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Seismic Analysis of Under Ground Water Tank Considering Different Ground Condition Using Staad Pro

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A B S T R A C T

Liquids such as water, petroleum, or chemicals are kept in storage using water tanks and reservoirs. Water tanks are an absolute necessity for every home and business to meet their daily needs. Since this is an underground water tank, the lateral earth pressure and water pressure are also taken into consideration for analytical purposes. An attempt is made in this work to build a rectangular underground water tank with three distinct ground conditions. The tank is to maintain atmospheric conditions. Fluids (such as water, oil, gas, etc.) are stored in underground water tanks. Both external earth pressure and internal water pressure are applied to these tanks. Soil reaction from below and internal water pressure are applied to the base of tanks. The examination of an 80000 liter subterranean water tank is the focus of this endeavor. The project's design includes the tank's foundation slab and side walls. Staad-Pro is used to analyze subsurface water tanks. According to the I.S. Code, we are examining square water tanks in this study with three distinct ground conditions: moist clay, medium clay, and soft rock.

Keywords: STAAD PRO

1. Introduction

1.1 RAINFORCED CONCRETE WATER TANKS

The water is stored in subterranean reinforced concrete tanks. Water tanks made of reinforced concrete are designed in accordance with IS 3370: 2009 (Parts I–IV). The layout of the tanks—whether they are above ground, below ground, or underground—determines the design. Tanks can be constructed in a variety of shapes, the most common being round and rectangular. Steel or reinforced concrete may be used to make the tanks. The overhead tanks, also known as elevated tanks, are often raised via columns from the top of the roof. Conversely, the subterranean tanks are supported by the earth.

1.2 TYPES OF RCC WATER TANK

Based on the water tank location and their shapes, they are classified as shown in table below:

Table 1.1 Types of RCC water tank based on their location and shapes

Types of water tanks	
Based on water tank location	**Based on water tank shape**
Underground tanks	Rectangular and circular tank
Tank resting on grounds	Circular tank
Overhead tanks	Spherical tank
	Intze tank
	Circular tank with conical bottom

Figure 1.1 RCC water tank on earth surface

Figure 1.2 Underground Water Tank

Figure 1.3 Elevated RCC water Tank Classification on Basis of Material

1. **Plastic Tank:** Poly (plastic) Polyethylene, a food-grade plastic with UV stabilization, is used to make water tanks. The tanks come in a wide range of colors and have an extended service life. They are lightweight and require only a sand base to be placed on. Although many assert that a 15-year lifespan is quite reasonable, many poly tanks come with a 25-year warranty. In most cases, they are also the least expensive. The fact that polyethylene is derived from petrochemicals is one of its main drawbacks. Even after their useful lives have passed, a sizable chunk of plastic remains that will require millennia to decompose and emit toxins during that process. Instead of attempting to extend the life of a polyethylene tank by a few years, it's simply a matter of breaking it up and then taking it away as polyethylene tanks can still be easily recycled after 15 years. Certain poly tanks have a vertical seam, which is a weak spot that could fracture and lead to water loss. Polyethylene water tanks are not fire-resistant and will simply melt when exposed to fire. This poses a significant issue, especially in rural areas where water is essential for firefighting. Additionally, there are concerns about the long-term effects of storing drinking water in polyethylene tanks, as they are relatively new to the market and lack credible serviceable life studies. Some users have reported an unusual taste in the water if the tank is placed in direct sunlight. Therefore, before buying a polyethylene tank, it is important to check the warranty for any temperature-related conditions, as some manufacturers may void the warranty if the tank is installed in extremely hot environments.

2. **Steel Tanks:** Steel tanks, particularly galvanized ones, have been in use for over 150 years and are generally the most affordable type. The hot-dip galvanizing process coats steel or iron with zinc, which helps reduce corrosion. However, depending on environmental conditions, a galvanized tank may last less than five years due to electrolysis. Some modern metal tanks feature polyethylene linings to further prevent corrosion, making it challenging to avoid plastic entirely. When using a steel-based tank, it's important to consider the water's composition and its potential to accelerate corrosion in any exposed metal.

3. **Fiber Glass:** Fiberglass tanks offer a durable option suitable for both above-ground and below-ground installation. They are resistant to corrosion and generally unaffected by chemicals. However, because fiberglass tanks allow more light to penetrate than other materials, they can promote algae growth and should therefore be painted. Additionally, fiberglass can be brittle, making it prone to cracks, which is especially problematic for in-ground installations.

4. **Concrete Tank:** Concrete water storage tanks can be constructed above ground or partially hidden. Due to their weight, they are built on-site. Concrete is porous and requires sealing to prevent minerals from leaching into the water, but this can be effectively managed with proper sealing and construction techniques. Although the production and delivery of concrete are energy-intensive, its longevity and recyclability are significant advantages. Choosing the right tank material involves weighing the pros and cons, particularly regarding environmental impact, budget, and long-term costs. While concrete tanks have been common in rural areas for many years, they are increasingly popular in urban settings, especially pre-cast underground tanks installed under driveways or yards. Underground concrete tanks are ideal for properties with limited space, as they can store large volumes of water that would be difficult to accommodate with above-ground tanks. These tanks are beneficial for homes with small gardens but high internal water usage in laundries, toilets, and showers, providing a comprehensive water supply solution.

BASIS OF CONCRETE WATER TANK DESIGN

RCC water tank design should be based on sufficient resistance to cracking to avoid leakage and adequate strength. For achieving these following assumptions are made:

- Plain section before bending remains plain after bending
- Both concrete and steel are perfectly elastic and modular ratio value has a value given in IS 456.
- In calculation of stresses. Both for flexural and direct tension or combination thereof relating to resistance to cracking, the entire section of concrete including the cover together with reinforcement can be taken into consideration provided that tensile stress in concrete limited to values.
- Neglect concrete tensile strength during strength calculation.

PERMISSIBLE STRESS ON CONCRETE

Permissible stress for resistance of cracking

Water tank concrete shall be free of leakage. This may be achieved by selecting concrete M 20 grade and greater, and concrete near water face need to such that no crack occurs. So, to make concrete crack free at water face, water tank wall thickness shall be designed so that stress on concrete is smaller than values. In members less than 225mm. thick and in contact with liquid on one side these permissible stresses in bending apply also to the face remote from the liquid.

Table 1.2 Permissible Stresses in Concrete (For calculations relating to resistance to concrete) IS 3370-2-2009 (T-1)

Grade of Concrete	**Permissible Concrete Stresses**	
	Direct Tension (N/mm^2)	**Tension due to bending (N/mm^2)**
M15	1.1	1.5
M20	1.2	1.7
M25	1.3	1.8
M30	1.4	2
M35	1.5	2.2
M40	1.6	2.4

Permissible stress for strength calculation

In strength calculation, permissible concrete stresses should be in accordance with values provided below:

Table 1.3 Permissible stresses in concrete for strength calculation IS 3370-2-2009 (T-2)

Grade of concrete	**Permissible stress in compression, N/mm^2**		**Permissible stress in bond (Average) for plain bars in tension, N/mm^2**
	Direct	**Bending**	
M25	6	8.5	0.9
M30	8	10	1
M35	9	11.5	1.1
M40	10	13	1.2
M45	11	14.5	1.3
M50	12	16	1.4

Table 1.4 Permissible shear stress in concrete IS 3370-2-2009 (T-3)

100*As/bd	**Permissible shear stress in concrete, N/mm²**			
	M25	M30	M35	M40 and above
0.15	0.19	0.2	0.2	0.2
0.25	0.23	0.23	0.23	0.23
0.5	0.31	0.31	0.31	0.32
0.75	0.36	0.37	0.37	0.38
1	0.4	0.41	0.42	0.42
1.25	0.44	0.45	0.45	0.46
1.5	0.46	0.48	0.49	0.49
1.75	0.49	0.5	0.52	0.52
2	0.51	0.53	0.54	0.55
2.25	0.53	0.55	0.56	0.57
2.5	0.55	0.57	0.58	0.6
2.75	0.56	0.58	0.6	0.62
3 and above	0.57	0.6	0.62	0.63

STRESS DUE TO TEMPERATURE OR MOISTURE VARIATIONS

It is not required to perform the separate calculations for stress due to moisture and temperature variation in concrete provided that the following conditions are met:

- The reinforcement provided is not less than minimum reinforcement which described in the sections below.
- IS 3370 (Part 1) recommendations regarding movement joint provisions and for a suitable sliding layer beneath the water tank are executed properly.
- The tank shall be applied for the storage of water or aqueous liquids at or near surrounding temperature
- Concrete shall never dry out.
- Suitable measures are taken to prevent cracking of the concrete during the construction period and until the tank is put into use.
- Nonetheless, separate computation for moisture and temperature variation shall be conducted.
- Assumed shrinkage coefficient.
- Permeable lining used for the water tank. In this case, possible dry out of the tank shall be taken into consideration.

Note: cement content with a range from 330Kg/m3 to 550Kg/m3 shall be used to reduce shrinkage to as minimum as possible.

Floors of Reinforced Concrete Water Tank Movement joints

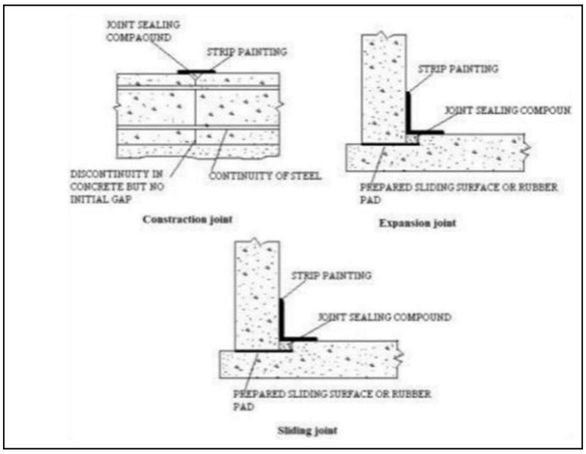

Figure 1.4 Various movement joints in water tank floor of RCC water tank rest on the ground

- Place layer of lean concrete not less than 75 mm thick over the ground.
- Commonly, use M15 for lean concrete.
- Employ M20 for lean concrete in the presence of aggressive soils or harmful water.
- Consider sulfate resisting concrete if required.
- Install polyethylene sheet layer between lean concrete and the floor.
- Cast the floor in single layer.

Figure 1.5 Reinforced concrete water tank floor above ground Floor of tanks rest on support

Figure 1.6 Overhead water tank floor

- It should be designed for bending moments due to dead load and water load.
- Special attention shall be practice during the design of floor of multi-cell water tank
- Lastly, when walls and floor are connected rigidly, then moment at the junction in combination with other transferred loads shall be considered in floor design.

Concrete Water Tank Walls Provision of joints IS 3370-2009

Sliding joints may be used if:

- It is desired to permit the walls to expand or contract separately from the floor.
- To prevent moments at the base of the wall because of fixity to the floor.

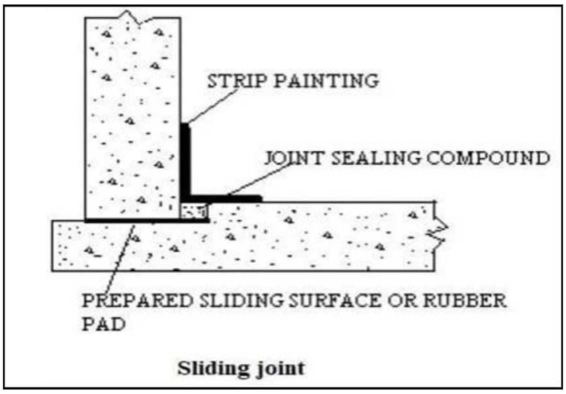

Figure 1.7 Sliding joint in water tank Pressure on RCC water tank wall

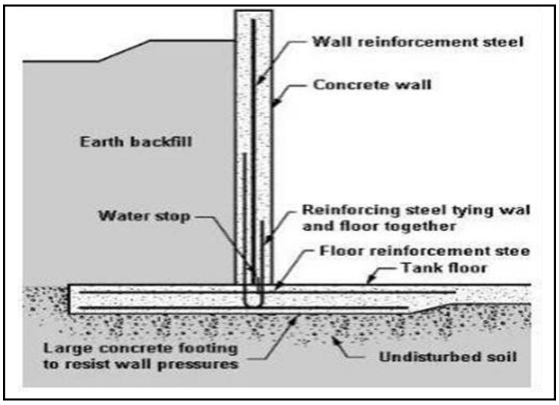

Figure 1.8 Earth fill-imposed earth pressure on RCC water tank wall

- Gas pressure, which is developed due to the presence of fixed or floated tank cover, shall be added to the liquid pressure.
- When water tank constructed in ground or earth embanked against it, then earth pressure shall be accounted in wall design.

RCC water tank roof

Figure 1.9 RCC water tank roof

Minimum reinforcement for RCC water tank

The minimum reinforcement required for sections 199mm thick is 0.3% of the concrete area, decreasing linearly to 0.2% for sections 450mm thick. For floor slabs of tanks resting on the ground, the minimum practical reinforcement should be at least 0.3% of the slab's gross sectional area. If the section thickness (wall, floor, or roof slab of the tank) is 225mm or more, two layers of reinforcing steel should be placed, one near each face of the section, to meet the minimum reinforcement requirements.

IMPORTANCE OF UNDERGROUND WATER TANK

1. **Seepage:** It is very important to store water and not to lose it. The tank should have a durable, watertight, opaque exterior and a clean, smooth interior. Below ground tanks must also be plastered well and correctly installed, otherwise they can collapse.
2. **Evaporation:** All storage tanks should have a roof made from locally available materials. A tight-fitting top cover prevents evaporation.
3. **Safety:** One should prevent mosquito breeding and keeps insects, rodents, birds and children out of the tank. A suitable overflow outlet(s) and access for cleaning are also important.
4. **Storage of water:** It is very imperative for all tanks to store water because the main process of the tank is to store water due to lack of running fresh water in all areas.
5. **Emergency:** Underground tanks are used as reservoirs where water is pumped to overhead tanks. When water is not available it will help us store and use water.

LATERAL FORCES

Horizontal or lateral loading causes storey drift, overturning moments, and storey displacement, which can lead to structural failure. To counter these effects, bracings and dampers are employed, especially in high-rise and significant structures. Structures with bracings and dampers demonstrate improved performance in reducing structural parameters (such as stress ratio) and systemic parameters (such as time period, base shear, and lateral displacement). Dampers are more cost-effective than bracings. The aspect ratio is crucial for structural performance; as it increases, the base shear capacity and roof displacement of the steel frame decrease.

- Arranged bracings to the structure should be of buckling resistant.
- Buckling restrained frames with special concentric bracings have effective performance than moment resisting and conventional frames.

OBJECTIVES OF THE RESEARCH

The main objectives of the present study are as follows:

1. To compare the analytical results of underground water tank with different ground condition.
2. To determine the effect of different soil pressure on under-ground water tank.
3. To determine the effect of water pressure on side wall of under-ground water tank.
4. To prepare the modeling and analysis of the underground water tank using Staad-ProV8i

Literature Review

The research papers were investigated from the authors across the globe, where the investigation was carried out on underground water tank using manual calculus and analytical applications for the structure analysis. The results were summarized in the review below.

A Nimade et al. 2018, A finite element model of an underground water tank was created using Staad Pro software to analyze the tank's behavior for different length-to-breadth (L/B) ratios. The node displacement and stress patterns of the tank were compared across various L/B ratios, considering both empty and full water conditions. The results indicated that the center shear stresses in the X direction (SQX) in the tank wall decrease as the L/B ratio increases. It was observed that stresses varied slightly when the L/B ratio changed from 1 to 1.5 but decreased more significantly at L/B ratios of 2 and 3 [1].

A Wad et al. (2014) studied RCC underground tanks, which are often used for water storage for domestic purposes, swimming pools, and sedimentation tanks. The vertical walls of these tanks face hydrostatic and soil pressures, while the base is subjected to the weight of water, soil pressure, and uplift. These tanks are designed according to IS 3370:2009 Part (I, II). The study focused on optimizing the cost design of underground tanks by considering variations in backfill soil unit weight, concrete grade, and height (depth) for the same capacity.

A.C. Chougule et al. (2017) analyzed spring mass models, focusing on the time period in impulsive and convective modes, the design horizontal seismic coefficient, base shear, and hydrodynamic pressure due to the impulsive and convective mass of water. They found that with increasing water depth to tank diameter ratio (h/D), more water mass is excited in the impulsive mode, while a decreasing h/D ratio excites more mass in the convective mode. The time period in the impulsive mode increases with a higher h/D ratio, while it decreases in the convective mode. The study concluded that for circular tanks with varying heights but the same capacity, base shear, bending moment, and maximum hydrodynamic pressure increase with a higher h/D ratio. For rectangular tanks with h/L ratios up to 0.6, these parameters increase gradually, surge between 0.6 to 0.8, and then decrease gradually.

Alexandros Tsipianitis et al. (2020) discussed how soil-structure interaction significantly affects the dynamic response of liquid-storage tanks. The ground motion transmitted to the superstructure can be amplified or de-amplified due to underlying soil layers, modifying the resonant period and effective damping. The study numerically examined the dynamic response and distress of cylindrical steel tanks with different foundation conditions under various ground motions.

D. Mondal and J.C. Guha (2018) conducted a comparative study of RCC underground and ground-level water tanks of various shapes (circular and rectangular) with a capacity of 500,000 liters. They designed and estimated these tanks using STAAD PRO software. The study aimed to design large capacity RCC water tanks and compare the results, concluding that if the aboveground portion has limited utility, underground tanks are preferable.

Hashemi, S. et al. (2013) analyzed the dynamic response of 3-D rectangular fluid containers with flexible walls subjected to seismic ground motion. Using the Rayleigh–Ritz method, they considered fluid–structure interaction effects and developed a mechanical model accounting for tank wall deformability. This model predicted maximum seismic loading at the tank base and a section immediately above it, proposing a 2-D simplified model for evaluating pressure distribution on flexible tank walls.

I. Kapadia et al. (2018) presented a design of combined rectangular water tanks, considering both surface and overhead tanks. Using STAAD Pro v8i, they aimed to minimize tank failure due to overturning. The study found that combined tanks had less deflection and moment compared to individual overhead tanks, with the absolute pressure being lower.

Issar Kapadia et al. (2018) explained that water tanks, crucial for storing water for various applications, can be underground or partially underground. They studied the behavior of UG rectangular tanks under different conditions using STAAD Pro software, analyzing how the tank's shape and filling status affected its structural response.

Jain Sudhir K. and Sameer U.S. (1990) described the complex hydrodynamic analysis of elevated water tanks involving fluid-structure interaction. Using finite element software ETABS, they evaluated different staging systems' performance concerning lateral stiffness, displacement, time period, seismic base shear, overturning moment, and flexure.

K. K. Wagh et al. (2021) designed and analyzed a rectangular underground water tank using STAAD Pro. They concluded that STAAD Pro provided satisfactory results compared to manual design, saving 15-20% of total steel. They noted that underground tanks face unique horizontal or lateral loads from earth and water pressure.

Kalyan Kumar Mandal and Damodar Maity (2016) investigated fluid-structure systems considering the coupled effect of an elastic dam and the adjacent fluid. Using eight-node isoperimetric elements, they showed that the flexibility of the dam significantly alters the dam-reservoir system's behavior, emphasizing the need for elastic effect consideration in seismic analysis.

M. H. Asgari et al. (2019) used the finite element method to study the seismic behavior of concrete rectangular liquid tanks on various topographic surfaces, considering soil-structure-liquid interaction. They found that topographic irregularities significantly affect tank response, particularly influencing natural frequencies, liquid sloshing height, impulsive mass displacement, base shear, and overturning moment.

Mostafa Farajian et al. (2017) examined how soil-structure interaction (SSI) affects the seismic response of liquid storage tanks, emphasizing the necessity for these structures to remain operational during severe earthquakes.

N. R. Neenu K. Mathew and Asha Joseph (2015) discussed the seismic response of large-capacity ground-supported tanks used for various liquids, highlighting the critical importance of their satisfactory seismic performance.

Nayana et al. (2015) investigated the dynamic response of rectangular water tanks, focusing on dimension changes, water levels, loading parameters, and past earthquake time histories using ANSYS.

Punith et al. (2015) analyzed the behavior of underground water tanks with different soil bearing capacities under seismic loads using the finite element method and SAP2000 FEM package.

R. Dave et al. (2017) designed rectangular ground-supported water tanks using the working stress method and conducted seismic analysis according to IS codes, focusing on reinforced area and moment capacity.

R. Dubey et al. (2021) investigated the seismic behavior and soil-structure interaction of underground water tanks in Indore, calculating seismic forces, base shear, and hydrodynamic pressure using Excel sheets.

Ranjit Singh Lodhi & Dr. Vivek Garg (2014) explained the design of Intze-type overhead water tanks according to IS: 3370, noting the widespread use of these tanks for public water distribution.

S. Tripathi et al. (2020) performed a seismic analysis of an underground water tank with reinforced concrete staging, using finite element simulations in SAP 2000 to minimize seismic effects.

Sani, J.E. et al. (2014) analyzed the failure of reinforced concrete rectangular underground water tanks using the First Order Reliability Method, focusing on ultimate and serviceability limit states.

Suraj P. Shinde et al. (2018) compared manual and computer-aided design (STAAD-PRO and SAP) of underground water tanks, emphasizing the efficiency and optimization achieved with software tools.

T.M. Vijaisarathi et al. (2016) detailed the design of liquid retaining structures (underground, ground-resting, and overhead tanks) using the working stress method, providing guidelines for safe and cost-effective designs.

Thalapathy et al. (2016) conducted a detailed analysis of liquid retaining structures, focusing on underground, ground-resting, and overhead tanks, and developed design programs to simplify calculations according to IS codes.

W. O. Ajagbe et al. (2010) investigated a fully submerged underground reinforced concrete water tank using beam-on-elastic-foundations principles, developing a Microsoft Excel design and analysis program (MESDAPro) for quick assessments.

Xun Meng et al. (2019) studied the earthquake response of cylindrical soil-supported tanks, emphasizing the impact of soil-structure interaction on natural frequencies, liquid sloshing, and structural responses.

Youssef M.A. Hashash and Jeffrey J. Hook (2001) reviewed seismic analysis and design approaches for underground structures, highlighting the need for robust designs to withstand seismic and static loads.

Research Methodology

Following steps are considered for analysis of study:

Step 1: To prepare geometry of the UG structure using analysis tool Staad.pro

Step 2: To create material for structural sections

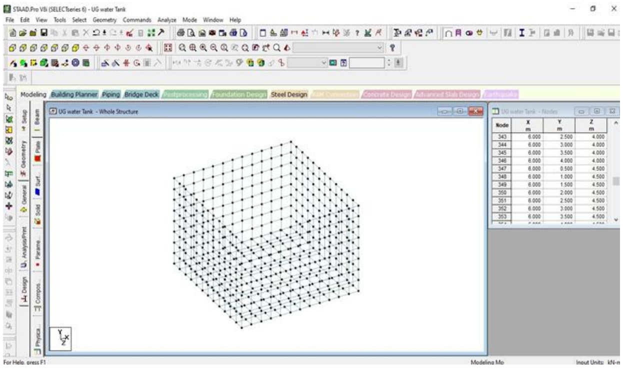

Figure 3.1 Geometric View of UG water tank

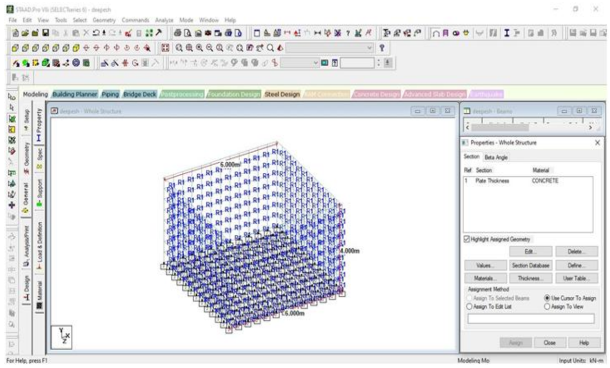

Figure 3.2 Assigning Material property

Step 3: To Assign and create sectional properties

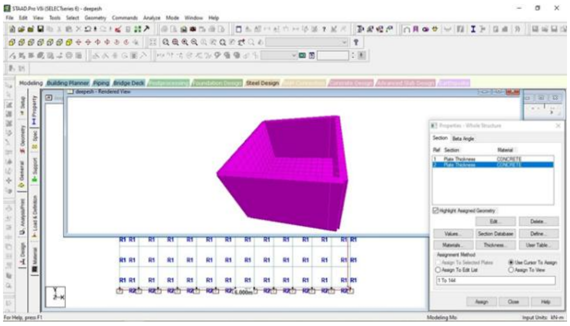

Figure 3.3 Section Details

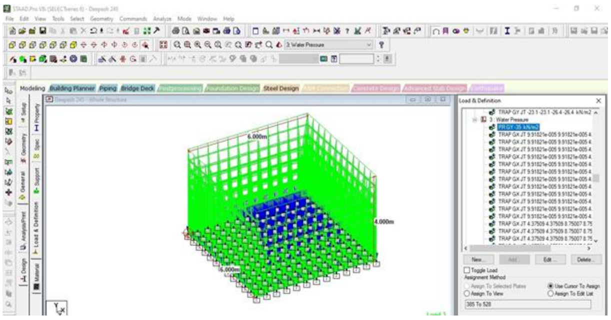

Figure 3.4 Support Condition

Step 4: Assign supports at base

Step 5: Assigning Hydrostatic Pressure

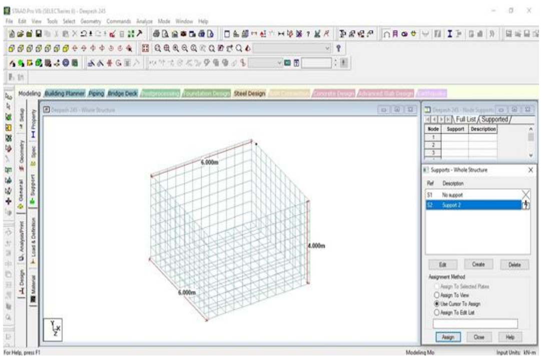

Figure 3.5 Hydrostatic Pressure

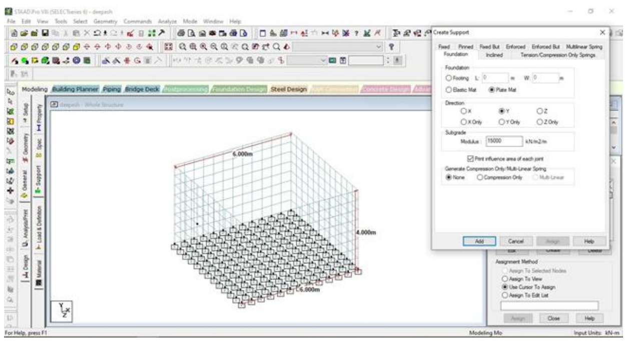

Figure 3.6 Hydrostatic Pressure

Step 6: Assigning Backfill Condition.

As we have three condition of ground as per IS-1893 Part-1

Table 3.1 The values of safe bearing capacity of different types of soils

S.No	Type of Soil	Safe Bearing Capacity (kN/m²)
	Cohesive Soils	
1.	Soft shale, hard or stiff clay in a deep bed, dry state	440
2.	Medium clay readily indented with a thumbnail	245
3.	Moist clay and Sand clay mixture which can be indented by thumb pressure	150

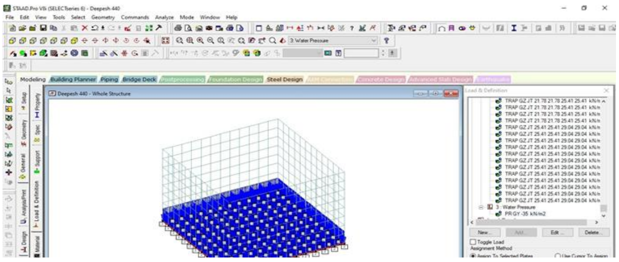

Figure 3.7 Backfill for moist clay condition

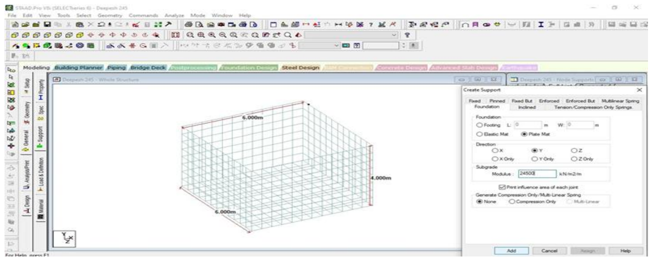

Figure 3.8 Backfill for medium clay condition

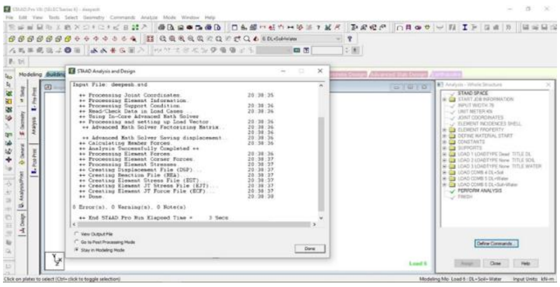

Figure 3.9 Backfill for Hard or stiff clay condition

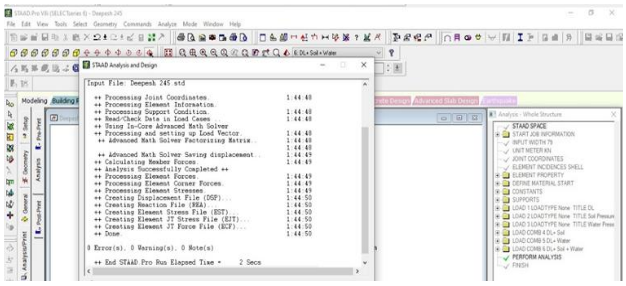

Figure 3.10 Analysis of the structure of moist clay condition

Step 7: Analysis of structure using analysis tool Staad.pro

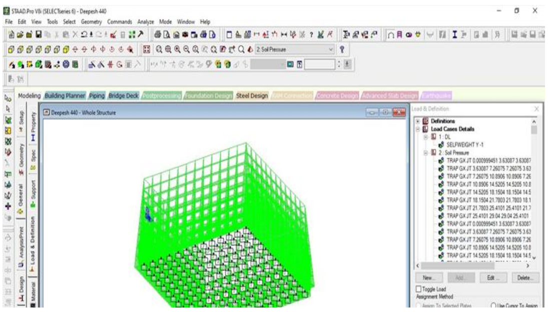

Figure 3.11 Analysis of the structure Of Hard or stiff clay condition

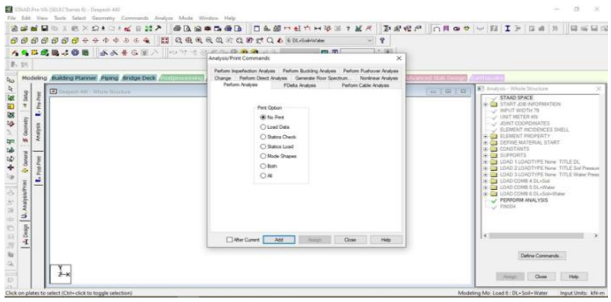

Figure 3.12 Analysis of the structure of Hard or stiff clay condition

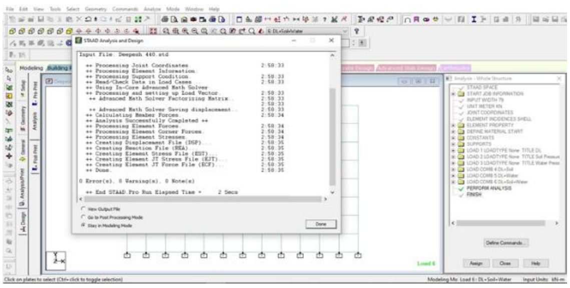

Figure 3.13 Perform Analysis

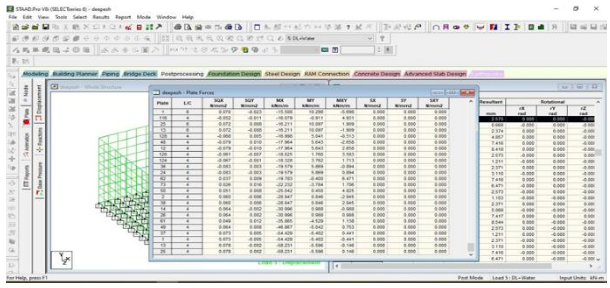

Figure 3.14 Plate stress Analysis

Problem Statement

MATERIAL PROPERTIES

Table 4.1 Properties of Material

<table>
<tr><th>SR.NO.</th><th colspan="2">PARAMETER</th><th>DESCRIPTION</th></tr>
<tr><td>1</td><td colspan="2">CONCRETE</td><td>M30</td></tr>
<tr><td>2</td><td colspan="2">REBAR</td><td>Fe500</td></tr>
<tr><td>3</td><td colspan="2">Modulus of Elasticity</td><td>1.95xE105 MPa</td></tr>
<tr><td rowspan="2">4</td><td rowspan="2">Soil type</td><td>Condition 1</td><td>Soft Rock</td></tr>
<tr><td>Condition 2</td><td>Medium Clay</td></tr>
</table>

		Condition 3	Moist Clay
5	Hydraulic pressure		Tension & stress

GEOMETRY OF THE UNDERGROUND WATER TANK

Table 4.2 Geometrical Structure

Height of the tank	4 m
Length in X direction	6 m
Length in Z direction	6 m
Length in Y direction	4 m
Area	36 m^2
Backfill Or Ground Condition	Moist Clay
	Medium Clay
	Soft rock
Grade of Concrete	M30
Grade of Steel	Fe500
Plate of Foundation thickness	800 mm
Plate Thickness	300 mm
Wall Thickness	300 mm

LOADING CONDITION

1. **Dead Loads**: as per IS: 875 (part-1)-1987.

Table 4.3 Load acting on the structure

Load acting on the structure				
Loading type	Calculation	Load	Unit	Remarks
Water Tank Wall	0.3 x 25kN/m2	7.5	kN/m2	-
Water Tank Foundation	0.8 x 25kN/m2	20	kN/m2	-

2. **Live Loads**: as per IS: 3370 LSM. Hydraulic load Horizontal 10 KN/m^2 & vertical 12.5 KN/m^2 at phase wall.

Table 4.4 Load Parameters on side Wall

S. No.	**Type of Soil Condition**	**Ca = Coefficient of active earth pressure**	**γ Dry Density Value (KN/m^3)**		**H Height (m)**	**Soil Pressure Ca* γ * H (KN/m^2)**
			Range	**Value Taken**		
1	Moist Clay	0.33	16-18	18	4	23.76
2	Medium Clay	0.33	18-20	20	4	26.40
3	Soft Rock	0.33	20-22	22	4	29.04

3. Water Pressure on the surface or base on the underground water tank

Height of the underground water tank except free board Density of Water

3.5 m * 10 KN/m^3 = 35 KN/m^2

I.S. 3370 HYDROSTATIC LOADING STEPS

Step-1 Permissible stresses in Steel and Concrete.

Step-2 Movement of joints shall be provided in accordance with IS 3370 (Part I).

Step-3 the floors of tanks resting on ground shall be in accordance with IS 3370 (Part I).

Step-4 Walls of cylindrical tanks are either cast monolithically with the base or are set in grooves and keyways (movement joints).

Step-5 Coefficient for ring tension and vertical moments for different conditions of the walls for some common cases are given in IS 3370 (Part 4) for general guidance.

STRUCTURAL ANALYSIS OF WATER TANK

The method of analysis adopted in this study was the theory of beams on elastic foundation and this was due to the fact that past analysis that has been carried out did not considered the effect of soil which is acting as a bed of spring on the tank. This method of analysis was used in deriving bending moment and the shear force at any section of the walls and base slab using equations below. The equations were based on the load type and end conditions of the beam where M and Q represents the moment and sheer force of the beam respectively.

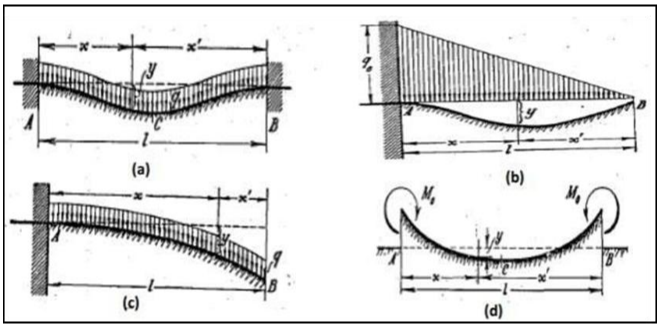

Figure 4.1 (a) uniformly distributed loaded beam fixed at both ends, (b) varying distributed loaded for a cantilever beam, (c) uniformly distributed loaded for a cantilever beam and (d) beam subjected to equal moment at both ends.

MODULUS OF SUB GRADE REACTION

The modulus of sub grade reaction is a conceptual relationship between soil pressure and deflection that is widely used in the structural analysis of foundation members. It is the ratio of applied pressure in kNm-2 divided by the corresponding soil movement or displacement in metres (m).

PRINCIPLE OF SUPERPOSITION

The principle of superposition is a powerful mathematical technique for analyzing certain types of complex problems in many areas of science and technology, and it hasan important application in analysis of underground water tank. The principle of superposition states that problem solutions can be added together to obtain composite solutions. This principle applies to linear systems governed by linear differential equations. The principle of superposition means that for linear systems, the solution to a problem involving multiple inputs (or stresses) is equal to the sum of the solutions toa set of simpler individual problems that form the composite problem.

UNDERGROUND WATER TANK ANALYSIS USING THE RIGID APPROACH

The rigid approach analysis of underground water tank is the conventional method of analysis. This is achieved by assuming that the soil modulus of sub grade is zero (0). The maximum bending moment considering tank wall to be a triangular loaded and uniformly loaded as a simple cantilever fixed at the left-hand end and base slab to be uniformly loaded for a beam fixed at both ends.

Result and Discussion

In this section we show the results of RCC slab & Brick Composite slab. The analysis of Brick Composite slab under the static incremental four point loading has been performed by hydraulic jack and pressure pump and readings were recorded by dial gauge. Afterward these results are compared with experimental results of Flexural behavior of reinforced cement concrete slabs. This is followed by the cracking behavior & load deflection curve of slabs are obtained from the analysis.

BASE PLATE STRESS MOMENT KN-M

Moment at X Direction

Table 5.1 Moment at X Direction kN-m

Moment at X Direction KN-m			
Positive / Negative	**Moist Clay**	**Medium Clay**	**Soft Rock**
Positive	67.908	25.388	27.768

Negative	-58.231	-75.601	-64.324

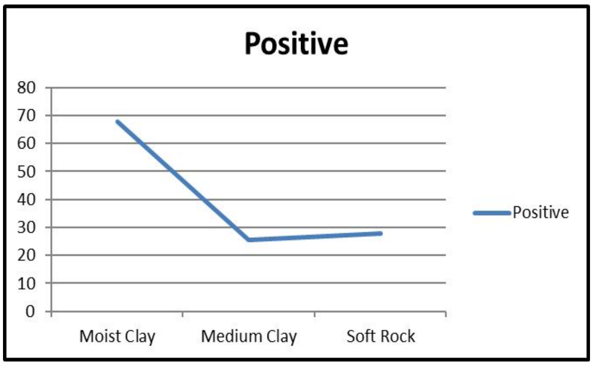

Figure 5.1 Positive Moment in X Direction KN-m

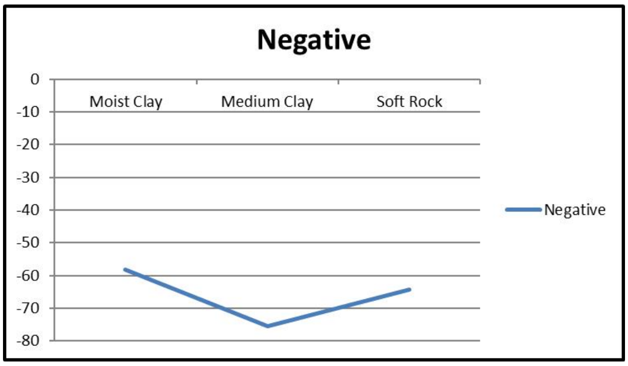

Figure 5.2 Negative Moment in X Direction KN-m

Moment at y direction

Table 5.2 Moment at Y direction kN-m

Moment at Y Direction KN-m			
Positive / Negative	**Moist Clay**	**Medium Clay**	**Soft Rock**
Positive	67.908	29.231	30.766
Negative	-46.867	-101.215	-64.324

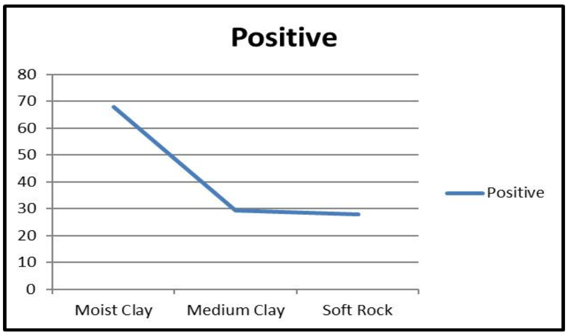

Figure 5.3 Positive Moment in Y Direction KN-m

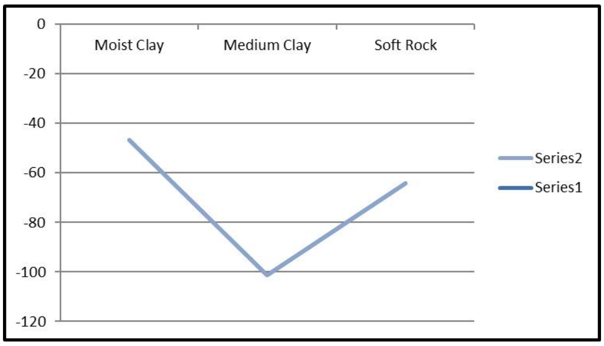

Figure 5.4 Negative Moment in Y Direction KN-m

Shear at x direction

Table 5.3 Shear at X direction N/mm²

Shear at X Direction N/mm²			
Positive / Negative	**Moist Clay**	**Medium Clay**	**Soft Rock**
Positive	0.08	0.124	0.077
Negative	-0.083	-0.124	-0.077

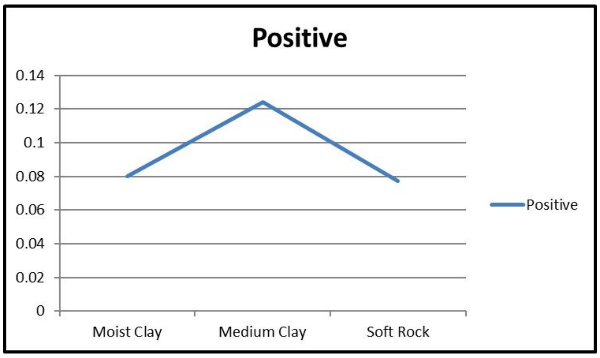

Figure 5.5 Positive Shear at X Direction N/mm^2

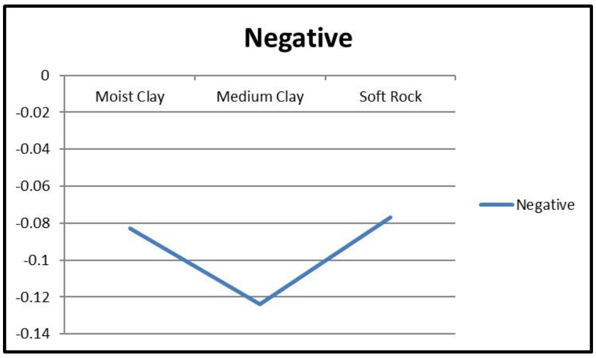

Figure 5.6 Negative Shear at X Direction N/mm^2

Shear at Y direction

Table 5.4 Shear at Y direction N/mm^2

Shear at Y Direction N/mm2			
Positive / Negative	**Moist Clay**	**Medium Clay**	**Soft Rock**
Positive	0.08	0.133	0.077
Negative	-0.08	-0.084	-0.077

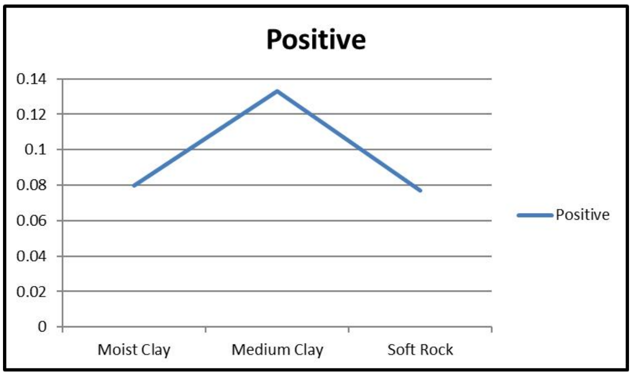

Figure 5.7 Positive Shear at Y Direction N/mm^2

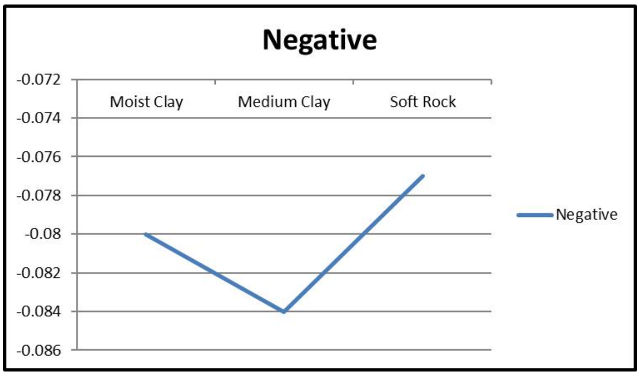

Figure 5.8 Negative Shear at Y Direction N/mm^2

WALL PLATE STRESS MOMENT KN-M

Stress at X direction KN-m

Table 5.5 Moment at X direction KN-m

Positive / Negative	**Moist Clay**	**Medium Clay**	**Soft Rock**
Positive	31.498	32.205	29.302
Negative	-29.357	-29.338	-29.338

Stress at Y direction

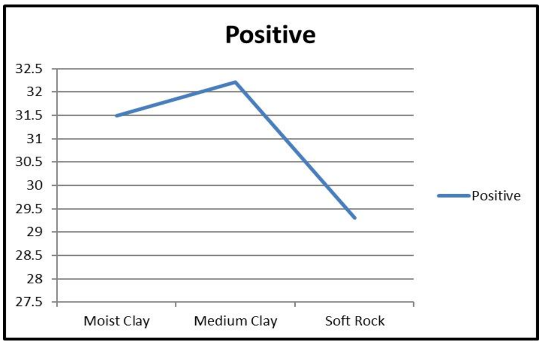

Figure 5.9 Positive Moment in X Direction KN-m

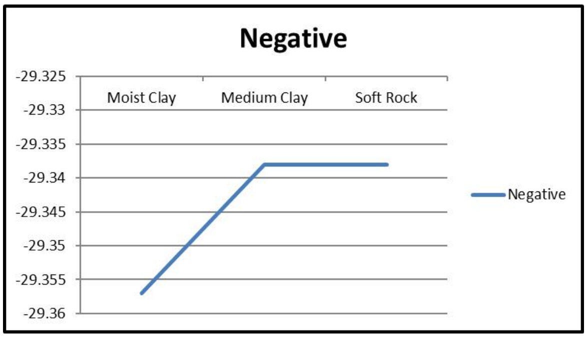

Figure 5.10 Negative Moment in X Direction KN-m

Table 5.6 Moment at Y direction kN-m

Positive / Negative	Moist Clay	Medium Clay	Soft Rock
Positive	29.357	32.204	29.302
Negative	-49.68	-29.338	-29.338

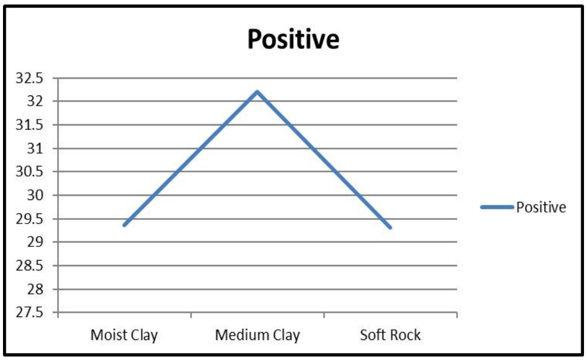

Figure 5.11 Positive Moment in Y Direction KN-m

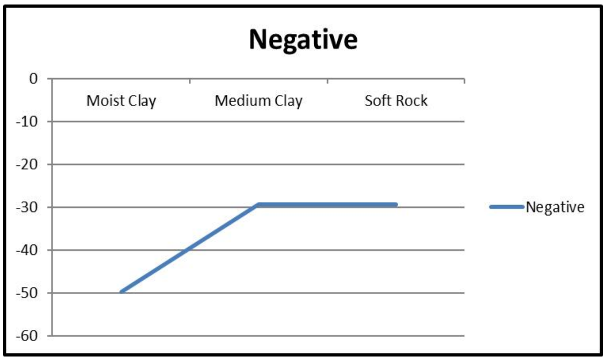

Figure 5.12 Negative Moment in Y Direction KN-m

Shear at X direction

Table 5.7 Shear at X direction N/mm^2

Positive / Negative	**Moist Clay**	**Medium Clay**	**Soft Rock**
Positive	23.977	0.193	0.215
Negative	-24.671	-0.215	-0.215

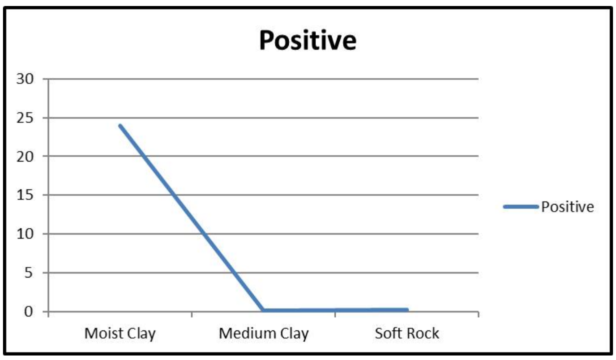

Figure 5.13 Positive Shear in X Direction N/mm^2

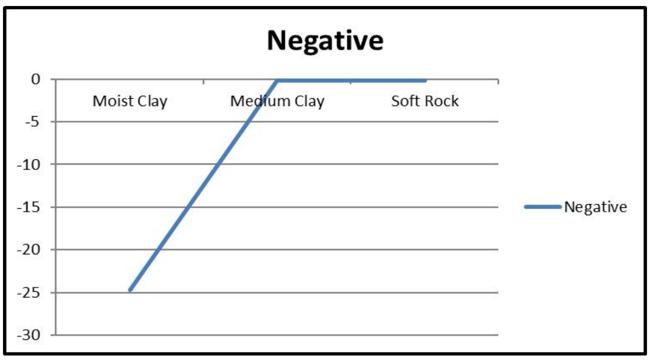

Figure 5.14 Negative Shear in X Direction N/mm^2

Shear at Y direction

Table 5.8 Shear at Y direction N/mm^2

Shear at Y Direction N/mm2			
Positive / Negative	**Moist Clay**	**Medium Clay**	**Soft Rock**
Positive	29.357	0.231	0.215
Negative	-49.68	0.231	0.215

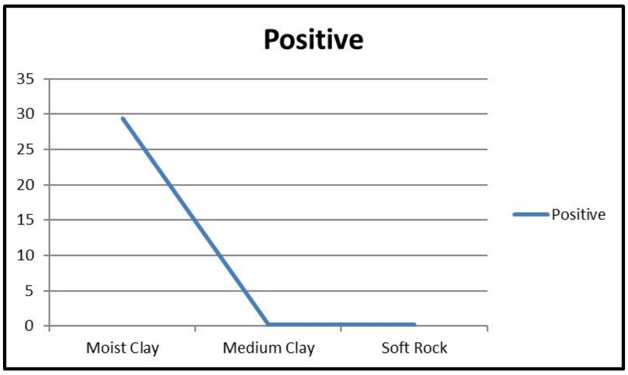

Figure 5.15 Positive Shear at Y Direction N/mm^2

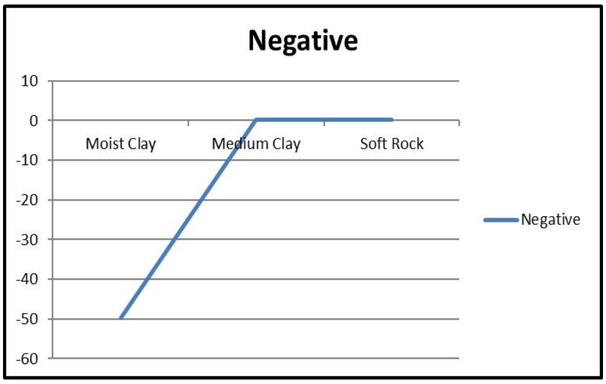

Figure 5.16 Negative Shear at Y Direction N/mm^2

Conclusion

1. In terms of base plate stress near the foundation observed that as we are comparing in moist clay, medium clay and Soft rock. In X Direction in medium clay the stress as compare to moist clay is 42 % less and soft rock 09 % less is observed.
2. In terms of base plate stress near the foundation we observed that as we are comparing in moist clay, medium clay and Soft rock. In Y Direction in medium clay the stress as compare to moist clay is 57 % less and soft rock 05 % is less observed.
3. In terms of Shear at X Direction it is observed that as comparing in medium clay the shear as compare to moist clay is 55% more and soft rock 66% more also. So that in medium clay the shear at X direction is more as compare to other two.
4. In terms of Shear at Y Direction it is observed that as comparing in medium clay the shear as compare to moist clay is 66% more and soft rock 72% more also. So that in medium clay the shear at X direction is more as compare to other two.
5. In terms of side wall plate stress observed that as we are comparing in moist clay, medium clay and Soft rock. In X direction in medium clay the stress as compare to moist clay is nothing but 2.25 % more and soft rock also almost 10 % more.
6. In terms of side wall plate stress observed that as in Y Direction in medium clay the stress as compare to Moist clay is almost 10 % more and soft rock also 10 % more.
7. In terms of Shear at X Direction the value is very less as compare to two others. Or it is negligible
8. In terms of Shear at Y Direction the value is very less as compare to two others. Or it is negligible

So that the underground water tank should be on the Medium Clay ground condition.

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