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Response of Overhead Water tank staging considering Fluid-Structure-soil Interaction

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***ABSTRACT:* R*C Elevated Water tanks are one of the important and indispensable Structure at time of Earthquake and especially after the earthquake. During the Past Study of many Failure of ESR. For this reason, relating to Earthquake behavior of storage tanks has attracted attention of many researchers. Current Approach analysis does Not Consider the Behavior of Soil Under Neath the Structure it's Know as SSI.Which Cases Affect of EVT Significantly during the time of Earthquake. The main aim of Study is to behavior of EVT at under different type of soil-layered condition by Using FE-ANSYS Software to Obtained Result of different Stress pattern and Deformation and Von-Mises Stress and the results will be compared. Considering the Parameter of Staging System for EVT and different filling (Empty, Half, Full) condition and five Kinds of Soil In layered system softer soil (type-1) is placed just blow the foundation and then soil type-2, type-3, type-4 is medium soil and soil type 5 is placed at bottom and have been used in RC EVT.*

Key words: *RC Elevated water tank Static analysis, dynamic analysis, interaction of soil and structure, Fluid, Finite element Method,FE-ANSYS Software.*

1. INDRODUCTION

RC elevated Storage reservoirs and RC overhead Water tank are Generally used to Supply water, liquid petroleum, petroleum products and similar liquids and also used Fire Preservation. In The motion of the Storage reservoirs is the without Consider of the Liquid nature of the product is due to lateral or Circumduct Motion. lateral and Circumduct vibrations due seismic motion. These lateral forces induce there are two different types of vibration in the water of the tank. Upper portion of tank container is in including sloshing effect that's convective and bottom lower portion is call impulsive. Generally All tanks are designed as crack free structures to Discharge any leakage because of one of the major problems that may have to failure of these structures is due to earthquakes. Therefore the analysis of RC elevated Water tank must be carefully performed, so that safety can be Confident when earthquake occurs and the Reservoirs remain Utility even after earthquake.RC Elevated water tank is different irregular part but higher Eucharist is at the top of EVT like as container is so more sensitive area to any seismic load, especially due to an earthquake. Structural seismic behavior deals with methods to determine the stresses pattern and deformation of a structure subjected to dynamic loads. A stress analyst generally ignores the influence of the settlements of layered supporting soil on the structural behavior of the super structure of the tank. In general, however, the structure will be interaction with the surrounding Layered soil. In this paper Earlier studies have to indicated that interaction behaviors and effects are actually significant, particularly for the tank resting on highly compressible settlement soils.

Theory of Soil-Structure Interaction

Soil Structure Interaction is the Interaction between Structure and soil it's called Soil Structure interaction. Soil structure interaction involves two mechanisms, (1) kinematic interaction and (2) inertial interaction. The “free-field” is the space far Sufficient from any understructure that the ground locomotion (called free-field ground locomotion) is not affected by the locomotion of nearby structures. In general, understructure locomotion do not match the free field ground locomotion at indicate distance that are shorter than the substructure dimensions. This effect is termed kinematic interaction. On the other hand, the structure has a wide mass and transmits inertial motion to the soil which induces soil displacement. This phenomenon is termed as inertial interaction (Wolf1985).

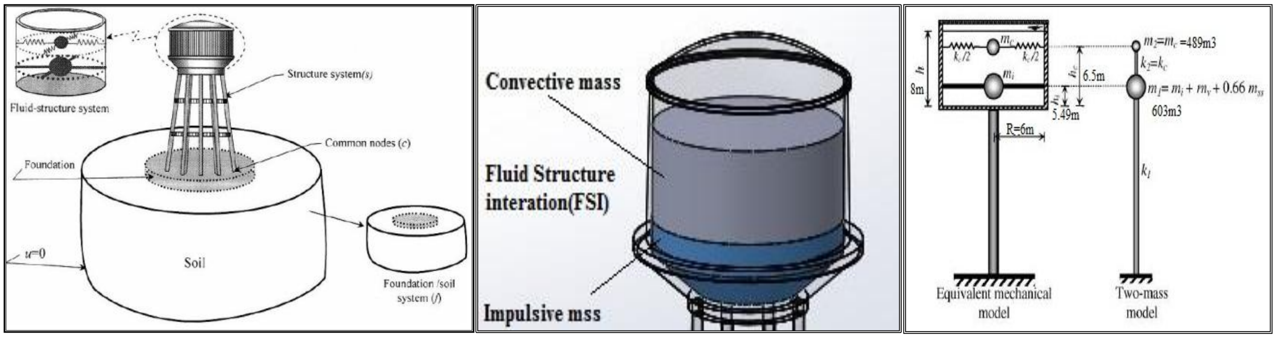


Figure 1 Soil-Structure Interaction and FSI (Source.Livaoglu and A.Dogangün)

A structure interaction with its surrounding soil layered and this causes changes in effect of dynamic waves. In Dynamic analysis, interaction between structure and soil should be considered. Dynamic response of soil-structure interaction system is a purpose of three constituent, seismic parameters of site, motion and stimulation and seismic model of the system when it is affected by a seismic loading. seismic parameters of the site include supporting layered soil modulus of elasticity(E), density(D), Soil Poisson coefficient(ν), and damping in soil. Damping is also divided into two different type internal and radiation damping. Internal damping is caused by transit of motion waves through soil Layered and can be consider as factor is loss of energy due to residue in soil but radiation damping causes energy loss due to release of waves from footing of the structure to half-space and for this reason, such algebra dispensation of elastic motion is called geometrical damping. Proper seismic analysis of reaction of soil-structure interaction system requires for there are different components of the system and excitations which include determination of free field motion. Earth motion without presence of structure and calculation of scattering of earthquake waves due to the soil and structure interaction system. According to principle of superposition, excitations resulting from free field and interaction analysis with each other are added and seismic model of the system includes relation of dynamic model of the foundation environment. there are Many models are available for consideration and analysis of interaction. Soil and structure interaction is generally classified into two direct and sub-structure approach and each is complicate separately.

2. LITERATURE REVIEW

George W.Housner (1963) The aim of this paper is to investigate Dynamic behavior of Water tank. Some simple expressions are given for the pertinent dynamic properties of tanks with free water surface. A simplified dynamic analysis is indicated for the response of elevated water tanks to earthquake ground motion.

R.Livaoglu and A.Dogangün (2006) The main focus of the current study is Simplified Seismic Analysis Procedures For elevated tanks Considering fluid–Structure–Soil interaction. Single lumped-mass model four different type of water tank. Ten models for the seismic design is evaluated by using mechanical and finite-element modeling techniques consider. The models defined here, single lumped-mass models underestimate the base shear and the overturning moment.

R.LivaogluandA.Dogangün(2008)The aim of this paper is to investigate how the soilstructure interaction affects sloshing Response of elevated water tank. For this purpose,the elevated tanks with (frame,Shaft)two different types of supporting systems which are built on six different soil profiles are analyzed for both embedded and surface foundation case consider. By use of Ansys FE Software. To Calculate Roof displacement ,Sloshing displacement, Base shear Forces With Embedment and non Embedment Case of foundation.

H.Shakib(2008)In this research,Seismic vulnerability of elevated water tanks using Performance based-design Analyzed in dynamic time history and the tank's responses including Under seven earthquake records consider. Base shear, overturning moment, tank displacement, and sloshing displacement under these seven record have been calculated. And then the results have been compared and contrasted.

H. Shakib, F.Omidinasab and M.T. Ahmad (2010) In the present work, three reinforced concrete elevated water tanks, with a capacity of 900 cubic meters and height of 25, 32 and 39 m were subjected to an ensemble of earthquake records. The behavior of concrete material was assumed to be nonlinear. Seismic demand of the elevated water tanks for a wide range of structural characteristics was assessed. The obtained results revealed that scattering of responses in the mean minus standard deviation and mean plus standard deviation are approximately 60% to 70 %. Moreover, simultaneous effects of mass increase and stiffness decrease of tank staging led to increase in the base shear, overturning moment, displacement and hydrodynamic pressure equal to 10 - 20 %, 13 - 32 %, 10 - 15 % and 8 - 9 %, respectively.

M. Moslemi, M.R.Kianoush, W.Pogorzelski,(2011) The main focus of the current study is to evaluate the performance of elevated tanks under seismic loading. In this study, the finite element (FE) technique is used to investigate the seismic response of liquid filled tanks. The fluid domain is modeled using displacement-based fluid elements. Both time history and modal analyses are performed on an elevated tank. Using the FE technique, impulsive and convective response components are obtained separately. Furthermore, the effect of tank wall flexibility and sloshing of the water free surface are accounted for in the FE analysis. In this study complexities associated with modeling of the conical shaped tanks are discussed. This study shows that the proposed finite element technique is capable of accounting for the fluid-structure interaction in liquid containing structures. Using this method, the study of liquid sloshing effects in tanks with complex geometries such as conical tanks is made possible. The results of this

Uma Chaduvulaa, Deepam Patela, N Gopalakrishnanb,(2012) An experimental investigation for a 1:4 scale model of cylindrical steel elevated water tank has been carried out on shake table facility at CSIR-SERC, Chennai. Elevated steel water tank consisted of combined horizontal, vertical and rocking motions, for a synthetic earthquake excitation for 0.1g and 0.2g accelerations, with increasing angle of rocking motion is consider. The impulsive and convective base shear and base moment values increase with increase in earthquake acceleration. Using various codes available on water tanks, the recorded experimental results were used to Calculate and compare the base shear, base moment, pressure variation in the tank.

Pallavi S.Dhama, Prof.V.R.Rathi, Prof.Dr.K.B.Ladhane (2014) In the present study attempt have been made to study the effect of soil structure interaction (SSI) on the performance of water tank. Cohesive type of soil has been considered. Three dimensional FEA is carried out using Abaqus software. The results obtained for water tank considering SSI are compared with water tank without SSI.

Neeraj.Tiwari and MS.Hora (2014-2015) The aim of this paper is interaction analysis of intze tank-fluid-layered soil system and transient analysis of elevated intze water tank fluid- soil system The conventional analysis (non-interaction analysis) of over head water tank assumes that columns rest on unyielding supports. In reality, the structure is supported by deformable soil strata which deforms unevenly under the action of loads and hence causes redistribution of forces in the components of overhead water tank. In the present work, 3-D interaction analysis of intze type water tank-fluid-layered soil system is carried out using ANSYS software to evaluate the principal stresses in different parts of the tank and supporting layered soil mass. The resultant deflections, Von-mises stress, neural frequency of the tank are calculated and also evaluate acceleration by Transient analysis under different filling conditions of the intze tank. The intze tank, supporting frame, foundation and soil mass are considered to act as single compatible structural unit for more realistic analysis. The tank, foundation and soil are considered to be follow linear stress-strain relationship. The natural frequency of the tank is evaluated for different filling conditions and comparison is made between the non-interaction and interaction analyses.

3. STATEMENT OF PROBLEM

In this study, an RCC Overhead Intze water tank with Container capacity of $1000m^3$ resting on supporting layered soil mass and subjected to Earth gravity and water mass loading is analyzed. The elevated tank has a frame and shaft supporting on Rc Staging number of 8 columns are connected by the enclosing beam at usually, at 4m,8m,12m and 16m height level and also use Shaft supporting staging is 16 m height level is connected to below the foundation. The container is full filled with water. The container and the supporting structure are being used in most part of India located in earthquake prone zone. To investigate underneath the Soil Structure interaction conduct, the interaction.

The dimension of geometric properties of RC intze tank, foundation, and soil Strata mass are provided in Table-1. The material properties of RC tank, foundation, and soil mass are provided in Table-2 Table-3 provides loading data on different Structural parts of the tank which include self weight and imposed load due to full filled water.

Table-1. Geometrical properties of tank, foundation and soil mass.

Name of component	Description	Data/Value
Intze water tank	Inside diameter of tank (D)	12.0 m
	Average depth (0.75D)	9.0 m
	Height of cylindrical portion of tank (2/3D)	8.0 m
	Top dome thickness	0.2m
	Bottom dome thickness	0.25m
	diameter of tank staging (d)	7.2 m
	Height of top dome (0.15 to 0.20D)	2.0 m
	Height of conical dome (0.2D)	2.5 m
	Height of bottom dome (0.15D)	1.8 m
	Diameter of staging (0.6 D)	7.0 m
	Bracing at 0.3D c/c	4.25 m
	Dimension Circular ring beam	600mm x 650 mm
	Dimension of bracing beam	500 mm x 700 mm
Foundation	Diameter of foundation	12 m
	Depth of foundation	1.5 m
Soil	Semi-finite extent of soil mass	21 m x 14 m

Table-2. Material properties of tank and soil mass.

Material Type	Young modulus(N/mm^2)	Poission's Ratio	Density (kN/m^3)
Concrete	25490	0.20	24.00
Soil type-1	35000	0.28	17.10
Soil type-2	40000	0.29	17.40
Soil type-3	45000	0.30	18.00
Soil type-4	55000	0.32	19.20
Soil type-5	60000	0.33	19.90

Table-3. Loads on various parts of tank.

Component	Description	Dead load + Live load
Intze water tank	Top dome	3.85 kN/m^2
	Maximum hoop tension at base of side wall	480.00 kN/m
	Bottom ring beam	86.34 kN/m

	Total load at base of conical dome slab	110.50 kN/m^2
	Total load at base of spherical dome	92.50 kN/m^2
	Total design load on circular girder	753.00 kN/m
	Total vertical load on each Column	2234.64 kN
Foundation	Axial load on all columns	19274.40 kN

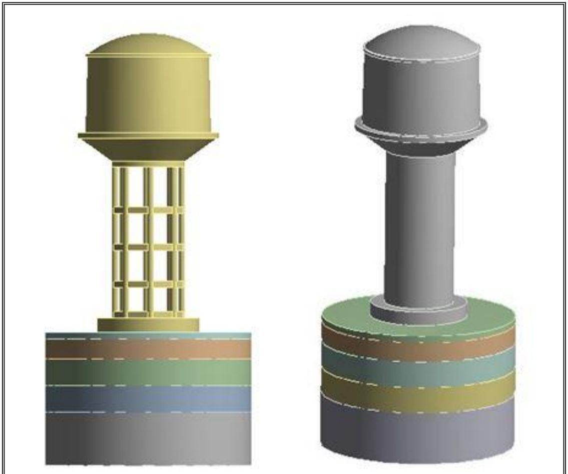


Figure 1.1 Frame type staging and shaft type staging of EWT

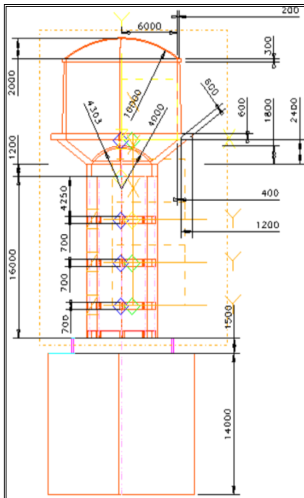


Figure-2. Geometry and dimensions.

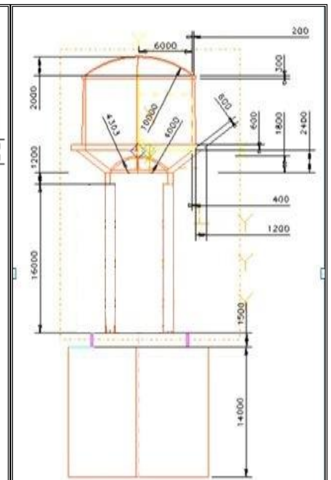


Figure-2. Geometry and dimensions.

3.1 Calculation for earthquake (Seismic) load

3.1.1 Centre of gravity of empty tank

Taking moment of weight of element about bottom of circular girder Centre of gravity = 30074.7/5481.5 = 5.49 m above bottom of circular girder..

3.1.2 Centre of gravity of full tank

Taking moment of weight of element about bottom circular girder. Centre of gravity = 103722/15967.5 = 6.5 m above bottom of circular girder.

4. FINITE ELEMENTMODELING

The Non interaction analysis and linear interaction analysis (LIA) of the problem is carried out using FE- ANSYS software. The top dome, Top ring beam, side wall, bottom ring beam, conical dome spherical dome, circular girder , circular ring beam, column, foundation and soil mass are discredited with TETRAHEDRON element which is a higher order 3-D 10-node quadratic element. TETRAHEDRON has a quadratic displacement modeling and is well suited for base asymmetrical meshes. The quadratic element is defined by 10 nodes having each node three degrees of freedom convectional in the x, y, and z directions.

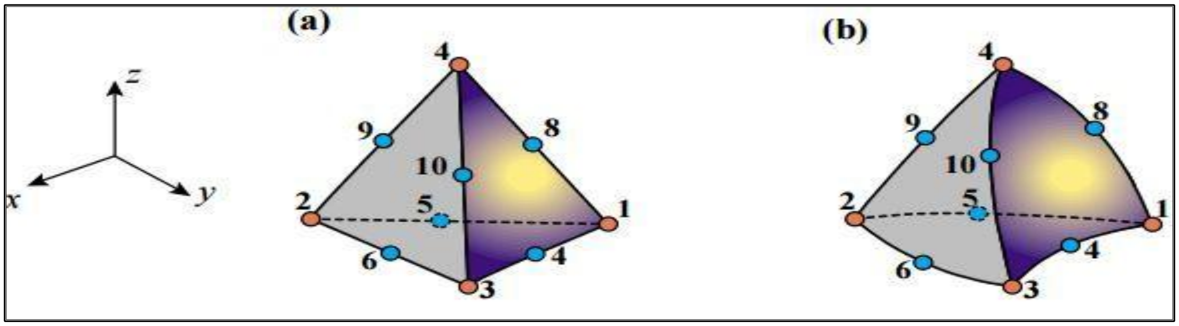


Fig-3 Tetrahedron element

The quadratic element has more plasticity, hyper elasticity, creep, stress pattern, large displacement and large strain capabilities. It also has mixed formulation capability for simulating displacement of nearly unyielding elasto-plastic materials, and fully unyielding hyper elastic materials. The structure of the water tank and soil mass are modeled with the TETRAHEDRON element as shown in Figure-4 and

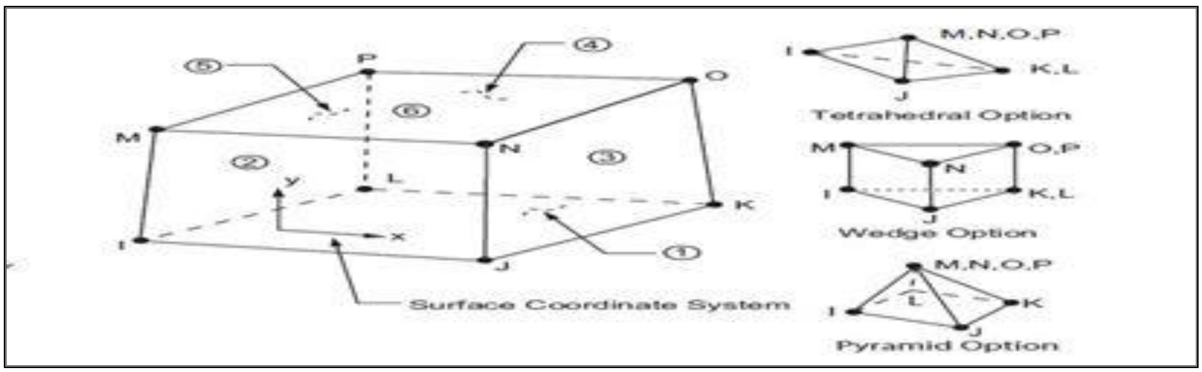


Fig-3.8-Nodel hexahedral element

fluid within the container of tank are modeled with the 8-Nodel hexahedral (Acoustic-3D) as shown in Figure-3 8-Nodel hexahedral is used for modeling the fluid mass and the consolidate in fluid/structure interaction problems. The governing equation for acoustics, namely the 3-D motion equation, has been disgrace taking into account the coupling of acoustic pressure and structural motion at an unrestricted variable in a frequency distribution per node convectional in the knobs x, y and z directions.

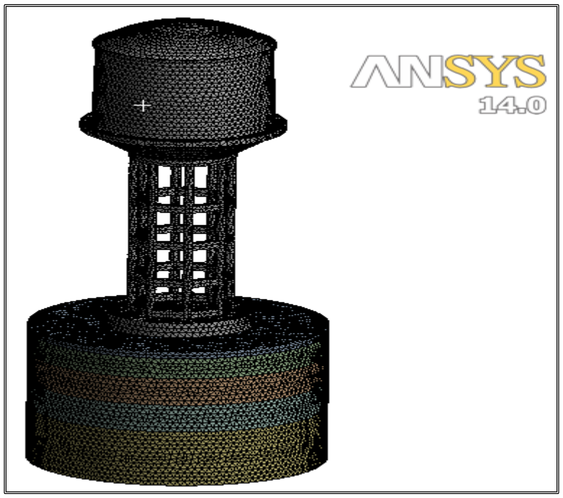


Fig-4 Mashing of tank with soil by FEM

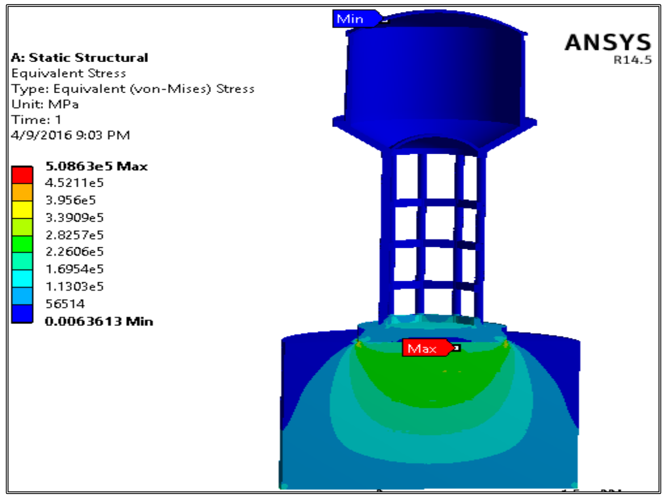


Fig-5 Formation of Pressure bulb

pressure. The convectional, however are applicable only at nodes that are on the interface. The rate of change of velocity effects, such as in sloshing motion effect of water may be included. The element has the ability to include damping of sound tendency to compulsive material at the interface as well as damping within the water. The element can be used with other 3-D structural elements to perform unbalanced or damped modal, and full transient method analyses. If there is no structural motion effect, the element is also applicable to modal analyses. The finite element putting values of a continuous set of data into groups of the problem is shown in Figure-4.

The semi-infinite area of the soil strata is considered to be of 21m diameter at top and 14m depth which is achieved by trial and error. The area of soil mass is decided where vertical and horizontal stresses Pattern are found to be negligible due to loading on the superstructure. The vertical movement in soil mass are steady at the bottom boundary whereas horizontal movement are steady at vertical boundaries. show in fig-5.

It is found that for uniformly loaded circular area the vertical pressure intensity becomes negligible at a distance of 5 times the diameter of raft in the vertical direction and nearly 3 times the diameter in the horizontal direction. The soil mass is idealized as isotropic, homogeneous. The element size is taken as 300 mm. The soil mass is discredited with finer meshes in close vicinity of foundation where stresses are of higher order.

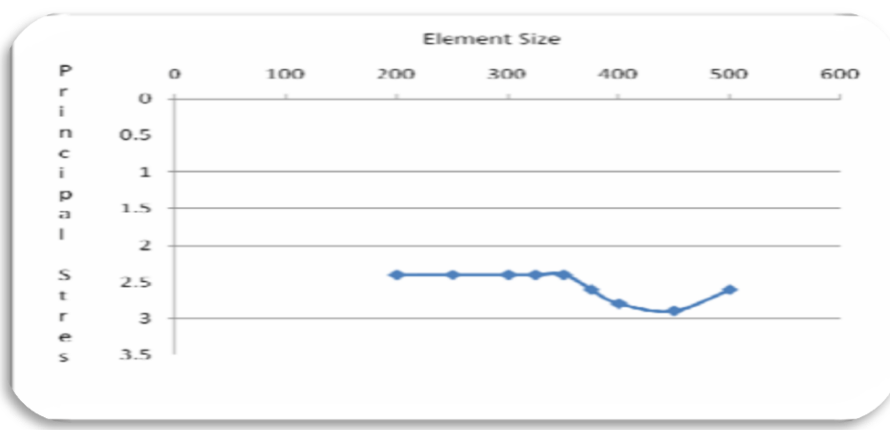
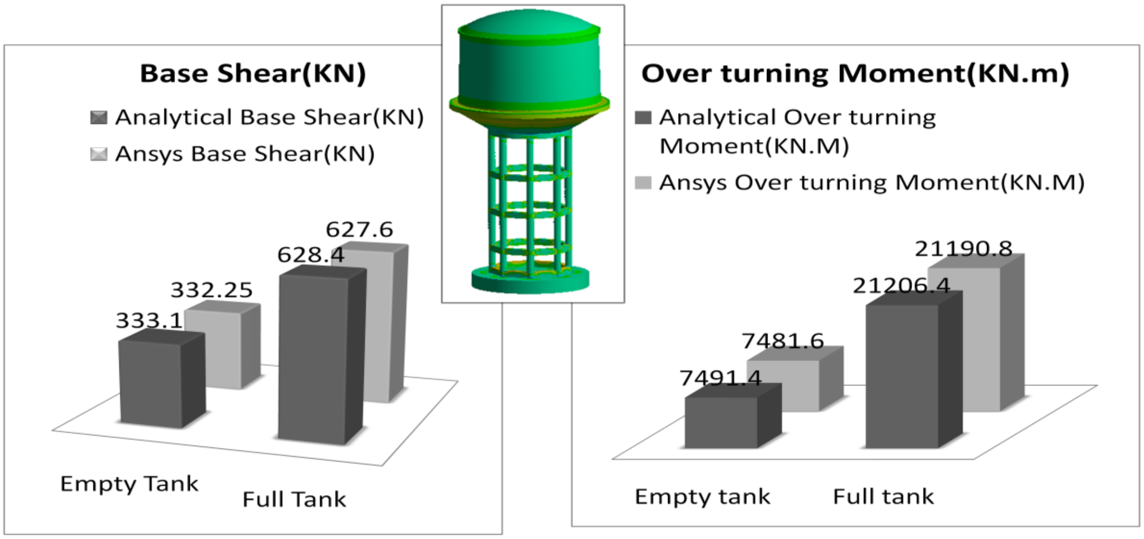


Figure-6. Plot of element size and major principal stress.

5. VALIDATION OF RESULTS



5.1.STATICAL ANALYSIS VALIDATION OF PROBLEM (NIA)

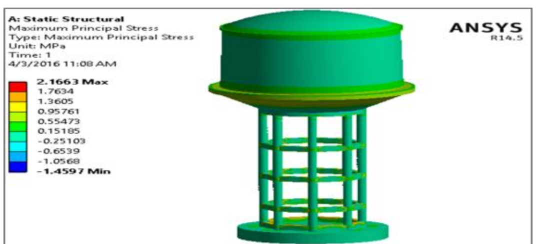


Fig-9Major principal stress in the interaction system

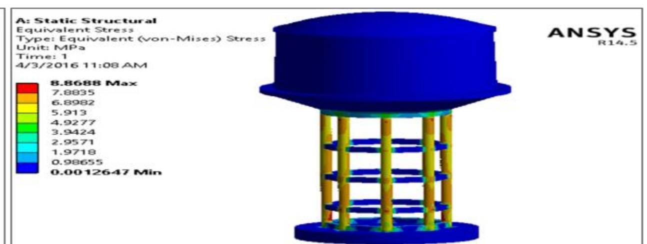


Fig10. Von-Mises stress in the interaction system.

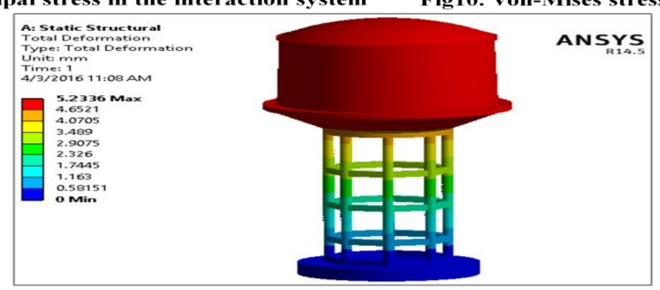


Fig 11.Deformation in the interaction system.

The results obtained by the FE-ANSYS software are validated with the results obtained by analytical method using IS-code method for the same geometry, material properties and loading conditions.

Table-4.Comparison of major principal stress in various components of water tank for non-interaction analysis.

S. No.	Component of the tank	Major principal stress N/mm2		
		Analytical values (I S code) (1)	FEM values NIA (2)	% Difference (1) and (2)
1	Top dome	0.335	0.3259	2.98%
2.	Side wall	0.6923	0.7043	-1.73%
3.	Bottom ring beam	0.7426	0.72782	1.99%
4.	Conical dome	1.0923	0.9986	8.578%
5.	Spherical dome	0.8960	0.8765	2.176%
6.	Bottom Circular girder	2.146	2.168	-1.025%
7.	Column	1.7352	1.7136	1.24%

Table-4 shows the values of major principal stress obtained by analytical method using IS-code) and finite element method (FEM). The values are found to be in close agreement. The percentage difference between analytical values and FEM values are found to be less than 8.57% for all components, and the values obtained are found to be within permissible range. It is found that maximum value of major principal stress occurs in the bottom circular girder, that's why this is a critical component of the tank. using added mass approach for fluid-structure interaction with the distributed mass techniques. An equivalent cylinder is considered.

6.INTERATION ANALYSIS

In present analysis is to define Maximum principle stress , von-mises stress and deformation of all component of structure and also to define ten mode shape with different filling condition ,Natural Frequency in various component of for the estimation of equivalent masses and stiffness of fluid. The impulsive mass and Convective mass make in FE-ansys modeling software. In the present analysis the hydrodynamic pressure distribution acting on container wall is estimated by (Housner).In present work water mass is behavior like in gravity mode. The damping values for the reinforced concrete are taken as 5% for the impulsive mode and 0.5% for the convective mode as recommended in most of the literature. The analyses are also carried out on layered model considering five different fluid structure soil Interaction is evaluate NIA and LIA+FSI and discuss about sub equation. Five different types of soil (Type-1 to Type-5) as supporting media. The soil properties consider are provide in table-2.

6.1 STATICAL ANALYSIS FOR FRAME STAGING (LIA+FSI)

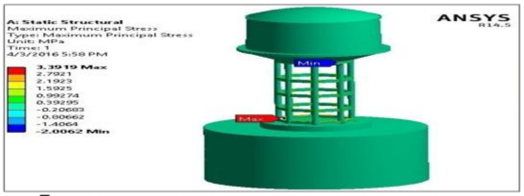


Fig-12Major principal stress in the interaction system

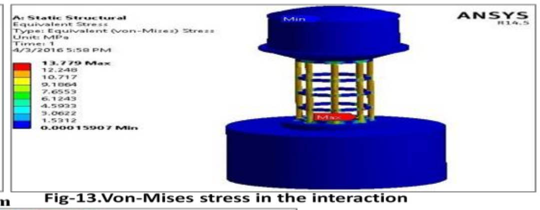


Fig-13.Von-Mises stress in the interaction

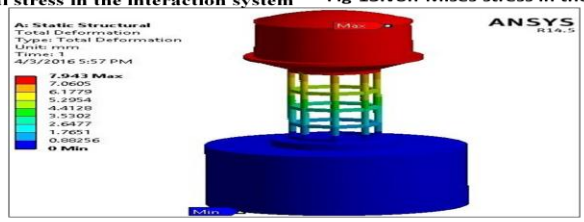
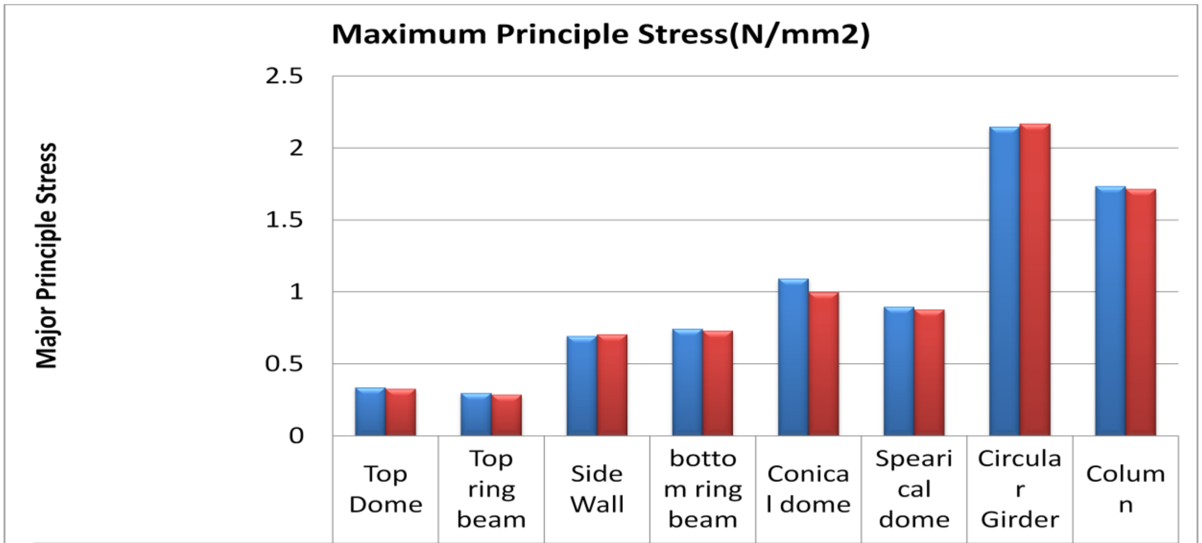


Fig-14 deformation in the interaction system.

Table 5. Statical analysis for freme elevated water tank

S. No.	Component of the tank	Major principal stress N/mm2				
		Analytical values (I S code) 1	FEM values NIA(2)	FEM values LIA+FSI	% Difference in (1 and 2)	% Difference in (NIA and LIA+FSI)
1	Top dome	0.335	0.3259	0.2341	2.98%	28.16%
2.	Side wall	0.6923	0.7043	0.2851	-1.73%	59.52%
3.	Bottom ring beam	0.7426	0.72782	0.3056	1.99%	58.01%
4.	Conical dome	1.0923	0.9964	1.1279	8.578%	-13.1%
5.	Spherical dome	0.8960	0.8765	0.5135	2.176%	41.41%
6.	Circular girder	2.146	2.168	3.3391	-1.02%	-54.1%
7.	Column	1.7352	1.7136	2.6385	1.245%	-53.98%
8.	Foundation	-		1.182		
9.	Soil	-		0.08230		

Table-5 shows the values of of the maximum principal stress in various components of the interaction system and analytical values (IS- Code). The values of maximum principal stress obtained using analytical method and FEM are found to be in close agreement. The interaction analysis causes significant decrease in the maximum principal stress in top dome, side wall, bottom ring beam and column whereas significant increase is found in the conical dome, spherical dome and circular girder. The interaction analysis causes significant decrease of nearly in the maximum principal stress in the top dome, 28.16%in the side wall, 59.52% in the bottom ring beam and 58%in the columns. The increase of nearly -13.1%% is found in the maximum principal stress in conical dome,41.41% in spherical dome, -54.1% in circular girder. The magnitude of major principal stress is quite higher in Circular girder as compared to other components and therefore it is a critical component of the tank. which shows that the circular girder of the tank is the most critical component and is prone to failure under vertical loading. The first principal stress and Von-mises stress in the tank-foundation-soil system are shown in Figure-12 and Figure-13 respectively



	Top Dome	Top ring beam	Side Wall	bottom ring beam	Conical dome	Spearical dome	Circular Girder	Column
Analytical value(NIA)	0.335	0.2956	0.6923	0.7426	1.0923	0.896	2.146	1.7325
FEM(NIA)	0.3259	0.2845	0.70432	0.7278	0.9964	0.8765	2.168	1.7136

6.2.STATICAL ANALYSIS FOR SHAFT STAGING EVT (NIA) and (LIA+FSI)

Statical analysis for Shaft staging EVT (NIA)

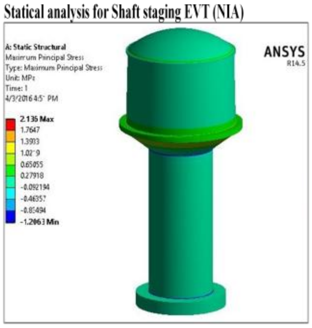


Fig-15. Major principal stress in the interaction system

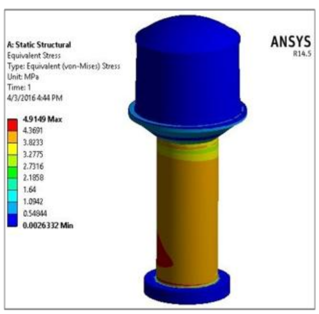


Fig-16. Von-Mises stress the interaction system for shaft

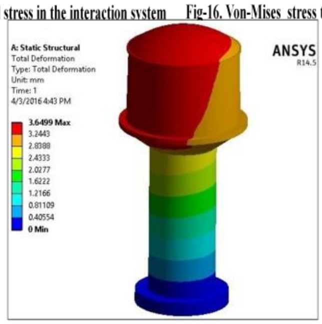


Fig-17. Deformation in the interaction system for shaft tank

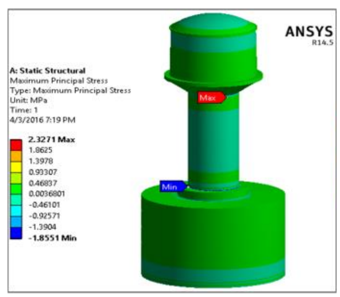


Fig18. Major principal stress in the interaction system

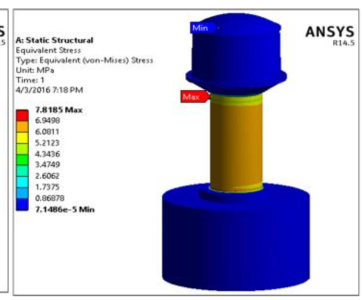


Fig19. Von-Mises stress the interaction system for shaft

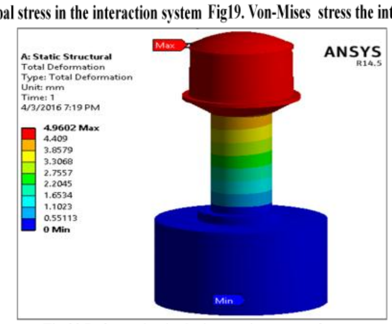


Fig-20.Deformation in the interaction system for shaft tank

Table -6.STATICAL ANALYSIS FOR SHAFT ELEVATED WATER TANK

S. No.	Component of the tank	Major principal stress N/mm2		
		FEM values		% Difference in (NIA and LIA+FSI)
		NIA	LIA+FSI	
1	Top dome	0.32664	0.2360	27.74%
2	Top ring Beam	0.28268	0.1436	49.186%
3	Side wall	0.72102	0.2753	61.817%
4	Bottom ring beam	0.74109	0.2960	60.05%
5	Conical dome	2.136	1.6755	21.558%
6	Spherical dome	0.85329	0.96392	-12.98%
7	Circular ring Beam	1.9235	2.3271	-20.98%
8	Circular shaft	1.5219	0.5440	64.255%
9	Foundation		0.857716	
10	Soil		0.6772	

Table-7 The interaction analysis causes significant decrease in the maximum principal stress in top dome, side wall, bottom ring beam and column whereas significant increase is found in the conical dome, spherical dome and circular girder. The interaction analysis causes significant decrease of nearly in the maximum principal stress in the top dome, 27.74%in the side wall, 61.81% in the bottom ring beam and 60.08%in the columns. The increase of nearly -12.98% is found in the maximum principal stress in conical dome,21.558% in spherical dome, 12.98% in circular girder. The magnitude of major principal stress is quite higher in Circular ring beam as compared to other components and therefore it is a critical component of the tank. which shows that the circular ring beam of the tank is the most critical component and is prone to failure under vertical loading. The first principal stress and Von-mises stress in the tank-foundation-soil system are shown in Figure-18 and Figure-19 respectively

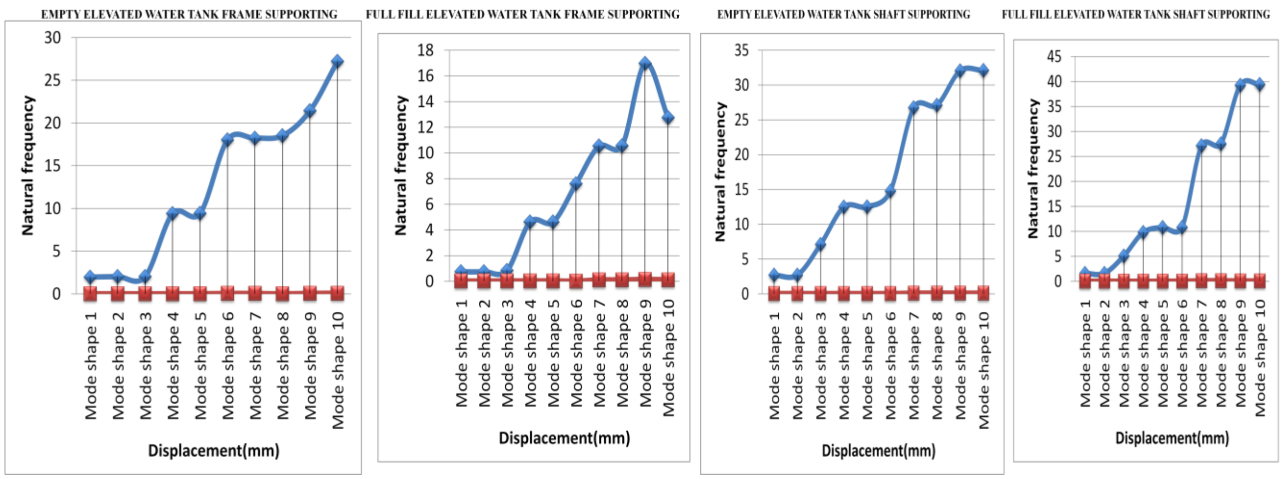
6.3.Model analysis for frame elevated water empty and full tank for both supporting (10 mode shape)

TABLE 8.MODEL ANALYSIS FOR FRAME ELEVATED WATER TANK

Mode Shape	Natural Frequency(empty)	Natural Frequency(Half)	Natural Frequency (full)
1	1.9787	0.83366	0.7432
2	2.033	5.701	4.4010
3	2.0352	10.079	6.8257
4	9.4255	16.1795	11.043
5	9.4447	20.187	14.370
6	18.052	22.517	15.178
7	18.235	23.853	16.452
8	18.536	25.334	17.835
9	21.447	26.255	18.408
10	27.225	26.982	19.523

Table 9.MODEL ANALYSIS FOR SHAFT ELEVATED WATER TANK

Mode Shape	Natural Frequency(empty)	Natural Frequency(Half)	Natural Frequency (full)
1	2.7155	2.6038	1.6141
2	2.7229	2.6112	1.6187
3	7.122	7.3763	5.0812
4	12.502	14.783	9.793
5	12.529	17.335	10.804
6	14.790	17.358	10.823
7	26.746	40.951	27.155
8	27.116	40.957	27.522
9	32.006	43.812	39.269
10	32.116	44.499	39.421



In the present model analysis with of supporting water tank in frame supporting with different filling condition continuous decrease in empty tank natural frequency 28hzthan after half tank natural frequency 26hz and full filed tank decrease natural frequency 19.25hz but i shaft supporting in different filling condition in empty tank lower than half tank increase natural frequency and full tank is lower tann half filled water tank.

7. CONCLUSION

- The interaction effect in Frame supporting tank causes increase in the stresses in the range of -13 to 59.52% in various components of the tank. The maximum principal stress occurs in the circular girder portion. The decrease of nearly 13% is found in the maximum principal stress in the conical dome .
- The interaction effect in shaft supporting tank causes increase in the stresses in the range of -12 to 64.22% in various components of the tank. The maximum principal stress occurs in the circular ring beam portion. The decrease of nearly 12% is found in the maximum principal stress in the ring beam .
- In The interaction effect in Frame and shaft supporting tank in NIA and LIA+FSI condition maximum principle stress at circular girder 2.10N/mm^2 and 3.3391n/mm2 and in shaft tank maximum principle stress is at circular ring beam 1.92n/mm2 and 2.32n/mm2.

- In The interaction effect in Frame and shaft supporting tank in NIA and LIA+FSI condition von -misses stress 9.2/mm^2 and 14n/mm2 and in shaft tank maximum principle stress is 4.92n/mm2 and 7.82n/mm2.

- In The interaction effect in Frame and shaft supporting tank in NIA and LIA+FSI condition displacement is 5.23mmand 7.94mm and in shaft tank maximum principle stress is 3.64 mm and 4.96mm.

- In The interaction effect in Frame and shaft supporting tank in NIA and LIA+FSI condition minimum principle stress at top dome 0.335N/mm^2 and 0.2341N/mm2 and in shaft tank minimum principle stress is at top ring beam 0.2826N/mm2 and 0.1436N/mm2.

- In frame supporting Tank for all filling condition is safe up to 10 mode. But column lying on bending axis are very unsafe under EQ load so circular girder and column lying on bending axis must be design for EQ load and these are the critical component of the tank

- Principal stresses are same in Both staging of the various component of the tank for different type of homogeneous soil mass below the foundation or layered soil mass below the foundation of the tank.

- In Shaft staging Tank for all filling condition is safe up to 10 mode. But column lying on bending axis are very unsafe under EQ load so circular ring beam and column lying on bending axis must be design for EQ load and these are the critical component of the tank.

- The natural frequency of the interaction system decreases as the weight of water increases in the tank so failure criteria will be different for different filling condition. The natural frequency of the vibration up to tenth mode contributes to the dynamical response in the range of 0.5-28Hz for different filling conditions. Up to third mode NIA gives all most same natural frequency but natural frequency for (LIA+FSI) increases from 0.5-28Hz up to tenth mode shape. These natural frequencies are very useful for harmonic and transient analysis since the tank collapses when Earthquake load frequency matches with the natural frequency of tank for any mode causing resonance to occur. In empty condition maximum natural frequency 28Hz and half condition 26.98Hz and Full filled condition 19.52Hz In frame supporting system.

- The natural frequency of the interaction system in shaft supporting 0 to 44.49 Hz and In empty condition maximum natural frequency 32.116Hz and half condition 44.49Hz and Full filled condition 39.42Hz In Shaft supporting system.

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