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DESIGN OF OVERHEAD WATER TANK BY AMERICAN STANDARD (COMPARISON BETWEEN INDIAN (WSM) AND AMERICAN STANDARD

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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 questions about the dangers and implications of projects, vulnerability and design practice of structures, especially concrete buildings. Design codes have being updated to include seismic provisions but structures build before 1971 have to be retrofitted. Studies after the earthquake have shown that the biggest problem with concrete structures is columns. The focus of this concept is on reinforced water tanks (RC). Reinforced concrete water tanks are widely used to provide 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 the aspect ratio of the tank on its performance. Keeping this in to view, this study is carried out to analyze the structural performance and cost analysis of overhead water tanks of a fixed capacity, having different heights and diameters so as to determine the most economical H/D ratio to be adopted in the design of the tank by comparison with different parameters. To optimize the results and check the accuracy of design, three circular water tanks of fixed capacity with top and bottom dome pattern are designed by varying H/D ratio in STAAD.Pro. After assuring the safety of all the structures, further analysis is done to calculate the cost effectiveness of the structures by comparing the approximate total cost of materials. Furthermore, the model of tank with ideal aspect ratio is placed in a higher seismically active zone and a case study is carried out to determine the optimum retrofitting strategy. This will help the designers in making the optimum choice for their design in terms of structural performance and cost efficiency.

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1. Objective

The aim of this study is to compare design of 100KL existing elevated rectangular 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 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. Furthermore, the model of existing tank with ideal aspect ratio is placed in a higher seismic active zone i.e. zone 3 because the zone 2 is covered by Raipur city. When the model is shifted from zone 2 to zone 3, the further analysis is done for the failure of structure. Now a case study is carried out to determine the optimum retrofitting strategy.For this column jacketing and steel bracings are used. This will help the designer in making the optimum choice for their design in terms of structural performance and economy.

1. METHODOLOGY

1.1 Structural Analysis Software

I have chosen STAAD Pro because of its following advantages:

- Accuracy of the solution.
- easy to use interface,
- conformation 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, powerful analysis and design engines with advanced finite element and dynamic analysis functions. From model generation, analysis and design to visualization and verification of results, STAAD.Pro is professional choice for the design of steel, concrete, timber, aluminum and cold rolled low and tall buildings, culverts, petrochemical plants, tunnels, bridges, piles and much 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 inimum 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.

1.2 1.2Loads 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 specifies 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, 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 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, loadbearing walls, pillar supports and foundations.

c) **Wind Loads: -**The wind load is primarily horizontal load caused by the movement of air relative to the ground. Wind loads should be considered in the design of the structure, 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 act uniformly. Above 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 deals with snow loads on roofs of the building. The minimum snow load on a roof area or any other area above ground which is subjected to snow accumulation is obtained by the expression
Types of Loads on Structures - Snow Loads.

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

(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 to a significant degree or slide significantly as a result of the earthquake.

Table 1 - Eigen 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

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 which was constructed by RMC having H / materially the safety and serviceability of the structure:

(a) Foundation movement (IS 1904)

(b) Elastic axial shortening

these models has_been noted to give a preliminary idea of the costof 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. This can be shown as:

2. RESULT AND CONCLUSION

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 IS1893:2002 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.

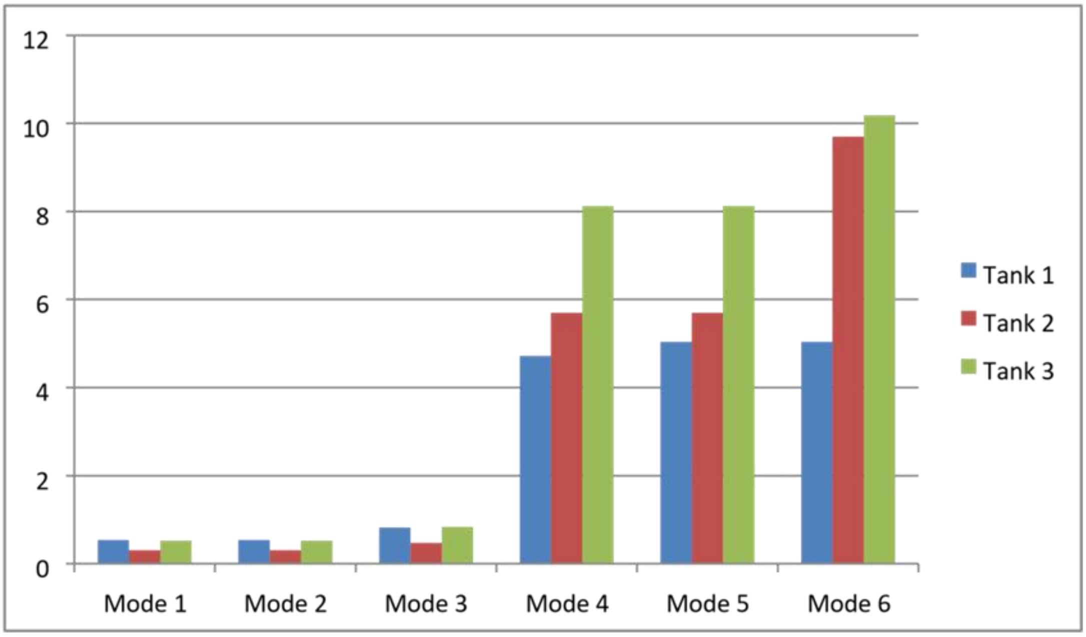

Fig. 1 – Frequency Comparison

Table 2 - Eigen Solutions - Time Period (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

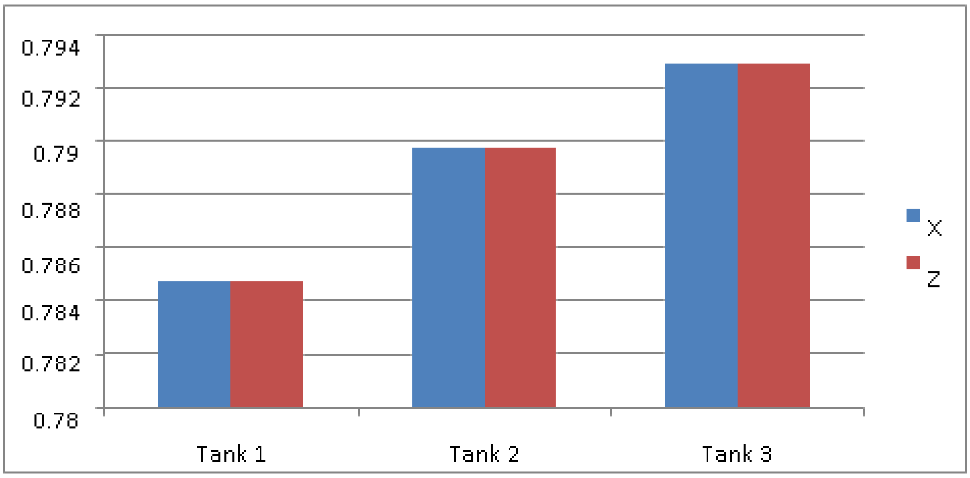

Fig. 2 – Time Period Comparison

Table 2 - Base Shear (in kN)

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

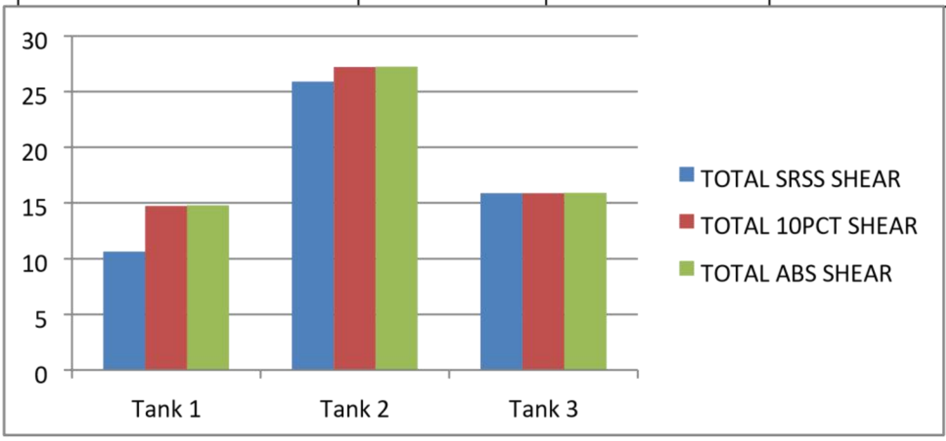

Fig. 3– Base Shear Comparison

Table 3

Maximum Absolute Stress (N/mm2)	Tank 1	Tank 2	Tank 3
Minimum	0.0299022	0.0177475	0.0511432
Maximum	0.464035	0.486181	0.390894

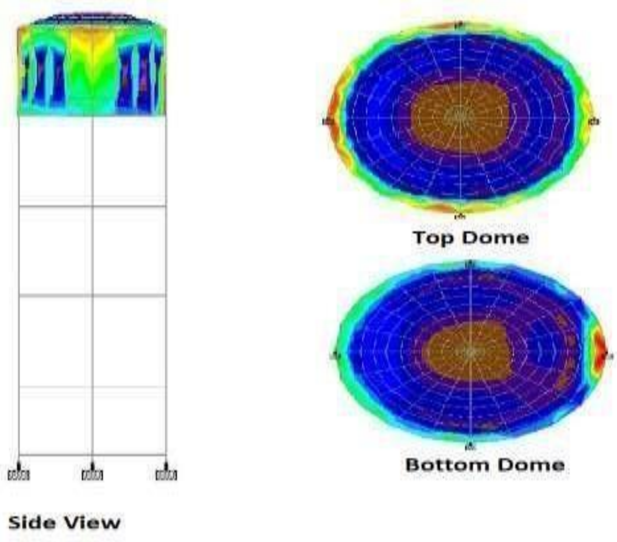

Fig. 4 Stress Distribution in Plates of Tank 1

The figure shows the areas of stress green, blue and orange) whereas concentration in the model 1. The minimum stresses are occurring at maximum stresses are occurring at the centre of the bottom dome and at the bottom ring beam (indicated by the top dome (indicated by brown).

Table 4– Storey Drift

Storey	Tank 1	Tank 2	Tank 3
Base	0.000000	0.000000	0.000000
Top	0.000400	0.000200	0.00020

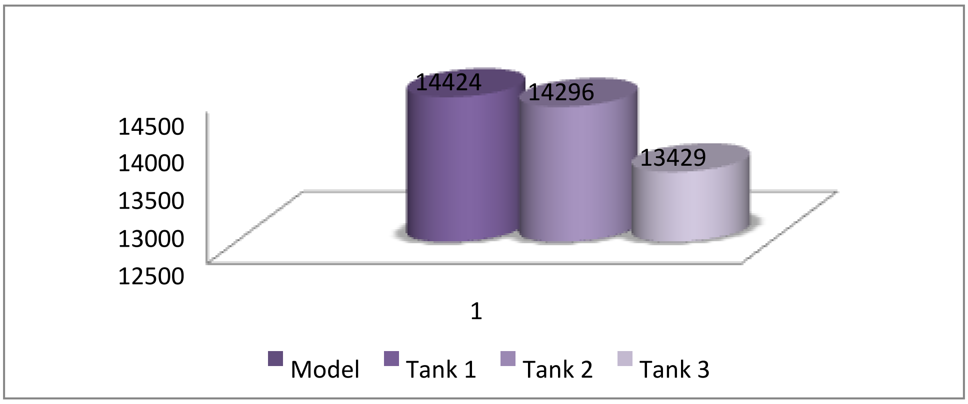

Fig. 5 – Comparison of Amount of Steel used in different Models

Table 5– Cost estimation of various materials for different models

S No	Model Description	D (m)	H (m)	Volume of Concrete(in m^3)	Volume of Steel (in kg)	Total Cost ofmaterials (Approx.) (in 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

3. SUMMARY

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 –

- For the same capacity of tank, there exist countless possibilities of height and diameter combination for the tank.
- The tanks with smaller diameters generally require lesser volume of concrete.

4. CONCLUSION

It also observed that the columns of this tank originally designed for seismic zone II were failing under combined action of crushing and buckling when placed in seismic zone III for the purpose of analysis. Two possible retrofitting strategies namely concrete jacketing and addition of steel braces were evaluated in order to determine the optimum retrofit strategy. Addition of concrete jacketing although helped mitigate the seismic demand but also led to an increase in the dead weight of the structure which may lead to the failure of foundation. Since the initial investment needed for steel bracings is comparatively larger, many researchers would simply suggest to adopt concrete jacketing. However looking at the life cycle assessment, it is inevitable that the bracings is a relatively cheaper solution as the steel Sections can fetch a resale value even at a later age.

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