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AN ANALYTICAL STUDY ON LIQUID STORAGE TANKS USING ANSYS

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ABSTRACT

Liquid storage tanks are commonly used in industries for storing chemicals, petroleum products, and storing public water distribution systems. Importance of ensuring safety of such tanks against seismic loads cannot be over emphasized. The collapse of such tank will affect the normal life of people. Codes of practice realize that it is uneconomic to design a structure to remain elastic during a severe earthquake and therefore generally allow some inelastic behaviour. It is an unresolved issue that how much ductility can be assigned to the structure.

In an elevated water tank for a supporting structure especially the staging does not have much redundancy and hence toughness is present in the building framing system. Seismic behaviour of an elevated tank under sudden loading has been studied. The dynamic analysis (time history analysis) of the water tank for empty and full conditions using different types of forces were carried out and the displacement results were obtained and compared with permissible limits. It is found that providing suitable bracing limits the displacement within the permissible value.

1. INTRODUCTION

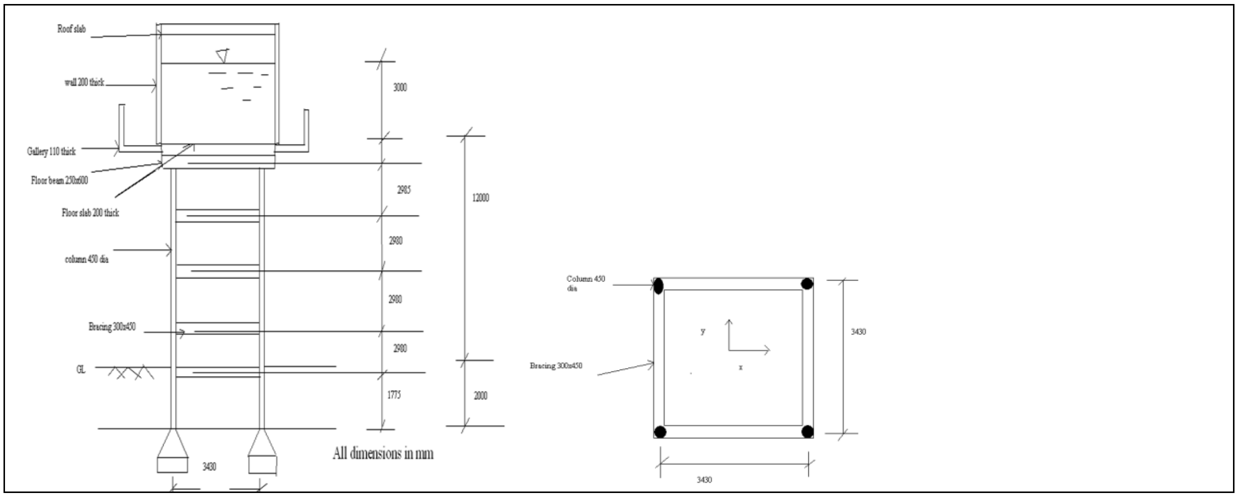
1.1 GENERAL

Liquid storage tanks are mainly of two types: Ground supported tanks and Elevated tanks. It is well recognized that liquid storage tanks possess low ductility and energy absorbing capacity as compared to the conventional buildings. Due to this, liquid storage tanks designed for higher seismic forces as compared to conventional buildings.

Codes of practice realize that it is uneconomical to design a structure to remain elastic during a severe earthquake and therefore generally allow some inelastic behaviour. It is an unresolved issue that how much ductility can be assigned to the structure. The reduction in design forces specified by various codes on account of inelastic behaviour or ductility is significantly smaller for such elevated tank structure when compared to building structure.

The tanks located near a fault are found to be vulnerable under near fault pulses with a large duration compared to the lateral period of tank. The shaft support of elevated water tank should have adequate strength to resist axial loads, moment, and shear force due to lateral loads. These forces depend on total weight of the structure which varies with the amount of content present in tank container. Due to lateral forces the maximum moment occurs at the base of the staging due to which the maximum bending stress occurs. The reduction in the design forces is due to little redundancy present in the structure i.e. one plastic hinge in a staging can cause collapse of the whole structure. In an elevated water tank for a supporting structure especially the staging does not have much redundancy and hence toughness is present in the building framing system. This lack of redundancy is extremely serious in circular shaft type staging where lateral

Stability depends only on the shaft, also thin section of shaft type staging does not have an increased level of ductility which can dissipate the seismic energy and consequently reduce the design force. The slender staging resulting from low design forces are unfavorable for seismic areas.



1.2 OBJECTIVES:

The present work aims:

1) To study the response of an elevated water tank under different types of forces.
2) To analyze the failure pattern of the elevated water tank (EWT) by considering all the forces in tank.
3) To analyze the same elevated water tank (EWT) after providing a suitable retrofitting technique.

2.0 TANK DATA

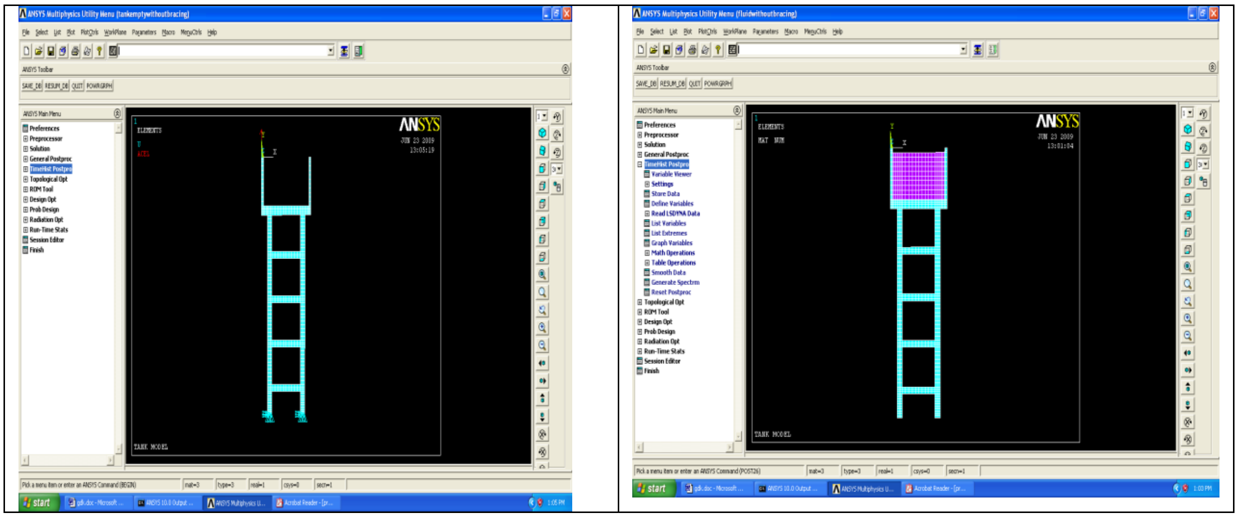
For the present analysis work, a problem given as explanatory example in (Ref: 2) is considered. The tank is a RC frame type elevated water tank with a capacity of 50m^3 and tank diameter is 4.85m and height of 3.3 m (including free board of 0.3m). It is supported on RC staging consisting of four columns of 450 mm diameter with horizontal bracings of 300x450 mm at four levels. The lowest supply level is 12 m above ground level. Staging columns have isolated rectangular footings at a depth of 2m from ground level. Tank is assumed to be located on soft soil. Grade of staging concrete and steel are M_{20} and Fe-415, respectively. Density of concrete is 25kN/m^3. Details of sizes of various components and geometry are shown in below fig.

Table 1 - Sizes of various Components

Tank diameter	4850mm
Total height of tank including staging	17300mm
Wall Thickness of tank	200mm
Column dimension	450mm diameter
Tank height	3300mm

Roof Thickness	120mm
Floor beam	250mm x 600mm
Young’s Modulus	25000MPa
Poisson’s ratio(assumed)	0.15
Boundary condition at the base	Fixed

3.0 MODELLED 2D-ELEVATED WATER TANK USING ANSYS



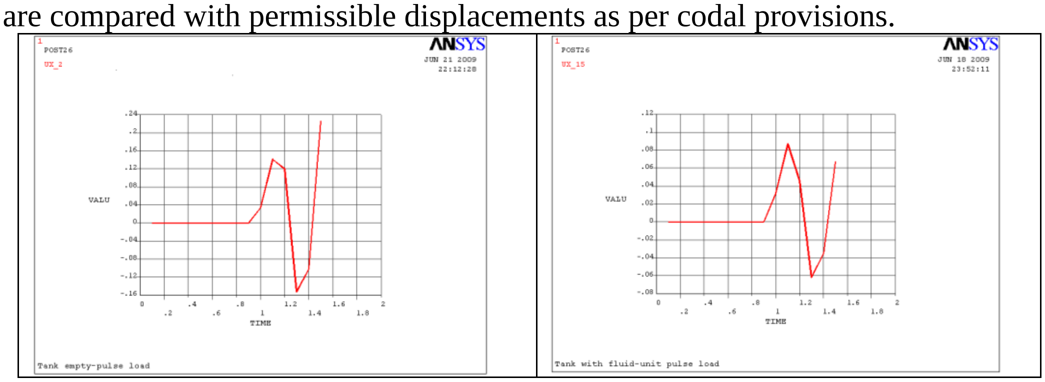
Modelled Tank at Full condition using ANSYS

3.1 TYPES OF FORCES

The type of forces taken in to the analysis is Unit impulse force and Rectangular pulse force

3.2 DYNAMIC ANALYSIS FOR ELEVATED WATER TANK:

The dynamic analysis for Elevated Water tank at different types of forces was carried out for tank empty and full tank conditions and the displacement results were obtained. The results are compared with permissible displacements as per codal provisions.



Maximum displacement-Under empty & Full condition for Unit Pulse Force

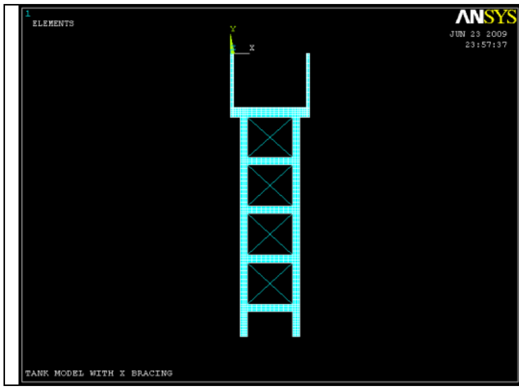
Table 2 - Comparison of displacement along the height of tank under empty and full condition – Unit Pulse Force

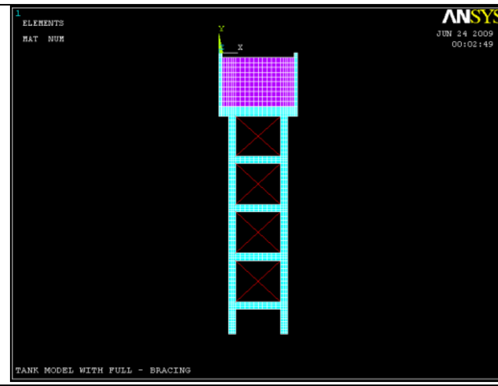
Height(m)	Displacement(mm)		
	Tank at empty	Tank at full	Permissible Limit (H/250)
0.00	0.00	0.00	0.00
1.55	8.14	4.54	6.20
2.00	11.32	6.30	8.00
4.53	45.81	26.02	18.12
4.98	50.11	28.52	19.90
7.51	84.23	50.18	30.00
7.96	88.05	52.68	31.80
10.49	113.77	72.79	41.90
10.94	116.16	74.85	43.76
13.40	128.54	86.74	53.60
13.80	130.35	86.76	55.20
14.00	131.45	86.81	56.00
17.00	215.12	86.90	68.00
17.30	225.99	86.90	69.20

Table 3 - Comparison of displacement along the height of tank under Empty and full condition – Rectangular Pulse Force

Height(m)	Displacement(mm)		
	Tank at empty	Tank at full	Permissible Limit (H/250)
0.00	0.00	0.00	0.00
1.55	7.57	5.17	6.20
2.00	10.57	7.16	8.00
4.53	43.39	29.27	18.12
4.98	47.67	32.02	19.90
7.51	82.16	55.36	30.00
7.96	86.25	57.99	31.80
10.49	116.29	78.69	41.90
10.94	120.08	80.77	43.76
13.40	143.05	92.72	53.60
13.80	144.80	92.74	55.20
14.00	145.82	92.79	56.00
17.00	206.98	92.88	68.00
17.30	214.86	92.88	69.20

4.0 DYNAMIC ANALYSIS FOR BRACING TANK:





Modelled Tank with bracing at empty and Full condition using ANSYS

4.1 DISPLACEMENT FOR UNIT PULSE FORCE

The displacement were obtained for empty and full tank condition under unit pulse force, with X – bracing of steel pipe 20mm thick, 100mm dia at various staging level.

Comparison of displacements along height of tank with bracing for unit pulse force

Height(m)	Displacement(mm) with Bracing		
	Tank at empty	Tank at full	Permissible Limit (H/250)
0.00	0.00	0.00	0.00
1.55	3.74	2.87	6.20
2.00	4.87	3.62	8.00
4.53	12.55	7.99	18.12
4.98	13.89	8.57	19.90
7.51	23.92	13.04	30.00
7.96	25.56	13.64	31.80
10.49	37.30	17.83	41.90
10.94	39.74	18.35	43.76
13.40	53.63	21.26	53.60
13.80	54.50	21.27	55.20
14.00	54.95	21.30	56.00
17.00	64.49	21.36	68.00
17.30	65.53	21.36	69.20

4.2 DISPLACEMENT FOR RECTANGULAR PULSE FORCE

The displacements were obtained for both empty and full tank condition with bracing under rectangular pulse force. For rectangular pulse force the bracing is done with 25mm dia bars and steel pipe of 20mm thick, 100mm dia at various staging level. From the bottom of the tank, first and third staging was braced by 25mm bars and second and fourth staging was braced by steel pipe of 20mm thick with100mm dia

Comparison of displacements along height of tank with bracing for Rectangular Pulse force

Height(m)	Displacement(mm) with Bracing		
	Tank at empty	Tank at full	Permissible Limit (H/250)
0.00	0.00	0.00	0.00
1.55	3.17	3.99	6.20
2.00	4.32	5.39	8.00
4.53	14.82	18.02	18.12
4.98	15.86	19.07	19.90
7.51	21.05	23.79	30.00
7.96	22.06	24.78	31.80
10.49	32.20	35.78	41.90
10.94	33.73	36.74	43.76
13.40	40.71	39.65	53.60
13.80	41.20	39.66	55.20
14.00	41.45	39.69	56.00
17.00	63.14	39.76	68.00
17.30	67.11	39.76	69.20

5.0 RESULTS AND DISCUSIONS

- For the two conditions such as tank at empty, full without bracing, the displacement obtained exceeds the permissible limit for chosen forces.
- From the time history analysis, under empty tank condition the maximum displacement obtained is 225.99mm for unit pulse force and 214.86mm for rectangular pulse force
- In an empty condition the maximum displacement obtained exceeds the permissible limit, particularly for unit pulse force displacement is maximum.
- From the time history analysis under full tank condition without bracing the maximum displacement obtained is 86.90mm for unit pulse force, and 92.88mm for rectangular pulse force
- In a full tank condition the maximum displacement obtained exceeds the permissible limit; particularly for rectangular pulse force displacement is maximum.
- For the displacement to be within the permissible limit two retrofitting techniques were tried, 1) 25mm dia bars and 2) Steel pipe of 100mm dia with 20mm thick used as diagonal bracing. While using first retrofitting technique displacements were reduced but are not with in the permissible limit
- So, second technique was chosen, as a result the displacement due to unit pulse force and triangular force came with in the permissible limit, but still displacement due to rectangular pulse force exceeds the limit
- For rectangular pulse force a combination of two retrofitting techniques were provided (a) diagonal bracing, 25mm dia bar were provided at first and third staging level and (b)

steel pipe of 100mm dia, 20mm thick at second and fourth staging level from the bottom of the tank, as a result the displacement came with in the permissible limit.

- For unit pulse force, after providing suitable bracing the displacement came within permissible limit as 65.53mm for empty tank and 21.36mm for full tank
- For rectangular pulse force the displacement after providing bracing is 67.11mm for empty and 39.76mm for full tank it is with in the permissible limit

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