Dynamic Analysis of Intze Tank on SlopedGround

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Abstract - Reinforced concrete water retaining structures (underground, on the ground, and overhead) are most widely used in construction as they are rigid and are easyto construct. Water tanks are one of the most important lifeline structures. Water tanks form an integral part of thewater supply scheme in most cities and rural areas. India isa large country with diverse geographic conditions. Overhead water retaining structures (Intze tanks) are widely used as they have a larger water holding capacity and require lesser space. Intze tanks are preferred as they are constructed over the ground and hence the energy required to operate them is less compared to other types of tanks. As the discharge of water by the Intze tank depends on the potential energy (which in terms depends on the elevation of the water tank above the delivery point), the height the level of the tank above the delivery point greater is the efficiency. India is divided into various seismic zones. The construction of the Intze tank in hilly areas requires additional structural analysis to take into account the seismic effect. Housner's two-mass model for the water tank is selected for dynamic analysis where the whole mass of water is divided into two, impulsive liquid mass and convective liquid mass. The analysis is carried out to find the base shear and base moment. The manual dynamic analysis is done with a varying height of water level in the tank using IS 1893 (Part 2) guidelines and studies the effects due to changes in height of water level. The manual dynamic analysis is compared with the dynamic analysis performed in FEM software STAAD.Pro V22 for varying heights of water levels.

Keywords — Seismic effect, RCC structure, IS1893 (Part2), Dynamic analysis, STAAD.Pro V22.

I. INTRODUCTION

RCC water retaining structures can be classified in various ways. Based on the position of the structure, RCC water tanks are classified as Underground, On the ground, and overhead water tanks. All these types of water tanks have their merits and limitations. As India is a vast country with varying landforms the choice of the water tank will depend on the location. In hilly areas of North-East India overhead tanks are more suitable than other types of tanks. But hilly areas of India falls in seismic zone IV and V which are frequently subjected to Earthquakes. In the case of an earthquake, the damage caused to the Intze tank can be very severe and can lead to destruction. Intze tanks constructed on the slope are subjected to multiple types of forces during an earthquake. Intze tanks are water-containing structures. In event of an earthquake, both the Intze tank and the water inside it will experience shaking which introduces various complex stresses to the RCC structure. To simplify it, IS 1893(Part 2) utilizes a two-mass model. During an earthquake, a portion of the water contained in the tank will undergo sloshing motion and other portions will act as a part of the RCC structure. The water level in the tank affects the seismic performance of the water tank. The parameters like base shear and base moment help to understand the seismic performances of a structure. The seismic design should be based on these parameters. The water level in the tank has animportant role in contributing to base shear and base momentin the case of the water tank. During an earthquake, the water inside the tank also undergoes sloshing motion. That sloshing motion depends on the seismic performance of the tank. Here manual dynamic analysis and software dynamic analysis wasconducted to find out the base shear and base moment of the Intze tank constructed on the sloped ground with a capacity of 500m3 in hard soli. Dynamic analysis was performedusing the well-known software STAAD.Pro V22

II. OBJECTIVE BEHIND THE STUDY

1. To perform dynamic analysis for Intze Tank constructed on the sloped ground using the analytical method as described in IS 1893-2016part-2.
2. The ground slope increases from 0^0 to 25^0.
3. To calculate lateral stiffness of staging and modal mass using the FEM analysis approach.
4. To calculate horizontal seismic coefficient, base shear, base moment.

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III. SCOPE AND NEED OF STUDY

1. This study will help to analyze the Intze tank on sloped ground.
2. This study will help to create an easy approach to analyzing and designing complex structures like the Intze tank where a two-mass system is present.
3. This study will bring a bridge between the existing procedure as given in IS1893-2002 and FEM approach done using Staad.Pro.

IV. LITERATURE STUDY

George W. Housner [1] discussed the relation between the motion of water with respect to the tank the and motion of the whole structure with respect to the ground. He had considered three basic conditions i.e. tank empty, tank partially filled and tank fully filled for the analysis, and finely concluded that the maximum force to which the partially filled tank is subjected is less than half the force to which the full tank is subjected. The actual forces may be little as 1/3 of the forces anticipated on the basis of a completely full tank. Sudhir Jain and U. S. Sameer [2] had given the value of performance factor K =3, which is not included in IS 1893:1984 for the calculation of seismic design force, and also given some expressions for calculation of lateral stiffness of supporting system including the beam flexibility. Sudhir Jain & M. S. Medhekar [3] had given some suggestions and modifications in IS 1893: 1984. He had replaced the single degree of freedom system with two degrees of freedom system for the idealization of the elevated water tank, the bracing beam flexibility is to be included in the calculation of lateral stiffness of thesupporting system of the tank, the effect of convective hydrodynamic pressure is to be included in the analysis. Sudhir Jain & Sajjad Sameer U. [4], added more suggestions other than above i.e. accidental torsion, the expression for calculating the sloshing wave height of the water, effect of hydrodynamic pressure for tanks with rigid walls and the tanks with flexible wall should be considered separately.

M. K. Shrimali & R. S. Jangid [5] discussed the earthquake response of elevated steel water tanks isolated by the bearings which are placed at the top and bottom of steel tower structure and concluded that the earthquake response of the isolated tank is significantly reduced and more effective for the tanks with a stiff tower structure in comparison to the flexible tower. O. R. Jaiswal & Sudhir Jain [6] had recognized the limitations and shot coming in the IS 1893:1984 and suggestions given by all the above authors. He had proposed the different values of response reduction factor for different types of tanks, and also considered the expression for Design Horizontal Seismic Coefficient given in revised IS 1893 (Part-1): 2002, a single spring-mass modelfor both the tanks i.e. tanks with rigid & flexible wall are proposed, correction in expression for convective hydrodynamic pressure, a simple expression for sloshing wave height of the water is used and added the effect of vertical excitation in the seismic analysis. R. Livaoglu & Dogangun [8] discussed the response of the supporting staging system of the water tower. He had considered frame supporting as well as cylindrical shell supporting systems, and concluded that the frame supporting system is more effective than the shell supporting system. Gareane A. I, S.

A. Osman & O.A. Karim [8] discussed the soil and water behavior of elevated concrete water tanks under seismic load and concluded that significant effects obtained in shear force,overturning moment, and axial force at the base of the elevated water tank. Lyes Khezzar, Abdennour Seibi & Afshin Gohazadeh [9] discussed the steps involved in a test ring to study the water sloshing phenomenon in a rectangular container subjected to impulsive impact and concluded that the water level for both simulation and experimental results compared well during the motion and showed the minor discrepancy after impact which may be due to tank bouncing.

W. H. Boyce [10] discussed the response of a simple steel water tank measured during the earthquakes and vibration tests and concluded that the effect of water sloshing must be considered when calculating the period of vibration of water towers. Dr. Suchita Hirde & Dr. Manoj Hedaoo [11] discussed the seismic performance of elevated water tanksfor various Zones of India for various heights and the capacity of tanks for different soil conditions. The effect of the height of water tanks, earthquake Zones, and soil conditions on earthquake forces are discussed and finally concluded that the seismic forces are increases with Zones and decrease with a height of a supporting system, seismic forces are higher in soft soil than in medium soil, higher in medium soil than hard soil. Earthquake forces for soft soil are about 40-41% greater than that of hard soil for all earthquake Zones. IITK-GSDMA [12] discussed the guidelines for seismic design of liquid storage tanks. Is: 3370 (Part-II) [13] discussed the criteria for earthquake-resistant design of the structure. IS 1893(Part-II): 2002 [14] discussed the criteria for earthquake-resistant design of the structure. Detail analysis procedures for elevated water tanks are not maintained in this IS code, till today it is under revision.

V. METHODOLOGY

The design and analysis of the Intze tank is a complex process. As the Intze tank contains water it should be taken as a two-mass model. The following steps are followed in theresearch:

Step-1: A total of 6 models will be created with the structuralproperties given below: the sum of the mass of the empty tank and one-third mass of staging. The mass of the

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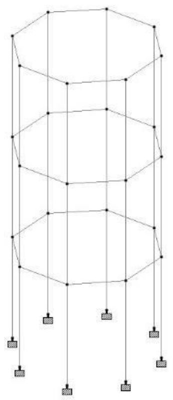
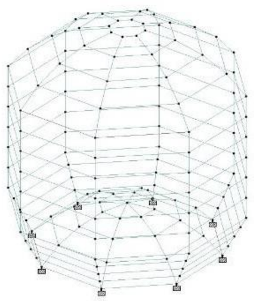
empty container and mass of staging is calculated using the FEM models created in Step-2. The mass of the FEM model is calculated using Staad.Pro by designing the empty container and staging as per the specifications given in Step-1. The load case consists of only one load case as a dead load. After performing the analysis the total downward reaction is computed (in k N) which is then converted into mass.

Step-4: For an elevated tank with a circular container, parameters m_i, m_c, h_i, $h^{\#}$, h_c, $h_c^{\#}$ and K_c shall be obtained

Step-2: As the slope increases the height of columns changes and hence it is advised to model the upper water tank part(the dome) and the lower part (staging) separately in Staad.Pro. These two models will be combined together to create the actual model of the Intze tank under the different ground slopes.



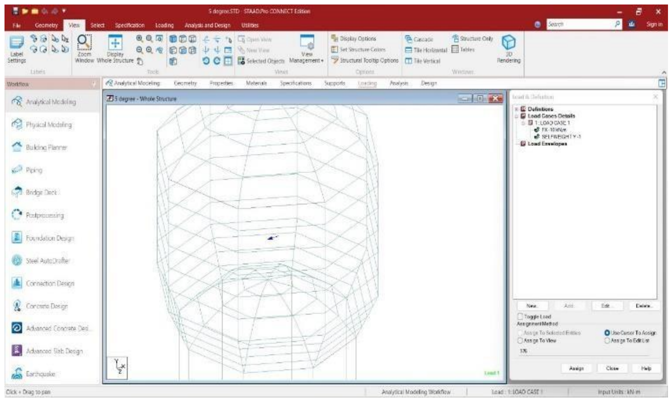
FEM model of the staging of Intze Tank



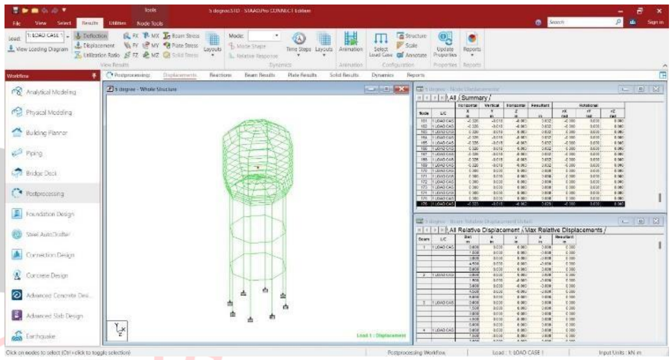
FEM model of the upper portion of Intze Tank

Step-3: Calculation of the Model mass of the structure. As the structural mass is divided into two parts namely the mass of water and the mass of RCC structure. The mass of water is calculated by multiplying the density of water and the volume of water. The mass of the RCC structure is taken as from IS 1893 part-2.

Step-5: Calculation for lateral stiffness of staging. The lateral stiffness of staging is calculated by performing FEM analysis in the model as shown below. To calculate the lateral stiffness, we have applied a load of 10k N at the center of gravity of the structure in the X-direction and performed the analysis. The deflection of the center of gravity in the X- direction is obtained from Staad.Pro using print result command. The lateral stiffness of staging is obtained by dividing the total load in the X-direction by the total deflection in the X-direction.



Load case for calculation of K_s



The calculation for deflection of CG using Staad.Pro

Step-6: Calculation for Time period. The time period is calculated for both impulsive mode and convective mode using the formulas given on page 24 of the IITK-GSDMA Guidelines for seismic design of liquid storage tanks.

Specifications	
The capacity of the tank	500 m^3
Unit weight of concrete	25 k N/m^3
The thickness of the Top Dome	0.1 m
Rise of Top Dome	2m
Size of Top ring Beam	0.2m x 0.2m
Diameter of Tank	10m
Height of Cylindrical wall	6m
The thickness of the Cylindrical wall	0.25m
Rise of Conical Dome	2m
The thickness of Conical shell	0.2m
Rise of the Bottom dome	1.25m
Thickness of Bottom	0.3m
Number of Columns	8
Number of Bracing levels	4
Size of Bottom ring Beam	0.3m x 0.2m
Distance between Intermediate bracing	6m
Diameter of Columns	0.5m
Size of Bracing	0.35m x 0.35m

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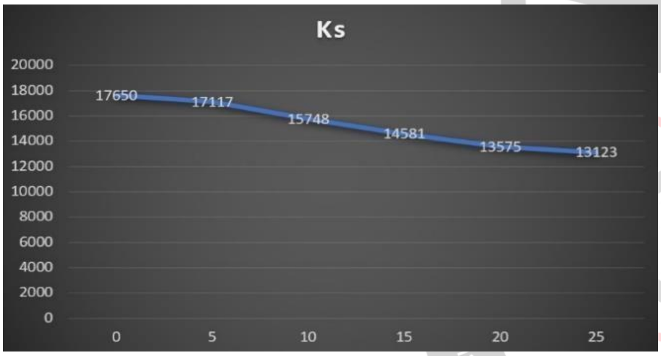
Step-7: Calculation for Design Horizontal Seismic Coefficient. The design horizontal seismic coefficients are calculated using the formulas given on page 28 of the IITK-GSDMA Guidelines for seismic design of liquid storage tanks. Here, the response reduction factor is taken as 5, the zone factor is taken as 0.24, and the important factor is taken as 1.5. The Average response acceleration coefficient as given in Figure 2 and Table 3 of IS 1893(Part 1): 2002 and subject to Clauses 4.5.1 to 4.5.4 of this guideline which depends on the value of the time period.

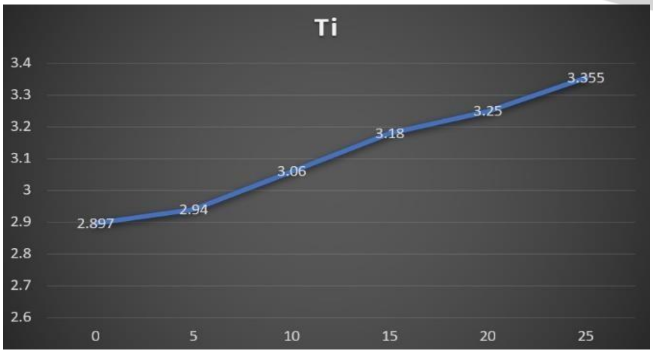
Step-8: Calculation for Base shear. The base shear values are calculated using the formula given on page 34 of the IITK- GSDMA Guidelines for seismic design of liquid storage tanks.

Step-9: Calculation for the Base moment. The base shear values are calculated using the formula given on page 36 of the IITK-GSDMA Guidelines for seismic design of liquid storage tanks.

2- The variation of lateral stiffness of staging with an increase in ground slope. As the ground slope increases the lateral stiffness of staging decreases.

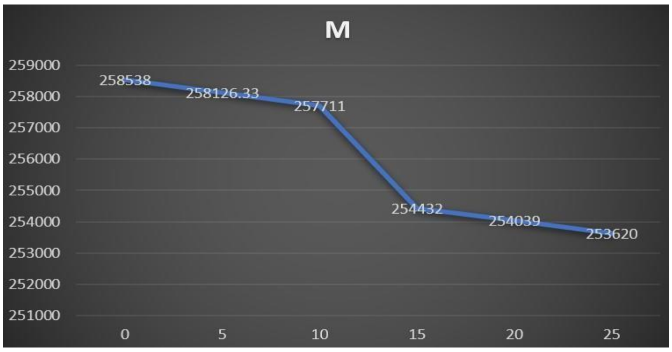


3- The variation of the time period in impulsive mode with an increase in ground slope. As the ground slope increases the time period in impulsive mode also increases.

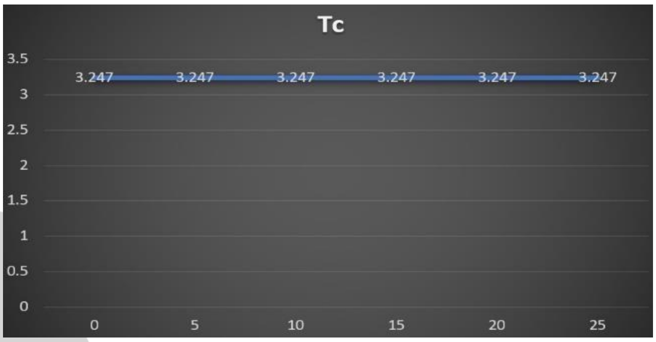


VI. RESULTS

1- The variation in the mass of staging with an increase in ground slope. As the ground slope increases the mass of staging decreases.

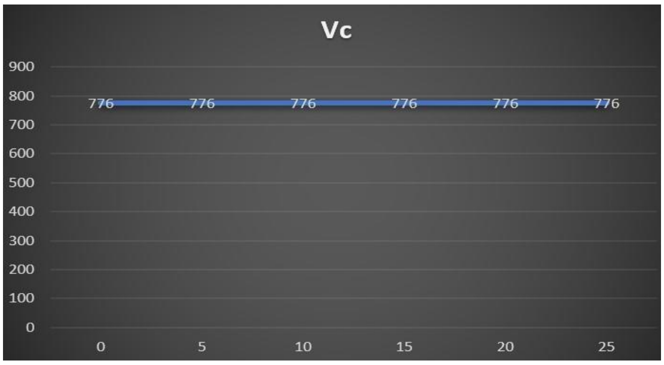


4- The variation of the time period in convective mode with an increase in ground slope. As the ground slope increases the time period in convective mode remains constant.



5- The variation of base shear at the bottom of staging in impulsive mode with an increase in ground slope. As the ground slope increases the base shear at the bottom of staging in impulsive mode decreases.

6- The variation of base shear at the bottom of staging in convective mode with an increase in ground slope.



7- The variation of resultant base shear at the

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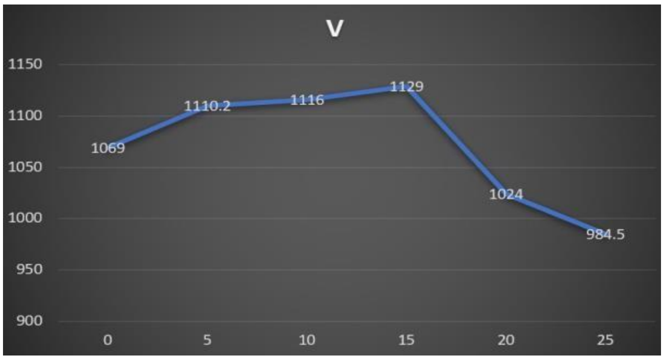
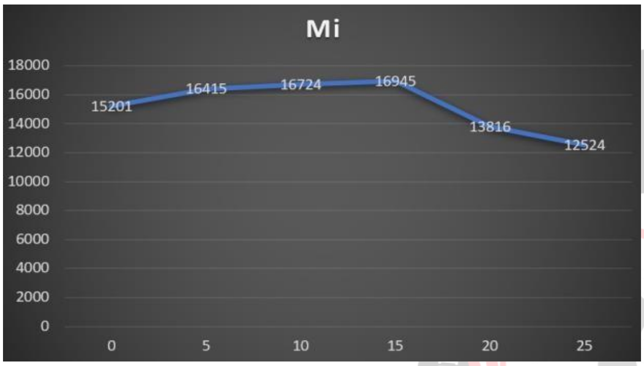
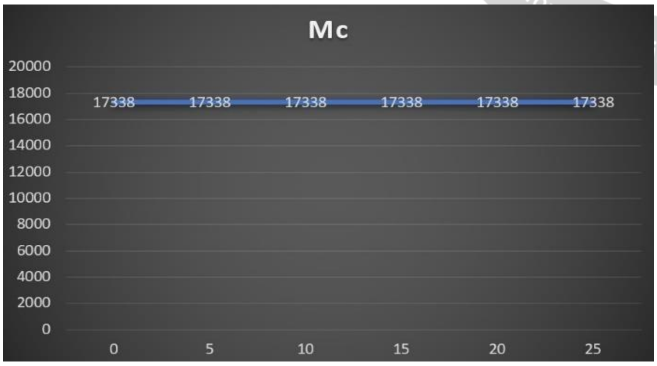
bottom of staging with an increase in ground slope. As the ground slope increases the resultant base shear at the bottom of staging decreases.



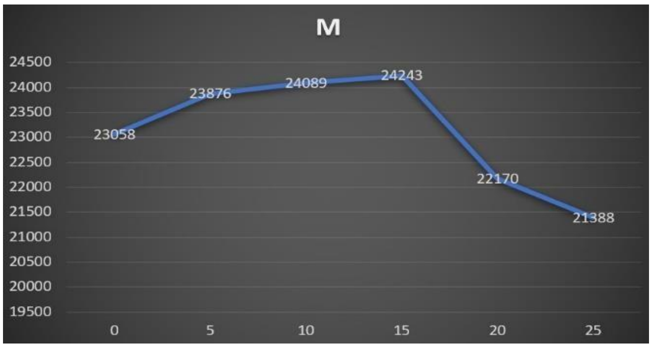
The variation of the moment at the bottom of staging in impulsive mode with an increase in ground slope. As the ground slope increases, the moment in impulsive mode at the bottom of staging decreases.



8- The variation of the moment at the bottom of staging in convective mode with an increase in ground slope. As the ground slope increases the moment at the bottom of staging in convective mode remains constant.



9- The variation of the resultant moment at the bottom of staging with an increase in ground slope. As the ground slope increases the resultant moment at the bottom of staging decreases.



VII. CONCLUSION

1- The mass of staging decreases as the ground slope increases.

2- The lateral stiffness decreases as the ground slope increases.

3- As the ground slope increases the period in impulsive mode also increases.

4- As the ground slope increases the period in convective mode remains constant.

5- As the ground slope increases the base shear at the bottom of staging in impulsive mode decreases.

6- As the ground slope increases the base shear at the bottom of staging in convective mode remains constant.

7- As the ground slope increases the moment at the bottom of staging in impulsive mode decreases.

8- As the ground slope increases the moment at the bottom of staging in convective mode remains constant.

9- As the ground slope increases the resultant moment at the bottom of staging decreases.

VIII. FUTURE SCOPE

1- This study will help to analyze the Intze tank on sloped ground.

2- This study will help to create an easy approach to analyzing and designing complex structures like the Intze tank where a two-mass system is present.

3- This study will bring a bridge between the existing procedure as given in IS1893-2002 and FEM approach done using Staad.Pro.

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