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OPTIMUM ASPECT RATIO FOR DESIGN OF AN EXISTING ELEVATED WATER TANK USING STAAD.PRO

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Abstract

The recent earthquake, starting with the San Fernando earthquake in 1971 in California, left extensive damage, damaged infrastructure, and raised many questions about the dangers and implications of projects, vulnerability and design practices of structures, especially in field of concrete buildings. Design codes have being revised to include seismic provisions but structures constructed before 1971 have to be retrofitted. Studies after the earthquake have shown that the biggest problem with concrete structures is vertical member i.e. columns. The focus of this concept is on reinforced water tanks (RC). Reinforced concrete water tanks are widely used to provide potable/safe drinking water. Most water supply systems in developing countries, such as India, where urbanization is increasing day by day depending on the storage tanks are higher and therefore there is a need to build more number of water tanks. Although a large no of water tanks have been designed till date, not much importance was given on the effect on selecting aspect ratio of the tank on its performance. Keeping this in to view, this project is carried out to analyze the structural performance and cost analysis of overhead water tanks of a fixed capacity, having different diameters and heights and so as to find out the most economical H/D ratio to be adopted in the design of the tank by comparison with different parameters. To optimize results and check the exactness/accuracy of design, three circular water tanks of fixed capacity with bottom and top dome pattern are designed by varying H/D ratio in Staad.pro software. After satisfying the safety of all structures, further analysis is done to determine the cost effectiveness of the structures by comparison the approximative total cost of materials.

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1. Objective

The aim of this study is to compare design of 100KL existing elevated circular water tank (domed bottom and roof) situated at Daldal Seoni, Raipur city, Chhattisgarh with the water tank designed by in STAAD.PRO. The existing water tank is designed manually and constructed by Raipur Municipal Corporation (RMC). First of all, the existing structure which is constructed by RMC will be modeled in Staad.pro software. Now, we have designed two more water tanks of varying height and depth ratio in Staad.pro software and we have done analysis for its structure so that it can provide more strength and stability and we have done analysis of its cost too so that it can become economical.

2. Methodology

2.1 Structural Analysis Software

I have chosen STAAD Pro because of its following advantages:

- Precision of the solution.
- Simple to use interface,
- Confirmity with the Indian Standard Codes,
- Versatile nature of solving any type of problem.
- It offers faster methods of designing the structure.
- It helps save time and increase efficiency because it does not comprise any manual calculation.
- It is extremely scalable and easy to learn.

Staad.pro includes visualization tools, effective analysis and design engines with advanced finite element and dynamic analysis functions. From model generation, analysis and design to conception and verification of results, Staad.pro software is professional choice for the design of aluminium, steel, concrete, timber, and cold rolled low and tall buildings, culverts, petrochemical plants, tunnels, bridges and many more. The structure design depends on the minimum requirements set out in Indian code standards. The minimum structural safety requirements for structures are met by specifying the minimum design loads to be assumed for self load, service loads and other external loads that the structure would have to withstand. We hope that strict compliance with the load standards recommended in this code will ensure the structural safety of the designed buildings.

2.2 Loads on Structure

In construction, two main factors to be considered are safety and economy. If we increase the load, it will affect the economy. If economy is considered and the load is reduced, safety will be compromised. Therefore, estimates of various load effects can be accurately calculated. The Indian Standard Code IS 875-1987 set out various design loads for buildings and structures. The load types are as follows:

a) **Dead loads**: - The first vertical load to be considered is the self-weight. Dead loads are permanent or stationary loads that are transferred to the structure throughout its service life. The self-load is mainly due to the self-weight of structural elements, fixed partition walls, fixed fixtures and the weight of various materials. It mainly consists of the weight of roofs, bricks, beams, walls, columns, etc. which are otherwise fixed parts of the building. The calculation of the self-loads of each structure is calculated from the volume of each one section and multiplied by the unit weight.

b) **Imposed load** :-The second vertical load that is taken into account when designing the structure is service or live loads. Moving loads are moving or moving loads without acceleration or impact. These loads are assumed to be caused by the intended use or use of the building, including the weight of movable partitions, furniture, fluid etc.

Live loads change from time to time. The designer should take these loads appropriately. This is one of the main loads in the design. The minimum assumed values of the active loads are given in IS 875 (Part 2) –1987. It depends on the purpose of the building/structures. The code gives both uniformly distributed loads and concentrated loads. Floor slabs must be designed to accommodate uniformly distributed loads or concentrated loads, whichever is the greater stress on the part under consideration. As it is unlikely that all floors will not bear the maximum load at any particular point in time, the code allows some reduction in service loads when designing columns, load bearing walls, pillar supports and foundations.

c) **Wind Loads** :-The wind load is horizontal load caused by the movement of air relative to the ground. Wind loads should be considered in the design of all structures, especially when the heath of the building exceeds twice the dimensions across the exposed wind surface. For low-rise buildings, up to say four to five storeys, the wind load is not critical because the drag torque provided by the continuity of the floor system connection to the columns and the walls between the columns is sufficient to balance the effects of these forces. In addition, in the limit state method, the design load factor is reduced to 1.2 (DL + LL + WL) when wind is considered, compared to a factor of 1.5 (DL + LL) when wind is not taken into account.

When designing a building, the horizontal force exerted by wind elements should be taken into account. The calculation of the wind load depends on two factors, namely wind speed and building size. Full details of the structure wind load calculation are given below (in IS875 (Part 3) -1987). The map of India shows the baseline wind pressure 'Vb' in a color code. The designer may increase the value of Vb depending on the location of the building. To get the design wind speed Vz, the following expression should be used:

Vz = k1.k2.k3.Vb Where k1 = Risk coefficient

k2 = Coefficient based on terrain, height and structure size.

k3 = Topography factor The design wind pressure is given by pz = 0.6 Vz*Vz

where pz is in N/m2 at height Z and Vz is in m/sec. Up to a height of 30 m, the wind pressure is considered to react uniformly. Over 30 m height, the wind pressure increases.

d) **Snow loads**: - Snow loads constitute to the vertical loads in the building. But these types of loads are considered only in the snow fall places. The IS 875 (part 4) – 1987 shares with snow loads on roofs of the building.

e) **Seismic load:** - The forces of an earthquake are both vertical and horizontal forces acting on a building. The total vibration caused by an earthquake can be broken down into three mutually perpendicular directions, usually taken as vertical and two horizontal directions. Movement in the vertical direction does not cause any significant forces in the supporting structure. However, the horizontal movement of the structure during an earthquake must be taken into account when designing. The reaction of the structure to ground vibrations is a function of the type of foundation soil, the size and method of construction as well as the duration and intensity of ground movement. IS 1893–2014 gives details of such calculations for structures standing on soils that do not settle to a significant degree or slide significantly as a result of the earthquake.

f) Other Loads and Effects acting on Structures: **-** As per the clause 19.6 of IS 456 – 2000, in addition to above load discussed, account shall be taken of the following forces and effects if they are liable to affect materially the safety and serviceability of the structure:

(a) Foundation movement (IS 1904)

(b) Elastic axial shortening

(c) Soil and fluid pressure (IS 875, Part 5)

(d) Vibration

(e) Fatigue

(f) Impact (IS 875, Part 5)

(g) Erection loads (IS 875, Part 2) and

(h) Stress concentration effect due to point load

In Staad.pro, three separate models have been prepared to verify or check the behavior of elevated circular water tanks under the action of applied forces/loads and the value of the concrete and steel used for these models has been noted to give a preliminary idea of the cost of the overall structure after assuring the safety of all structures with all parameters. The results thus obtained are compared with the existing design data for a tank of the same capacity and conclusions are drawn. The first model D = 0.639 and later models had an H/D ratio with an increase of 0.10.For all structural elements, M25 (excluding tank portion), M30 (tank portion) & Fe415 are used. The top and bottom dome of the tank have a diameter of 12.20 m and 11.80 m, seismic zone II as per IS 1893,height of Staging = 18 m (In all the models).Tank if assumed to be in full condition. It is resting on 4 columns placed at the periphery of the tank. This can be shown as:

Table 1. Model Description

S. No.	Model Description	H (m)	D (m)	H/D
1	Tank 1	3.90	6.10	0.639
2	Tank 2	4.21	5.70	0.739
3	Tank 3	4.44	5.30	0.839

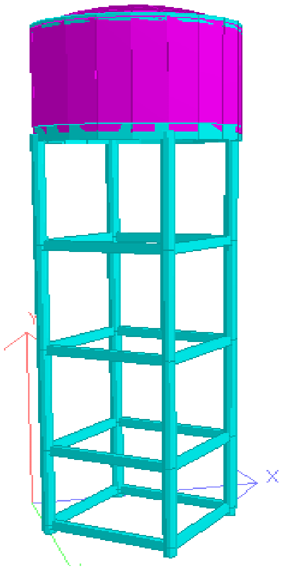

Figure 1. Staad.pro Model of Tank

3. RESULTS AND DISCUSSION

The behavior of the three frame systems is considered a basic study of the modeled structure. The drift / lateral deflection ratio is checked against clause 7.11.1 of IS18932002 i.e. under transient seismic loads. Many parameters such as nodal deflection to assess the safety of structures, base shear and slab stresses have been taken into consideration. Once found to be safe, the amount of materials used was analyzed to present a comparison between the different frames.

Table 2. Eigan Solutions - Frequency (Hz)

Mode	Tank 1	Tank 2	Tank 3
Mode 1	0.539	0.304	0.525
Mode 2	0.539	0.304	0.525
Mode 3	0.825	0.473	0.836
Mode 4	4.718	5.701	8.119
Mode 5	5.036	5.701	8.119
Mode 6	5.036	9.697	10.185

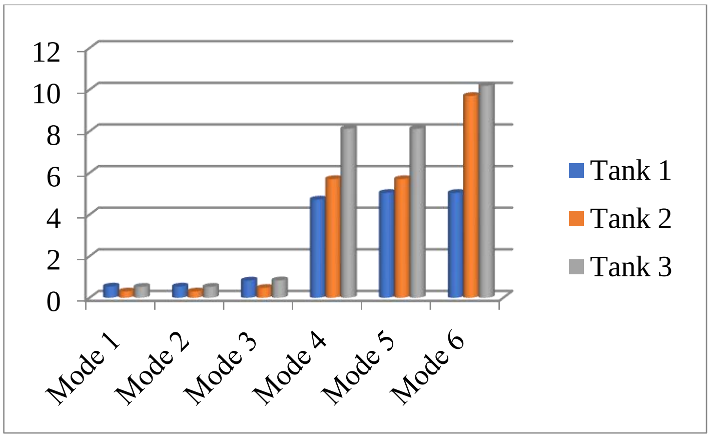

Figure 2. Frequency Comparison

Table 3. Eigan Solutions (Time Period in Sec)

Mode	Tank 1	Tank 2	Tank 3
Mode 1	1.85357	3.28992	1.90370
Mode 2	1.85357	3.28992	1.90370
Mode 3	1.21171	2.11230	1.19599
Mode 4	0.21197	0.17541	0.12317
Mode 5	0.19856	0.17541	0.12317
Mode 6	0.19856	0.10312	0.09818

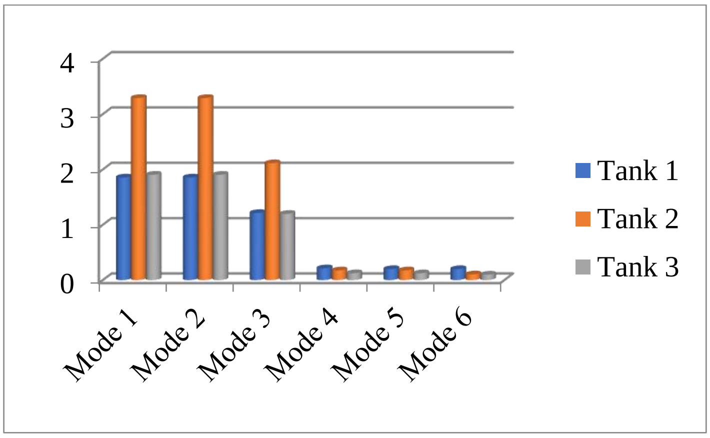

Figure 3. Time Period Comparison

Table 4. Base Shear (in kN)

Description	Tank 1	Tank 2	Tank 3
SRSS SHEAR	10.62	25.90	15.88
10PCT SHEAR	14.74	27.21	15.89
ABS SHEAR	14.77	27.25	15.91

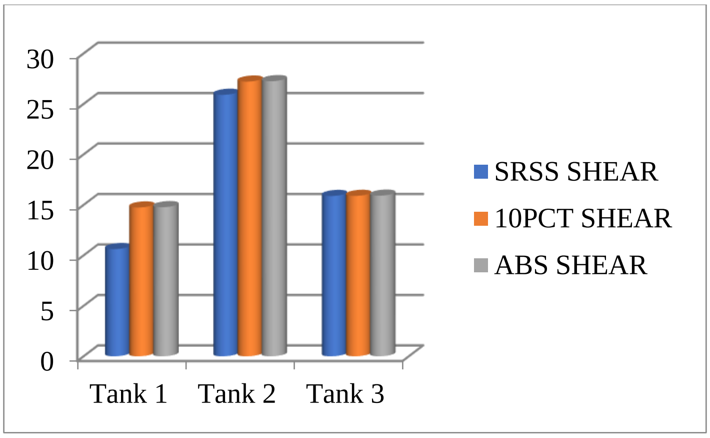

Figure 4. Base Shear Comparison

Table 5. Cost Estimation of Various Materials for Different Models

S No	Model	D (m)	H (m)	Vol. of Concrete (m^3)	Weight of Steel (kg)	Total Cost (Lacs)
1	Tank 1	6.10	3.90	20.6	1470.33	1.70
2	Tank 2	5.70	4.21	20.0	1457.28	1.67
3	Tank 3	5.30	4.44	19.4	1368.90	1.59

Rate: INR 4391/- per Cum. of Concrete and INR 54.50/- per kg. of Steel

Table 6. Stress at Tank Portion

Maximum Absolute Stress (N/mm2)	Tank 1	Tank 2	Tank 3
Minimum	0.029	0.017	0.051
Maximum	0.464	0.486	0.390

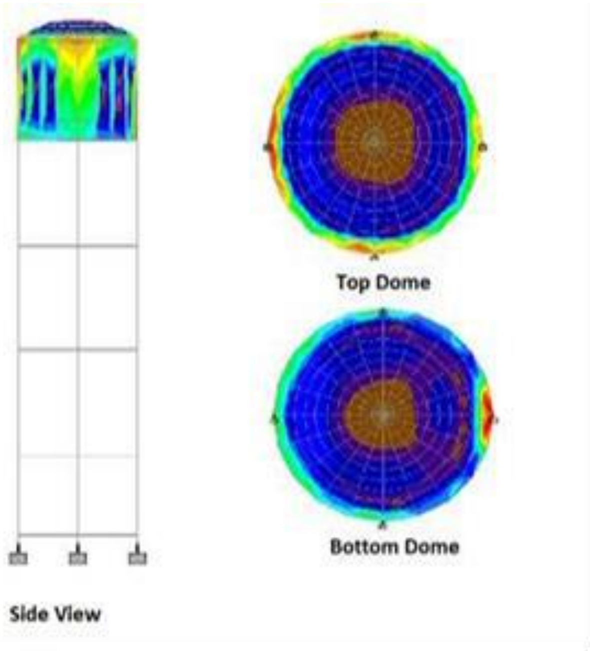

Figure 5. Stress Distribution in Plates of Tank

From the all graph and figure above can be seen that the costs for tank 1 and tank 2 are almost the same. However, the performance of the tank 1 is relatively better, providing satisfactory performance in terms of important parameters such as Nodal Deflection, Base Shear, Storey Drift, Time Period and Slab Stresses.

4. Summary and Conclusion

It is clear to all that the loading hazards should be carefully assessed before the construction of major structures and tall buildings such as elevated water tanks. Based on the above analytical study carried out on 3 different models with different diameters and heights, the following outcomes are –

(1) For the same capacity of tank, there exist countless possibilities of height and diameter combination for the tank.

(2) The tanks with smaller diameters generally require lesser volume of concrete.

(3) In all the cases, the diameter was linearly decreased by 0.40 m. It was seen that tanks with larger diameters have smaller heights and thus cover a larger ground span.

(4) It has been observed that the volume of steel is greater in the case of tanks of smaller diameter.

(5) The model Tank 1 showed the best results with minimum cost, INR 4.70 Lacs (approx.) leading us to conclude that H/D = 0.639 is the best. The height and diameter provided in this case are 3.90 m and 6.10 m respectively whereas the same used for the design of water tank at Daldal Seoni, Raipur. Thus it can be said that the design opted for the construction of tank of 100 kL capacity located at Daldal Seoni, Raipur is safe because the structure is stable, safe in all parameters as well as economy

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