Design, Analysis and Soil-Structure Interaction of an Intze Tank using ETABS, ANSYS and SAFE

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***Abstract*— Though India is a developing country yet India lacks to fulfill many day to day requirements of the society. Some villages in India still do not have good water supply system which results in people walking miles away to collect water for their daily use. This project work basically deals with the design and analysis of an over-head tank resting on four columns. It also includes the study of soil structure interaction between the foundation of the water tank resting on the columns and the soil. Being a civil engineer it is a great opportunity to work for the benefit of the society and hence I opted to this project thinking that it will benefit the society and help India to step ahead of being a developed country.**

In this project, the general design of the water tank, column and the foundation is done by using MS Excel. The water tank and the columns are modeled and analyzed using ANSYS. The columns and the bottom slab of the water tank is modeled and analyzed in ETABS. This analysis is then exported to SAFE for doing the soil structure interaction. The soil structure interaction is done by importing the analysis from ETABS to ANSYS and then the uplift pressure of the soil to the structure is studied.

While modeling and analyzing the water tank and columns in ANSYS, many limitation of the software is seen which will the discussed later in the chapters.

Keywords*— *Intze tank, finite element analysis, soil-structure interaction.

I. INTRODUCTION

A storage tank is one of the most important elements in a particular area or society. It may be described as a storage device of any type of fluid such as water, chemical, fuel, etc. one of such type of storage tanks is the water tank. Water tank is used to store water for using it in many application such as water used for bathing, cooling, drinking, irrigation, agricultural farming, fire suppression, chemical manufacturing, etc. Water tank parameters include choice of materials such as plastic, concrete, fiber-glass, stone and steel. It also depends on the linings

A. History

In early times, there was also use of water tanks. They were made of wood, stone and ceramic. Some of them naturally occurred while the others were made by men which are still giving its service.

In 15th September 1916, Britain used water tanks for the first time in the battle of Flers-Courcellette. Because of the increased in production and reliability, they had to use a large number of water tanks. By the end of 1918, about 2600 water tanks were manufactured. Leonardo da Vinci invented a war machine which looked like a water tank

B. Soil-structure Interaction

In most of the cases of earthquake analysis, it is assumed that the structure rest on a fixed based. But the fact is when earthquake forces hits up a structure the soil is affected by its motion. Hence, the soil transfers some forces to the super-structure. When the ground motion transfers some energy to the super-structure, the super-structure also transfers some amount of energy to the soil. This relation is clearly defined as a soil-structure interaction. Soil-structure interaction is a very important phenomenon which includes the study of the co-relation between the soil and the structure. The structure rest on the footing which is again supported by the soil beneath it. This helps to know how every particle of the soil will behave when it is exposed to the loads coming from the structure. Here, if any external force is acted upon it, the motion of the soil will influence the motion of the structure and vice-versa.

SSI is often neglected. The SSI clauses of seismic design codes are optional and hence it give the designers a reduction in the design base shear of the building by considering SSI as an important effect.

In this study uplift pressure is studied which results when the pore-water pressure under the ground exceeds the mean overburden pressure. It may result from earthquake forces.

II. DIMENSIONING AND ASSUMPTIONS

- Height of the cylindrical portion of the water tank = 8m
- Height of the supporting tower = 16m
- Number of columns = 4
- Density of water = $9.81 kN/m^3$

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III. ANALYSIS

A. Analysis of the Overhead Water Tank Using Ansys

An overhead water tank supported by four columns and braces is modelled in ANSYS. A static structural analysis is carried out by the Finite Element Method (FEM) which gives the total stresses and deformation in the structure. M30 grade of concrete and Fe415 steel is considered for the design.

ANSYS is basically a mechanical department software which is been rarely used by the civil department. Thus, while modelling and designing the structure of the project, some of the limitations of the software were observed. The limitations include the diameter of the bars should be considered same in a particular area for stirrups and the main bars. While the water tank has a top dome slab and bottom dome slab both has to be ignored while designing since giving reinforcement portion in the dome part is cumbersome. Though the length of the column in the manual design is 16m, this software did not take up 16m length due to large number of nodes formation. So, 8m column is been considered. Beyond these limitations ANSYS is very user-friendly software which gives the analysis solution by FEM within a short duration of time.

B. Modelling in Ansys

SOLID65 is usually a concrete material. It is generally used for a block or a rectangular section. The overhead water tank considered in the present stydy is cylindrical in shape. Hence, SOLID65 cannot be used. In this case either SOLID187 or SOLOID92 has to be used. SOLID92 cannot be used for random load analysis. Therefore, for the analysis purpose SOLID187 is used. As it is not a concrete material, its properties are over-written as that of the concrete material with the help of commands. We are defining the property of SOLID187 element using stress-strain curve of concrete at 22 ° C temperature. It is defined in commands. For the reinforcement of the section, lines are drawn. In the lines, the cross-section property and the material properties are defined in commands by considering reinforcement as isotrophic element (considering only one direction).

The nodes of the reinforcement and concrete are joined using CEINTF command.

C. Analysis in Ansys

After the modelling is done a static analysis is carried out in ANSYS which gives the value of equivalent stress and the total deformation of the structure. For the analysis the mesh is first created to do finite element analysis of the overhead water tank structure.

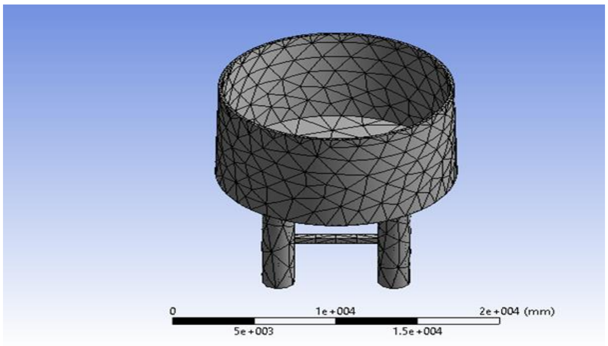

Fig.1: Meshing of the structure

Loads considered are the wall load is acting along the circumference of the bottom slab of the tank and the hydrostatic pressure due to water present is considered.

D. Analysis of Bottom Slab of Water Tank znd Columns By Etabs2016

The columns and the bottom slab of the overhead water tank in modelled in ETABS2016. After the modelling is completed, the dynamic analysis is carried out by using response spectrum. Base shear is been calculated and seen if the model is safe against seismic loading.

E. Analysis of Soil-Structure Interaction Using Safe

To study the soil-structure interaction, the columns along with the bottom slab of the overhead water tank is modelled and designed in ETABS2016. The structure is then exported to SAFE. Importing the model from ETABS2016 to SAFE, the soil-structure interaction is studied which shows the uplift pressure of the soil due to the load from the structure and maximum level of pore-water pressure.

IV. RESULTS

By doing the analysis in ANSYS, the results are obtained for equivalent stress and total deformation which is discussed below.

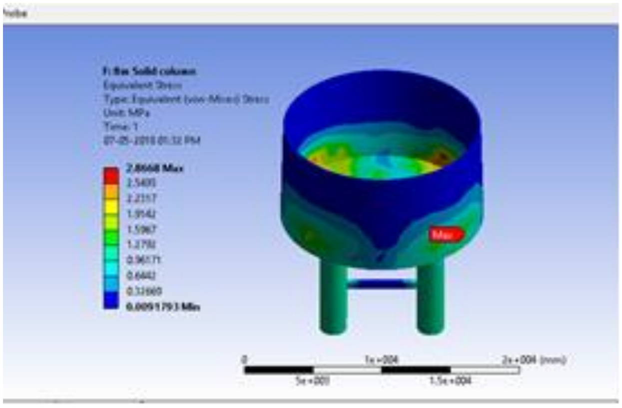

Fig.2: Equivalent stresses.

After the analysis is done, the solution for the analysis is obtained. In the above figure it shows that the maximum equivalent stress is 2.8668MPa which is present inside the cylindrical portion and a minimum equivalent stress of 0.0091793MPa acting outside the cylindrical portion.

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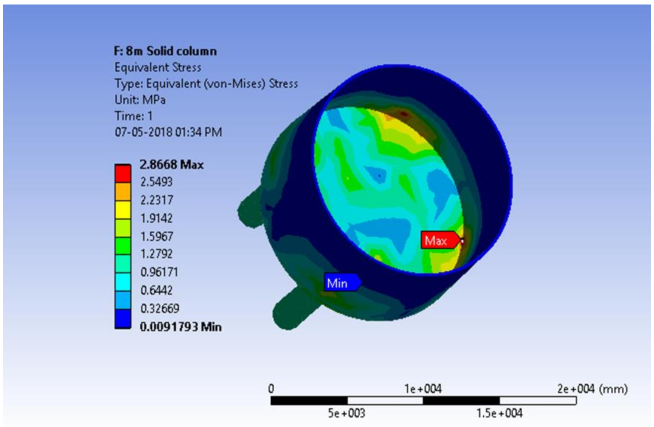

Fig.3: Maximum and minimum equivalent stresses

Figure above shows the maximum and minimum stresses in the structure. Since the maximum stress is very less. Hence, the structure is safe and can withstand 1500m^3 of water easily. The proposed model is safe to construct in field.

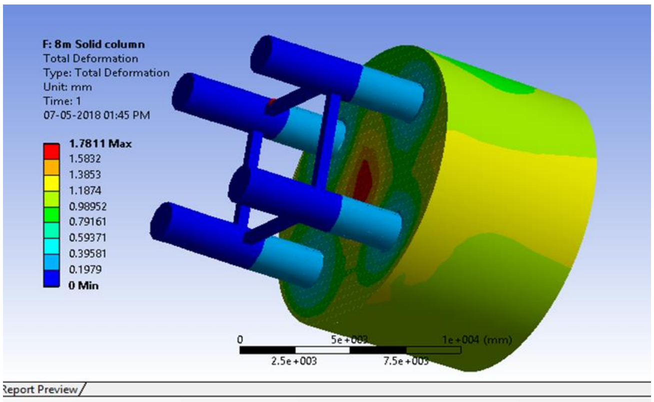

Fig.4: Deformation of the structure

In the figure above, the total deformation of the structure is shown. The maximum deformation occurs at the centre of the bottom slab. The zoomed view of the total deformation is shown in the figure. It is concentrated at the bottom slab because the maximum hydrostatic pressure is concentrated at the bottom surface of the tank.

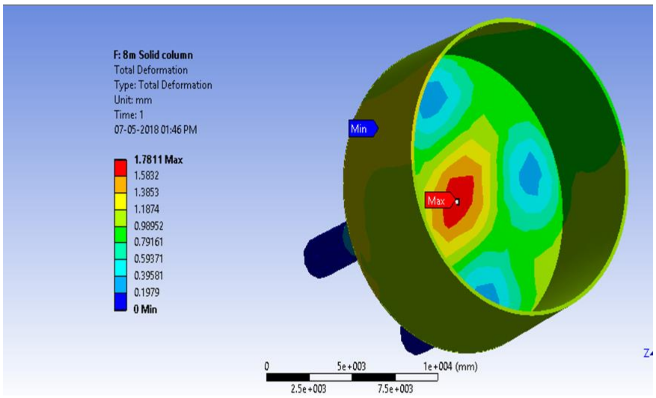

Fig.5: Maximum and minimum deformation

The maximum and minimum stresses are shown in the figure. The maximum total deformation is 1.7811mm which is very less and minimum is 0mm. Hence, the proposed structure is safe.

From analysis done in ETABS 2016.

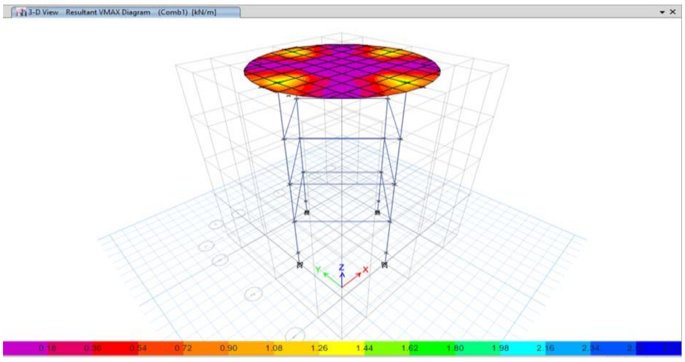

Fig.6: Stresses generated in bottom slab for 1.5DL+1.5LL (Vmax)

In the above figure stresses obtained from analysis is shown. Among the various load combinations used, in this figure 1.5DL + 1.5LL is shown. The stresses generated are equivalent to zero and hence it is safe. The analysis is done based on maximum shear force. The minimum stress generated is 0.18N/mm2 and maximum stress generated is 2.52N/mm^2.

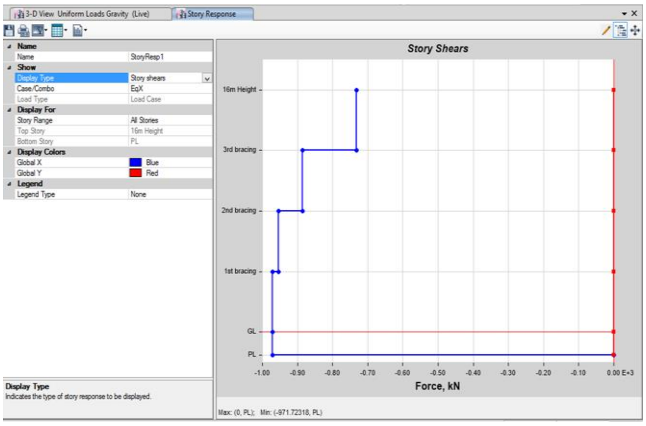

Fig.7: Response spectrum graph due to storey shear

While doing the response spectrum analysis in ETABS2016 a storey shear graph is obtained which is shown in the figure. Response spectrum is a steady state response of displacement, velocity or acceleration of a series of oscillators of varying natural frequency that are forced into motion by the same base vibration or shock.

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By analysing in SAFE, results obtained are as follows:

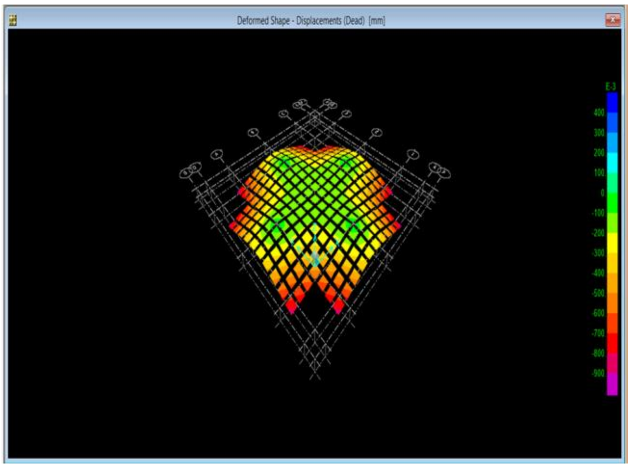

Fig.8: Deformed shape of mat foundation due to uplift pressure

Uplift pressure results when the pore-water pressure under the ground rises. Therefore, because of the uplift pressure the structure will be affected. The deformed shape of the raft slab is shown in the figure due to the uplift pressure. The maximum deformation observed is 400mm and minimum is -900mm. It is seen in the figure that the centre is almost green hence has a value of -100mm and at edges it is -900mm.

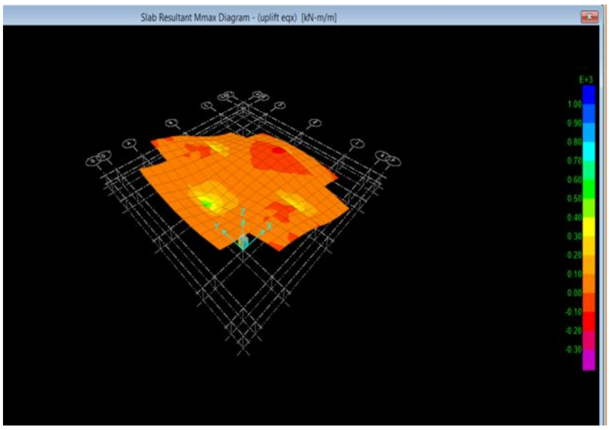

Fig. 9: Maximum moment due to uplift pressure

Figure shows the maximum moment in the raft slab due to the application of uplift pressure. It is seen that that maximum moment is 1kNm and minimum is -0.3kNm. The colour represented in the figure is orange-yellow and the value is between 0.10 to 0.00kNm.

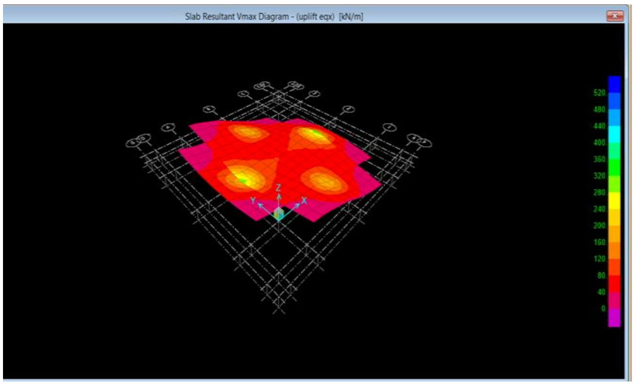

Fig.10: Maximum shear forces due to uplift pressure

When uplift pressure is applied to the raft slab maximum shear force occurs at a particular area in the slab. Figure shows the maximum shear force because of the pressure applied. The shear force value obtained from the analysis is maximum of 520kN and minimum of 0kN. From the figure it can be seen that at centre it has a shear force of 80kN to 40Kn and at edges it has 0 kN.

V. CONCLUSION

An overhead water tank is considered with 14m diameter and the height of the cylindrical tank is 8m. Number of columns used to support the overhead water tank is 4 with 16m height. The overhead tank is analysed using different softwares namely ANSYS, ETABS2016 and SAFE. From the study it can be concluded that

- The maximum equivalent stresses obtained from ANSYS analysis are 2.866MPa which is present inside the cylindrical portion.
- The minimum equivalent stresses from ANSYS analysis is 0.009173MPa.
- The maximum deformation obtained from ANSYS analysis is 1.7811mm.
- The minimum deformation obtained from ANSYS analysis is 0mm.
- From SAFE analysis, the maximum deformation is 400mm.
- From SAFE analysis, the minimum deformation is -900mm.
- The maximum moment obtained from SAFE is 1kNm.
- The minimum moment obtained from SAFE is -0.3kNm.
- From SAFE, the maximum shear force is 520kN.
- From SAFE, the minimum shear force is 0 kN.
- From ETABS2016, storey shear graph is obtained.
- From ETABS2016, maximum moment is obtained by 1.5DL + 1.5LL combination.
- From ETABS2016, minimum moment is obtained by 1.5DL + 1.5LL combination.

It can be concluded that the stresses generated is very minimum and hence the structure is safe for constructing in field. The soil structure interaction is an important phenomenon and has to be given more priority before the construction of the structure. Most of the structures are constructed with doing analysis based on soil structure interaction and thus the structure can fail mainly due to the soil structure correlation during severe earthquake. Hence, the analysis is carried out in this project with SAFE and the deformation obtained is minimum. From this analysis it can be concluded that the structure will have a good service period. From response spectrum analysis done in ETABS2016, it is derived that the structure is safe against severe ground motion.

VI. ACKNOWLEGEMENT

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