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Design and Analysis of Under Ground Water Tank Considering Different Fill Conditions Using STAAD.PRO : A Review

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ABSTRACT

Water tanks and reservoirs are used to store liquids like water, petroleum or chemicals. For any domestic and commercial purposes, water tanks are very basic need to meet their day to day use. In this project an attempt is made to design the rectangular underground tank, the tank is to maintain atmospheric temperature and provided optimum height for easy pumping of water to overhead tank. Since it is underground water tank the lateral earth pressure and water pressure also considered for the design calculations, so the design is to be carried out as per IS code norms. In this paper we are presenting review of literatures related to analysis of water tank.

Keywords: Analysis, Water Tank, Structure, Forces, Moment, Deflection.

I. INTRODUCTION

Now days, expressive constructions were taking place in hilly areas due to lack of plain ground. As a result the mountain areas have marked effect on the buildings in terms of style, material and method of construction leading to lot of structures in hilly areas. Due to sloping profile, the different levels of such structures step back towards the hill slope and may also have setback also at the same time. These structures become highly uneven and unsymmetrical, due to different version in mass and stiffness distributions on different upwards and downwards axis at each floor. Such construction in seismic prone areas attracts greater shear forces and torsion compared to usual construction.

In some parts of world, mountain area were more likely to get earthquakes; e.g. northeast area of India. In this hilly areas, usually material like, the clay, brick, stone masonry and dressed stone masonry, timber reinforced concrete, bamboo, etc., which is locally available, is used for the construction of houses. The money based growth and rapid growth of the cities with more people in hilly areas has speed up the Real Estate Development.

The research papers were investigated from the authors across the globe, where the investigation was carried out on underground water tank using manual calculus and analytical applications for the structure analysis. The results were summarized in the review below.

II. LITERATURE SURVEY

Wagh et al (2021) research paper presented the design of underground water tank of Rectangular shape was designed and analysed using Staad pro. Underground water tank faces different type of loads compared to other structures, they mainly face horizontal or lateral loads due to earth pressure and water pressure or any liquid pressure which was stored in the tank. The side walls of the underground water tank will face greater load at the bottom and the load linearly decreases towards the top.The analysis and design were done according to standard specifications using IS-456:2000 & SP-16, for the design of the STRUCTURAL MEMBERS. i.e., followed the LIMIT STATE method. Materials used are M20 grade concrete and Fe 415 steel unless mentioned in the particular design elements. Conclusion stated that STAAD Pro gives satisfactory results when compare with manual design also. STAAD PRO analysis and design is always beneficial over the conventional method of analysis and design of water tank. Manual analysis and design requires lengthy and complicated procedure while STAAD PRO requires less time & easy design &analysis process. By using STAAD PRO software there is saving of 15% to 20 % of total steel in the whole structure.

Dubey et al (2021) the primary objective of the research was to investigate the behaviour of underground water tanks subjected to seismic loading and soil structure interaction and comparison of their output result to understand its behaviour. For the study existing underground water tank was used and finite element modelling of the same tank was done in ETABS17 for two different soil conditions as per IS 1893 part- 2-2014. The existing water tank situated at Solsinda, Sanwer, Indore (M.P) was considered in the investigation. Clay of high Compressibility (CL) and Silt of high

Compressibility (MH) was taken for this experiment as per IS 1893-Part- 1-2016. CL was categorized under medium or stiff soil and MH was under soft soil. Both water pressure and soil pressure are assigned as non-uniform shell loads on walls of UGT in ETABS. Walls are designed for a nonuniform load of 30 kN/m2 for water pressure and 27 kN/m2 of earth pressure. Seismic zone-3 was considered for earthquake analysis with two different soil conditions i.e. medium stiff (CL) and soft soil (MH). Classification of soil was taken from IS1893-Part 1-2016. Excel sheet was used to calculate seismic forces in terms of total base shear, total moment at base of wall and hydrodynamic pressure on wall in both X and Y direction considering impulsive and convective modes for medium and soft soil categories. Soil dynamic pressure for CL soil is 94.18 kN/m2 and 75.34 kN/m2. Results concluded that considering seismic forces is beneficial for underground water tank. On considering seismic forces the moments in walls along both X and Y at the base, exceeds moments in walls of existing tank. Although soil condition does not influence design force significantly. Shear force dominates the thickness of wall, on considering seismic forces shear forces increased which tends to redesign thickness of slab. On considering SSI effect with elastic spring at base, design forces increased as compared to seismic design with rigid base. Although SSI effect is not very much significant.

Tripathi et al (2020) the research paper presenetd seismic analysis of an Underground water tank with reinforced concrete staging structure. The structure was designed according to IS code provision to reduce Effect and minimize the consequence of seismic wave. The time-history assessment was carried out by a detailed finite element simulation of the UG water tank. For the study of nonlinear dynamic analysis, SAP 2000 software for different seismic intensity.The result of the study shows the deflected shape of tank at different condition considered as empty and full. Time history method becomes necessary to ensure safety against earthquake forces. the rectangular shape UG water tank of capacity 80000 liter. The dimension of UG tank was 6m*4m*3.5m. IS:456 2000 was been used and for seismic analysis IS:1893 2002. After providing all required structural configuration assign time history data of Nepal earthquake which was happened in 2015/04/25 (LAMJUNG, NEPAL) magnitude of (7.8). The deflected shape of UG tank by the action of time history method for different case of storage was being determined . Since time history analysis was a realistic and significantly used for the determination and design of better structure by considering factor of safety as per

IS Code. On analyzing the structure with different time history data one get different mode of deflected shape for empty tank as well as for full tank for UG reservoir.

Shinde (2018) research paper presented a comparative analysis of the computer-aided design of an underground water tank. Manual Analysis and design of the Underground Water tank by using IS code method was presented comparing with STAAD-PRO and SAP software design result, comparison of reinforcement was done and optimize results are determined. This report gives in brief, the theory behind the design of liquid retaining structure (Rectangular water tank) using working stress method. This water tank of 1,00,000-10,00,000 liters capacity was designed in computer added analysis. The deflected shape was analyzed and also the axial force of respected tank cases and develop programs for the design of water tank of flexible base and rigid base and the underground tank to avoid the tedious calculations. Comparison was made between IS code method design and various software design result to understand governing loads and carry out literature review related to underground water tank. The base deflection criteria, shell stresses and joint reaction of underground water tank structure by considering dynamic type of loading when the tank is empty and full water level conditions was presented. Results stated that the calculation of deflection in the manual design and the deflection results from STAAD and SAP software were nearly same. The shell stresses in full water condition and full empty condition was within the permissible limit that was not greater than 7000 kN/m2 and mainly the results obtained from both software's were same. If suppose tank has less dimension then unsatisfied results were obtained.

Kapadia et al (2018) research paper presented a design of Combined Rectangular Water Tank in which combined surface rectangular water tank and overhead rectangular water tank was considered in the investigation. The design and analysis of the water tank wa done using analytical application STAAD.Pro v8i. The objective of the research was to minimise the failure of water tank due to an overturning of overhead water tank. More storage of water as ground and overhead means. If there required to supply the water at long distance then by use of overhead water tank else ground water tank. Less deflection, moment as compare to that individual overhead water tank. Results stated that the absolute pressure is less compare to general one. The Hydrostatic Pressure assumed as for overhead 200kN/m3 and for Ground Tank 300kN/m3 and deflection was less.

Mondal and Guha (2018) research paper presented a comparative study of R.C.C. underground & rest on ground water tanks of various shape (circular and rectangular) for a capacity of 500000 lit. or 130000 gallon (US).The work included the design and estimates for circular and rectangular R.C.C. underground & resting on ground water tanks. The aim of this research was to design large capacity R.C.C water tanks of various shapes and then compare the results. For both water tank the analysis was done in STAAD PRO software. Results stated that water tank has less utility or the above portion will be utilize for any other purposes then there must have to made underground tank. Sometimes for considering aesthetic view and location we have to made underground reservoir. But here area of construction is not restricted, that's why for economical purposes we can make a circular rest on ground water tank. So according to availability of place for construction, design (using excel sheet), drawing (using auto cad) and analysis (using staad pro) this is concluded that RCC circular rest on ground water reservoir is the most effective and economical project.

Nimade et al (2018) the research paper presented finite element model of underground water tank using Staad Pro software and analyze the behavior of underground water tank for different L/B ratio. The Node displacement and Stress pattern of underground water tank was compared for different L/B ratio in order to the base Pressure, Plate moments of underground water tank structure by considering the tank was empty and full water level conditions. Results stated that center shear stresses in X direction i.e. SQX in tank wall decreases with increasing the length by width ratio of the tank, its observe that stresses slightly vary when L/B ratio vary 1 to 1.5 and more decreases at L/B ratio 2 and 3. Center shear stresses in Y direction i.e. SQY in tank wall decreases with the increasing L/B ratio, but there is no variation observed when L/B ratio increases up to 1.5 but after that stresses rapidly decreased at L/B ratio 2 & 3. 3) The Principal top stresses in water tank walls decrease at the rate of 10% with increasing L/B ratio i.e. 1.2, 1.5, 2, 3 respectively. The Principal Bottom stresses in tank walls decrease up to 60% at L/B ratio 3 but there is no variation seem when L/B ratio varies from 1 to 2. The Von Mis Top & Bottom stresses in water tank wall under pressure will decreases at the rate of 10% at L/B ratio 1, 1.2, 1.5, 2 & 3 respectively. Similarly, Tresca Top & Bottom stresses in water tank wall under pressure will decreases at the rate of 10% at L/B ratio 1, 1.2, 1.5, 2 & 3 respectively. Bending Moment at tank wall i.e. Mx, My, Mxy decreases with increasing the L/B ratio. Its decreases about 50% at L/B ratio

at 3. There is negligible displacement in X & Z direction when L/B ratio varies but in due to water pressure and self-weight of structure i.e. tank full condition node displacement occurs in vertically downward direction i.e. Y direction. Base Pressure increases with increasing the L/B ratio. Hence, results concluded that the underground water tank with the full and empty condition when $L/B < 2$ the effect of stresses, node displacement & base pressure variation is negligible but if $L/B > 2$ the effect of stresses, node displacement and base pressure will be more varies with increasing L/B ratio.

Chougule et al (2017) the research paper conducted parametric study on spring mass model, Time period in impulsive and convective mode, Design horizontal seismic coefficient, Base shear and Hydrodynamic pressure due to impulsive and convective mass of water was considered. It was found that under influence of seismic forces with increasing ratio of maximum depth of water to the diameter of tank (h/D) the more mass of water will excite in impulsive mode while decreasing ratio of (h/D) more the mass of water will excite in convective mode. The Time period of Impulsive mode increase with increase in (h/D) ratio and Time period in convective mode decrease with increase in (h/D) ratio. It was assumed that tank is located in seismic zone IV. The results concluded that For circular water tank with same storage capacity and different height; the Base shear, Bending Moment & Max. Hydrodynamic pressure gradually increases with increase in h/D ratio In case of rectangular water tank with same storage capacity and different height of tank wall if the h/L ratio is up to 0.6 the base shear, Bending Moment& Max. Hydrodynamic pressure increases gradually and if the h/L ratio is in between 0.6 to 0.8; it suddenly increases & after that it decreases gradually. So for water tank at ground level the h/L ratio up to 0.6 is feasible. For circular & rectangular water tank with same storage capacity but different height of tank wall, sloshing wave height increases up to certain limit & after that it decreases gradually. The increase in the ratio of maximum depth of water to the diameter of tank i.e. (h/D) or (h/L) will lead to increase in impulsive mass participation factor and decrease in convective mass participation factor. The graph also illustrate that the sum of mass participation factor (impulsive & convective) exhibit the unit value all along the horizontal axis.In case of circular water tank for h/D ratio 0.4, the mass participation factor for impulsive & convective are nearly equal. In case of rectangular water tank for h/L ratio 0.5, the mass participation factor for impulsive & convective are nearly equal.

Dave et al (2017) research paper presenetd the design of liquid retaining structure (rectangular ground supported water tank) using working stress method further including seismic analysis and design of the tank. Top of the tanks may be covered and is designed by using IS 3370:2009 Part (I, II) and IS 1893:2007 (part-2) draft code is used for the seismic analysis of the tank. The result values were computed to determine reinforced area v/s capacity of tank and the moment v/s capacity of tank. With increase in the capacity of tank the reinforced area and moment increases. Base shear v/s impulsive height and overturning moment v/s convective height was also determined which shows that as the height increases the time period also changes and as a consequence base shear and overturning moment also changes. Design of underground water tank involves tedious mathematical formulae and calculation. It is also time consuming, hence the relationship is derived which can be helpful in deriving the base moment and wall reinforcement as well as the base shear and overturning moment. The relationship gives values of reinforcement area and moment capacity which increases with increase in the tank capacity. On the other hand as the convective and impulsive height increases, overturning moment and base shear increase respectively. These relationships are useful for easy analysis and design for tank. Also understands the seismic behavior of ground supported tank.

Thalapathy et al (2016) the research paper presented detailed analysis of the design of liquid retaining structure using working stress method. The project takes into consideration the design of reservoir for the cases namely, Underground Tank, Tank Resting on ground and Overhead water tank. The primary objective of the research was to analysis and design of water tank and prepare guidelines for the design of liquid retaining structure according to IS code. The study focused on developing program for water tank to avoid tedious calculations. Results stated that the height to diameter ratio 0.45 is safest economical design. In the results of the rectangular tank (resting on ground) 8×5×2.5 having a moderate shear, deflection, bending moment, etc. 8×5×2.5 / 10×1.25×6 sections are given a moderate results for the underground water tank. Cost- wise 8×5×2.5 section is more economical in tank resting on the ground. Increase in shear force & bending moment becomes milder as one goes towards the downwards side of slope. The thickness of cylindrical wall, conical dome and bottom dome of intze water tank are increased due to the considerations of new IS code:3370-2009 and earthquake forces. It was clearly seen from the results that the formwork required for the constructions of water tanks is minimum for circular shaped tank as compared to square shaped and rectangular shaped tanks. Limit state method was found to be most economical for design of water tanks as the quantity of steel and concrete needed is less as compared to working stress method.

Nayana et al (2015) the primary motive of the project was to investigate the effect of change in dimensions on the dynamic response of rectangular water tank, to find out the effect of water level in the tank on the dynamic response of rectangular water tank, to analyze the effect of variation in loading parameter on the dynamic response of rectangular water tank and the time history of a past earthquake was analyzed and the loading pattern is applied to the water tank and the corresponding dynamic response was investigated using ANSYS. Results stated that deformation values are increased from fully filled to quarterly filled condition of the tank. As length-to-width ratio of the tank decreases the resulting deformation increases. The time-history analysis shows that the water tank exhibits a satisfactory behaviour with the time history pattern of Kobe(1995) earthquake.

Punith et al (2015) the research paper used Underground water tank with different safe bearing values of soil in order to analyze the typical behavior caused by seismic load. The finite element method (FEM) was selected as the examination method for the underground water tank. The most challenging part of dissertation was seismic calibration stage executed using SAP2000 FEM package. Primary objectives of the research included Development of finite element model of underground water tank using Structural Analysis Package (SAP 2000) software and investigate the behavior of underground water tank under different safe bearing values of soil using analytical methods. Investigate the design philosophy for the safe and economical design of water tank and the displacement and deformation pattern of underground water tank and are compared for different safe bearing values of soil. Results stated that Time period is high when the underground water tank is full water level compared to empty. If the underground water tank is full of water obviously it takes more time to complete one cycle of free vibration than the empty tank. 3) Frequency is less when the tank is full compared to empty. If the tank is full obviously it takes less rotation per second. The maximum deformation due to full water load was only 364*E-3m. Due to uniform distribution of water, and external loading at top, the deformation is more at the center of the side walls of tank. Due to water hammering action displacement is high in full

water level condition compared to empty condition in both X and Y direction, due to seismic vibrations. Acceleration is little bit high in full water condition due to water hammering action by earthquake compared to empty condition in both X and Y direction. Base moment value is very high in safe bearing value 150KN/m2 compared to safe bearing value 500KN/m2 , in all conditions. Due to high lateral force and water force, the base moment is high in full water level condition compared to empty condition in all considered safe bearing values. Hence results concluded that for every load case the soil with safe bearing value 150KN/m2 has higher value. The underground water tank in soil with safe bearing value 150KN/m2 will get affect more than the underground water tank in soil with safe bearing value 500KN/m2 during earthquake.

Wad et al (2014) Underground tanks (RCC) are commonly used for storage of water for domestic use, swimming pool, sedimentation tank, etc. The vertical wall of such tanks is subjected to hydro-static pressure and soil pressure &the base is subjected to weight of water and soil pressure & uplift and it is designed by using IS 3370:2009 Part (I, II).This study focused on the optimum cost design of underground tank due to effects of unit weight of backfill soil variation, variation in grade of concrete and for same capacity change in height (Depth). The main aim was to achieve the economy. Material saving results in saving in construction cost at the same time the safety is also considered. The model was analyzed and design by using MATLAB software. Optimization is formulated is in nonlinear programming problem (NLPP) by using sequential unconstrained minimization technique (SUMT). Results stated that Interior penalty function method can be used for solving resulting non-linear optimization problems. for underground tank walls & base slab thickness It is possible to obtain the global minimum for the optimization problem by starting from different starting points with the interior penalty function method. The minimum cost design of underground tank is fully constrained design which is defined as the design bounded by at least as many constraints as there are the design variables in the problems. The optimum cost for a underground rectangular rcc tank is achieved in M25 grade of concrete and Fe415 grade of steel. The cost of underground tank unit increased rapidly with respect grade of concrete and increase in height keeping the capacity of underground tank is constant.

Ajagbe et al (2010) research paper presented the analysis and design of a fully submerged underground reinforced concrete water tank using the principle of beam on elastic foundations. To achieve this, a Microsoft Excel Spreadsheet Design and

Analysis Program (MESDAPro) was generated for quick assessment of various moments of the tank, geometrical features and soil conditions for both full and empty conditions of the tank. It was observed that the wall moments, moment at base of wall and base slab moment decreases with increase in soil sub-grade modulus at constant capacity, height and breadth of the tank. However, wall moments, moment at base of wall and base slab moment increases with increase in height of the tank at constant value of sub-grade modulus, tank capacity and breadth.

III.CONCLUSION

In the previous researches following outcomes can be drawn as:

- Authors illustrated the analysis of elevated water tanks but none of them explained the effect over underground tank considering soil pressure.
- Authors performed analysis using softwares but none of them provide detailed modelling, hydraulic loading and lateral load effect over the structure.

IV. REFERENCES

[1]. A. C. Chougule, P. A. Chougule and S. A. Patil, [Study of Seismic Analysis of Water Tank at Ground Level], International Research Journal of Engineering and Technology (IRJET), Volume: 04 Issue: 07 | July -2017.

[2]. Aditya Wad, N. G. Gore, P. J. Salunke and V. G. Sayagavi, [Cost Optimization of Rect. RCC Underground Tank], International Journal of Recent Technology and Engineering (IJRTE) ISSN: 2277-3878, Volume-3 Issue-3, July 2014.

[3]. Anshuman Nimade, Niraj Soni, Goutam Varma, Vikas Joshi and Sharad Chaurasia, [Parametric Study of Underground Water Tank using FEM], International Journal of Science Technology & Engineering | Volume 4 | Issue 09 | March 2018.

[4]. Dhritiman Mondal and J.C. Guha, [Comparative Study On Various Shapes Of Rcc Underground & Rest On Ground Water Reservoir], International Journal of Innovative Research & Studies, ISSN NO : 2319-9725, Volume 8, Issue IV, APRIL/2018.

[5]. Issar Kapadia, Purav Patel, Nilesh Dholiya and Nikunj Patel, [Design, Analysis and study of the combined Rectangular Water Tank: COmbination of the Rectangular Overhead

Water Tank and the Rectangular Ground Water Tank using STAAD.Pro Software.], International Journal of Current Research Vol. 10, Issue, 04, pp.67632-67635, April, 2018.

[6]. Komal K Wagh, Akshay K Ghuge, Deepak N Gaidhane and Gajendra R Gandhe, [Design and Analysis of underground water tank by using Staad Pro], International Research Journal of Engineering and Technology (IRJET), Volume: 08 Issue: 04 | Apr 2021.

[7]. Nayana R, Neenu K Mathew and Asha Joseph, [Dynamic Response of Ground Supported Rectangular Water Tank], International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181, Special Issue - 2015.

[8]. Punith C, Usha, Jayalakshmi Raju and M. Adil Dar, [Finite Element Analysis of Underground Water Tank with different Safe Bearing Values of Soil], SSRG International Journal of Civil Engineering (SSRG-IJCE) – EFES April 2015.

[9]. Rahul Dubey, Vaibhav Singh and Vijayant Panday, [Seismic Analysis of Underground Water Tank Considering Soil-Structure Interaction], International Journal of Engineering Research and Applications, Vol. 11, Issue 10, (Series-I) October 2021, pp. 21-25.

[10]. Rishi Dave, Rahul Patel and Prutha Vyas, [Design and Seismic Analysis of Ground Supported Water Tank], Kalpa Publications in Civil Engineering Volume 1, 2017, Pages 1–6.

[11]. Suraj P. Shinde, [Computer aided analysis and Design of Underground water tank as per BIS], International Journal of Advance Engineering and Research Development (IJAERD) Technophilia-2018.,Volume 5, Special Issue 04, Feb.- 2018.

[12]. Suraj Tripathi, Annu Dubey and Madan Chand Maurya, [Time History Analysis of Underground Water Tank for Different Seismic Intensity], International Journal of Science and Research (IJSR) ISSN: 2319-7064, Volume 9 Issue 6, June 2020.

[13]. Thalapathy.M, Vijaisarathi.R.P, Sudhakar.P, Sridharan.V and Satheesh.V.S, [Analysis and Economical Design of Water Tanks], IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 3 Issue 3, March 2016.

[14]. W. O. Ajagbe, E. O. Ilugbo, J. O. Labiran and A. A. Ganiyu, [Analysis and Design of a Fully Submerged Underground Water Tank Using the Principle of Beam on Elastic Foundations], (2010). Cost effectiveness and tradeoff on the use of rainwater tank: An empirical study in Australian residential decision-making. Resources, Conservation and Recycling. 54(3), 178-186.

[15]. Youssef M.A. Hashash, Jeffrey J. Hook, Birger Schmidt and John I-Chiang Yao, [Seismic design and analysis of underground structures], Tunnelling and Underground Space Technology 16 2001 247 Ž . 293.

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