Analysis of Service Reservoir Based On the Variation of Alignment of Side Wall with Base Slab

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Abstract - *Service reservoirs are structures used for storage of water and other types of liquids for serving various purposes. The elevated service reservoir is a structure supported at a particular height to provide for the necessary pressure for supply of water through gravity. Elevated water tanks consist of huge water mass at the top of a slender staging which is most critical consideration for the failure of the tank during earthquakes. Due to the lack of knowledge of supporting system some of the water tank were collapsed or heavily damaged. So there is need to focus on seismic safety of lifeline structure with respect to alternate supporting system which are safe during earthquake. The major damage of the structure is caused by the sloshing effect of the water at the side walls. The provision of slanting walls in reducing the sloshing effect is checked for other characteristics of elevated water tank under seismic force. A time history analysis of the elevated water tank is studied here.*

Key Words: Elevated water tank, Seismic force, Time history analysis, Sloshing, Base shear

1. INTRODUCTION

Service reservoirs are structures used to store the treated water and other types of fluids for their supplying in necessary conditions. Mainly storage reservoirs or distribution reservoirs are terms used to denote structures storing water. These structures help in the distribution of water at emergency situations like fire, repairs etc. and also help in absorbing the hourly fluctuations in the normal water demand. The need for water storage tanks are considered as important all over the world. There are various types of reservoirs like underground reservoir, small ground level reservoirs, large ground level reservoirs and overhead tanks. The location and height of the tank of these reservoirs are decided based on the center of demand and keeping in view the water level in the reservoir which must be at a sufficient elevation to permit gravity flow at an adequate pressure. The storage capacity of the tank is decided based on the balancing storage (operating storage), breakdown storage (emergency storage) and fire storage. The water tanks are placed over a supporting tower to acquire the necessary power through gravity instead of heavy pumping. A water tower is an elevated structure supporting the water tank constructed at height sufficient to pressurize a water supply system. The elevated water tanks rely on hydrostatic pressure produced by elevation of water (due to gravity) to push the water in to domestic and industrial water distribution system. The water is refilled by pumping once the level of water falls down. The elevated service reservoirs are not only used to store water but also other liquids of different density. Due to the lack of supporting system some of the water tank were collapsed or heavily damaged during an earthquake. Many storage tanks are considered essential facilities and are expected to be functional after severe earthquakes. This is partly due to the need for water to extinguish fires that usually occur during such earthquakes. Elevated water tanks consist of huge water mass at the top of a slender staging which is most critical consideration for the failure of the tank during earthquakes. Various factors like zone of earthquake, soil pattern, design of the structure, staging pattern, material used for construction etc. effects the seismic resistivity of the elevated water tank.

1.1 Behavior of elevated water under seismic force

Sachin.U.Pagar and Prof.P.R.Mehetre [3] (2015) conducted a study on the earthquake analysis and earthquake resisting design of elevated water tank. Elevated water tank having eight types based on shape and material used for construction out of that the Frame and shaft type water tank analysis was done. As staging levels increased, the Dead weight of staging also increased and hence the Lateral Seismic Force. In comparison with reinforced concrete elevated water tanks with shaft staging, the reinforced concrete elevated water tanks with frame staging have shown better seismic behavior to resistant against lateral loads.

J. Yogeshwarana and C.Pavithra [4] (2015) studied the behavior of an elevated RC tank subjected to various earthquake responses. The performance of the elevated concrete tanks with frame staging along with seismic behavior of these construction types were studied considering the response of the liquid with that of the tank structure. Pressure generated from the liquid excitation has significant impact on the walls and base slab of the structure of the tank. The maximum base shear varies along with percentage of filling were studied. Under fully filled condition, the free board provided gives the enough space for the water to oscillate. The variation in roof and floor displacement shows the need for the wall to be designed as earthquake resistant to ensure failure under these circumstances.

Dhiraj Virkhare, Prof. Laxmikant Vairagade etal [6] (2015) studied pushover analysis of water tank staging. The behavior of an elevated water tank by 'Pushover Analysis'. Base shear, Bending Moment, Axial Force and Displacement for Constant Staging height and water storage capacity, different h/d ratio, number of periphery columns (Eight, Ten, and Twelve) and different types of staging arrangement (Normal, Cross, Hexagonal) were considered for the study. Base Shear is more for h/d ratio 0.5 normal staging type as compare to other h/d ratio and value of base shear is more for tank full condition than tank empty condition. It concludes that for 0.7 h/d ratio cross staging type gives best performance for absolute displacement, axial force, moment-Y and moment-Z.

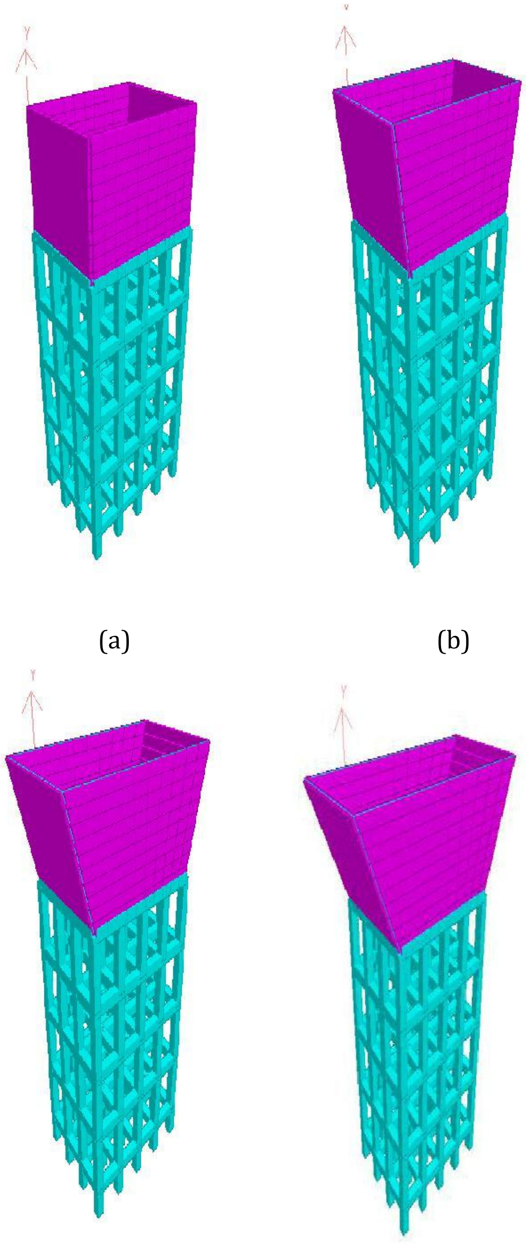
2. Analysis of elevated water tank by variation of side wall alignment with base slab

A suitable structure for the analysis has been determined and modeled by varying the alignment of the wall of the water tank with the base slab. Initially a normal rectangular water tank of height 5m and 8m long and 6m wide is modeled and then a 100,110,120 degree variation to the alignment of the walls of the water tank with the base slab is modeled. Staging height is 12m. The details of the model selected for the analysis is given in table 1.

Table -1: Details of the elevated water tank selected for analysis

Staging height	12m
Plan area	8m x 6m
Height of water tank	5m
Free board	0.5m
Base slab thickness	0.35m
Side wall thickness	0.40
Volume	240 m^3
Column size	0.6m x 0.6m
Beam size	0.6m x 0.4m

The loads applied to the structure are the water pressure on the side walls applied as triangularly varying load. The water pressure at the bottom slab as uniformly varying pressure. The time history analysis is done to the structure considering Elcentro earthquake vibration data. Elcentro earthquake is a high intensity earthquake of magnitude of 6.5. The damage caused by the earthquake was immense. The dimensions of the elevated water tank considered for analysis is done keeping the limits provided in the code for liquid storage structures. The structure modeled for time history analysis is as shown on the figures.



(a) (b) (c) (d)

Fig -1: Model of elevated water tank by variation of angle of alignment of side wall at angles (a)90^o (b)100^o (c)110^o (d)120^o

The analysis of the structure is done in Staad.pro software. M30 concrete is material considered for the elevated water tank. A constant volume of 240 m ^{3} is considered. The side wall inclination is provided with the base slab by keeping the volume of the water tank constant. El Centro earthquake data is considered for analysis since it is one among the most destructive earthquakes happened till now.

3. Results Obtained from Analysis

The study showed the difference of various characteristics like displacement, base shear and shear stress with the variation in inclination of side wall with base slab. The results are studied to find the scope of construction of trapezoidal elevated water tank considering the fact that the normal water pressure acting on the side wall is less in trapezoidal structure than in rectangular water tank. The displacement plots obtained are given below.

Fig -2: Displacement when angle with base slab is 90⁰

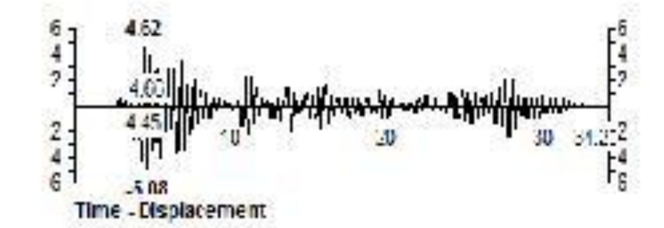


Fig -3: Displacement when angle with base slab is 100⁰

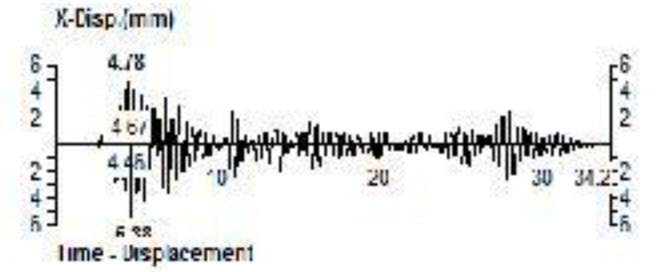


Fig -4: Displacement when angle with base slab is 110⁰

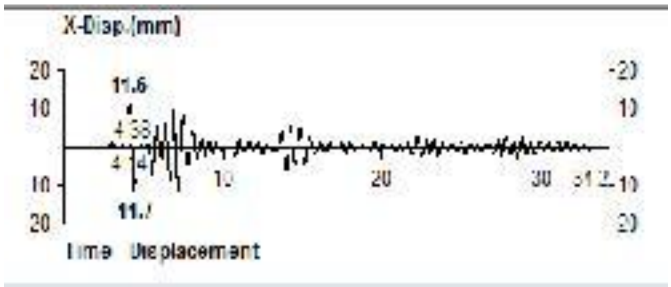


Fig -5: Displacement when angle with base slab is 120

The displacement value is found to increase as the angle of alignment of side wall with base slab increases. A large variation in the displacement value is found when the angle of alignment changes from 110⁰ to 120⁰. The values obtained are shown in the table 2.

Table -2: Results obtained from the analysis of elevated water tank

Angle of alignment with base slab	Displacement(mm)	Base shear(kN)	Shear stress(N/mm^2)
90	4.45	407.6	0.048
100	4.62	418.32	0.054
110	4.78	423.2	0.067
120	11.6	439.12	0.443

The base shear value and shear stress values is also found to increase as the angle of side wall with base slab increases. The values are comparable for the angle of alignment till 110⁰. The values show a large variation when the alignment angle with the base slab reaches 120⁰. The bar chart showing the variatioin of displacement, base shear and shear stress are given from chart 1 to chart 3.

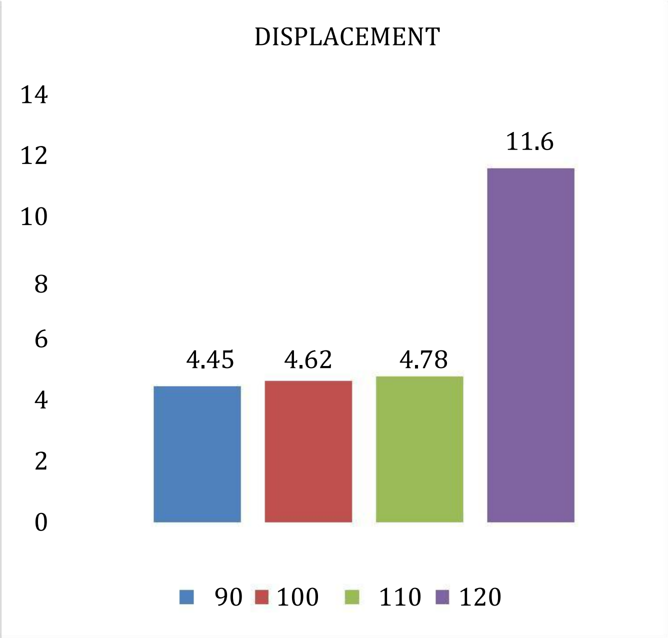


Chart -1: Comparison of displacement by variation of alignment of side wall with base slab

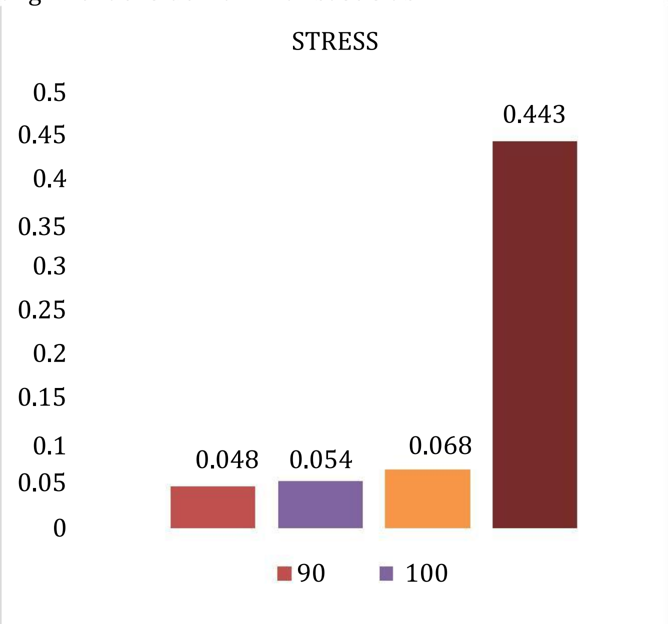


Chart -2: Variation of shear stress due to variation of alignment of side wall with base slab

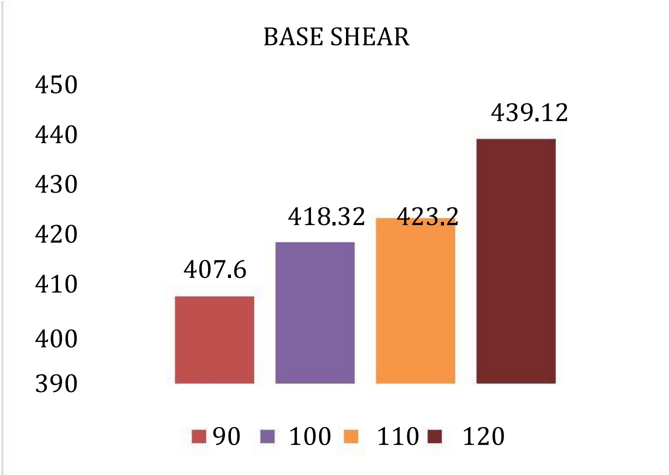


Chart -3: Base shear values of elevated water tank by varying the alignment of side wall with base slab

The slanting wall with the base slab had been studied considering the fact that the direct pressure effect of the water to the side walls gets reduced to the slanting walls, but the analysis conducted shows that the base shear value and the shear stress value gets increased as the alignment angle of the side walls with the base slab increases. A rectangular water tank has the least base shear value compared to the other alignments.

4. CONCLUSIONS

The analysis of the elevated water tank for the variation of the alignment of the side walls with the base slab is done considering the fact that the maximum direct pressure of water acting on the side wall due to the seismic force I less for the trapezoidal water tanks than for the normal rectangular water tank of constant volume. The results obtained shows that

- For a constant volume the displacement value increases as the angle of alignment of side wall with the base slab increases. The variation is comparatively small till the angle of alignment is 110^o and at an angle 120^o, it shows a large variation of about 61.6%.
- The value of base shear is found to be minimum for the rectangular water tank under a very high earthquake like El Centro.
- The shear stress value is found to have a large variation at 120^o. A variation of about 89% is observed at 120^o compared to the normal rectangular water tank.

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