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FEM-Based Seismic Performance Evaluation of Underground Water Storage Tanks in All Zones

Chaitra K
Assistant Professor
Department of Freshmen Engineering (Civil Engineering)
St. Martin's Engineering College, Dhulapally, Kompally, Secunderabad, Hyderabad, 500100
Email ID: *kchaitrace@smec.ac.in*

ABSTRACT

Underground liquid storage tank primarily used for water and sewage treatment plants and other industrial wastes. Normally, they are constructed of reinforced concrete in the form of rectangular or circular configurations. The behaviour of liquid storage underground tank during earthquakes is more important than the economic values of the tanks and their contents. A good understanding of the seismic behaviour of these structures is necessary in order to meet safety objectives while containing construction and maintenance costs. In this paper Underground water tank with seismic load in different zones is used to analyze the typical behaviour caused by seismic load. The finite element method (FEM) is selected as the examination method for the underground water tank. The model is performed by ETABS software.

KEYWORDS: *underground water tank, Finite element modelling, seismic loads, ETABS*

INTRODUCTION

Underground water storage tanks are used for underground storage of potable ingesting water, wastewater & rainwater collection. Generally, they're built of reinforced concrete in the form of rectangular or circular configurations. All tanks are designed as crack free structures to eliminate any leakage. So whether you name it a water tank or water cistern, so long as you're storing water underground those are the storage tanks for you. However, on certain occasions, roof catchments also can be channelled into underground tanks. Reservoir is a common term applied to liquid storage structure and it can be below or above the ground level. Also, the Underground water tank is most advantageous when large volumes are to be stored. Three basic components of the UG water tank are

a) Top slab b) Side walls c) Base slab

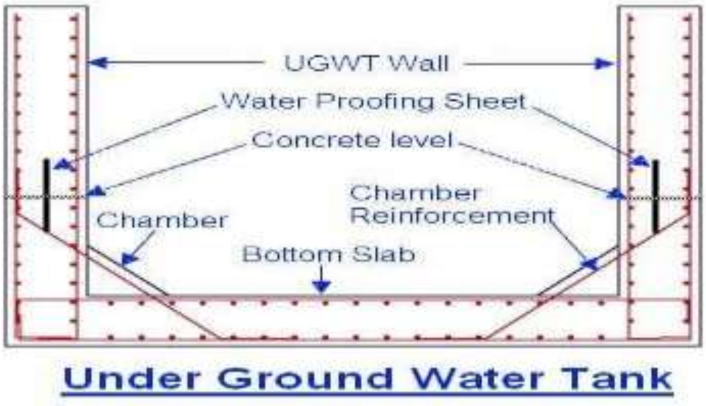


Figure: 1

DESIGN EARTHQUAKE CRITERIIA

When the seismic peril at the site is described, the degree of plan tremor or seismicity must be characterized. For instance, the originator should choose the likelihood of exceedance for the arrangements of ground movement boundaries. Current seismic plan theory for some, basic offices requires double (two-level) plan standards, with a higher plan level.

Seismic tremor focused on life security and a lower configuration level quake planned for monetary danger openness. The two plan levels are generally characterized as 'most extreme plan quake' or 'wellbeing assessment tremor' and 'functional plan quake' or 'capacity assessment quake', and have been utilized in numerous new underground underlying ventures.

FINITE ELEMENT METHOD

Finite element method (FEM) is a numerical method for solving a differential or integral equation. It has been applied to a number of physical problems, where the governing differential equations are available. The method essentially consists of assuming the piecewise continuous function for the solution and obtaining the parameters of the functions in a manner that reduces the error in the solution. In this article, a brief introduction to finite element method is provided. The method is illustrated with the help of the plane stress and plane strain formulation

Table: 1

Rectangular underground water tank	
Volume	50000 liters
Length	5.64m
Breadth	2.82m
Depth	3.13m

OBJECTIVES

- To create rectangular underground water tank models using ETABS (Extended three-dimensional analysis of building system) software.
- To create 'Finite element analysis' of underground water-tank subjected to both live load and lateral load (earthquake load) in different zones.

METHODOLOGY

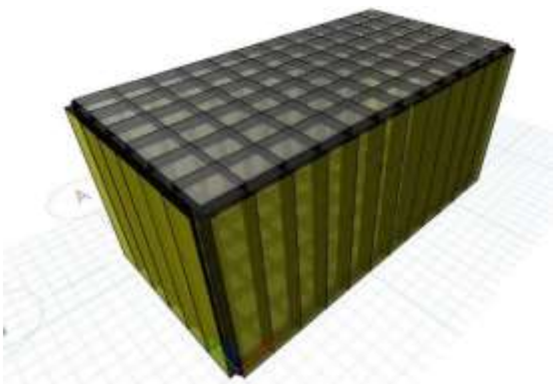
Finite Element Method used for analysis of underground water tank by using ETABS software. 5mmx5mmx5mm Meshing is consider for analysis.

ETABS (Extended three dimensional analysis of building system] is a software used to analysis and design of the structures. In ETABS software static or dynamic analysis for basic or advanced system may be done. ETABS software is easy to use and user friendly, for the multi-storied building it is very suitable.

Table 2: Dimensions of tank

PARAMETERS	REFERRENCE VALUES
Capacity	50000 litres
Tank Length	5.64 m
Tank Height	3.13 m
Tank Width	2.82 m
Concrete grade	M30
Wall thickness	250 mm
Top slab	150 mm
Bottom slab	250 mm
Meshing	5mm x 5mm x 5mm
Live load	2kN/m^2
Soil pressure	20.86 kN/m^2
Water pressure	31.3 kN/m^2

Model



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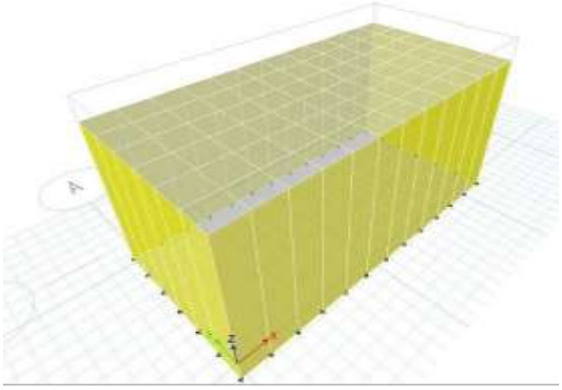
Deformed Structure



ZONE II

Table 3: Max Bending and Shear stresses in zone 2

LOADS	MAX BENDING STRESS(kN/m2)	LOCATION	MAX SHEAR STRESS(kN)	LOCATION
Dead Load	7.5	Centre of bottom slab	18.7	Horizontal to bottom slab
Live Load	1.02	Centre of top slab	2.88	Horizontal to bottom slab
LATERAL LOAD	110	Towards right of bottom slab	250	Horizontal to bottom slab
Soil Pressure	135	Corners	16.5	Centre of top slab
Water Pressure	21.05	Centre of bottom slab	28	Horizontal to bottom slab

Dead Load:

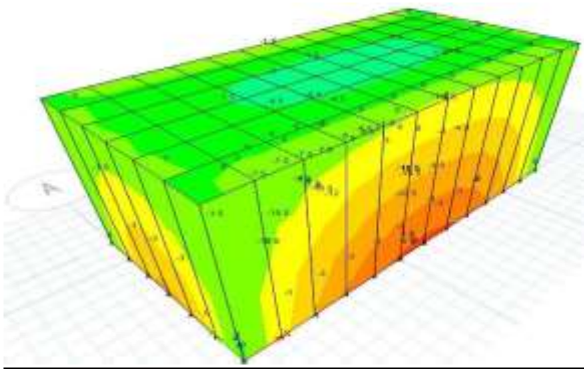


Figure 1(a): Bending stress for dead load in zone 2

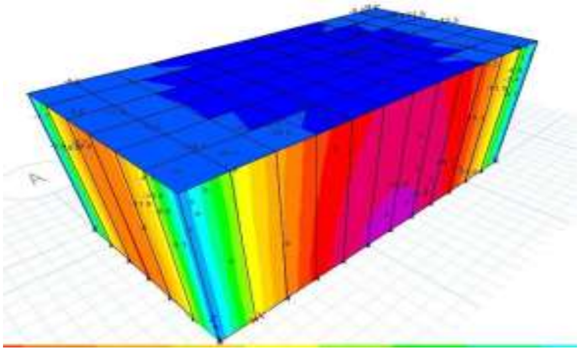


Figure 1(b): Shear stress for dead load in zone 2

Live Load:

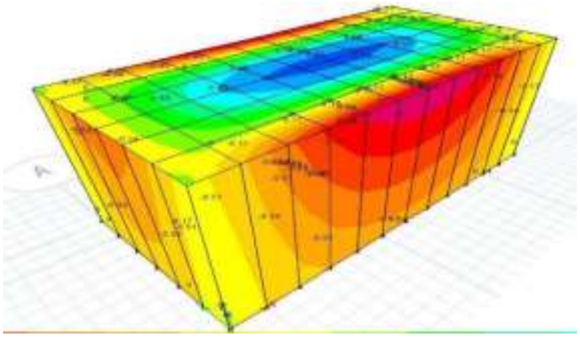


Figure 1(c): Bending stress for live load in zone 2

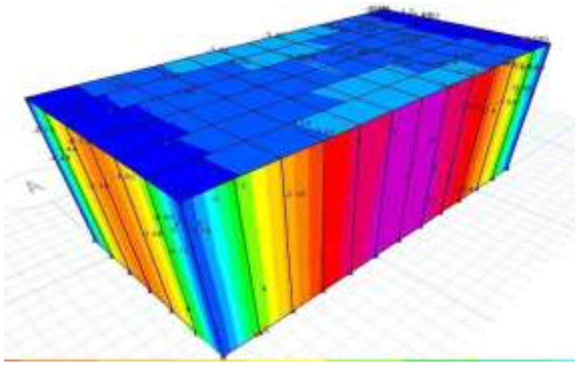


Figure 1(d): Shear stress for live load in zone 2

Lateral Load:

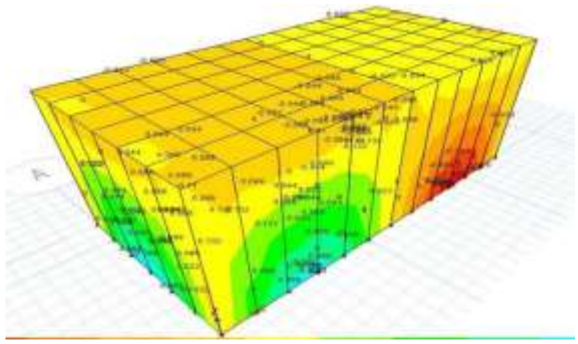


Figure 1(e): Bending stress for lateral load in zone

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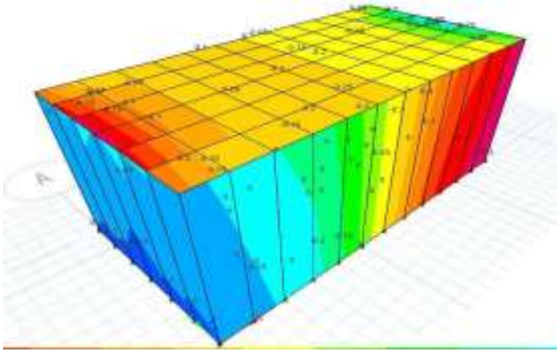

Figure 1(f): Shear stress for lateral load in zone 2

Soil Pressure:

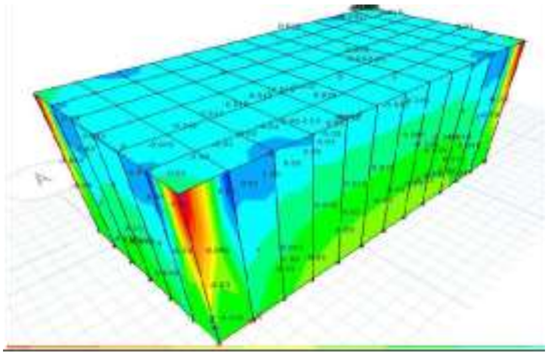

Figure 1(g): Bending stress for soil pressure in zone 2

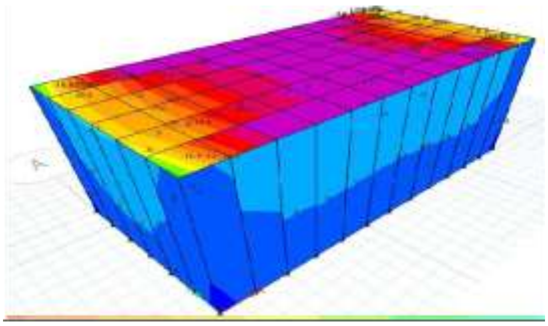

Figure 1(h): Shear stress for soil pressure in zone 2

Water Pressure:

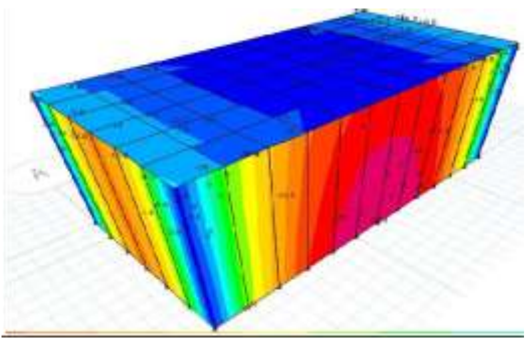

Figure 1(i): Bending stress for water pressure in zone 2

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ZONE III

Table 4: Max Bending and Shear stresses in zone 3

LOADS	MAX BENDING STRESS(kN/m2)	LOCATION	MAX SHEAR STRESS(kN)	LOCATION
Dead Load	10.5	Centre of bottom slab	20.4	Horizontal to bottom slab
Live Load	1.02	Centre of top slab	2.88	Horizontal to bottom slab
Lateral Load	200	Towards right of bottom slab	375	Horizontal to bottom slab
Soil Pressure	216	Corners	26.4	Centre of top slab
Water Pressure	35	Centre of bottom slab	40.5	Horizontal to bottom slab

Dead Load:

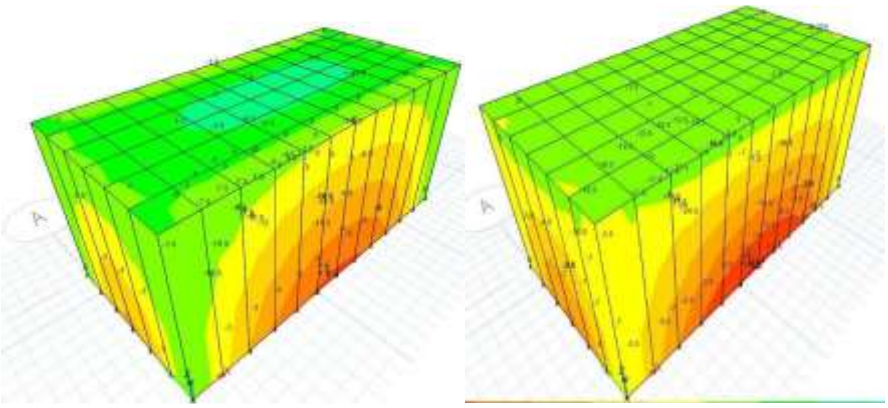


Figure 2(a): Bending stress for dead load in zone 3

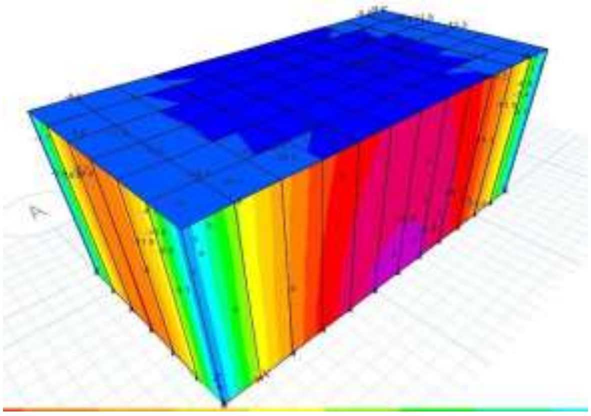


Figure 2(b): Shear stress for dead load in zone

Live Load:

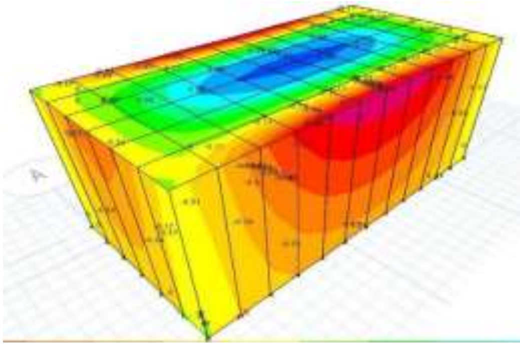


Figure 2(c): Bending stress for live load in zone 3

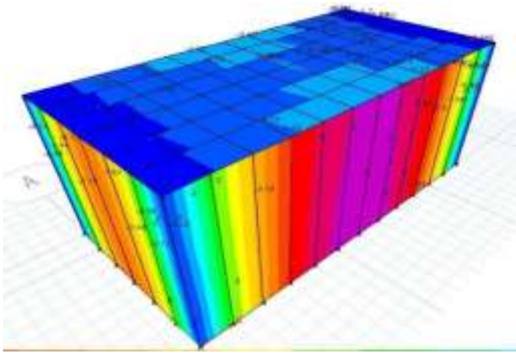


Figure 2(d): Shear stress for live load in zone 3

Lateral Load:

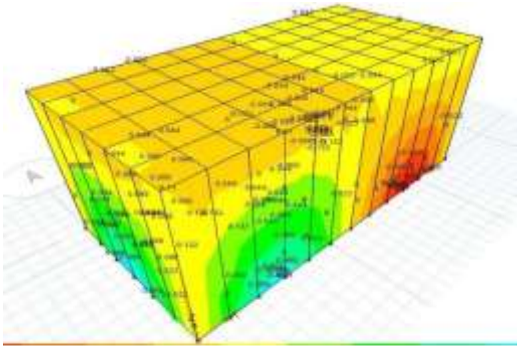


Figure 2(e): Bending stress for lateral load in zone 3

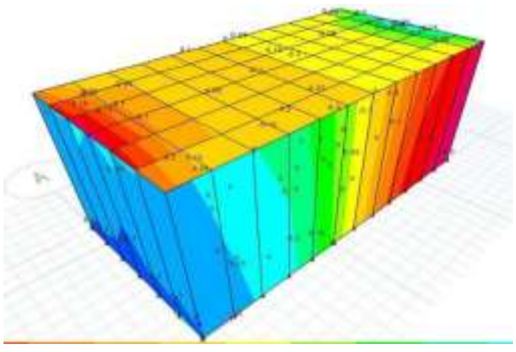


Figure 2(f): Shear stress for lateral load in zone 3

Soil Pressure:

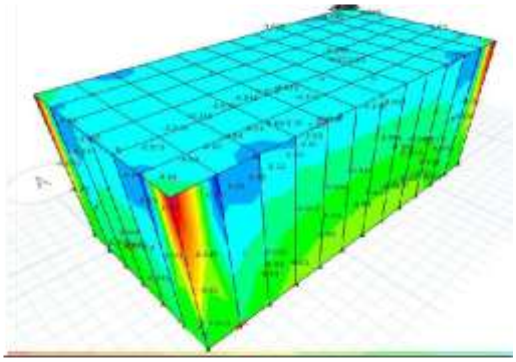


Figure 2(g): Bending stress for soil pressure in zone 3

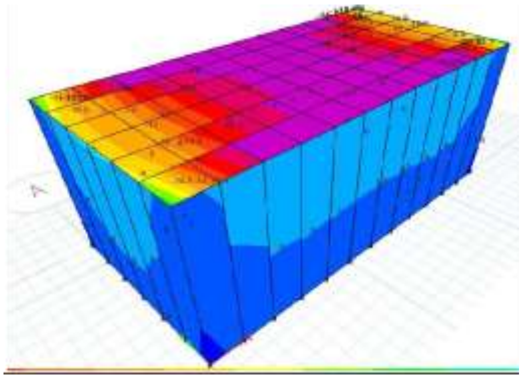


Figure 2(h): Shear stress for soil pressure in zone 3

Water Pressure:

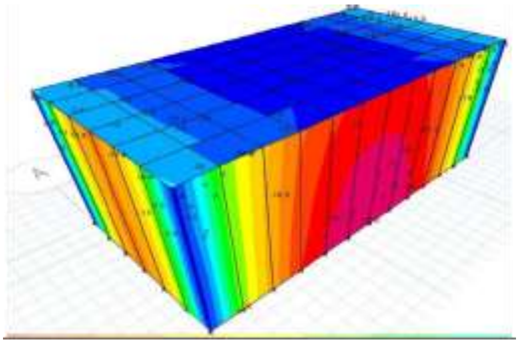


Figure 2(i): Bending stress for water pressure in zone 3

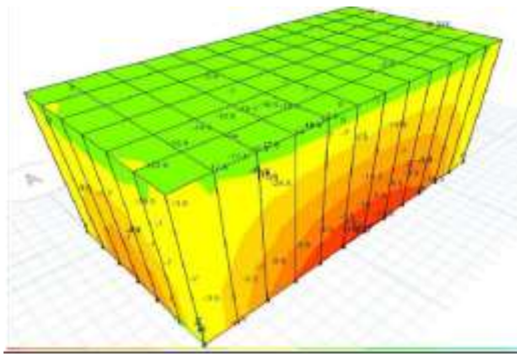


Figure 2(j): Shear stress for water pressure in zone 3

ZONE IV

Table 5: Max Bending and Shear stresses in zone 4

LOADS	MAX BENDING STRESS(kN/m2)	LOCATION	MAX SHEAR STRESS(kN)	LOCATION
Dead Load	12	Centre of bottom slab	23.8	Horizontal to bottom slab
Live Load	1.02	Centre of top slab	2.88	Horizontal to bottom slab
Lateral Load	257	Towards right of bottom slab	429	Horizontal to bottom slab
Soil Pressure	276	Corners	32	Centre of top slab
Water Pressure	47.05	Centre of bottom slab	49.73	Horizontal to bottom slab

Dead Load:

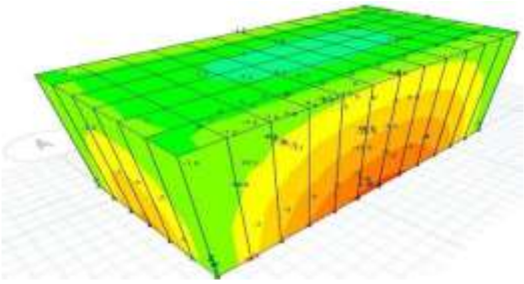


Figure 3(a): Bending stress for dead load in zone 4

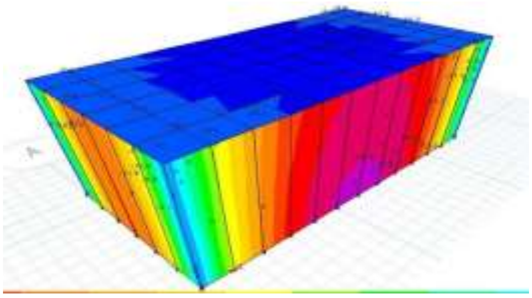


Figure 3(b): Shear stress for dead load in zone 4

Live Load:

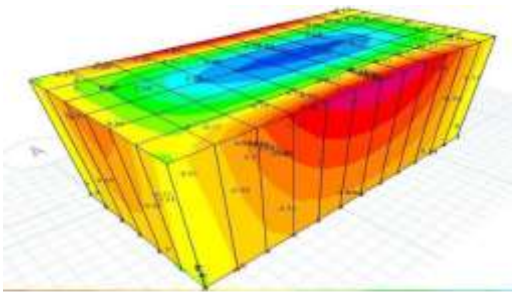


Figure 3(c): Bending stress for live load in zone 4

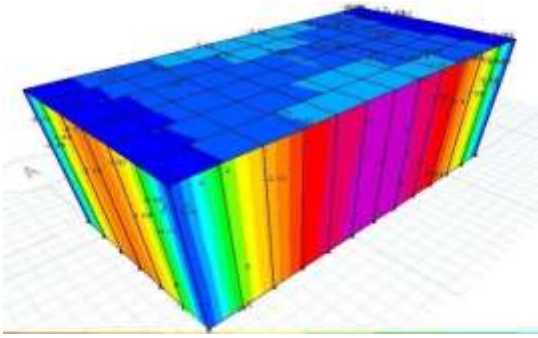


Figure 3(d): Shear stress for live load in zone 4

Lateral Load:

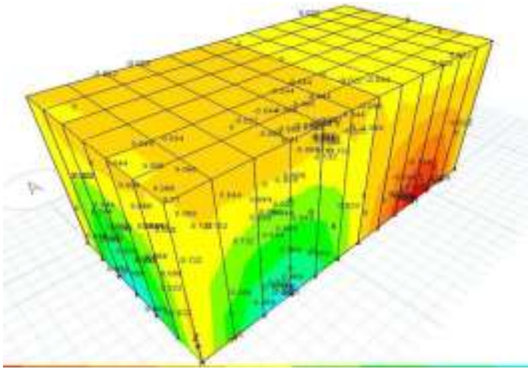


Figure 3(e): Bending stress for lateral load in zone 4

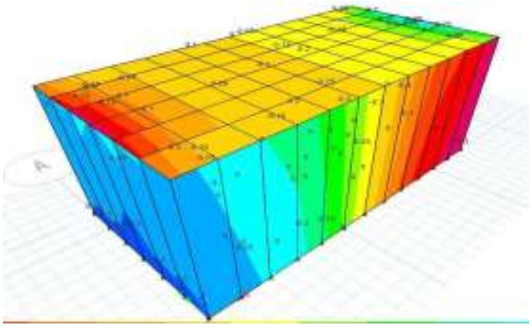


Figure 3(f): Shear stress for lateral load in zone 4

Soil Pressure:

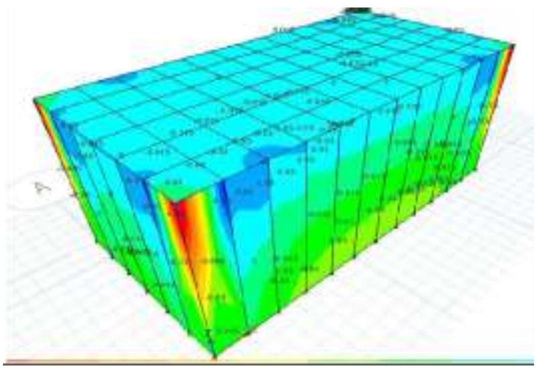


Figure 3(g): Bending stress for soil pressure in zone 4

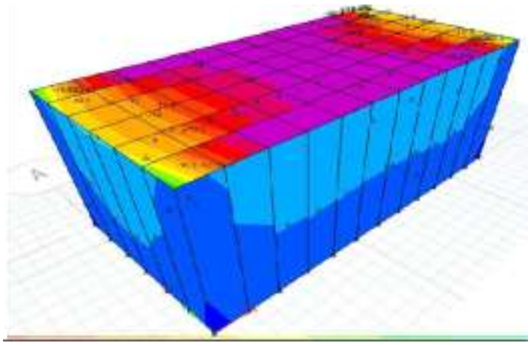


Figure 3(h): Shear stress for soil pressure in zone 4

Water Pressure:

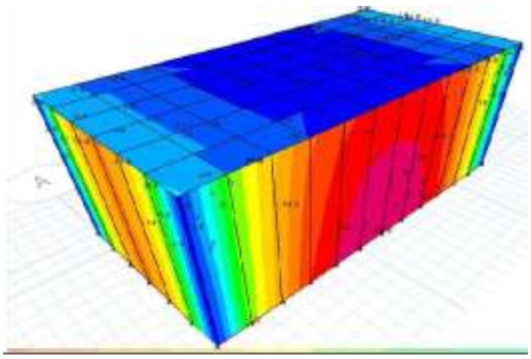


Figure 3(i): Bending stress for water pressure in zone 4

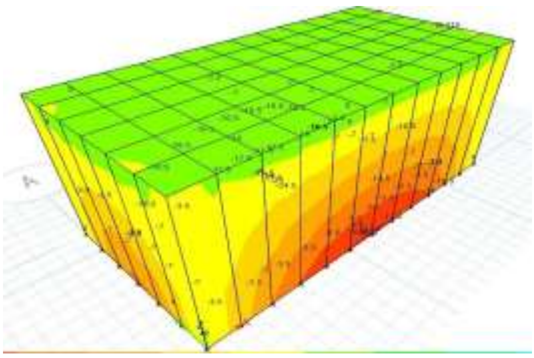


Figure 3(j): Shear stress for water pressure in zone 4

ZONE V

Table 6: Max Bending and Shear stresses in zone 5

LOADS	MAX BENDING STRESS(kN/m2)	LOCATION	MAX SHEAR STRESS(kN)	LOCATION
Dead Load	15.3	Centre of bottom slab	27.4	Horizontal to bottom slab
Live Load	1.02	Centre of top slab	2.88	Horizontal to bottom slab

Lateral Load	310	Towards right of bottom slab	486.5	Horizontal to bottom slab
Soil Pressure	323	Corners	44	Centre of top slab
Water Pressure	51.9	Centre of bottom slab	59	Horizontal to bottom slab

Dead Load:

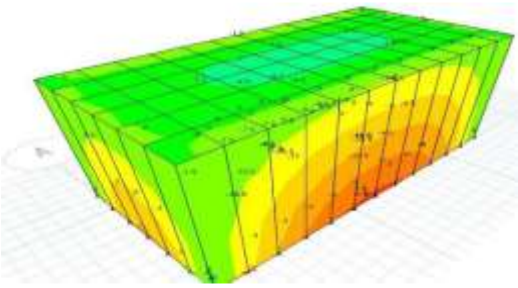


Figure 4(a): Bending stress for dead load in zone 5

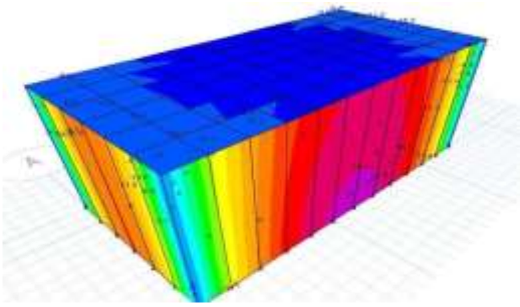


Figure 4(b): Shear stress for dead load in zone 5

Live Load:

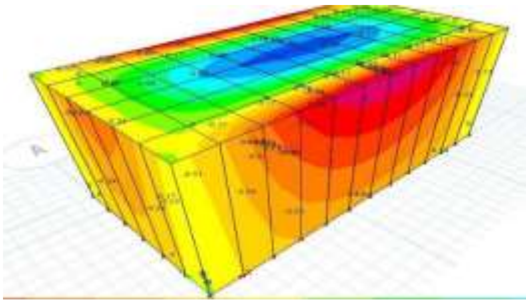


Figure 4(c): Bending stress for live load in zone 5

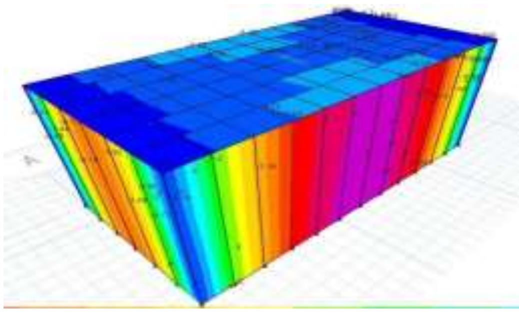


Figure 4(d): Shear stress for live load in zone 5

Lateral Load:

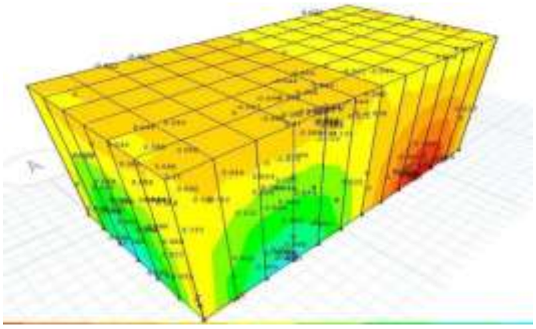


Figure 4(e): Bending stress for lateral load in zone 5

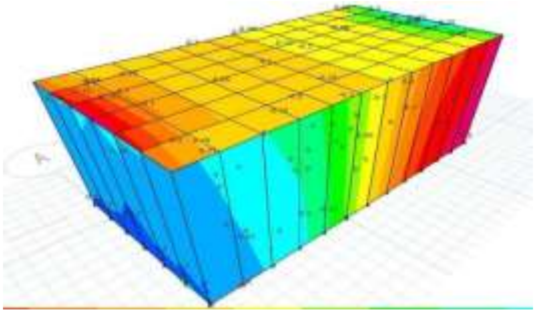


Figure 4(f): Shear stress for lateral load in zone 5

Soil Pressure:

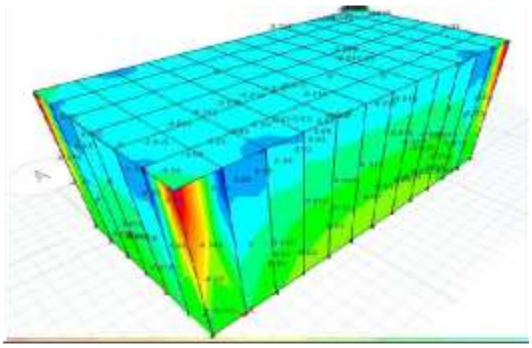


Figure 4(g): Bending stress for soil pressure in zone 5

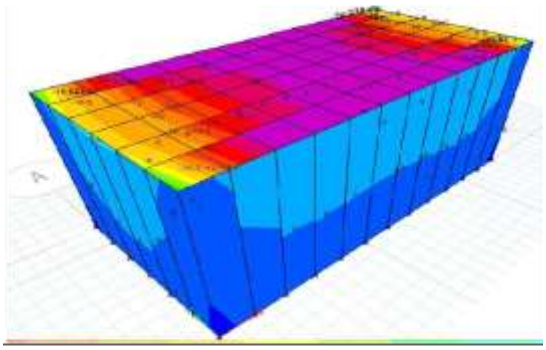


Figure 4(h): Shear stress for soil pressure in zone 5

Water Pressure:

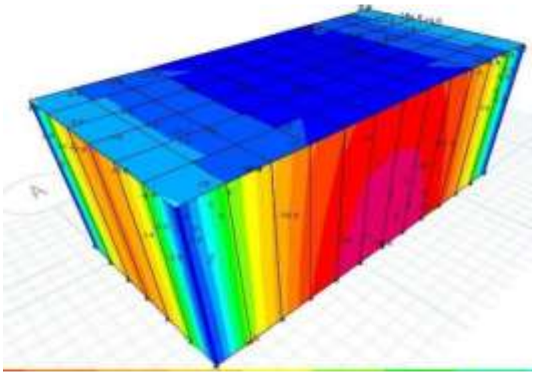


Figure 4(i): Bending stress for water pressure in zone 5

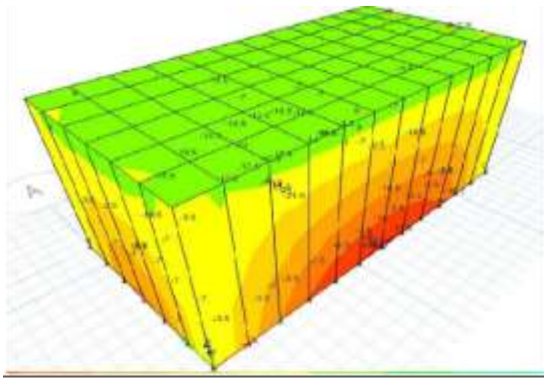


Figure 4(j): Shear stress for water pressure in zone 5

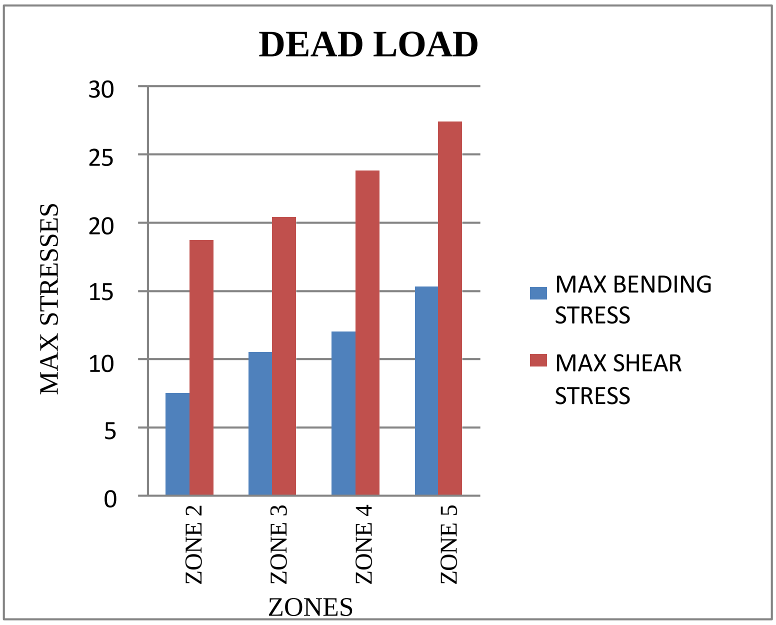
RESULTS AND DISCUSSION

As per IS codes the loads are applied and analysis is made, then designing is done for the rectangular underground water tank by limit stress method. The results obtained are plotted and discussed.

Dead Load:

Table 7: Max Bending and Shear stresses for dead load in all zones

ZONES	MAX BENDING STRESS	MAX SHEAR STRESS
ZONE 2	7.5	18.7
ZONE 3	10.5	20.4
ZONE 4	12	23.8
ZONE 5	15.3	27.4



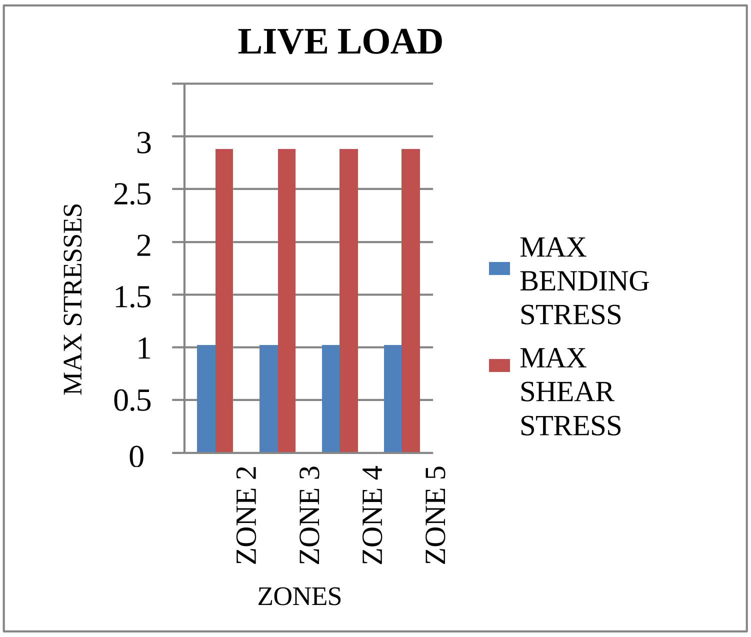
Graph 1: Max Bending and Shear stresses for dead load in all zones

Above graph describes the bending and shear stresses for dead load in each zone. The graph is plotted by considering zones in X direction and maximum stresses in Y direction. After analysing the graph as the zones increases bending and shear stresses also increases due to varying loads. For zone 5 Bending stress and Shear stress will be more that is 15.3kN/m^2 and 27.4kN/m^2 compared to other zones because different loads will be acting on that zone. Zone 2 & zone 3 are much stronger that other zones due to less stress acting on that zones. Maximum bending stress will act on centre of the bottom slab and shear stress will act on horizontal of bottom slab.

Live Load:

Table 8: Max Bending and Shear stresses for live load in all zones

ZONES	MAX BENDING STRESS	MAX SHEAR STRESS
ZONE 2	1.02	2.88
ZONE 3	1.02	2.88
ZONE 4	1.02	2.88
ZONE 5	1.02	2.88



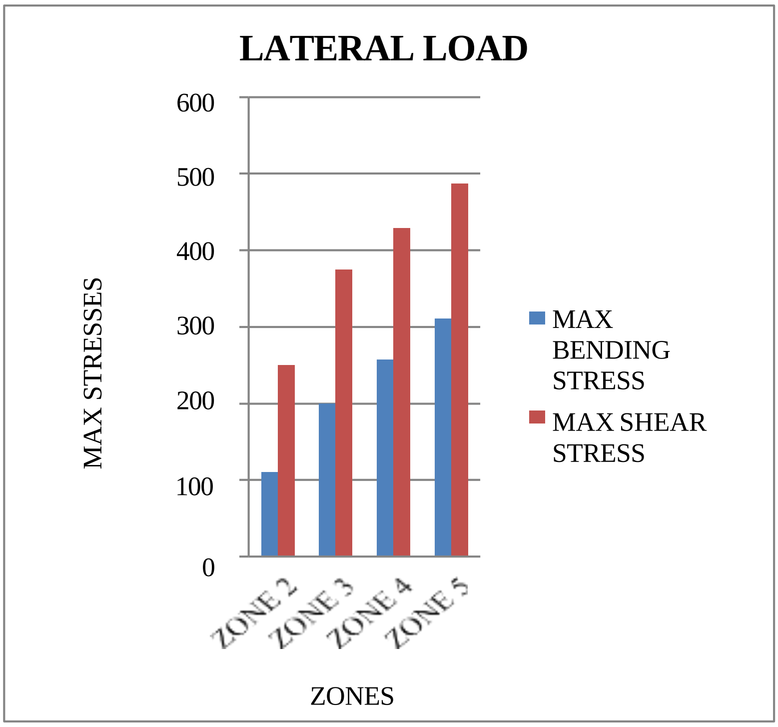
Graph 2: Max Bending and Shear stresses for live load in all zones

Graph describes the bending and shear stresses for live load in each zones. The graph is plotted by considering zones in X direction and maximum stresses in Y direction. After analysing the graph Bending and Shear stress for live load that is 1.08kN/m^2 and 2.88kN/m^2 will be constant for every zone. Live load is taken as 2kN/m^2 for every zone as per the IS 875(part 2), so the stresses in each is same for all the zones. Maximum bending stress will act on centre of the top slab and shear stress will act on horizontal of bottom slab.

Latreral Load:

Table 9: Max Bending and Shear stresses for lateral load in all zones

ZONES	MAX BENDING STRESS	MAX SHEAR STRESS
ZONE 2	135	16.5
ZONE 3	216	26.4
ZONE 4	276	32
ZONE 5	323	44



Graph 3: Max Bending and Shear stresses for lateral load in all zones

Graph shows the bending and shear stresses for lateral load in each zones. The graph is plotted by taking zones in X direction and maximum stresses in Y direction. For lateral load also bending stress and shear stress will be more for higher zone that is for zone5 the maximum bending and shear stress is 310kN/m^2 and 486.5kN/m^2 when compared other zones. Maximum bending stress will act towards right of the bottom slab and shear stress will act on horizontal of bottom slab.

Soil Pressure:

Table 10: Max Bending and Shear stresses for soil pressure in all zones

ZONES	MAX BENDING STRESS	MAX SHEAR STRESS
ZONE 2	110	250
ZONE 3	200	375
ZONE 4	257	429
ZONE 5	310	486.5

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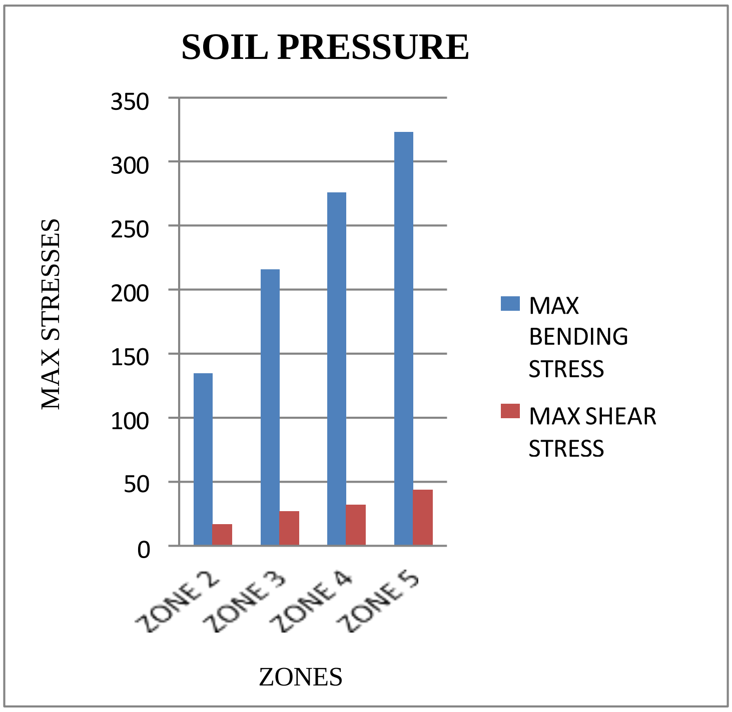


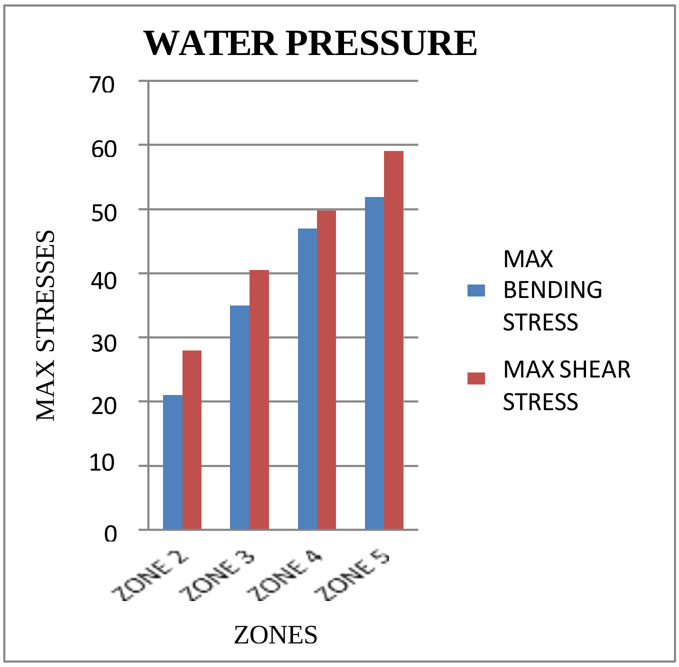
Graph 4: Max Bending and Shear stresses for soil pressure in all zones

Graph depicts the bending and shear stresses for soil pressure in each zones. The graph is plotted by taking zones in X direction and maximum stresses in Y direction. After analysing the graph bending stress will be more compared to shear stress, bending stress is more due to Earth pressure. Higher zone has high bending and shear stress value of 323kN/m^2 and 44kN/m^2 where as the other zones having less stress values. Maximum bending stress will act at corners and shear stress will act on centre of top slab.

Water Pressure:

Table 11: Max Bending and Shear stresses for water pressure in all zones

ZONES	MAX BENDING STRESS	MAX SHEAR STRESS
ZONE 2	21.05	28
ZONE 3	35	40.5
ZONE 4	47.05	49.73
ZONE 5	51.9	59



Graph 5: Max Bending and Shear stresses for water pressure in all zones

Graph gives the bending and shear stresses for water pressure in each zones. The graph is plotted by taking zones in X direction and maximum stresses in Y direction. After analysing the graph there is no much difference in bending and shear stress in every zones due to movement of water in the tank. Zone5 having highest bending and shear stress value of 51.9kN/m^2 and 59kN/m^2. Maximum bending stress will act on centre of bottom slab and shear stress will act on horizontal to bottom slab.

CONCLUSION

The following are conclusion which has been archived from the present study,

- The analysis and design is done for rectangular underground water tank for the different zones. The maximum bending and shear stress are compared for different zones for all the loads.
- Failure of water tanks can be brought about by different reasons. The primary issue is water tank are very little protected under various stacking conditions because of absence of its solidarity and ability to sustain the conditsions.
- Therefore planning a water-tank whiich gives a lot of security and strenngth is a difficult undertaking for the specialists.
- For this, it is realize to know the tank response under various loading and its failure patterns. Efforts are also made to optimize the structure so that it is economically affordable.
- Thus, the bending and shear stresses for each zone gives the strength and capacity of the tanks under different loadings and failure of the tank can be prevented.
- By this, we can say that construction of underground water tank in zone2 and zone3 is much

easier and economical compared to other zones (zone4 & zone5) due to different lateral loads in every zones.

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