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DESIGN AND ANALYSIS OF DIFFRENT WATER TANKS BY CONSIDERING SLAB WALL AND CAPACITY IN SEISMIC ZONES

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Abstract:

Elevated water tanks subjected to dynamic loads supported on RC framed structure and concrete shaft structure with varying capacity and located in different seismic zones. The history of the earthquake demonstrates that it has inflicted numerous losses to the life of people in its active time. Also, post-earthquake time had made people suffer owing to damages caused to the public utility services. In urban or rural locations, elevated water tanks are a crucial element of the water supply infrastructure, thus their operation pre- and post-earthquake remains equally important. To determine out which raised water tanks' structural parts operate in the presence of wind, researchers used a large-scale computer simulation. Elevated water tanks in high susceptibility to an earthquake are one of the greatest structures of support system. These structures have a large concentration on slender support structures and are at risk of horizontal forces due to the earthquake in specific. They are essential elements in municipal water deliver hearth combating structures and in many commercial centres for garage of water. Hence increased water tanks ought to continue to be functional even after the earthquake. In this study guide seismic analysis of improved square water tank is achieved according with IS: 1893-1984 (i.e. Lumped mass version) and IS: 1893-2002 (Part-2) draft code (i.e. Two mass version). The structures are analysed with different simulated soft ware's Staad-pro and E-tabs. The results are compared for optimal value analysis in particular forces.

Key words: Elevated water tanks, shear stresses, base slabs, Seismic zones

I. INTRODUCTION

The elevated water tanks are mostly damaged during earthquake. Because water tanks contain a huge load on their top portion and their safety performance is critical in earthquakes. They must not fail during earthquake to provide of drinking water to the society. Severely damaged water tank in past earthquake due to lack of design efficiency. reported that the dominant failure of water tank is due to earthquake forces. Tanks are the containers used to store crucial liquids and other important items, such as grains, which is why water is so important to human life. Because of this, the volume of the tank is also important. For liquid storage, there are a variety of tanks that can be found in practice, such as those that are either elevated or submerged in water. Among the various types of tanks, elevated tanks are the most important because of their high tank capacity and their ability to meet demand from the public or industry. [1]. Water tanks play an important part in public utility and industrial structures, as they are essential for providing a steady flow of water over an extended distance with appropriate static head Reservoirs that hold water and other liquids are located on the ground and in the air. Reservoirs and tanks have a similar force analysis regardless of the chemical composition of the product. To prevent leaks, all tanks are constructed with no cracks or crevices. If the reinforcement is well maintained, reinforced concrete can be used to build walls and slabs for the storage of water or petroleum products. [2] A additional treatment is needed on the concrete surface since water and petroleum react with it. Concrete tanks can be used to collect and handle industrial waste, with a few exceptions. Special membranes must be installed in tanks to prevent leakage of petroleum products such as diesel fuel. Structures used for liquid storage are commonly called reservoirs. They can be located above or below ground. Generally, reservoirs built below ground level are designed to hold a considerable amount of water at a given time. However, overhead distribution systems are often lower in size because they rely on gravity to distribute products.

Classification of Water Tank:

Water Tanks Based on	
Sahpe	Reetangular, Circular, Hexagonal, Intze, Conical, Funnel
Material	Reinforced Concrete, Steel, Masonry, Aluminium, Fiber
Dimensions	Small Scale, Medium Scale, Large Scale
Type of Roof	No roof, Normal Roof, Floating Roof
Base Support Type	Rigid Foundation, Soil-Tank Interaction, Base Isolation
Height From Ground	Elevated, Above Ground, Partially or Full Buried

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Structural Features:

The major components of a reinforced concrete elevated water tank, from the standpoint of analysis are the container, staging and foundation. A typical elevated water tanks are shown in figure 1.1. Containers can be of various shapes, such as circular, rectangular, intze, spherical, etc. However, when the required capacity of the water tank is very large, an intze type of shape is quite desirable, because it requires less reinforcement compared to other types It consist of a number of shells of revolution: two spherical, one cylindrical, and one conical. Below the cylindrical container is a conical shell with a spherical dome shaped tank floor that provides an economical substitute for otherwise thick floor slabs in elevated tanks. The dimensions of the conical walls and the spherical bottom domes are such that the outward thrust from the spherical dome is balanced by the inward thrust from the conical shell Because of its optimal load balancing configuration, this type is quite popular and is mostly adopted.

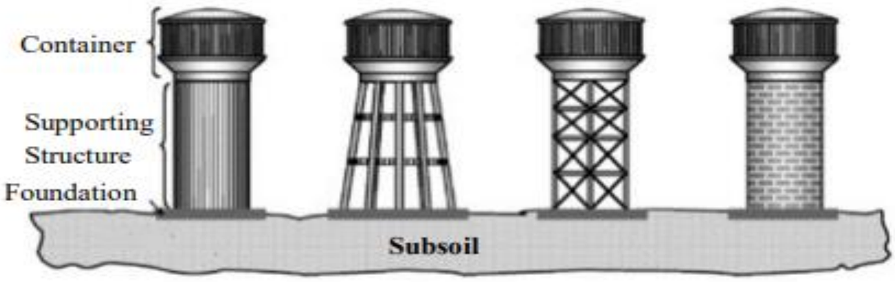

Figure 1.1 Typical elevated water tanks

To hold the container of elevated water tank at a particular height, different types of supporting structure or staging are used. Mainly trestle (frame) and shaft type of staging are used in practice. A frame type of staging has a number of columns, symmetrically arranged on the periphery of girder Generally it has the following components

- Peripheral girder at top of the staging for transferring loads from container.
- Columns, which might be vertical or inclined.
- Braces at different levels for reducing the effective length of the columns.
- Additional diagonal and radial braces for improving seismic resistance.

Figure: Elevated water tank with frame type of staging

Figure: Elevated water tank with shaft type of staging

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SHEAR FAILURE MODES IN BEAMS

This type of failure due to high shear force in the end of beams, 45-degree angle shear cracks appears in the plastic joints and creating the end of beams is their failure.. The tank so that instability and in some columns due to the high-performance large columns create moment is low (PEER). Damaged tank struts. Some columns worked slightly at tops due to high moments Sample of this sort of failure as shown in Figure

Figure: Elevated water tank of Puetro Varas Hotel, May 22nd, 1960, Chile earthquake (PEER).

The earthquake in Chile (South America) in May 22, 1960 with a magnitude M= 8.5, for the elevated water tank with a volume of 50 cubic meters, bracket has the form of eight square column dimensions of 40 cm and 180 cm distance each other columns, beams loss creating a joint plastic strut has been reported and No damage has been reported in Columns (PEER).

Figure: Elevated water tank with 50 m3 capacity in May 22nd, 1960, Chile earthquake (PEER)

The inappropriate design connections and poor detailing of column beam joints. If connections are not designed for seismic forces, they lead to failure in elevated water tanks. Columns from one side, where the beams connecting the columns had shear cracks suffered and caused unstable side frame of the outcome, then so the elevated water tanks collapsed.

(a) (b)

Figure (a) – Collapsed slender and weak framed staging of water tanks in Manfera village; Figure (b) - Severe damage occurred to elevated water tanks with frame staging which caused water tank pulled down

BENDING-SHEAR FAILURE IN BEAMS:

This type of failure in the bending-shear cracks beams occurs in the middle section beams with a gradual increase toward the middle of support prevent occurrence of shear failure and conduct joint with plastic end of beams to the middle of beams to create this kind provide failure. An illustration of this type of earthquake failure is Chile in 1960 with a magnitude M=8.5, for the elevated water tank volume of 700 cubic meters; it has been shown that joint damage in plastic beams creating a strut has been reported. Stirrups the W shape and size during

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the earthquake within the water tank near 600 cubic meters has been reported. Also reported that pipe broke underneath the tank, and separated one meter as the water discharged from the tank (PEER). The design seismic shear forces frame members should be closed tight took advantage. Figure 4 using open stirrups W shape show that the shear failure beams are in the middle.

Figure: Elevated water tank with 700 m3 capacity in earthquake

Axial failure in columns:

Another type of the failure to vertical cracks occurs due to forces column compressive is on them. An example of this type of failure is Bhuj earthquake in India in 2001 with a magnitude M=7.7, for the elevated water tank with 20 cubic meters capacity located in Gujarat near Anjar, built in 1958 that has occurred so relatively severe damages column was created. Deep cracks in the columns were observed.

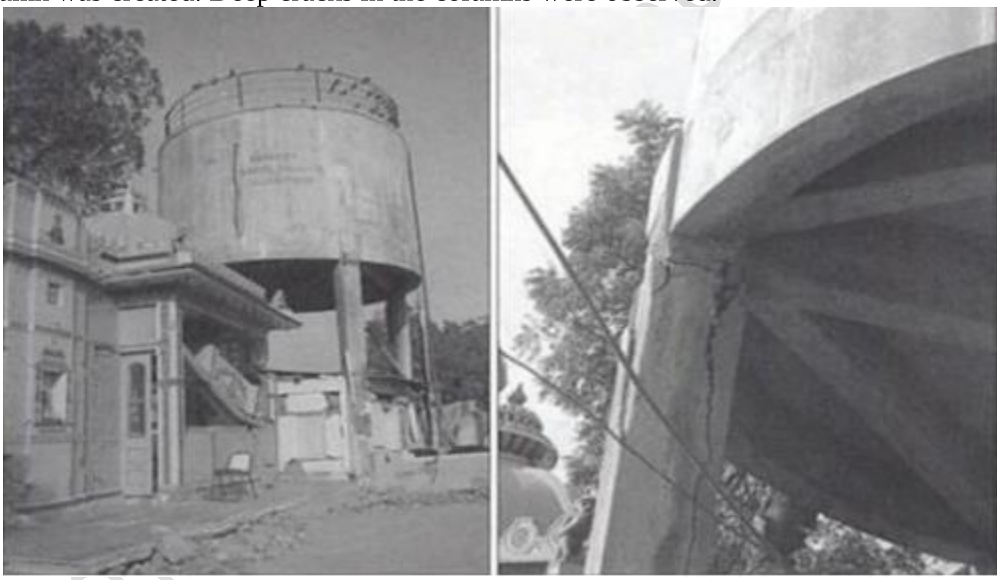

Figure: Elevated water tank of Gujarat, located in India

II. LITERATURE REVIEW

Rai Durgesh C., (2002) discuss unfavourable features related to shaft supported elevated tanks in high seismic areas and suggest retrofitting technique to overcome with seismic deficiencies. Also, raised the issue related to the weaknesses of the current Indian code (IS 1893, 1984) of seismic design and analysis of structures against other international codes and ignorance of Housner's two-mass idealization.

Rai Durgesh C., (2003) enclosed extreme vulnerability of current designs for staging of elevated water tanks under lateral forces considering illustration of the) earthquake. It recorded the flexure cracks in shaft staging at various lift and collapse of frame type tank staging due to not meeting the ductility and toughness requirements by brace and column member joints. Also, concluded that, currently IS: 1893-1984 underestimates the forces for water tanks and failures of framed staging was primarily due to non-compliance of ductility provisions of IS codes intended for earthquake resistance.

Bhadauria and Gupta, (2006) carried out a systematic in situ condition documentation survey, and assessment of water tank structures based on an empirical damage scale which contains component wise deteriorated water tank structures of rural as well as urban areas, which reflect the resultant deterioration process and also helps in validation of experimental and theoretical methods of performance evaluation.

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III. METHODOLOGY

The process comprises the simulation of a $100m^3$-liter water tank. These overhead water tanks are analyzed at staging heights of 15m, 25m accordingly. I'm observing a wind speed of 44 m/s. It is done using the Staad.Pro software for wind load dynamic analysis. The design of the water tank must be able to endure earthquake loads, which increases as the seismic zones increase.

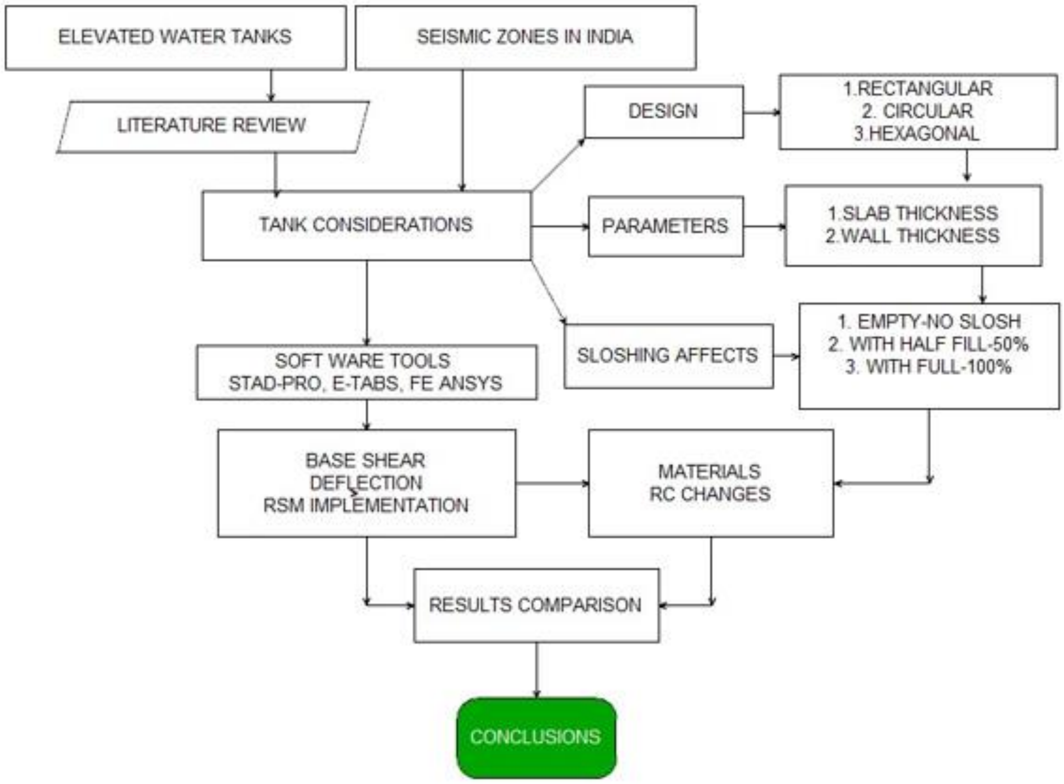

Figure: Research flow chart

The methodology includes the determination of water tank type, the measurement and linear dynamic analysis of the components in the water tank they are considering. The construction tank is analysed for various zones, i.e. heavy metal and soft ground strata, for two different underground structures. Seismic responses, such as base shear, base time and hydrodynamic pressure are tested for maximum tank conditions and tank empty conditions.

The elevated water tank involved in to two types of analysis,

- Equivalent Static analysis of elevated tanks of water
- Dynamic analysis of elevated water tanks

The traditional research focused on the conversion of seismic load into equal static load is an equivalent static analysis of elevated water tanks. Seismic loads were historically considered to be equivalent static accelerations that were altered by a variety of factors in terms of locations of earthquake, their soil properties, their normal structural frequency and their expected use. For the situation, i.e. tank full condition and tank empty condition, a Evaluated-water tank may also be analyzed. The tank can be idealized with a different mass structure for both conditions.

Design considerations

The rectangular container of $100m^3$ RC water has an internal diameter of 6 m. (including a freeboard of 0.3 m). Four columns with a diameter of 500 mm, and 4 horizontal brackets with a diameter of 500 mm by 250 mm are available on the RC frame, and also a top ring beam with a diameter of 250mm. The RC position has a beam with a diameter of 250mm. They are supported. The lowest level of supply is 12 meters high. The city is consistent with IS 13920 ductile detail. Stage columns are separated from the ground at a depth of 2m from a rectangular base. For any seismic zone, the tank is on medium soil. The concrete and steel stage grades are the grades M20 and Fe415 respectively. The density of the concrete is 25 kN/m3. Evaluate the tank for seismic loads. The method includes the selection of the tank type, the selection of its sizes, and the dynamic analysis by modeling the tank in one mass and two mass versions of zones 3 and 5 using the response speed strategy.

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Table: Parameters of Elevated Water Tank

Parameters	Value
Capacity of tank	500 m^3
Diameter of tank	10 m
Height of Cylindrical Wall	5 m
Thickness of Cylindrical Wall	150 mm
Height of staging	12 m
Height of Panel	3 m
Number of columns	8
size of column	450 mm dia
size of top ring beam	150x300 mm
size of bottom ring beam	450x800 mm
size of bracing	225x300 mm
thickness of bottom slab	225 mm
thickness of dome	75 mm
density of concrete	25 kN/sq.m
Response reduction factor	5
Importance factor	1.5 for water tank
Type of soil	hard soil

Soil type		unit	Soil type1	Soil type 2	Soil type 3	Soil type 4
Directions	r	m	0.50850	0.50850	0.5085	0.5085
	G_s	KN/m	1128920	58320	42240	19965.0
	Vs	-	0.450	0.20	0.30	0.350
Vertical	K_s	KN/m	4174940	148276.0	122736.0	62475.0
	C_s	KN.s/m	542.0	335.30	305.10	208.40
	m_s	$KN.s^2/m$	0.330	0.360	0.360	0.330
Horizontal	K_s	KN/m	3468110	159921.0	123092.0	59554.0
	C_s	KN.s/m	298.0	210.10	184.20	122.70
	m_s	$KN.s^2/m$	0.060	0.070	0.070	0.060

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 liters, 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 III on medium soil. For this study, concrete grade M30 and steel grade Fe-415 are taken into consideration. Staid Pro V8i was used to evaluate these models using Response Spectrum Analysis.

Table- : Parameters of Elevated Circular Tank

Particulars	Values or Dimensions
The Thickness of Top Dome	100mm
Rise of Top Dome	1.4m
Top Dome Radius at Base	8.0 m
Size of Top Ring Beam	250mmx250mm
Diameter of Cylindrical Wall	8.0 m
Height of the Cylindrical wall	4m
Dimensions and thickness of the cylindrical walls	150mm
Thickness of Bottom Slab	175mm
Size of Bottom Ring Girder	350mmx350mm
No. of Columns	6nos.
The distance between intermediate Braces	3.0 m

Size of Bracing	0.350mx0.450m
The Size of Columns	0.375mx0.375m

3D Rendering View of Tanks:


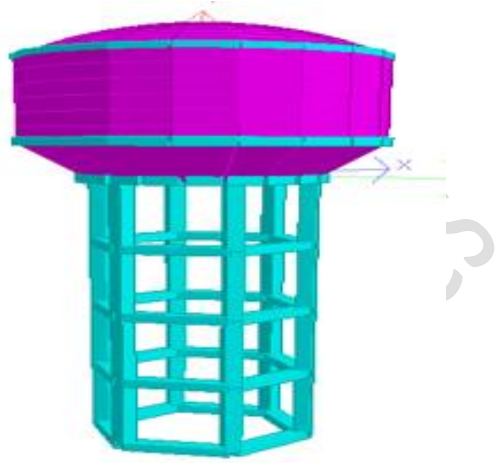

Figure: D model of Elevated Circular Tank Figure: Model of Elevated HH- intake Tank

IV. RESULTS AND DISCUSSIONS

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 III 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.

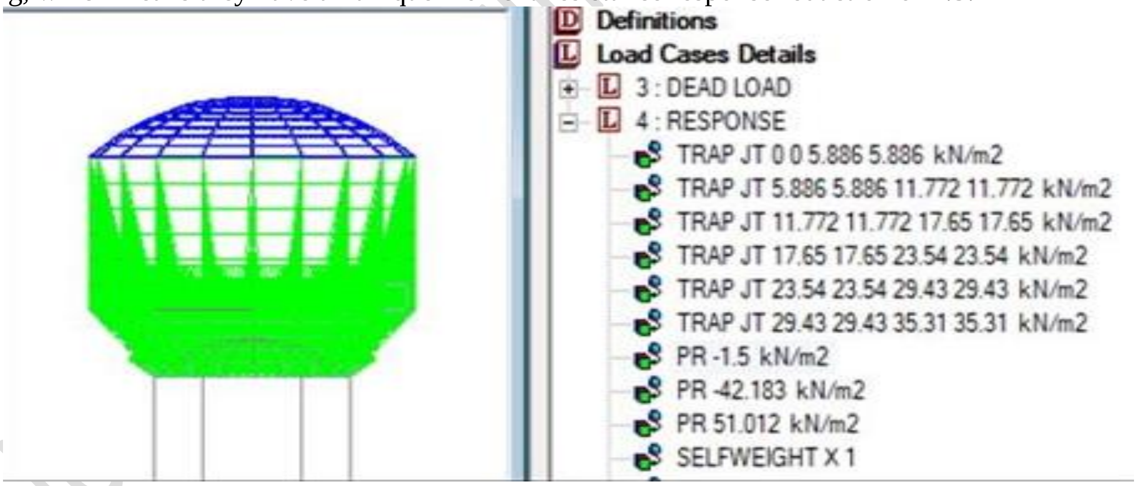

Figure: Water Load for Full Tank for HH- intake Tank

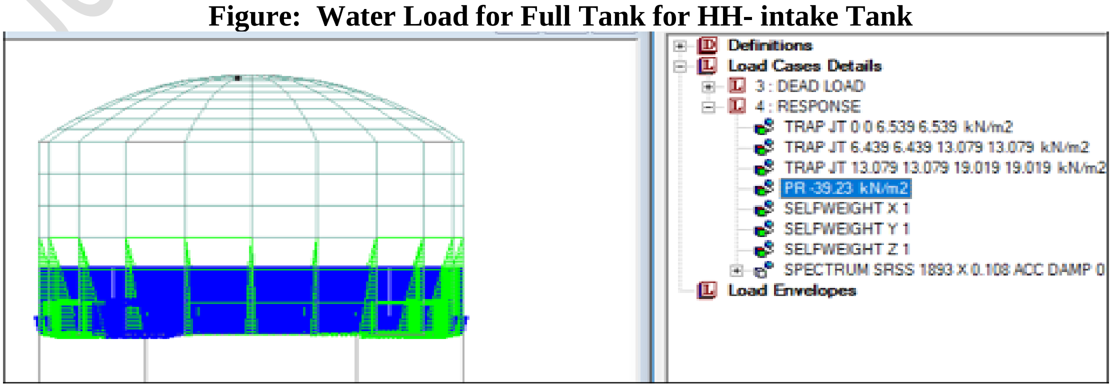

Figure. Water Load for Half Tank for Circular Tank

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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 staad.pro software is used to calculate base shear values for circular and H-intake models.

Table: Base Shear Values for Zone II

Base Shear Values for Zone– II,		
Water level sin tank	Circular Tank	H- intake Tank
	Fx(inKN)	Fx (inKN)
Empty Tank Level	75.31	81.15
Half Tank Level	81.13	112.17
Full Tank Level	98.14	125.88

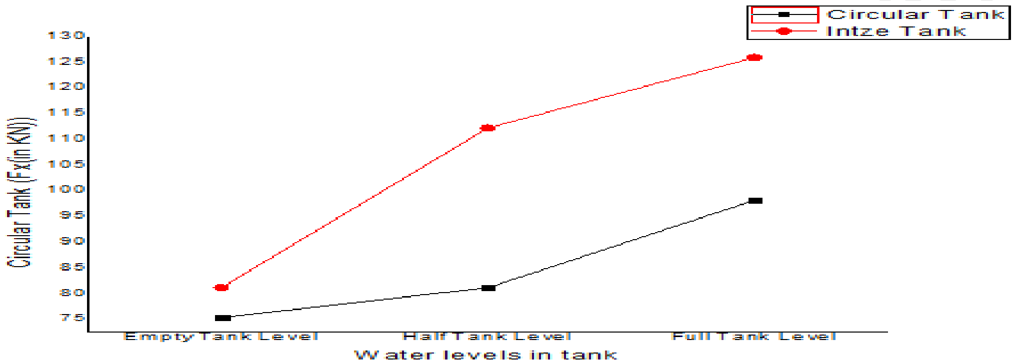

Chart: Bases hear values for circular tank and H- intake tank in zone II

Nodal Displacement:

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.

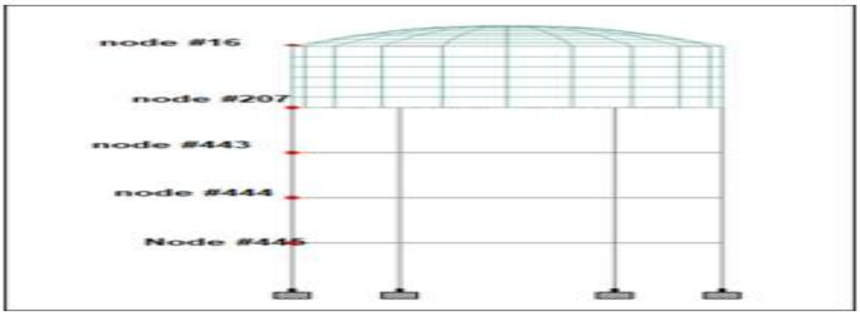

Figure: Nodes number sin circular tank

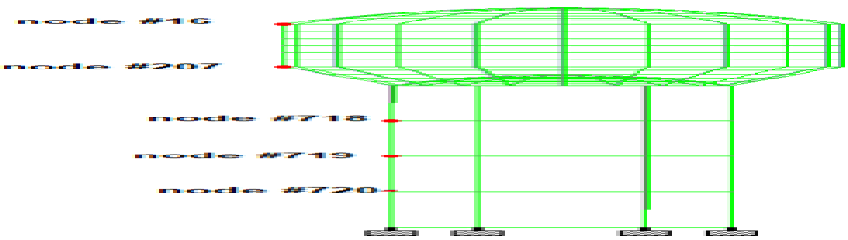

Figure: Nodes numbers in Intake tank

Table: Displace mint sin circular tank in zone II

Seismic Zone-II	
Response Spectrum Analysis of Elevated Circular Tank	
Node Numbers	Displacement sin mm

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	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

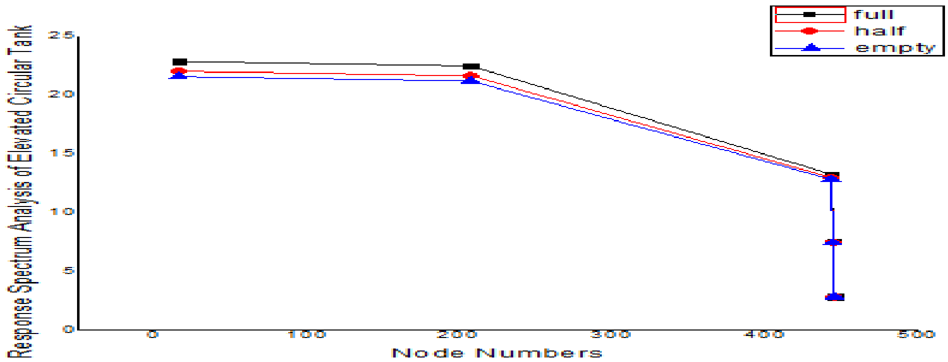
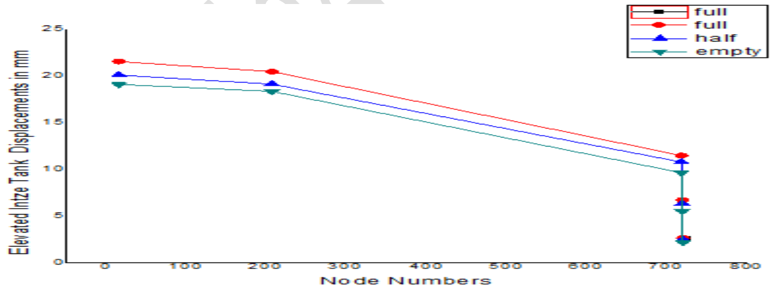


Table: Displacement sin H- in take tank sin zone II

Seismic Zone-II			
Response Spectrum Analysis of Elevated H- intake Tank			
Node Numbers	Displace men tsinmm		
	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



Graph: Response Spectrum Analysis of Elevated H- intake Tank

Data inputs

Results for Convective Pressure:

Convective Mode		
Mode	Frame Type	Shaft Type
1.00	2.09340	0.31858

Base shear for tank				
Soil type	Lumped mass model		Two mass model	
	Zone-II	Zone-III	Zone-II	Zone-III
Soft soil	60.82	121.64	84.46	206.29
Hardrock	40.54	81.09	55.3	124.59

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STAAD-Pro results

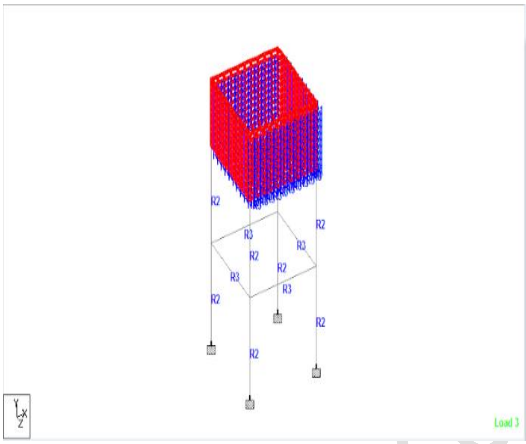
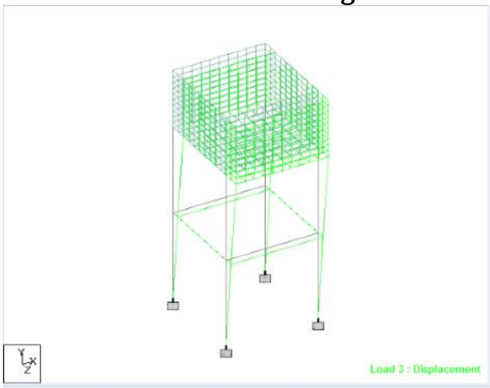


Figure: Whole structures modeling of elevated water tank, Applying load on elevated water tank



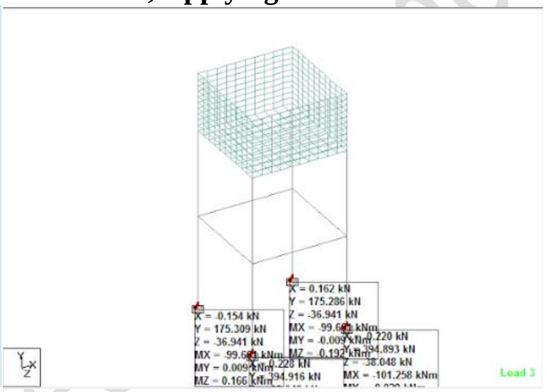
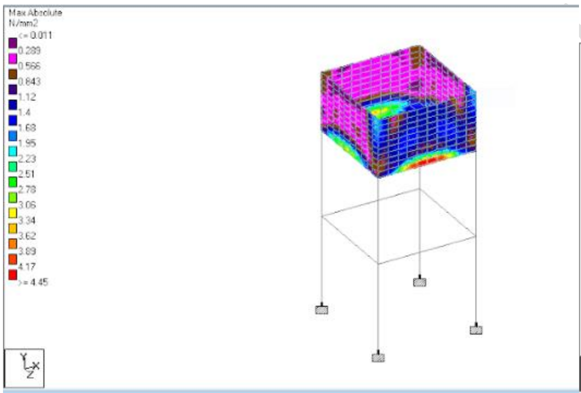


Figure: Displacement due to load figure: characteristics after displacement



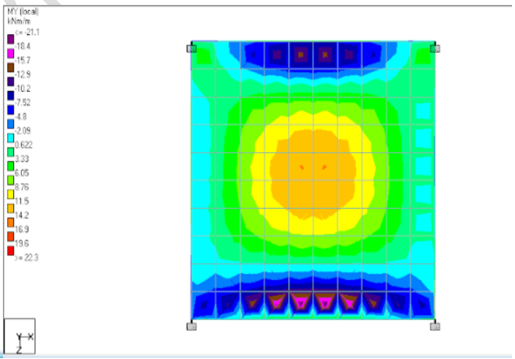
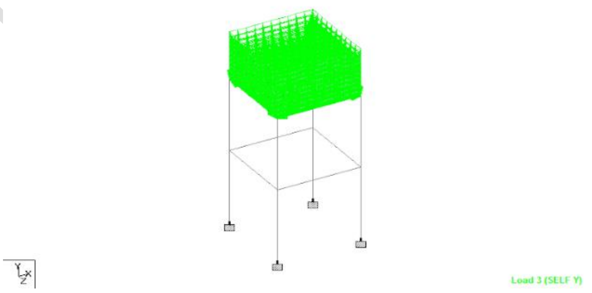
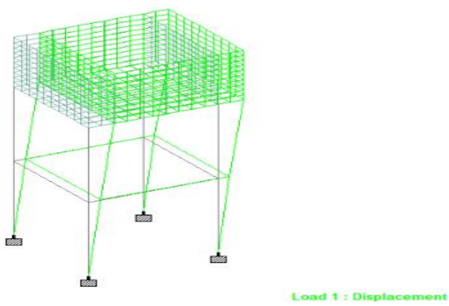
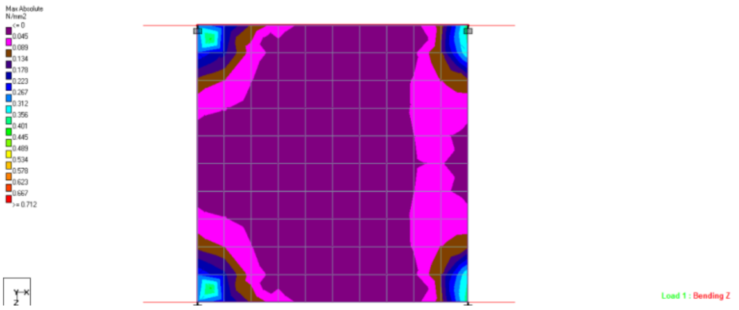


Figure: Maximum obstacle of the water tank Maximum yield of the water tank







Postprocessing | Steel Design | Concrete Design | Foundation Design | RAM Connection | Bridge Deck | Advanced Slab Design

All Relative Displacement | Max Relative Displacements

Beam	L/C	Length m	Max x mm	Dist m	Max y mm	Dist m	Max z mm	Dist m	Max mm	Dist m	Span/Max
1	1 EQ+X	5.000	-0.000	3.333	0.159	3.750	0.000	0.000	0.159	3.750	>10000
	2 EQ+Z	5.000	-0.000	4.167	0.002	2.083	0.000	0.500	0.002	2.500	>10000
	3 DL	5.000	-0.000	3.750	-0.093	2.500	0.001	0.500	0.093	2.500	>10000
	4 GENERATE	5.000	0.000	3.750	0.238	3.750	0.000	0.833	0.238	3.750	>10000
	5 GENERATE	5.000	0.000	3.750	-0.190	1.250	0.000	0.833	0.190	3.750	>10000
	6 GENERATE	5.000	0.000	4.583	0.192	3.750	0.001	0.667	0.192	3.750	>10000
	7 GENERATE	5.000	0.000	4.583	-0.250	1.250	0.002	0.583	0.250	1.250	>10000
	8 GENERATE	5.000	-0.000	3.750	-0.192	1.250	-0.001	0.333	0.192	1.250	>10000
	9 GENERATE	5.000	0.000	3.750	0.251	3.750	-0.002	0.417	0.251	3.750	>10000
	10 GENERAT	5.000	0.000	4.583	0.240	3.750	0.001	0.667	0.240	3.750	>10000
	11 GENERAT	5.000	0.000	3.750	-0.313	1.250	0.002	0.583	0.313	1.250	>10000
	12 GENERAT	5.000	-0.000	4.583	-0.240	1.250	-0.001	0.333	0.240	1.250	>10000
	13 GENERAT	5.000	0.000	3.333	0.313	3.750	-0.002	0.417	0.313	3.750	>10000
	14 GENERAT	5.000	0.000	4.583	0.145	3.750	0.001	0.667	0.145	3.750	>10000
	15 GENERAT	5.000	-0.000	4.583	-0.221	1.667	0.002	0.583	0.221	1.667	>10000
	16 GENERAT	5.000	-0.000	3.750	-0.145	1.250	-0.001	0.333	0.145	1.250	>10000
	17 GENERAT	5.000	-0.000	4.167	0.222	3.333	-0.002	0.417	0.222	3.333	>10000
2	1 EQ+X	0.500	0.000	0.458	-0.006	0.208	0.000	0.333	0.006	0.208	>10000
	2 EQ+Z	0.500	0.000	0.458	-0.000	0.458	-0.000	0.333	0.000	0.458	>10000
	3 DL	0.500	-0.000	0.458	-0.003	0.333	-0.001	0.333	0.003	0.333	>10000
	4 GENERATE	0.500	0.000	0.333	-0.010	0.208	-0.000	0.083	0.010	0.208	>10000
	5 GENERATE	0.500	-0.000	0.458	-0.008	0.250	-0.000	0.083	0.008	0.250	>10000
	6 GENERATE	0.500	0.000	0.375	-0.008	0.208	-0.000	0.417	0.008	0.208	>10000
	7 GENERATE	0.500	-0.000	0.417	-0.010	0.250	-0.001	0.333	0.011	0.250	>10000
	8 GENERATE	0.500	-0.000	0.417	-0.007	0.167	-0.000	0.750	0.007	0.167	>10000
	9 GENERATE	0.500	0.000	0.250	-0.006	0.167	0.001	0.333	0.006	0.167	>10000
	10 GENERAT	0.500	0.000	0.458	-0.010	0.208	-0.000	0.417	0.010	0.208	>10000
	11 GENERAT	0.500	-0.000	0.417	-0.013	0.250	-0.002	0.333	0.013	0.250	>10000
	12 GENERAT	0.500	-0.000	0.458	-0.009	0.250	-0.000	0.750	0.009	0.250	>10000

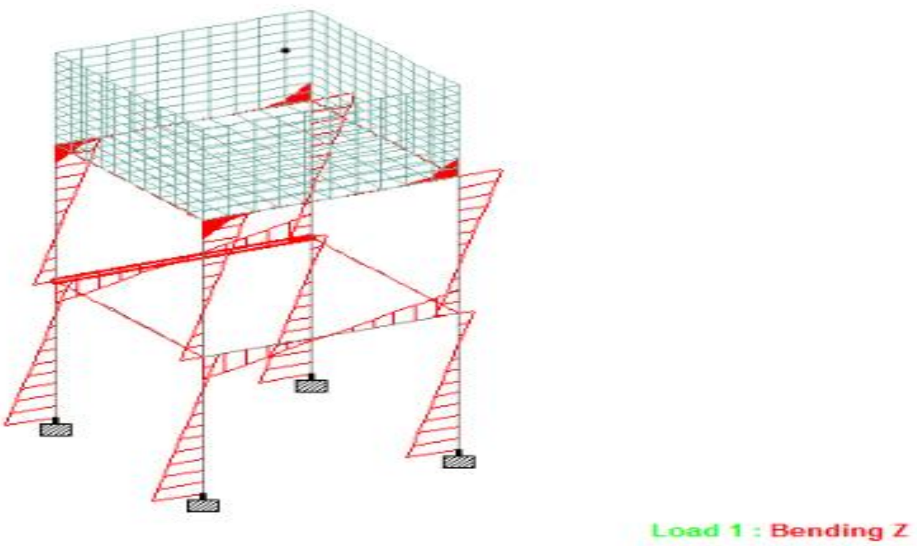


Figure: Forces occurring nodes

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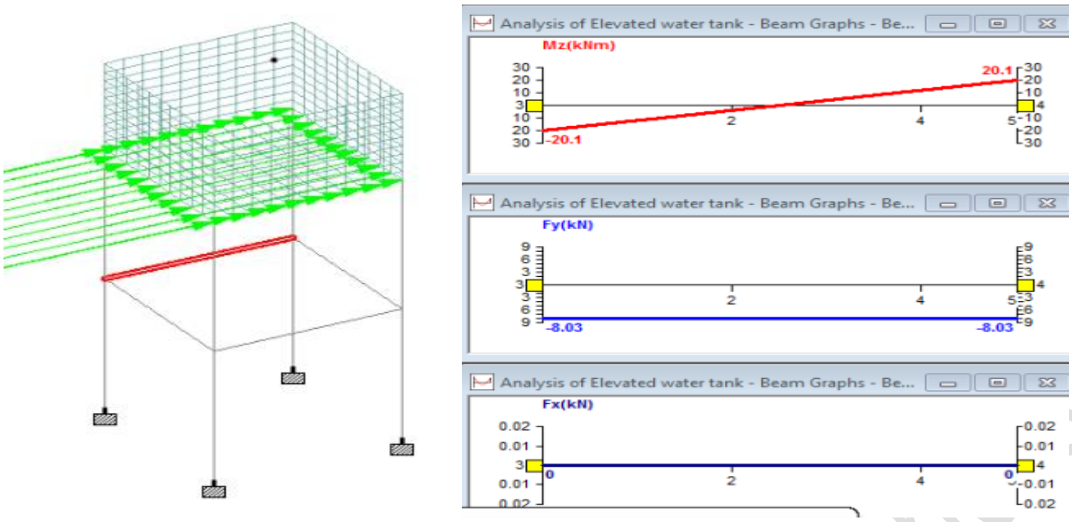

Figure: represents bending forces and deflections

STAAD PRO

Nodal Displacement						
Zone	Horizontal		Vertical		Horizontal	
	Max Z	Min Z	Max Z	Min Z	Max Z	Min Z
3	7.709	-7.709	0.221	-5.908	7.711	-7.711
5	17.344	17.344	0.496	- 5.908	17.35	-17.35

STAAD PRO Bending Moment

	FxkN	FykN	FzkN
ZONE			
3	84.787	186.296	84.787
5	190.771	419.166	190.771

E-Tabs:

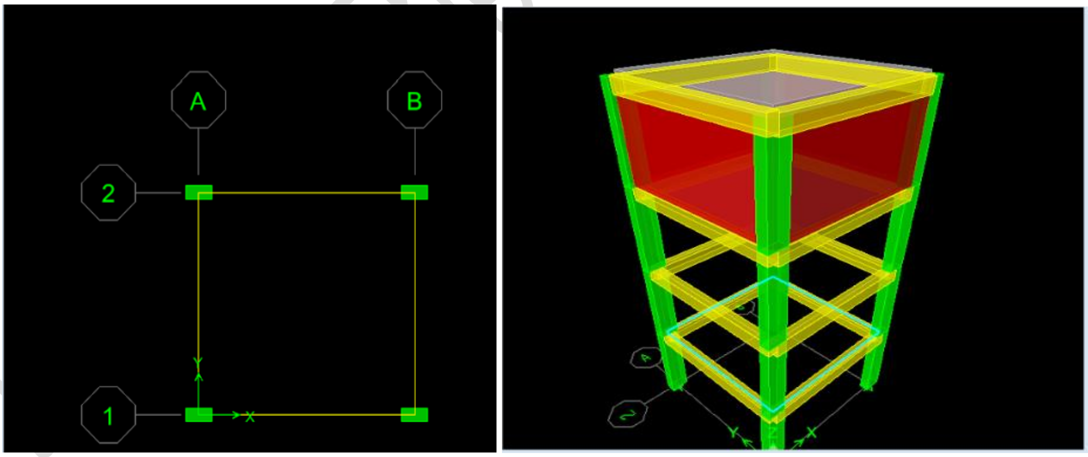

Figure: 3-point support elevation of the tank3D view of the tank

Conclusion:

Many good innovations and developments have been produced for the capacity of water in various designs and forms for water tanks, which are highly significant for open utility and modern structure. The following are the results of the Seismic Analysis of the Elevated Water Tank:

1. Because of the zone factor, response reduction factor, etc., the base shear of a full water tank and an empty water tank are both increased in seismic zone II-III.
2. Base shear in perfect working order the tank is slightly higher than an empty tank because to pressure difference or the absence of water.

3. Because of the zone factor, response reduction factor, etc., the displacement of a full water tank and an empty water tank are enhanced in seismic zones II-III.
4. When the tank is full, the wall of the tank has the maximum and smallest nodal deformations.
5. Comprehensive and empty water tanks are subjected to higher shear and bending moments due to the zone factor, response reduction factor, etc., in seismic analysis.
6. In a full tank, the shear force and bending moment are slightly larger than in an empty tank because of the lack of water or hydrostatic pressure.

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