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Design and Analysis of Elevated Water Tank

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Abstract - *Water tanks are widely used for storing potable water. Due to lack of water around the world, importance is given more on the water storage project. So water storage is very important as it plays a vital role in everyday life. The recent edition for the design concerning towards liquid retaining structure have been revised. The revised edition incorporated limit state design method. In this method the structure is first designed under limit state of collapse, then checked under serviceability. IS3370:2009 adopts limit state design. The Elevated rectangular RC water tank designed under limit state design method and analysis carried out for the empty tank, full tank condition using linear static analysis(equivalent static method) and linear dynamic analysis(response spectrum method)using ETABS Software. As per the results the area of steel required for the structure increases in limit state method. The limit state method provides more effective reinforcement and it is economical.*

***Key Words*: Elevated rectangular water tank, linear static analysis, linear dynamic analysis.**

1. INTRODUCTION

Water tanks are widely used for storing potable drinking water. In the current situation there is more emphasis on the water storage project around the world due to lack of water that is spreading. Water plays a very important role in everyday life, so water storage is very important. Not only did they store water and other liquids, they also had products stored in large-scale industries. Liquid retaining tanks have different sorts of supporting structures for example RC shaft, steel frame, RC braced frame and even brick work platform. In general, depending upon the location tanks are classified as tank resting on ground, underground water tank, overhead or elevated water tank. Depending upon their shape water tanks are further classified as rectangular tanks, circular tanks, intze tanks. The design of liquid retaining structures have been revised. The revised edition incorporated limit state design method. The structure is first designed under limit state of collapse and then checked under serviceability. IS 3370:2009 adopts limit state design method with precautions. Limit state design method adopts the criteria for limiting crack width. The principal motivation behind this work is to design elevated rectangular RC water tank using limit state method and analyse the seismic exhibition of the water tank considering, different zones and different soil conditions.

2. DESCRIPTION OF MODEL

The model considered here is rectangular elevated water tank of 250m^3capacity supported on RCC frame, staging of height 10m and four number of columns. The elevated tank is analysed for various soil condition they are hard, medium and soft soil and various zones were considered they are zone II, III, IV, V. The grade of concrete M30 and grade of steel Fe-415 are considered for study. The model is analyzed using linear static analysis and linear dynamic analysis method in ETABS.

2.1 Elevated Rectangular tank.

Table -1: Parameters of Elevated Rectangular Tank

particulars	dimensions
Thickness of wall	400 mm
Free board	0.3m
Lower slab thickness	500 mm
Bottom ring beam	500 × 1000 mm
Size of braces	300 × 500 mm
Column size	500 × 600 mm
Number of column	4
Staging height	10m
Height of tank	7m
Zone factor	0.1 , 0.16 , 0.24 ,0.36

Reduction factor	2.5
Importance factor	1.5

3. METHODOLOGY

The methodology includes design of elevated rectangular water tank using limit state method as per IS 3370:2009 as well as working stress method and then compared. In this examination the modelling of rectangular RC water tank is done in ETABS software. The manual estimation for seismic analysis has been accomplished using using IS 1893:2014.The analysis is carried in two different methods one is linear static method (Equivalent static method) of analysis and other one is linear dynamic analysis method (Response spectrum analysis). The investigation is accomplished for completely filled water condition and empty water condition for various seismic zones and distinctive soil conditions. The logical examination of a seismic response of raised water tank by response spectrum method by considering the convective mode for an earthquake data also included in the present study.

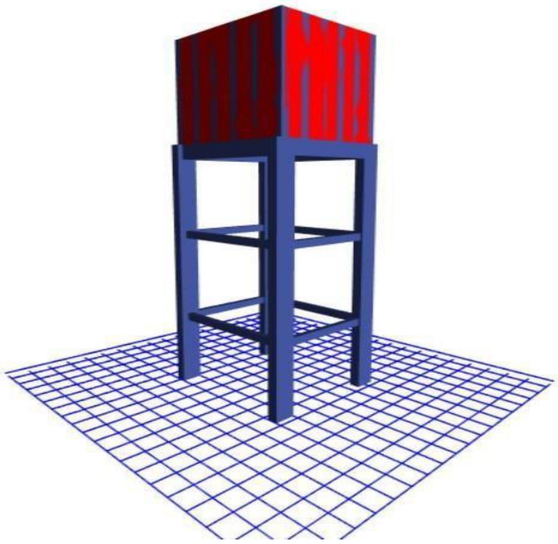


Fig 1. 3D model of Elevated Rectangular Tank

4. RESULTS AND DISCUSSIONS

In this study, elevated rectangular tank have been designed using limit state design method (IS 3370:2009) and working stress method (IS 3370:1965) and compared. Using ETABS the linearly static investigation and dynamic response spectrum investigation is carried out for empty tank condition and fully tank condition using above mentioned parameters. For each condition separate models have prepared for different soil sites and analysis is done. The results are noted down for base shear, base moment, and displacement at top, axial forces.

4.1 Comparative result of Elevated Rectangular RC Water Tank

Table -2: Comparsion of Working Stress Method and Limit State Method

STRUCTRAL ELEMENT	WORKING STRESS METHOD (IS 3370:1965)	LIMIT STATE METHOD (IS 3370:2009)
	COLUMN	
Area of C/S	500000mm^2	500000mm^2
Area of steel required	4000**mm^2**	18500mm^2
	VERTICAL WALL	
wall thickness	400mm	400mm
Area of steel required at support	2961mm^2	3428mm^2

Area of steel required at centre	2317 mm^2	3021 mm^2
	BASE SLAB	
Thickness	500mm	200mm
Area of steel required at support	1080mm^2	2314mm^2
Area of steel required at centre	1220mm^2	1852mm^2

4.2 DISPLACEMENT AT TOP STORY

Maximum story displacement values are obtained from ETABS for different soil types in empty tank and full tank condition.

Table -3: Displacement comparison

DISPLACEMENT COMPARISON (mm)		
SOIL	EMPTY TANK CONDITION	FULL TANK CONDITION
SOFT SOIL	34.099	49.924
MEDIUM SOIL	45.654	68.536
HARD SOIL	56.605	85.703

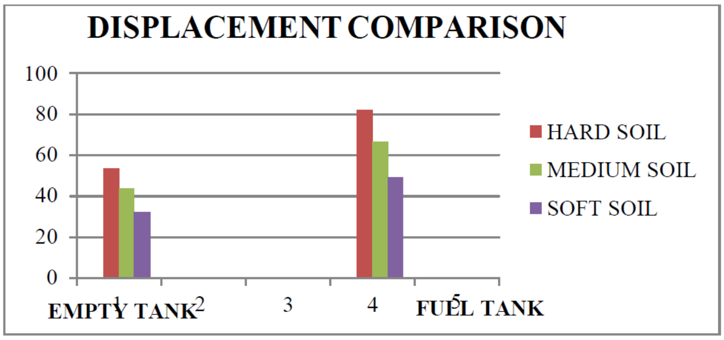
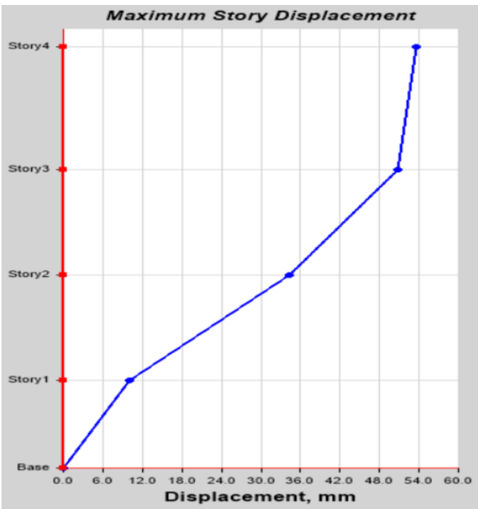


Chart 1: Displacement comparison



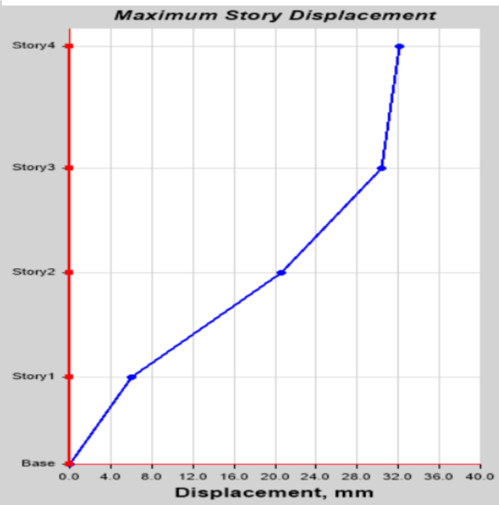


Chart 2: Displacement in hard soil Chart 3: Displacement in medium soil

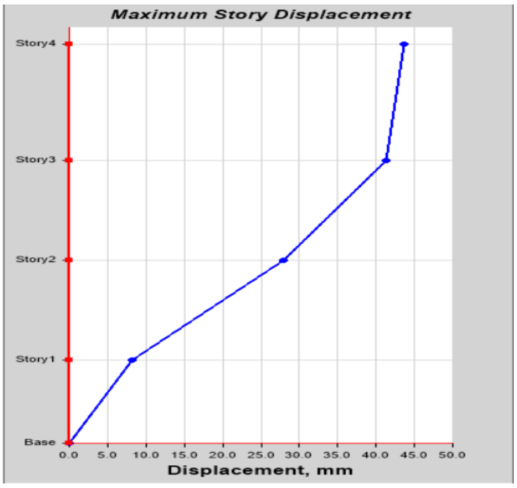


Chart 4 : displacement in soft soil

Discussion on displacement of the model.

1. The displacement is high in hard soil in full tank conditions compare with the hard soil in empty tank condition.
2. The lateral forces will be high in hard soil compared to other.
3. The graphs shown in chart 2, 3, 4 were obtained from ETABS for hard, medium and soft soil types for empty tank condition.
4. Same procedure were followed for plotting graphs for hard, medium and soft soil types for full tank condition.

4.3 BASE SHEAR AND BASE MOMENT

Base shear and base moment values are obtained from ETABS for different soil types in empty tank and full tank condition.

Table -4: Base shear and base moment for soft soil condition

EMPTY TANK CONDITION			FULL TANK CONDITION	
ZONE	BASE SHEAR	BASE MOMENT	BASE SHEAR	BASE MOMENT
	(KN)	(KN-m)	(KN)	(KN-m)
II	117.09	376.06	72.80	234.35
III	185.15	599.49	115.88	375.38
IV	277.23	899.72	174.32	565.06
V	416.34	1349.59	260.48	845.08

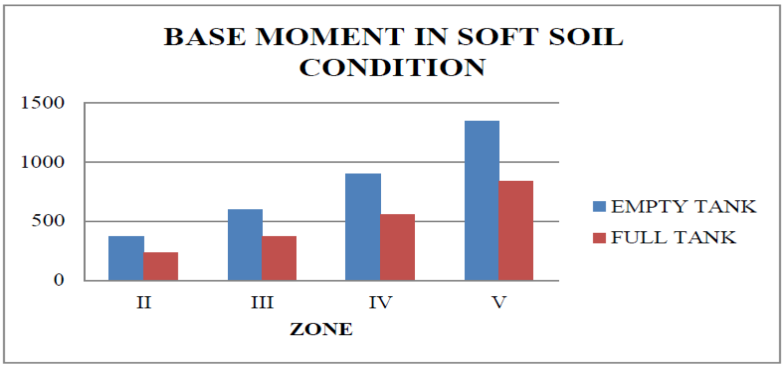


Chart 5: base moment in soft soil condition

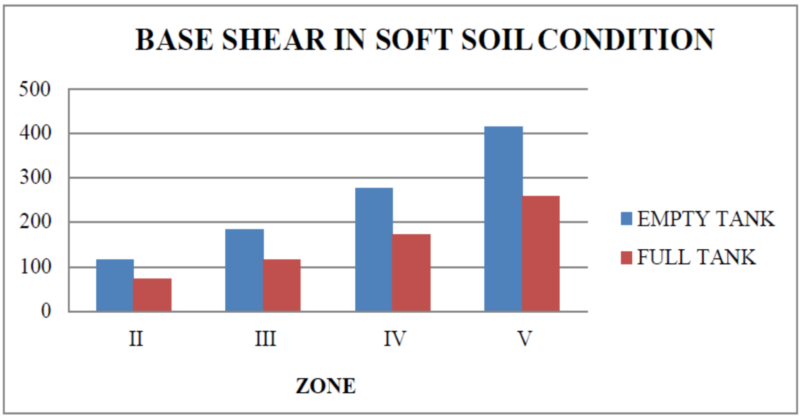


Chart 6: base shear in soft soil condition

Discussion on base shear and base moment of the model.

1. Base shear and base moment for empty tank condition is more compare to full tank condition in all the three soil condition.
2. Because water tank is empty hence no water pressure from inside, only earthquake forces are acting from outer side only.
3. Base shear and base moment for medium soil, hard soil condition were analysed and the results were obtained, procedure for plotting graph were same as of soft soil condition.
4. The base shear and base moment value for medium soil, hard soil was more in empty tank condition compare to full tank condition.

4.4 AXIAL FORCES

Axial forces values are obtained from ETABS for different soil types in empty tank and full tank condition.

Table -5: Axial force comparison

AXIAL FORCES FOR ALL SOIL TYPES 1.5 (DL+LL)		
	EMPTY TANK	FULL TANK
STORY 1	28725.75	28749.92
STORY 2	28237.79	28250.95
STORY 3	27667.81	27791.99
STORY 4	19324.007	19435.18

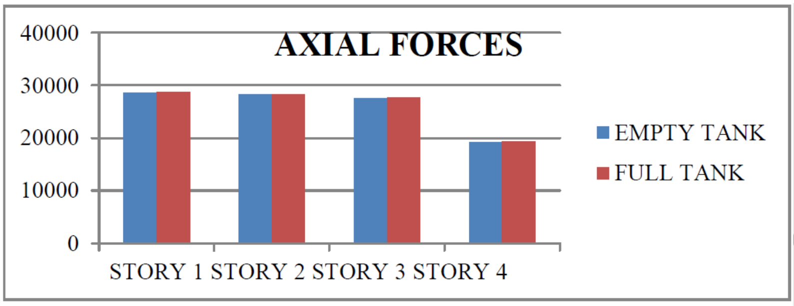


Chart 7: Axial force comparison

Discussion on Axial force of the model.

1. Axial forces are increased in the fully tank condition compare with the empty tank conditions.

2. The increased values in full tank condition are very small varying compare to empty tank.

5. CONCLUSIONS

1. From results it shows that the area of steel required in limit state method increase when compared to that of working stress method as the allowable stresses in steel were lower.

2. From the above outcomes and discussion, the displacement is high in hard soil in full tank conditions compare with the hard soil in empty tank condition because of in full tank condition lateral forces are more.

3. From the results we conclude that base shear and base moment for empty tank condition is more compare to full tank condition. Because of water tank is empty hence no water pressure from inside, only earthquake forces are acting from outer side only. Hence more base shear and base moment in empty tank condition.

4. Axial forces are increased in the fully tank condition compare with the empty tank conditions. the increased values in full tank condition are very small varying compare to empty tank.

5. The critical response of elevated water tanks does not always occur the same conditions as mentioned above, it may vary also due to depending on the earthquake characteristics

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