NUMERICAL INVESTIGATION ON INFLUENCE OF HORIZONTAL GROUND ACCELERATION IN LIQUID STORAGE TANKS

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Abstract:* Liquid storage tanks resting on the ground has main structural elements of the base block, aspect wall and roof. The walls of the tanks are subjected to hydrostatic pressure of the liquid contained within the tank in the static condition and hydrodynamic pressure of the liquid in the dynamic condition of the bottom block. The dynamic condition of the bottom block because of horizontal ground acceleration depends on the contact condition of the bottom block with the ground. Hydraulic pressure exerted on the walls depends on the contact of walls with a base block, roof and therefore the nature of the wall like rigid or versatile. To check the behaviour of cylindrical tanks caused by dynamic loading a finite part technique was used. Exploitation of the FEM the flexibleness of the shell wall and therefore the liquid properties will be enclosed. Because of the complicated nature of theoretical approaches particularly once considering the dynamic nature of structures, the employment of package becomes vital. To model this method the ABAQUS finite element package was used. The theoretical calculations are done using relative codes and guidelines. Finally, the moments computed in code provisions and package are compared..

***Key Words:* Hydrostatic pressure, Hydrodynamic pressure, Ground accelerations.**

I . INTRODUCTION

Ground tanks in cylindrical shape having huge storage capacity and have considerable importance in storage of variety of liquids. They are used for drinking, fire extinguishing purposes and in other applications. Inadequate design and particularization of the tanks shown severe damage during past earthquakes. The liquid in the tank vibrates during strong ground shaking exerts both hydrostatic pressure as well as impulsive and convective hydrodynamic pressure on tank base and wall. So, the tank is idealized as an equivalent spring mass model to include the effect of tank wall liquid interaction. By idealization impact of hydrodynamic pressure is suitably incorporated in the analysis. At the point when the tank having fluid with a free surface is subjected to even seismic tremor ground movement, both fluid and tank divider are encountered the flat increasing speed. The fluid in the lower layer of tank carries on like a mass that is unbendingly appended to the tank divider. This mass is characterized as impulsive fluid mass which quickens alongside the divider and prompts rash hydrodynamic weight on the tank divider and on base slab. Remaining liquid portion in the top layer of the tank start moving up and down relative to the tank wall. This movement of liquid is called sloshing motion. This mass is known as convective fluid mass and it applies convective hydrodynamic weight on the tank divider and base slab. This sloshing effect could result in damage of the roof and top of tank wall. So there is a need to focus on the study on seismic responses of ground storage tanks occur due to earthquake ground accelerations in order to ensure the satisfactory performance of tanks even after post earthquakes without having significant effect on modern facilities.

II. LITERATURE REVIEW

Housner, G.W., " Dynamic pressures on accelerated Fluid containers", Bulletin seismological society of America, Vol.47,No.1, January, 1957.

The fluid pressures developed when an earthquake occurs are very important in the design of structures such as water tanks and dams. These pressures are divided into impulsive and convective pressures. The impulsive pressures are related with the inertia forces developed due to the movement of the container. What's more, these weights are specifically relative to the increasing speed of the tank. The convective weights are delivered by the swaying of the liquid which are produced by the incautious weights. In this paper the impulsive pressures and convective pressures are determined separately. For the analysis of pressures the disentangled equations are given for the compartments having two fold symmetry, for dams with inclining faces and for adaptable holding dividers.

J.D.Wang, S.H. Lo, D. Zhou "Liquid sloshing in rigid cylindrical container with multiple rigid annular baffles: free vibration", Journal of Fluids and Structures, ELSEVIER 34(2012)138-156.

In this paper, a semi explanatory approach has been acquainted with get the normal frequencies and mode states of fluid sloshing in an inflexible barrel shaped holder with different astounds. For effortlessness the fluid space is separated into basic fluid sub-areas. To such an extent that the fluid speed potential in each sub-space is of class c and it has congruity limit conditions. In light of the superposition system, the logical arrangements of the fluid speed potential in every fluid sub-space are controlled by utilizing variable separable method. Lastly he made conclusions like the non-dimensional recurrence parameters proceeds with diminish as for the highest puzzle moving towards the free surface. For numerous astounds, the variety of the non-dimensional recurrence parameters isn't proceeds as for the situation of the lower baffle. The characteristic frequencies are increments with the expansion of the internal sweep of the baffles. The impacts of the upper most baffle on normal frequencies and modes are substantially more imperative than the other baffles.

G.W. Housner," The Dynamic behaviour of water tanks", Bulletin seismological society of America, Vol.53,No.2, pp.381-387.February, 1963.

In this paper, the dynamic investigation of water tanks are thinking about the movement of the water in respect to the tank and the movement of the tank in respect to the ground. In the event that a water tank is totally loaded with water or totally unfilled, it is considered as single mass structure. If the water tank has free water surface or half filled with water then there will be sloshing of the liquid which is essentially considered as the two mass structure. In this two mass structure the dynamic behaviour of water tank may be quite different. For dynamic analysis of this condition of tanks simplified formulas are given for ground tanks and elevated water tanks.

III. METHODOLOGY

In the present study, ground supported circular water tank of 1000 m^3 capacity is considered. Grade of concrete used is M30.The Tank is located in the soft soil which is in seismic zone IV. Tank wall of thickness 250mm and 500mm is considered in this study. Tanks are modelled and analyzed using ABAQUS software. Seismic responses are calculated in accordance with IS: 1893 (Part 1): 2016, IS: 1893 (Part 2): 2014. The tank is analyzed with roof and without roof.

3.1 CALCULATION OF SEISMIC RESPONSE

Step 1: Calculate the parameters of spring mass model m_i, m_c, h_c, h_i, c_i, c_c depending on h/D ratio of water tank. (fig 2 and fig 5 of IS: 1893 (Part 2): 2014)

Where m_i = impulsive mass of liquid
m_c = convective mass of liquid
h_i = height of impulsive mass above bottom of tank wall
h_c = height of convective mass above bottom of tank wall
c_i = coefficient of time period for impulsive mode
c_c = coefficient of time period for convective mode

Step 2: Calculate the impulsive mode & convective mode time period for water tank

$$T_i = c_i \frac{h\sqrt{\rho}}{\sqrt{(t/D)}\sqrt{E}},\ T_C = c_c\sqrt{\frac{D}{g}}$$ (Clause 4.3.1.1 &4.3.2.2 of IS: 1893 (Part 2): 2014)

Where h = maximum height of liquid ρ = mass density of liquid
t = thickness of tank wall
D =inner diameter of circular tank
E = modulus of elasticity of tank wall
g = acceleration due to gravity

Step 3: Compute design horizontal seismic coefficient for impulsive & convective mode
Design horizontal seismic coefficient

$$A_h = \left(\frac{Z}{2}\right) \times \left(\frac{I}{R}\right) \times \frac{S_a}{g}$$ (Clause 4.5 &4.5.1 of IS: 1893 (Part 2) : 2014)

Z = Zone factor from Table 3 of IS 1893(Part 1): 2016
I = Importance factor from Table 1 of IS 1893(Part 2): 2014
R = Response reduction factor from Table 2 of IS 1893(Part 2): 2014
Sa/g = Average response acceleration coefficient from Fig. 2 and Table 3 of IS 1893(Part 1): 2016 (assuming soft soil)

Step 4: Calculate base shear (V) at the bottom of tank wall in impulsive mode & convective mode

$V_i = (A_h)_i\,(m_i + m_w + m_t)\,g,\quad V_c = (A_h)_c \times m_c \times g$

Total Base Shear at the bottom $V = \sqrt{(V_i^2 + V_c^2)}$

Step 5: calculate bending moment (M) at the bottom of tank wall in impulsive mode & convective mode

$M_i = (A_h)_i\,(m_i{*}h_i + m_w{*}h_w + m_t{*}h_t)\,g,\ M_c = (A_h)_c \times h_c \times g$

Where h_w = height of centre of gravity of wall above bottom of tank wall

Total bending moment at the bottom $M = \sqrt{(M_i^2 + M_c^2)}$

IV.MODELLING OF GROUND WATER TANK

TANK DETAILS:

Capacity of the water tank	= 10 lakh litres
Diameter of the tank	= 14 metres
Height of the tank	= 7 metres
Free board of the tank	= 0.5 metres
Thickness of the base slab	= 0.4 metres
Grade of concrete	= M30
Type of soil	= soft soil
Seismic zone	= IV
Density of concrete	= 25 KN/m^3

Height of liquid(h_t) = 6.5 m

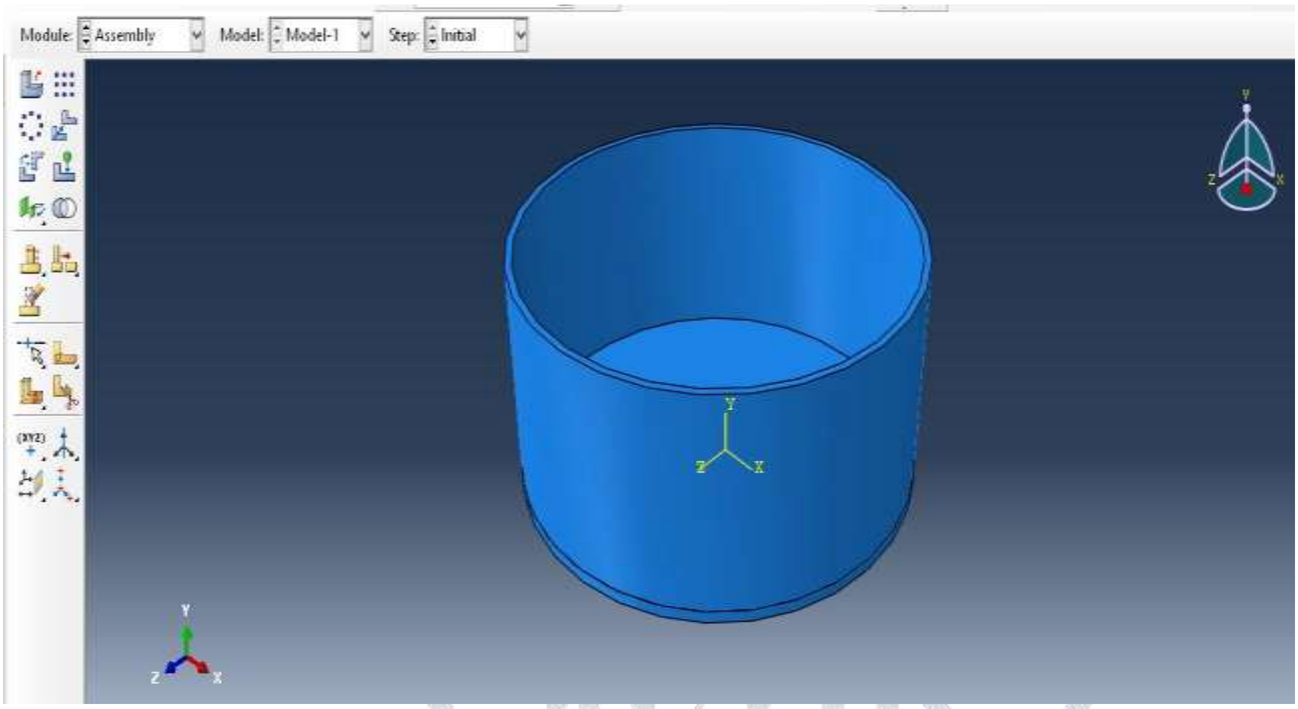

Fig 1 : Model of ground water tank without dome having 250 mm wall thickness

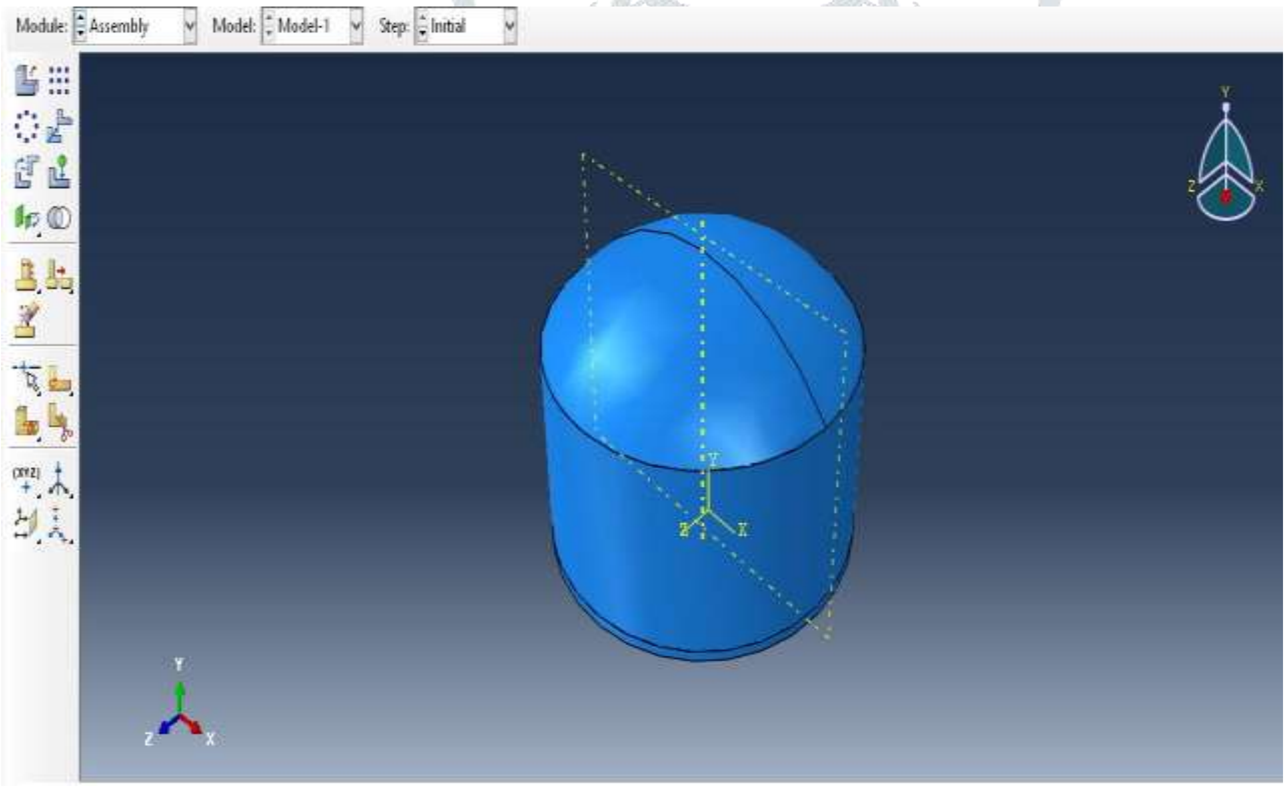

Fig 2 : Model of ground water tank with dome having 250 mm wall thickness

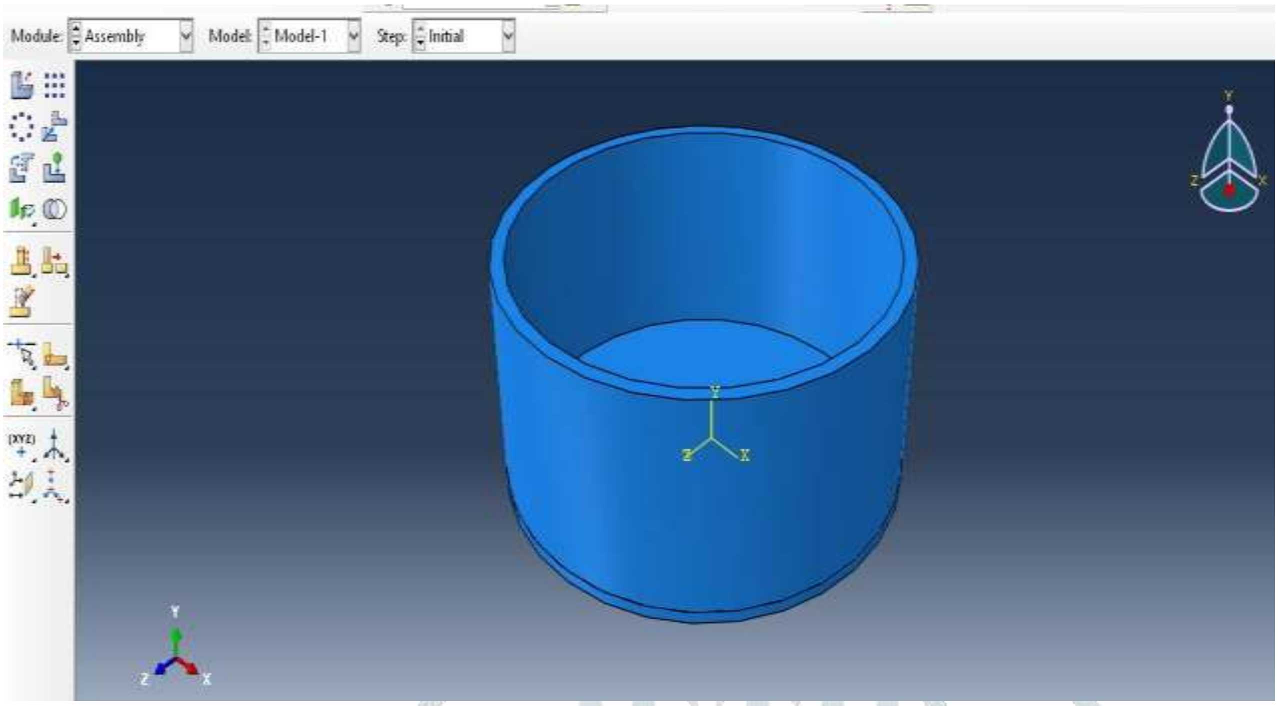

Fig 3 : Model of ground water tank without dome having 500 mm wall thickness

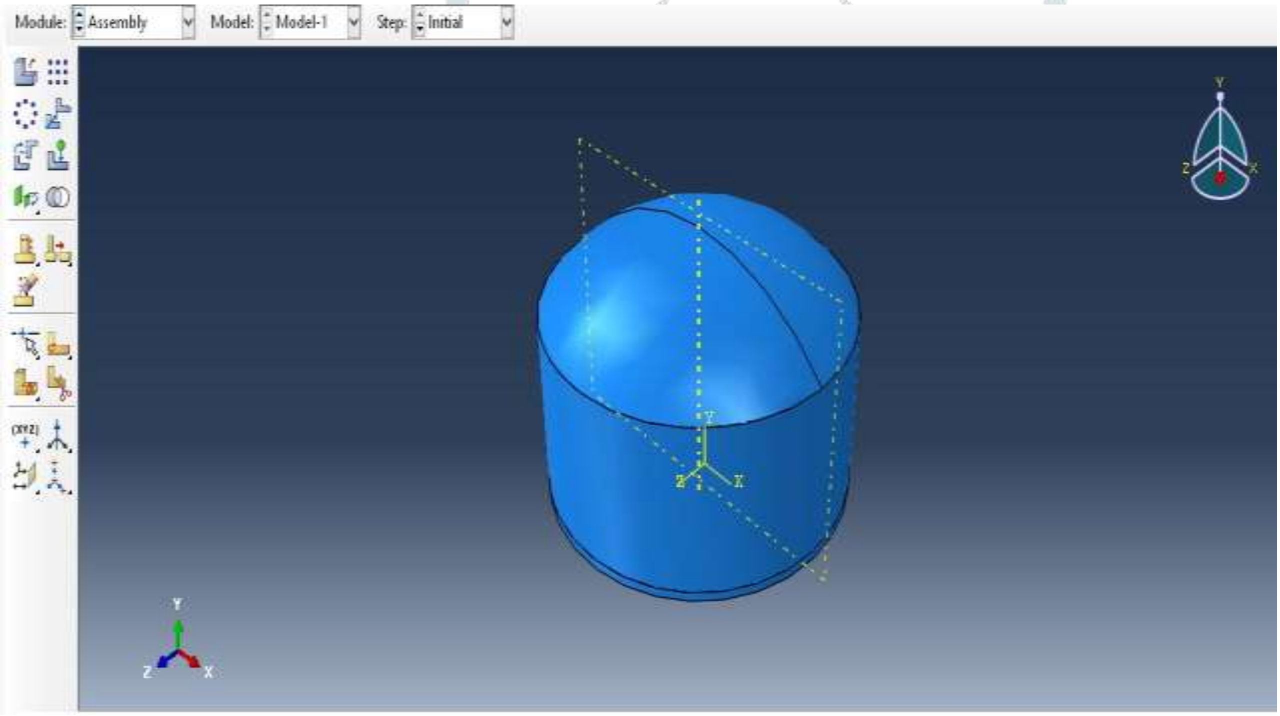

Fig 4 : Model of ground water tank with dome having 500 mm wall thickness

RESULTS:

The water tank is modeled in ABAQUS software. And the dynamic analysis is done using the Elcentro earth quake accelerations. The water tank is analyzed for two different wall thickness i.e, 250mm and 500mm. the moments are compared with the analytical results.

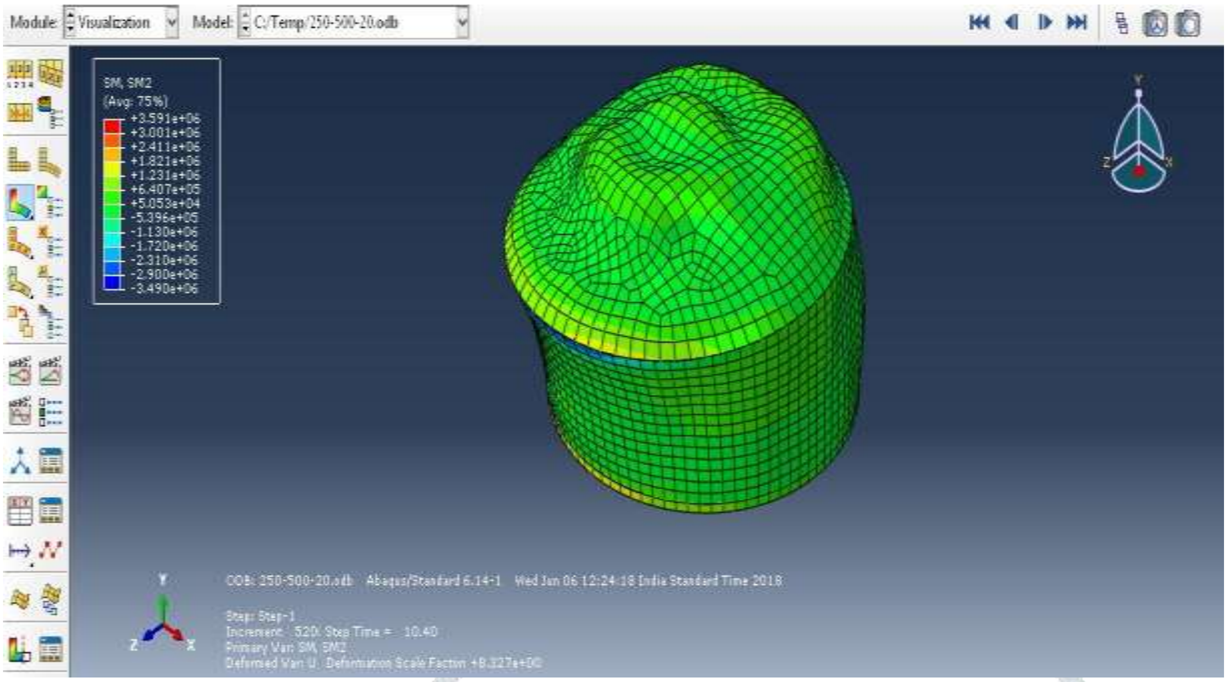

Fig 5 : Moments of tank with dome having 250 mm wall thickness

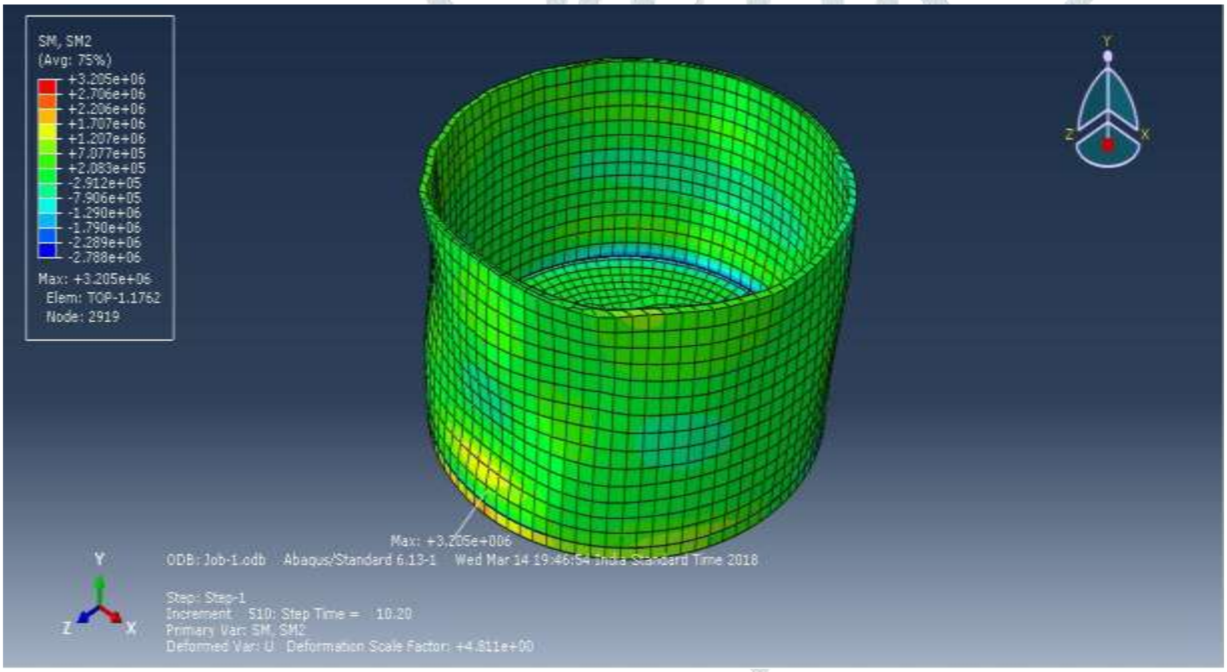

Fig 6 : Moments of tank without dome having 500 mm wall thickness

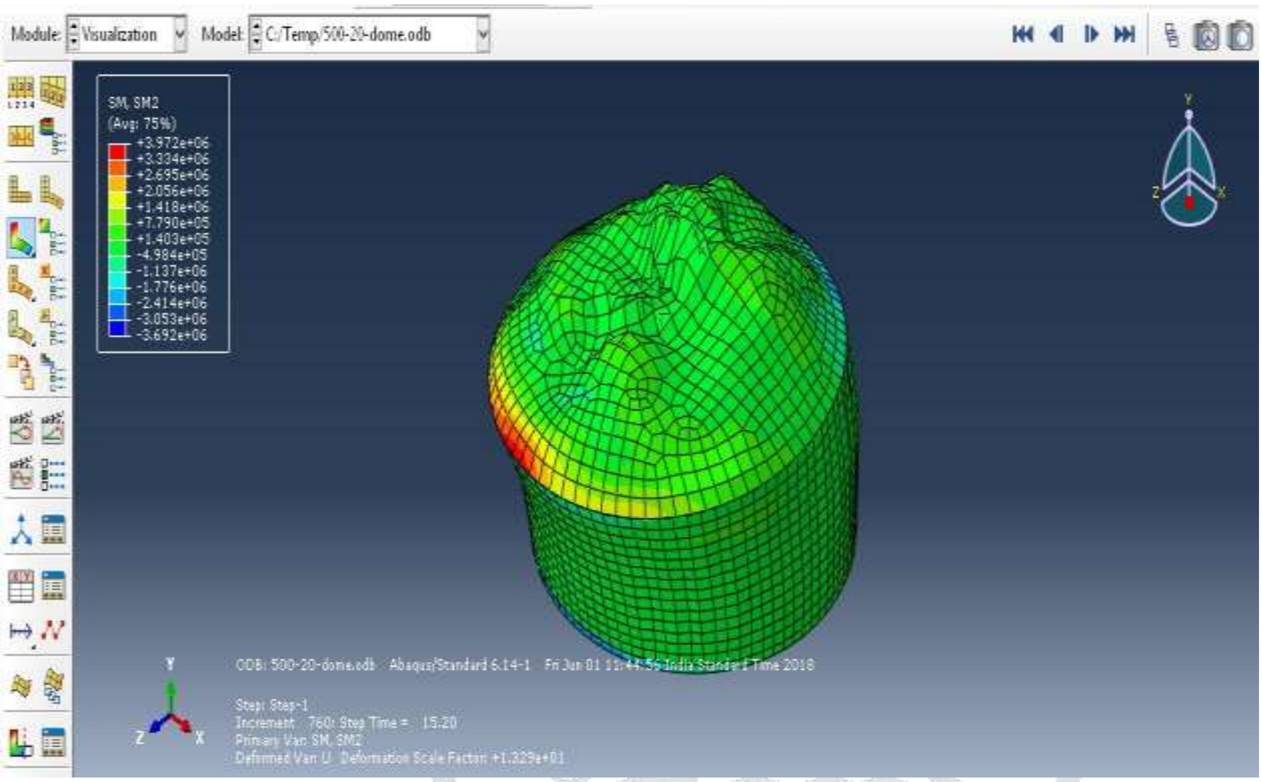

Fig 7 : Moments of tank with dome having 500 mm wall thickness

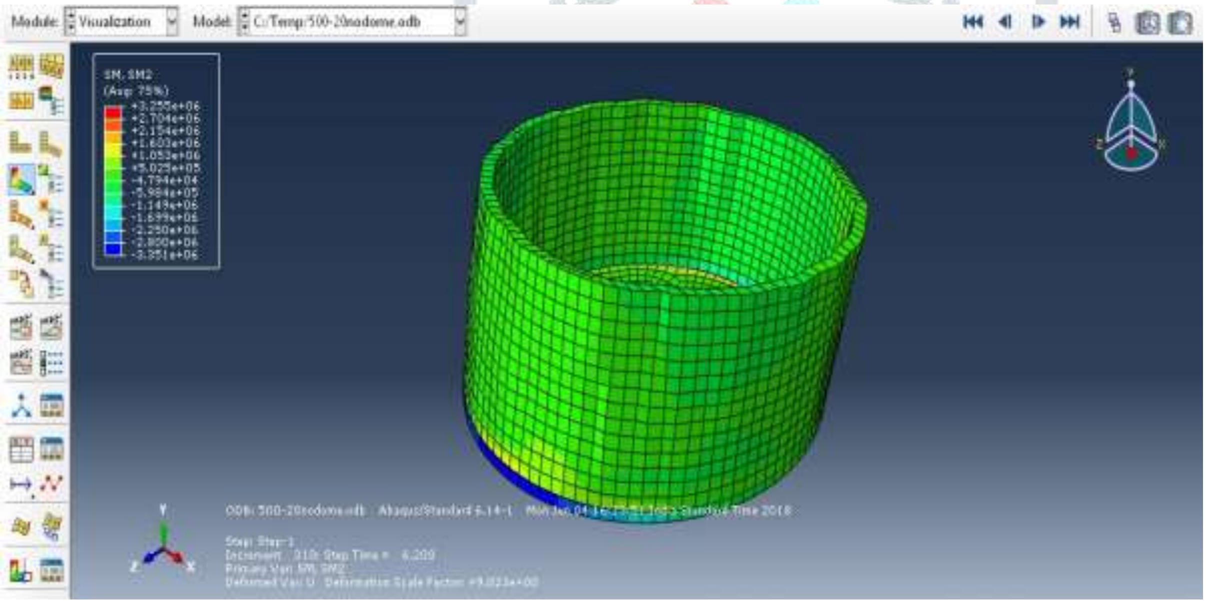

Fig 8 : Moments of tank without dome having 500 mm wall thickness

Table 1: Moments for water tank with 250 mm wall thickness in KN-m

S.No		Tank wall with roof	Tank wall without roof
1.	Codal provisions	3482.45	2976.48
2.	ABAQUS	3591	3205
	Error	3.02%	7.13%

Table 2 : Moments for water tank with 500 mm wall thickness in KN-m

S.No		Tank wall with roof	Tank wall without roof
1.	Codal provisions	3811.12	2723
2.	ABAQUS	3972	3255
	Error	4.0%	16.34%

CONCLUSIONS:

By comparing the moments obtained in codal provisions and ABAQUS the following conclusions are made.

1. The moments for tank wall with roof having wall thickness 250mm varied by 3.02%.
2. The moments for tank wall without roof having wall thickness 250mm varied by 7.13%.
3. The moments for tank wall with roof having wall thickness 500mm varied by 4%.
4. The moments for tank wall without roof having wall thickness 500mm varied by 16.34%.
5. The variation in moments is small for tank with roof compared to tank without roof.

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