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Analysis of underground rectangular water tank for the computation of shear force and bending moment coefficients

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ABSTRACT

Rectangular tanks are common as it is use for the storage of liquids such as water, oil, petroleum products, compressed gases, etc. Analysis of such tanks is quite difficult. So, in order to analyse these tanks various methods are used. Mostly Approximate method and Finite Element Method (FEM) are used to analyse water tanks. This paper presents a literature review on the analysis of rectangular tanks by using Finite Element Analysis (FEA) with thehelp of STAAD Pro software. The design and analysis of rectangular tanks requires various design charts and involves lengthy and monotonous calculations. To avoid these tedious calculations various codes and books are available which provide charts for shear force and bending moment coefficients for the design of water tanks with different support conditions.This paper gives an idea for an approach to the analysis of rectangular tanks by Finite Element Analysis (FEA).

Keywords: *Underground Tanks, Moment Coefficients, STAAD Pro V8i, Analysis of RC Tanks, L/H Ratio.*

1. INTRODUCTION

Underground rectangular tanks come under liquid retaining structures. Water is the basic requirement of living beings. As the Water table goes on decreasing, we need to conserve large amount of water. For the storage of such a large amount of water, underground tanks are most preferable. Not only for storage of water, underground tanks are used but alsoit is used for the storage of oil, beverages, petroleum products, etc. Tanks are of various size, shape and based on itsposition of installation. viz. rectangular tanks, circular tanks, intze tank. Tanks can be constructed above the ground (elevated water tank), resting on ground and underground.

Rectangular tanks are difficult toanalyse and hence it is analysed by Finite Element Method (FEM). Finite element method is the method which is widely used for getting the solution for engineering andmathematical models. In FEM, for solvingthe problem, a large model or system is subdivided into the smaller and simplerparts that are called finite elements. It can be done by constructing mesh to the object.FEM is used to minimize the error while finding the solution. Practical application of FEM is known as Finite Element Analysis (FEA). As a computational tool for performing engineering analysis Finite Element Analysis (FEA) is applied. It includes the technique of generating mesh for dividing complex problems into smallerand simpler parts, with this it is used in software programs which use the Finite Element Method (FEM) algorithm. Some of the software are STAAD Pro, Revit,ANSYS, SAP 2000, etc. are coded with theFEM algorithm.

While analysing rectangular tanks, it is analysed for the single wall panel by considering it as a thine plate with the support conditions such as top free, bottomand vertical edges fixed; top free bottom hinged and vertical edges fixed; top and bottom hinged and vertical edges fixed.Shear force and bending moment coefficients for all these conditions are provided in various books and codes of practice for civil engineering to minimize the calculations for the water tanks. These shear force and bending momentcoefficients are given on the basics of the length and the height of the tank i.e. lengthto the height (L/H). While analysing these tanks by Finite Element Analysis

Generally, in rectangular tanks wallpanels are meshed to form fine plates due to which a wide range of continuous platesoccurs and for static analyse of such structural system, various methods are available and for that number of equations to be solved. Exact analysis of these thin plate is only possible when the twoopposite sides of plate are simplysupported.

2. LITERATURE REVIEW

Anshuman Nimade, et.al (2018) studied thebehaviour and some parameters such asstresses, node displacement and base pressure which is produced in theunderground rectangular tanks. This studyis conducted on tanks with varying width and length ratio (L/H) and the height of thetanks are constant. The study is based on the Finite Element Method (FEM) using STAAD Pro V8i. For analysis 0.5*0.5 plate meshing is considered. For neglecting the uplift pressure due to deep ground water table, soil pressure and hydrostatic pressure on external walls are considered. The study in this paper is consists of:

1) By using STAAD Pro software finite element models of

underground rectangular tank are developed.
2) With the varying ratio of L/B, the behaviour of underground rectangular tanks is studied.
3) Stress pattern and node displacement occurred in underground rectangular tanks are studied and compared it with different tanks with different L/B ratio.
4) The main components acting on thetanks i.e. base pressure, external soil pressure on the walls of the tank and moments of underground rectangular tanks structure is studied with different tank conditions such as tank full condition and empty tank condition.

In this paper, five tanks are analysed in which length and height of the tanks are constant with varying width of the tank which gives different L/B ratio with constant design data such as thickness of wall, unit weight of soil, safe bearing capacity of soil, width of projection, etc.

From the above analysis, it is concluded that with the increase in L/B ratio bandingmoments (Mx, My, Mxy) in the wall decreases. Node displacements also occursin vertically downward direction in tank full condition and with the increase in L/Bratio base pressure also increases.

Suraj P. Shinde (Feb2018) In this paper, a computer aided analysis is done for the underground rectangular water tanks. The motive of the paper is to compare the design and manual analysis of undergroundrectangular water tanks by using IS code method with the SAP 2000 and STAAD Pro software analysis results. This paper gives a brief theory for the design andanalysis of underground rectangular water tanks by using Working Stress Method.

The main objective of the investigation is to design and analyse the underground rectangular water tanks by according to IScode method to know the axial force and deflected shape of the tank with empty tankcondition and tank full condition.

Steps involved in design and analysis are: to check for stability and strength of the structure. In empty condition of underground rectangular water tanks, it is mandatory to check for uplift pressure and critical sections. This analysis is helpful for deflection calculations as it is not calculated in manual calculations. Deflection calculations are done in twodifferent software i.e. in STAAD Pro and SAP 2000 and it was seen that the calculated deflection in both the software are nearly same. From the above analysis itis concluded that stresses on soil must be less than allowable stress (in case of tank full condition); and in uplift check, dead load must be greater than upward pressure. If the condition for the uplift check is not satisfied then increase the floor thickness and provide projections (toe) to each side which includes soil pressure.

Isaar Kapadia, et.al. (January 2017) This paper based on the study related to thebehaviour of underground rectangular storage tanks with empty condition andtank full condition. In thank full condition,hydrostatic pressure is acting on the inner walls of the tank and soil pressure is actingfrom the outer side of the tank which are counterforce to each other. In emptycondition, only soil pressure is acting on the wall from outer side, hence it is necessary to analyse the structure for its critical condition i.e. empty condition and tank full condition.

So, in this paper, empty tank condition andtank full condition are analysed for thestructural behaviour and shape deflection by using STAAD Pro and SAP 2000. In tank full condition it is not necessary to check for the stability of the structure but for empty tank condition it is necessary to check for uplift pressure to check the stability of the storage tank with respect tothe ground water table. In this paper, underground rectangular water tank of size 20m*10m*5.5m are analysed with different wall thickness and base slab thickness.

From the above analysis it is concluded thatif the uplift check fails, we need to increasebase slab thickness to increase the dead load of the structure as for the uplift check,dead load of the structure must be greater than upward pressure exerted on the base slab. If in case, after increasing base slab thickness then also check for uplift pressure fails, then it is necessary to provide projections from all side.

W. O. Ajagbe, et.al. while designing and analysis of underground or fully submerged storage tanks it is ensured that these tanks are designed crack free. This research is based on the study of fully submerged or underground storage tanks for wall moments and base slab moments in underground rectangular water tanks.This analysis of fully submerged storage tanks is done by using the principles of Beam on elastic foundation. For analysis wall and base slab of underground rectangular tank are divided into fine stripsand for analysis a single strip is considered. By an elastic medium the entire length is supported in a principal plane of the symmetrical cross section.

The principles of Beam on elastic foundation is based on the assumption that the foundation reaction forces are proportional ateach point of the beam where it is deflected and with this flexural rigidity (EI) is considered for analysis. And for foundation, soil is behaving as a bed of springs. By this method various equation was driven for bending moment and shearforce at any point of the wall panel and base slab.

Microsoft Excel spreadsheet design and analysis program which is commonly named as MESDA Pro is used to generate a spreadsheet for various tanks capacity and for different soil conditions.

From this paper it is concluded that, by using this method of Beam on elastic foundation gives an accurate results of bending moment and shear forces and withthe help of Microsoft Excel spreadsheet design and analysis program (MESDA Pro) the chart for bending moments and shear force are modified to reduce tedious calculations; and the modules of soil subgrade at constant capacity the momentsof wall and slab decreases.

Liaquat A. Qureshi, et.al. (2013) stated thata 2D and 3D finite element analysis ofunderground rectangular storage tanks by using software GTS (Geotechnical and tunnel analysis system) with soil structure interaction. Underground rectangular water tank which is a buried structure and whichis considered as an elastic spring supportedfor overlaying superimposed load. GTS (Geotechnical and tunnel analysis system) is a modern tool to analyse and design of soil structure interaction which is based on Finite Element Method (FEM) to solve complex problems.

In this paper analyses of two tanks of different dimensions are done based on 2Dand 3D Finite Element Analysis. By usingshell elements 2D and 3D finite element models are developed and under all the nodes of base slab elastic spring are provided. For 3D finite element model all the three principle directions for stability ofstructure are kept fixed and all three rotations are kept free for analysis.

From the above study and analysis, it is concluded that 3D Finite Element Method is more accurate and reliable for design and analysis for buried structures.

T. A. Verwey, et.al (2010) discussedvarious parameters and criteria which is must to be considered for safe and crack free structure of underground rectangular storage tanks. In this paper parameters suchas joint connections, water cement ratio, use of chemical admixture and most important parameter i.e. buoyancy calculations are discussed.

Underground structures need to analyse for buoyancy as the structure may can float dueto level of ground water table. If the dead load of the underground rectangular storage tanks is less than the buoyant forceexerted on the structure. The structures start floating and loses its stability. Buoyancy calculations is done for the empty tank condition.

In this paper factor of safety for buoyancy calculations are recommended with the help of ACI 350.4. From the study it is inferred and consideration for calculationsbuoyancy check for buoyancy is taken intoaccount.

FS= 1.10 When the ground water tablelevel is at the top of the structure and this isconsidered for the worst-case scenario.

FS=1.25 For this condition 100 years well defined flood cases are considered.

FS> 1.25 this condition does not consider well defined flood condition and soil friction is included in the resistance.

Rihanul Alan Chowdhury et.al (2015) stated that analysis of fully buried underground water tank model is conducted by changing only singleparameter at a time. In this paper free top and fixed base support and tank full condition is analysed with the soil pressureexerted on the outer side of the wall for different L/H ratio. A Finite Element Analysis (FEA) is done by using software SAP 2000 which is based on FiniteElement Method (FEM). With the influence of various extensive parametric study of a finite element model of underground water tank is developed for analysis purpose. For different values of parameters moment and shear force is calculated at different location of the model.

From the above research it is inferred that with the increase in soil density for same L/H ratio, maximum moment and shearalso increases for all axis. As width to the height B/H ratio decreases for short wallMaximum moment and shear also decreases at a certain point. If L/H ratio decreases, maximum moment and shearalso decreases expect at short wall it continues to decrease.

Mr. Manoj Nallanthel, et.al. (2018) haddone "DESIGN AND ANALYSIS OF WATER TANKS USING STAAD PRO."

In this paper study of stress distributions inthe plates is included. Various shapes of underground tanks such as rectangular tank, square tank and circular tank are analysed. Influence of shape factor in design load is taken into account.According to IS code loads and loading combinations are applied to the underground liquid storage tanks. Tank fullcondition and partially filled tank conditions are considered for design and analysis of the structure.

From the above paper with respect to the bending of plate due to loading applicationplate deflection is analysed. With the help of this deflection stresses in plates are calculated. It is concluded that the shear force and bending moment are accurately calculated by STAAD Pro than the conventional method. The uplift pressure and shape of the tanks plays a prominent role in design and analysis of undergroundrectangular tanks.

3. CONCLUSION

1. With the increase in L/H ratio banding moments (Mx, My, Mxy) in the wall decreases.
2. Uplift check, dead load >upward pressure.
3. If the condition for the uplift check is not satisfied then increase the floor thicknessand provide projections (toe) to each side which includes soil pressure.
4. If in case, after increasing base slab thickness then also check for uplift pressure fails, then it is necessary to provide projections from all side.
5. 3D Finite Element Method is more accurate and reliable for design and analysis forburied structures.
6. It is concluded that the shear force and bending moment are accurately calculated byusing software STAAD Pro.

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