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Analysis of Effect of Temperature Gradient in Response of Steel Storage Tank using SAP

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Abstract:
Steel structures are more popular in recent years. The steel structures are used not only in storage tank, they have used in several purpose such as factory building, exhibition center, airport, sports stadium etc. In steel structure temperature change is the important factor due to solar radiation. And this temperature change slight variation in nodal displacement and stress. In this study, the models are mainly considered as three types, open top, fully closed, and fully closed with dome shape top reservoirs and the geometry and capacity of structures taken from API 650. The main parameter considered as volume and support condition. 50%, 70% and 100% volume has been considered and in supports, simply support and clamped supports conditions. The main loading considered as oil pressure, uniform and gradient temperature loads. The analysis has been carried out by SAP 2000 v20. It has been found that as the height of reservoir increases displacement and stress will decrease stress will more at the bottom and clamped support shows better performance compared to simply support.

Keywords: Steel reservoirs, finite element modeling, Oil Pressure, thermal load and gradient load.

I. INTRODUCTION

Circular reservoirs are extensively applied for storing liquids such as oil, water wheat grains, etc. These reservoirs are constructed from concrete or steel material and in circular or cubic forms. The thermal loading of steel storage tank is defined as temperature loading, which is one of the important loading type behind soil pressure, hydrostatic and seismic loads are pointed out in building codes. The main objectives of this project is to found stress and displacement of effect of uniform and gradient temperature on cylindrical reservoir and effect of different capacity and height to diameter ratio is an important factor on the results. In this way, the finite element modelling of the reservoir can be done with different height to diameter ratio and capacity taken from API 650. Model is subjected to hydrostatic and thermal loads in the form of uniform and gradient temperature and results are compared each other. Finite element modelling of steel reservoirs is carried out by using SAP2000 software. Four nodes, thin shell element is applied for modeling wall and roof elements of steel reservoir. Here the main three types of reservoir considered are,

1. Top surface open cylinder
2. Fully closed cylinder
3. Fully closed cylinder with Dome shape top.

The capacity of the tank considered as low, medium and high capacity as per API 650. Here I have considered petrol as liquid which filling the tank. The volume of liquid has considered as 50%, 70% and 100%. And Support condition considered as simply support and clamped support, clamped support nothing but bolted connection. The major part of this project is applying loads, mainly dead load, hydrostatic load and thermal loading and results are concluded by taking the values of stress and displacement obtain due to applied loads.

II. METHODOLOGY

2.1 INTRODUCTION

Here we are studying the effect of temperature on the reservoir structure, the temperature mainly considered as uniform and gradient temperature. And also the effect due to different height to diameter ratio and capacity for different modelled reservoir structure. The structures considered here are to be open, closed and closed with dome shape structures. Based upon different parameters the methodology can be illustrated.

2.2 Parameters to be considered

Here there are some parameters which we are going to considered in the analysis of steel reservoir mentioned below,

- Model & Capacity
- Storage material and Volume
- Support Condition
- Thermal load cases
- Shell thickness

2.3 Types of model and capacity

The models are created based on different height to diameter ratio and capacity as per API 650. Finite element modelling of steel reservoirs are carried out by using SAP 2000 v20. Mainly there are three types of shapes are considered in cylindrical shape shown in figures below,

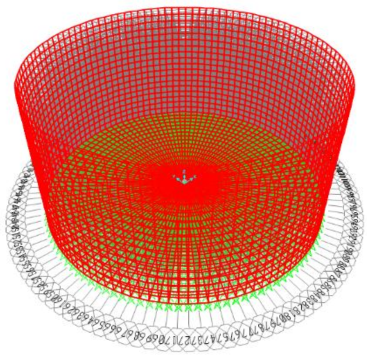


Figure.1. Top surface open cylinder

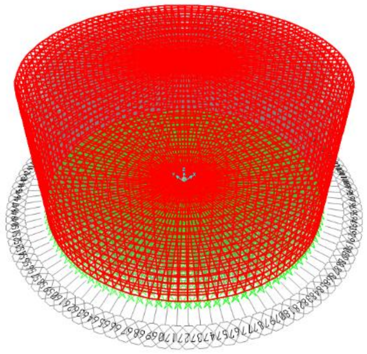


Figure.2. Fully closed cylinder

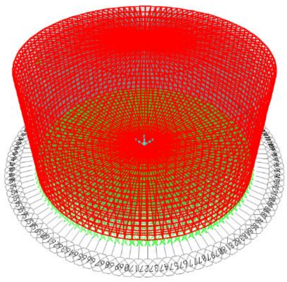


Figure.3. Fully closed with dome shape top Cylinder

2.4 Gradient temperature load

Here the effect of gradient temperature on the responses of the structure is found. The temperature is varied along the diameter of the tank. The side which is facing the sun is given maximum temperature and minimum temperature is applied on the other face. There difference of 10°c is maintained between the two ends. Average temperature is considered in the rest two sides. The temperature gradually decreases from maximum temperature to average and average to minimum temperature and also increases from minimum temperature to maximum temperature in the same way around the reservoir. This effect of temperature can be illustrated by using an equation obtained from the SAP software. Temperature variation will not affect the bottom plate, where as the top portion of reservoir will take maximum temperature as shown in figure below,

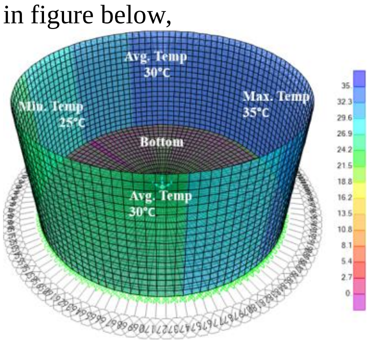


Figure.4. Gradient temperature acting at Low capacity model.

2.5 Shell thickness

The side wall of reservoir considered as the shell, here the shell thickness taken as 20mm. a shell which is having four nodes that can be equally divided on the basis of height and diameter of the steel reservoir. Therefore finite element is adopted to analyze the steel reservoir by considering each shell. Shell division can be easily done by using SAP software. The bottom and top portion of the reservoir is covered by same material which is considered in wall. Grade of steel considered here for the shell is Fe250. The material properties of Fe_{250} taken from IS Code 800: 2007 and IS Code 226: 1975 shown in below table,

Table.1. Material Properties of Fe250

Material Properties of Fe_{250}	
Values taken from IS Code 800: 2007	
Weight per Unit Volume	7850 kg/m^3
Modulus of Elasticity, E	2.0 X 10^5 N/mm^2
Poisson ratio, μ	0.3
Co-efficient of thermal expansion, α_1	12 X 10^{-6}
Values taken from IS Code 226: 1975	
Yield Stress, f_y	250 N/mm^2
Tensile stress, f_u	410 mm^2

III. ANALYSIS

a. General

Dimensions and capacity of steel reservoir are taken from American Petroleum Institute API 650. Here the liquid which filling the tank considered as Petrol of density 7.06 kN/m3 and the volume of liquid in the each model considered as 50%, 70% and 100%. The models of steel reservoir are mainly three types, Top surface open cylinder, fully closed cylinder and fully closed cylinder with Dome shaped top. Detailed description about the model has been discussed in the methodology. The wall thickness 20mm thick shell and the same material considered bottom and top portion of the steel reservoir. In the analysis part of this steel reservoir mainly considering hydrostatic pressure or oil pressure and Thermal loads of Uniform temperature load and Gradient temperature loads. And the result part of analysis carried out stress and displacements for particular loading. The results are tabulated based on the support, simply support and clamped support. The entire analysis carried out by using SAP 2000 v20. In this study it has been found that, there is no much effect due to uniform temperature and oil pressure in the reservoir, so here explaining the result due to gradient temperature load.

b. Gradient temperature load

The gradient temperature acts on a steel reservoir along x axis that is along its diameter. The gradient temperature is nothing but the variation of the temperature occur when the sun moved from one pole to another pole. There will be a minimum as well as maximum temperature when sun moves from one direction to the other direction. The maximum temperature and minimum temperature that is noted in Mangalore region is 35°C and 25°C respectively. The maximum temperature can be found out using the formula,

T=T_0+T_1 Cos (β)

Where, T is the Maximum temperature, T_0 is the average temperature, T_1 is the difference in temperature between Maximum and average and β is the angle between the line joining the two pole and any point on the steel reservoir in x direction. For maximum temperature the value of β will be zero, and the average temperature in Mangalore region is considered as 30°C.

Ax+By+Cz+D = T

Where, A, B & C are the constants corresponding to three axis, x, y & z are the three axis and In the above equation gradient temperature varies in the x axis, so the constant of x axis is considered and the constants of other two directions (B & C) are neglected. Therefore D can be calculated,

I.e., Ax+D=T………… (a)

Here x = 0 and T= 35°C, substituting these values in equation (a) D can be calculated. Which will be same for all the models for gradient temperature load. That is D = 30°C. Therefore the maximum temperature will occur at the center of the reservoir when the sun is directly above the tank. At this point the value of x will be same as that of the radius of the steel reservoir. The constant A which is calculated at this point will be same for different types of geometric structure. Constant A value with respect to the diameter of the steel reservoir. The below mention value are taken as the gradient temperature value which is calculated on the basis of value of x when it becomes equal to the radius of the reservoir. Finally the stress and displacement values are found and compared.

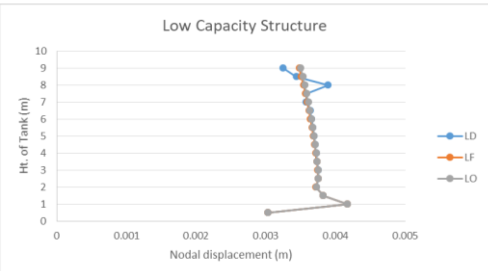
IV. RESULT AND DISCUSSION

Effect of gradient temperature on the Structural Responses

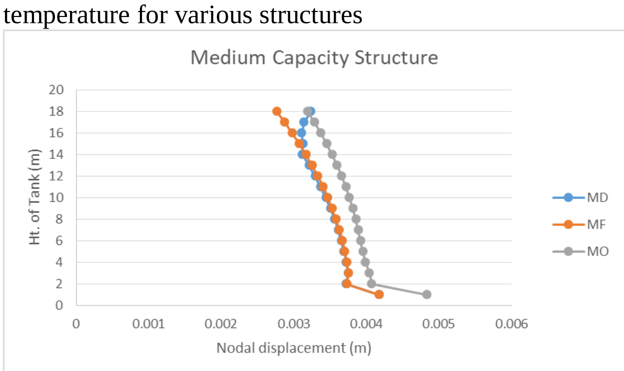
Here the effect of gradient temperature on the responses of the structure. The temperature is varied along the diameter of the tank. The side which is facing sun is given maximum temperature on the other face the minimum temperature is applied. There difference of 10°C is maintained between the two ends.

Study on the Nodal Displacement for the clamped structure

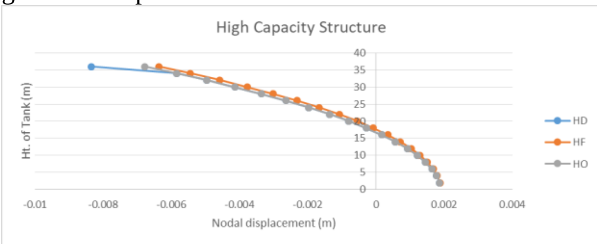
The displacement reduces as the height increase for all the type of structures. It can be seen that the temperature become negative for the high capacity structure. After a certain height the temperature variation is uniform. The maximum displacement is observed in the bottom potion and it reduces ad the height increase. The different trend has been observed for the high capacity structure. This may be due to the effect of gradient temperature. The results are shown in the graphical from as below.



Nodal displacements versus the height of the structure for Low capacity for clamped supported condition at for gradient temperature for various structures



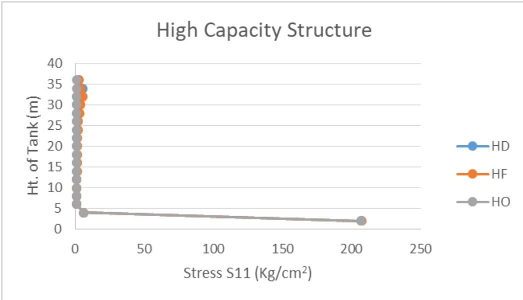
Nodal displacements versus the height of the structure for Medium capacity for clamped supported condition at for gradient temperature for various structures



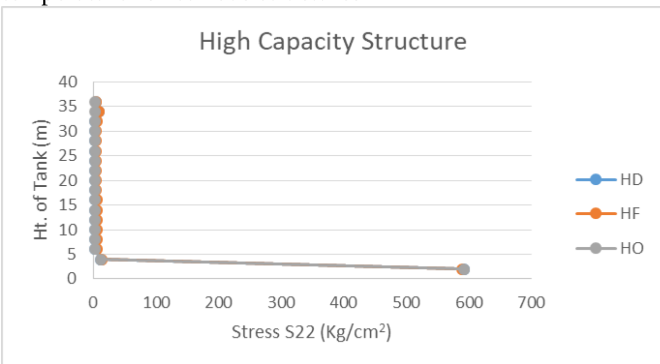
Nodal displacements versus the height of the structure for High capacity for clamped supported condition at for gradient temperature for various structures.

Study on the Stresses for the clamped structure

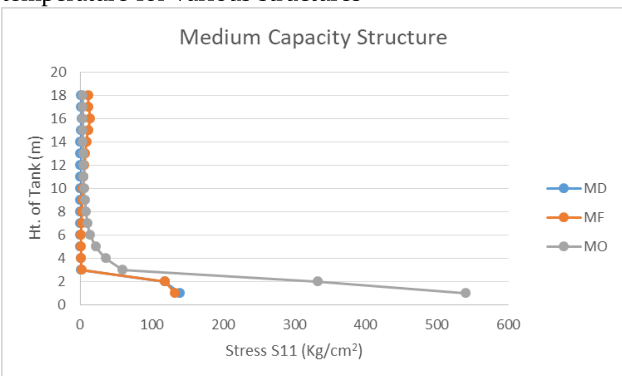
The same trend as that of the displacement is observed. The stresses increase as the height increases. From the graph it can be seen that the stress in the 2-2 direction is more as compared to the 1-1 direction. More temperature is observed for the medium capacity structure. A maximum stress of 820 N/mm2 is observed. The stress effect become negligible as the height increase.



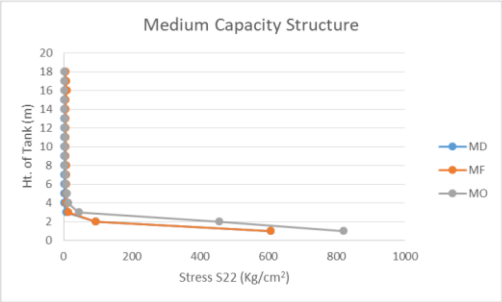
Stress (1-1) versus the height of the structure for High capacity for clamped supported condition at for gradient temperature for various structures



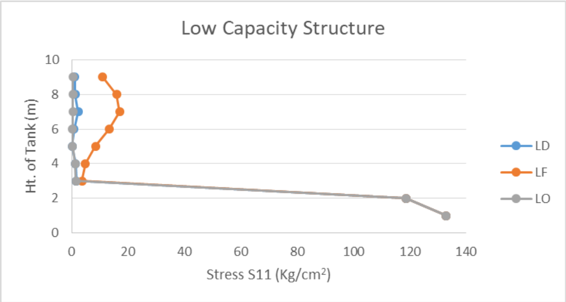
Stress (2-2) versus the height of the structure for High capacity for clamped supported condition at for gradient temperature for various structures



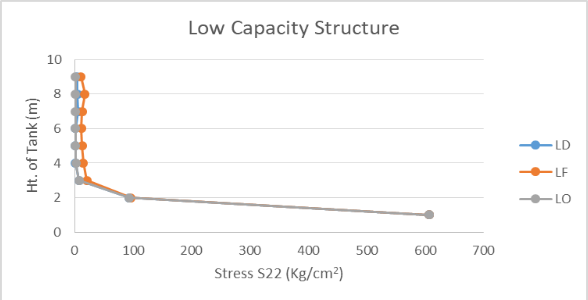
Stress (1-1) versus the height of the structure for Medium capacity for clamped supported condition at for gradient temperature for various structures



Stress (2-2) versus the height of the structure for Medium capacity for clamped supported condition at for gradient temperature for various structures



Stress (1-1) versus the height of the structure for Low capacity for clamped supported condition at for gradient temperature for various structures



Stress (2-2) versus the height of the structure for Low capacity for clamped supported condition at for gradient temperature for various structures

V. ACKNOWLEDGENMENT

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VI. CONCLUSION

c. Clamped Structure

The nodal displacement for the all the type of structure for the different load condition shows same variation. The nodal displacement is maximum at the bottom and as the height increases the displacement decrease and at the higher height the displacement is almost same. The stress variation also shows the same trend as the displacement for all the models with different loading condition. Maximum stress along 1-1 and 2-2 direction are observes at the bottom and as the height increases the stress reduces.

d. Simply supported Structure

The nodal displacement for the all the type of structure for the different load condition shows different response as compared to the clamped structure. The nodal displacement is maximum at the bottom and the displacement at the higher heights is more than the clamped structure. In the case of uniform and gradient temperature we can observe the higher displacement at the top of the structure. Stress in the structure along 1-1 and 2-2 direction are reduces as the height increases, the maximum stress observes at the bottom for the uniform and liquid loading condition. For the gradient temperature the stress increases to value higher at the top than the bottom stress.

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