	13.25	12.97	12.82
207.0	22.46	21.64	21.182
16.0	22.85	22.01	21.557

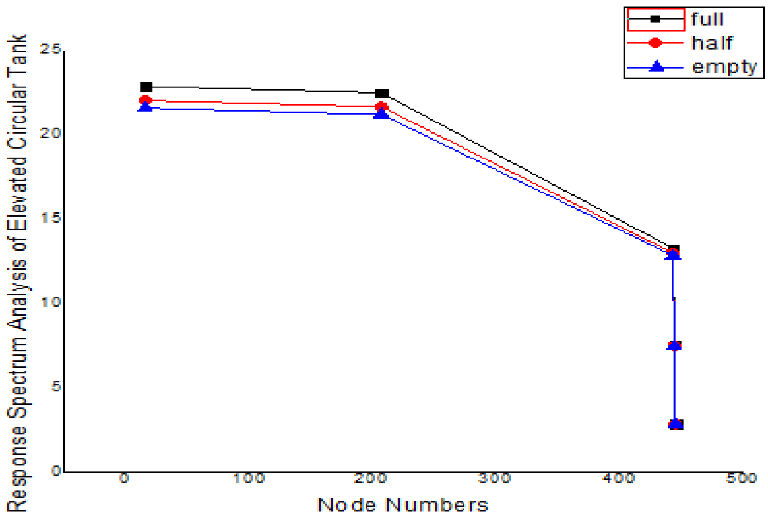

Figure 10: ResponseSpectrumAnalysisofElevated circular tank

Table7:DisplacementsinIntaketankinzonev

SeismicZone-V			
ResponseSpectrumAnalysisofElevatedH- intakeTank			
NodeNumbers	ElevatedH- intakeTank Displacementsinmm		
	full	half	empty
720.0	6.770	6.4460	6.430
719.0	17.220	16.365	16.247
718.0	29.4670	27.920	27.448
207.0	52.5330	49.495	47.965
16.0	55.3360	52.027	50.669

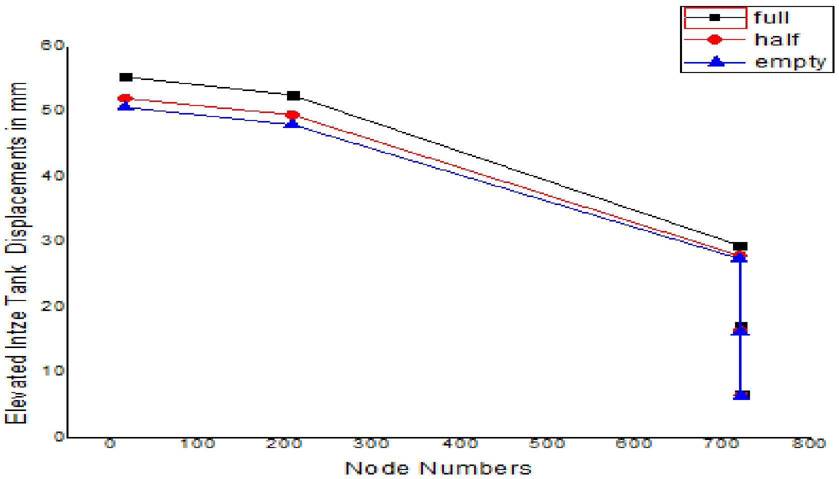

Figure 11: ResponseSpectrumAnalysisofElevatedH- intakeTank Zone-V

Table8:DisplacementsinH- intaketanksinzoneII

SeismicZone-II			
ResponseSpectrumAnalysisofElevatedH- intakeTank			
NodeNumbers	Displacementsinmm		
	full	half	empty
720.0	2.630	2.48	2.180
719.0	6.690	6.31	5.510
718.0	11.459	10.770	9.620
207.0	20.429	19.090	18.320
16.0	21.519	20.070	19.070

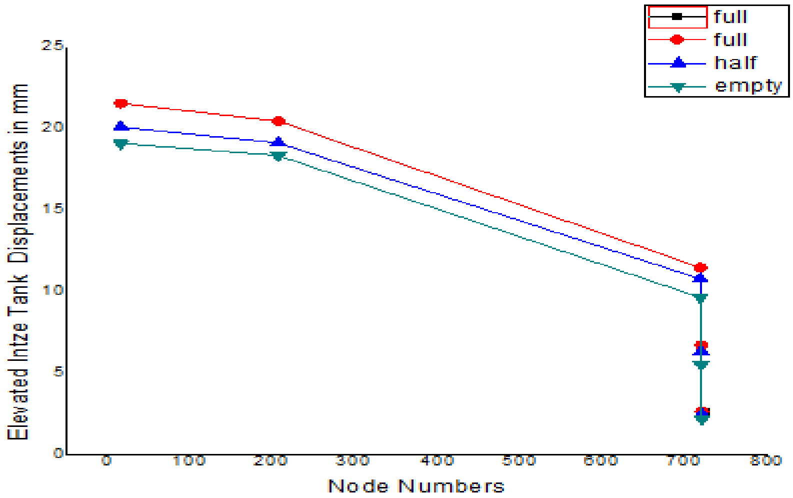

Figure 12: ResponseSpectrumAnalysisofElevatedH- intakeTank

4.1 Discussions

Base Shear: It has been shown that the radial staging type with H/D ratio 0.6 delivers the highest value of base shear for eight columns compared to another H/D ratio. As compared to other methods of staging, radial staging with a half tank and a full tank provides the highest base shear value for empty tanks. As the number of columns rises, the base shear increases for full tank, half tank, and empty tank conditions. As the h/d ratio grows, base shear decreases.

Axial Force: Radial staging with a central column produces the maximum axial force for full, half, and empty tanks. For an empty tank, the maximum axial force is attained when h/d=0.6, cross staging with eight column numbers, is employed. As the h/d ratio grows, the axial force falls for ten, twelve columns. The maximum axial force is obtained with a full tank as compared to a half tank and an empty tank.

Moment-y Direction: Comparing h/d ratios, it has been found that a normal staging type of 0.7 produces the lowest moment-y for eight columns. As compared to another h/d ratio for empty and half tank conditions, a radial staging type with a 0.5 h/d ratio produces the largest moment-y for ten columns. Moment-Y decreases with increasing h/d ratio for cross and radial staging with eight, ten, and twelve columns, compared to other staging for empty and half tank conditions.

Moment-z Direction: Comparing h/d ratios, it has been found that h/d ratios of 0.7 cross staging produce the lowest moment-z for eight column numbers, whereas 0.6 cross staging gives the highest moment-z for the same number of columns. For the half tank and full tank conditions, the 0.5 h/d ratio cross staging type produces the largest moment-z, compared to another h/d ratio.

Moment-x Direction (Torsion): Compared to another h/d ratio for a full tank, half tank, and empty tank condition, the hexagonal staging type with a ratio of 0.7 has the lowest twisting moment for ten numbers of the column h/d ratio 0.5 cross staging type provides a maximum twisting moment for 10 and 12 numbers of the column compared to another h/d ratio, for full, half, and empty tanks conditions.

Lateral Displacement: As the number of columns increases for a full tank, a half tank, and an empty tank, the displacement reduces. We find that the hexagonal staging type results in the least lateral displacement for empty, half and full tanks with 8, 10, and 12 column numbers, respectfully.

5.0 Conclusions and comparison of previous research

In the case of the rectangular water tank with the same storage capacity and different height of tank wall, if the h/L ratio is up to 0.6, the base shear, Bending Moment& Max. Hydrodynamic pressure increases gradually, and if the h/L ratio is in between 0.6 to 0.8, it suddenly increases & after that, it decreases gradually. So, for the water tank at ground level, the h/L ratio up to 0.6 is feasible. For circular & rectangular water tanks with same storage space but varying tank wall heights, the sloshing wave height grows up to a certain limit, then gradually declines. Increasing the ratio of maximum depth of water to tank diameter (h/D) or (h/L) will enhance impulsive mass participation factor and decrease convective mass participation factor. Impulsive and convective mass involvement factors are roughly equal in the circular water tank with a h/d ratio of 0.6 In the case of a rectangular water tank for an h/L ratio of 0.5, the mass participation factor for impulsive & convective is nearly equal.

6.0 Reference:

1. Nitesh J Singh1, Mohammad Ishtiyaque "Design analysis & comparison of H- intake type water tank for different wind speed and seismic zones as per Indian code", International Journal of Research in Engineering and Technology ISSN: 2319-1163 ISSN: 2321-7308 Volume: 04 Issue: 09 | September-2015.

2. Rupachandra J. Aware, "Seismic Performance of Circular Elevated Water Tank Shri Vitthal Education & Research Institute College of Engineering", International Journal of Science and Research (IJSR) ISSN (Online): 2319-7064Volume: 4 Issue: 12, December 2015

3. Sonali M. Maidankar1, Prof. G.D. Dhawale2, Prof. S.G. Makarande3"Seismic Analysis of Elevated Circular Water Tank using various Bracing Systems", International Journal of Advanced Engineering Research and Science (IJAERS), ISSN: 2349-6495, Vol-2, Issue-1, Jan.- 2015.

4. A.D.V.S. Uma Maheswari1, B. Sravani Performance of elevated circular water tank in different seismic zones International Journal for Technological Research in Engineering ISSN (Online): 2347 - 4718 Volume 3, Issue 5, January-2016

5. Jain, S.K., and Sajjad, S.U. (1993). "A Review of requirements in Indian codes for a seismic design of Elevated water tanks". The Bridge and structural Engineering, volume:4, Issue:1,12(1), 1-15.

6. O. R. Jaiswal and S. K. Jain, "Modified Proposed Provisions for Aseismic Design of Liquid Storage Tanks: Part II – Commentary and Examples", Journal of Structural Engineering Vol. 32, No.4, 2005.

7. O. R. Jaiswal, S. Kulkarni, P. Pathak, "A Study on Sloshing Frequencies of Fluid-Tank System", in Proceedings of 14th World Conference on Earthquake Engineering, Beijing, China, 2008.

8. S. Hirde, A. Bajare, M. Hedaoo, "Seismic Performance of Elevated Water Tanks", International Journal of Advanced Engineering Research and Studies E-ISSN2249 – 8974, 2011

9. M. V. Gaikwad, M. N. Mangulkar, "Seismic Performance of Circular Elevated Water Tank with Framed Staging System" International Journal of Advanced Research in Engineering and Technology (IJARET) Volume 4, Issue 4, May – June 2013, pp. 159-167, 2013.

10. Ankita Singh, Prashant ",Khutemate seismic analysis of the elevated water tank for variation in bracings patterns and water fill conditions", ISSN-2349-5162, Volume 8, Issue:1,2021 JETIR January 2021