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# Comparative Analysis of Water Tank Rest on Ground

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***Abstract***
All living things require water in order to survive. Water on-the-go is necessary for maintaining human health. Every person and every community should have access to portable water, so it is crucial to save water. Typically, water is stored in tanks and then transported to each destination via pipelines. A water tank that is lying on the ground is typically used to store water. This case study provides an example of a simpler, safer, and more cost-effective design. The principle of safe tank optimisation is explained in this article. This study offers numerous design requirements that have an impact on the stability and support of the structure for the safe and affordable construction of the tank. This case study is based on a liquid containment structure made of reinforced concrete that is sitting on the ground.
***Keywords— water tank, economic design, reinforcement, optimization, analysis etc.***

## 1. Introduction

Tanks are used to hold things like liquid petroleum products, water, and liquid oil. Regardless of the product's chemical makeup, tanks and containers have about the same strength analysis. To prevent leaks, every tank has a slotless construction. With sufficient reinforcement cover, the slab and walls storing water or oil can be made of reinforced concrete [1].

A container for keeping liquid is called a water container. Since the beginning of civilization, there has been a need for water reservoirs to store water for a variety of uses, including drinking water, irrigation, agriculture, firefighting, agriculture (for both plants and livestock), chemical manufacture, food preparation, and many more uses. [2].

Water tank parameters include general tank design, choice of construction materials, coatings. The design depends on the location of the tank, ie. above, underground or in underground water tanks, partly underground. Ground-based tanks include clean water tanks, sediment tanks, air tanks, etc., which rest directly on the ground. Pressure is exerted on the walls of these tanks and the weight of the water sinks to the bottom [3]

The usual types of water tanks are the following:

- Tanks situated on the ground.
- Tanks situated underground.
- Tanks situated above the ground level.

*Tank Resting on Ground*

This tank is on the ground and is used as an aeration tank and reservoir for drinkable water. Except for the base soil pressure, which is caused by the weight of the water inside the tank and the soil reaction from the outside, internal hydrostatic pressure is acting in this tank.

*Underground Water Tank*

Fluids (oil, water, gas, etc.) are stored in underground water tanks. Both internal water pressure and external ground pressure are applied to these tanks. Water pressure from inside tanks and soil reaction from below are both applied to the base. These are always covered at the top. These tanks ought to be built for the worst-case scenario of loading. Tanks that are buried in the earth share the same principles and design as tanks that are resting on the surface. The internal water pressure and external earth pressure are applied to the underground tanks' walls. The wall segment is made to withstand simultaneous action from both earth pressure and water pressure.

Fig. 1 Water Tank Rest on Ground


Fig. 2 Underground Water Tank

The partially underground tank combines the advantages of above-ground and below-ground storage into a single, straightforward, and affordable design. A partially underground tank also makes use of the soil's ability to provide support, eliminating the requirement for a structural component below ground.


Fig. 3 Partially Underground Water Tank

## 2. Problem Definition

The following are the project's identified issues: Tank durability and feasibility

- Effect of various stresses brought on by a change in the water tank's reversal level on the part sizes
- Minimum sizes of water tanks; a better location economically to complete the reverse level water tank in the event of a water supply project.
- Finding the best form of water tank that can withstand the most forces in comparison to other options will undoubtedly benefit from a comparative analysis of various characteristics and other aspects of ground water tanks.

## 3. Proposed System

In addition to gutters, irrigated agriculture, firefighting, agriculture, agricultural and livestock production, chemical production, cooking, and many more uses, water tanks are used to store water. In order to serve the community, water is mostly kept in concrete water tanks before being pumped to various locations.

Using software to analyse the water tank design allows for more rapid and accurate findings. One of the most crucial programmes for water tank analysis and design is called Staad pro. Staad software is used for the comparative study's analysis.

To get the best outcome possible, each mould is examined separately while maintaining the same capacity. Results are then taken into consideration and comparisons are made. The paper examines water tanks according to their categorization, looks into the numerous supports and loads that have an impact on the water tank, and analyses various water tank forms using Staad-Pro.

## 4. Methodology

Flow Chart of Project Process

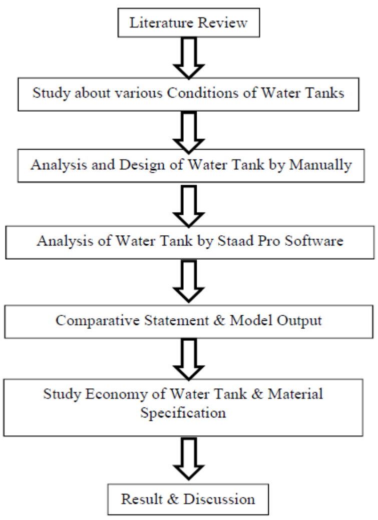

Fig.4. Working Methodology

**Using Staad Pro**

Create a new Space structure in V8i using metres and kilogrammes as the length and force units. The Snap Node/Beam window appears when you select the Beam page under the Geometry tab. Snap Node/Beam window should be closed. Create the necessary nodes in the Nodes window using the provided pertinent data. In order to produce the plates with the same orientation, we will now create the members in an upward direction. You cannot apply a single load case to plates with distinct orientations if the plates were manufactured in separate orientations. Create the members using the pertinent information. With the help of the circular repeat tool, we will now construct a section of the tank.

The 3D Circular dialogue box appears after selecting all of the members and selecting the Circular Repeat tool from the Geometry menu. Enter the values exactly as they were obtained. If you click OK, the model will be replicated at a 20-degree angle with the rotational axis acting as the Y-axis. The plates will automatically be formed in the regions that the members enclose if all of the members are selected and the Create Infill Plates option is chosen from the Geometry menu. Delete the beams on the outside periphery by selecting them. We'll now put loads on the plates. The Load & Definition window appears when the Loads & Definition page is selected from the General tab. In the Load & Definition window, select the Load Cases Details node, then select the Add button dialog box is displayed with the Primary node selected by default.

Enter Fluid Loads in the Title text box after choosing the Fluids option from the Loading Type drop-down list. By selecting the Add button, the main load case will be generated and added to the Load & Definition window's Load Case Details node. Close the dialogue box for Add New: Load Cases. The Add New: Load Items dialogue box is shown after selecting the freshly generated Fluid Loads load case and selecting the Add button from the Load & Definition window. In the Add New: Load Items dialogue box, select the Plate Loads node; by default, the Pressure on Full Plate page is shown. In the W1 text box, type as load intensity, and choose GY as the load direction. Selecting the Add button will add the load to the Fluid Loads load case. The Hydrostatic page is displayed when the Plate Loads node in the Add New: Load Items dialogue box is selected. Since no plates are chosen, the alternatives are not available. The Selected Items dialogue box is presented after selecting the Select Plate(s) button from the Add New: Load Items dialogue box.

The plate number is displayed in the Selected Items(s) dialogue box after selecting the plate with the Plates cursor in the Staad window. The Selected Items(s) dialogue box will close after selecting the Done button, and the options will now be available on the Hydrostatic page. In the Interpolate along Global Axis and Direction of pressure regions, respectively, choose the Y and Local Z radio buttons. Selecting the Add button adds the load to the Fluid Loads load case. In your Staad window, similarly, add the hydrostatic load on the plate just below the vertical plate. The tank's bottom plate will now receive the uniform pressure established in the earlier phases. Choose the uniform pressure load, then choose the plate as the recipient. Add self-weight and a constant railing load to a new load case for dead loads. We shall now give the model sectional characteristics.

The Properties - Whole Structure window appears when you select the Properties page from the General menu. The Plate Element/Surface Property dialogue box is presented when the Thickness button is selected in the Properties - Whole Structure window. Make sure the Concrete option is chosen from the Material drop-down list and enter the thickness in the Node 1 edit box. The dialogue box for the Plate Element/Surface Property is closed when you select the Add button. The property is allocated to each plate produced when the Assign to View radio button is selected in the Properties - Whole Structure window and the Assign button is subsequently selected.

The Property dialogue box appears when the Define button is selected in the Properties - Whole Structure window. The Rectangle page appears after selecting the Rectangle node. Type YD and ZD into the appropriate edit boxes. A property is added to the Properties - Whole Structure window and the Property dialogue box is closed when the Add button is selected. Give the model's members access to the newly generated property. The Supports - Whole Structure window appears when you select the Support page from the General tab. The Create Support dialogue box will appear after selecting the Create button, with the Fixed tab already selected. The fixed support is added to the Supports - Whole Structure window when the Add button is selected. Give the lowest nodes the fixed support you just created. The 3D Circular dialogue box appears after selecting the plates and members with the Geometry Cursor and selecting the Circular Repeat option from the Geometry menu. Type in the appropriate values. Selecting the OK button will cause the model to be reproduced 360 degrees with the rotating axis set to the Y-axis.

The Perform Analysis dialogue box appears when you choose the Perform Analysis option from the Analysis fly-out in the Commands menu. The STAAD Analysis and Design window is presented, displaying the progress of the solution, once you close the Perform Analysis dialogue box and choose the Run Analysis option from the Analyse menu. When the analysis is finished, click the Done button, select the radio button for Going to Post Processing Mode, and the Results Setup dialogue box will appear. Select the Apply and OK buttons, and the post-processing mode and various results are presented [2].

**Capacity (Volume) Calculation of Tank**

Capacity of Tank Calculation :-

Demand = 50 LPCD

Losses = 15 %

Demand = 50 x 1.15 = 65 LPCD

Population = 1,00,000

Flow = 75,000 x 65 = 64,7,588 L/d

Retention Time – 1.2 Hrs

Required Capacity = $\frac{1.2 \times 647588}{24 \times 1000.}$ = 315 Cum

**Design Data**

- Dimensions for Circular Water Tank –
- Volume – 315 Cum
- Diameter – 10.0 m
- Height of Water – 4.0 m
- Free Board – 0.5m
- Total Volume of Tank After Considering FB = 0.785 x 10 x 10 x (4 +0.5) = 354 Cum

- Dimensions for Rectangular Water Tank –
- Volume – 315 Cum
- Size – 9 m x 8.75 m
- Height of Water – 4.0 m
- Free Board – 0.5m

Total Volume of Tank After Considering FB = 10 x 7.5 x (4 +0.5) = 354 Cum

**Design Basis**

- Grade of Concrete – M30
- Grade of Steel – Fe500
- Unit weight of Concrete – 25 kN/Cum
- Unit weight of Soil – 18.85 kN/Cum
- Surcharge – 5 kN/Sqm
- Ground Water Table – Nill

**Rest at Ground Water Tank**

*Load Condition for Water Tank –*

- Dead Load
- Live Load – 1.5 kN/sqm (as per IS Code )
- Hydro test Condition - 10 x 4.5 = 45 kN/Sqm
- Working Water Pressure – 10 x 4 = 40 kN/Sqm

*Load Combination*

For Limit State of Collapse

- Hydro test = 1.5 (DL + Hydro test)
- Tank Empty = 1.5 (DL)
- Working Condition = 1.5 (DL + Working Condition)

For Limit State of Serviceability

- Hydro test = 1 (DL + Hydro test)
- Tank Empty = 1 (DL)
- Working Condition = 1 (DL + Working Condition)

**Fully Underground Water Tank**

*Load Condition for Water Tank –*

- Dead Load
- Live Load – 1.5 kN/sqm (as per IS Code )
- Soil Pressure – 18.85 x 4.5 x 0.5 = 41.59 kN/Sqm
- Hydro test Condition - 10 x 4.5 = 45 kN/Sqm
- Working Water Pressure – 10 x 4 = 40 kN/Sqm
- Surcharge – 5 kN/Sqm

*Load Combination*

For Limit State of Collapse

- Hydro test = 1.5 (DL + Hydro test)
- Tank Empty = 1.5 (DL + Soil Pressure + Surcharge)
- Working Condition = 1.5 (DL + Working Condition + Soil Pressure + Surcharge)

For Limit State of Serviceability

- Hydro test = 1 (DL + Hydro test)
- Tank Empty = 1 (DL + Soil Pressure + Surcharge)
- Working Condition = 1 (DL + Soil Pressure + Working Condition)

**Partially Under Ground**

*Load Condition for Water Tank –*

- Dead Load
- Live Load – 1.5 kN/sqm (as per IS Code )

- Soil Pressure – 18.85 x 2 x 0.5 = 18.85 kN/Sqm
- Hydro test Condition - 10 x 4.5 = 45 kN/Sqm
- Working Water Pressure – 10 x 4 = 40 kN/Sqm
- Surcharge – 5 kN/Sqm

*Load Combination*

For Limit State of Collapse

- Hydro test = 1.5 (DL + Hydro test)
- Tank Empty = 1.5 (DL + Soil Pressure + Surcharge)
- Working Condition = 1.5 (DL + Working Condition + Soil Pressure + Surcharge)

For Limit State of Serviceability

- Hydro test = 1 (DL + Hydro test)
- Tank Empty = 1 (DL + Soil Pressure + Surcharge)
- Working Condition = 1 (DL + Soil Pressure + Working Condition)

## 5. Results and Analysis

### 5.1. Plate Stresses

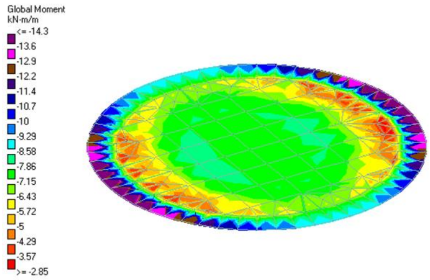


Fig.8. Plate Stress at Base Slab Circular Fully Underground Tank

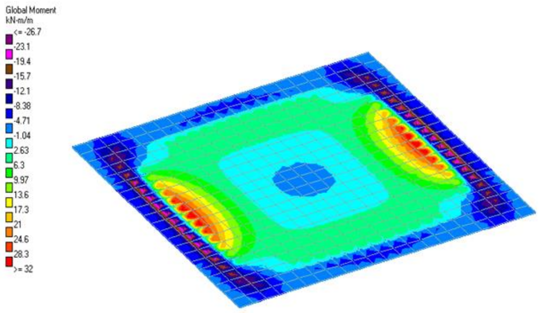


Fig.9. Plate Stress at Base Slab for Rectangular Fully Underground Tank

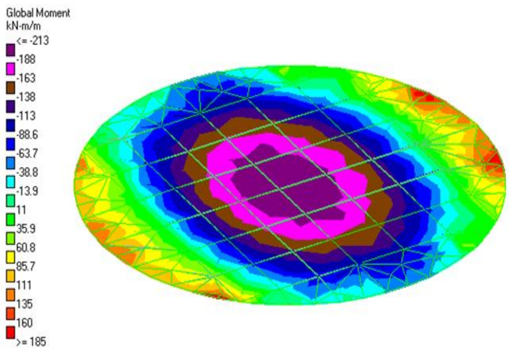


Fig.10. Plate Stress at Base Slab for Circular Tank Rest on Ground

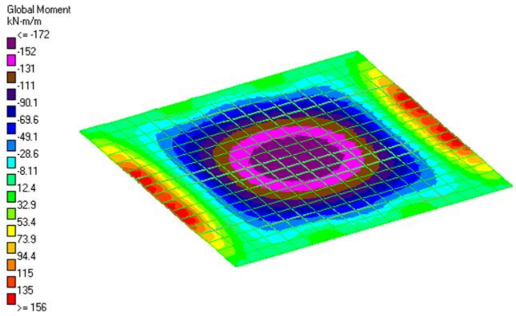


Fig.11. Plate Stress at Base Slab for Rectangular Tank Rest on Ground

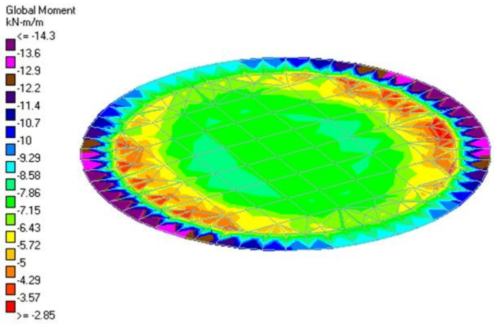


Fig.12. Plate Stress at Base Slab for Circular Partially Underground Tank

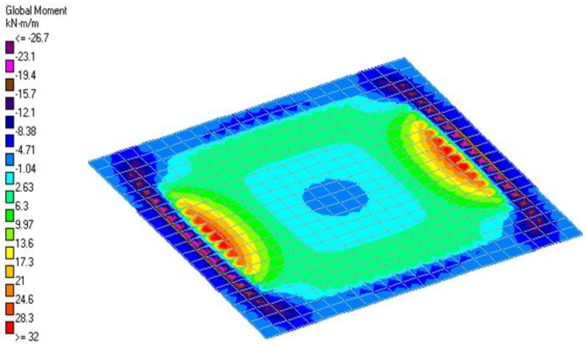


Fig.13. Plate Stress at Base Slab for Rectangular Partially Underground Tank

### 5.2. Staad Results for Wall and Base Slab

- *Circular Fully Underground Tank*

| Wall | SQX kN/m2 | SQY kN/m2 | MX kN-m/m | MY kN-m/m | MXY kN-m/m | SX kN/m2 | SY kN/m2 | SXY kN/m2 |
|---|---|---|---|---|---|---|---|---|
| MAX | 14.836 | 196.699 | 7.934 | 46.184 | 0.314 | 674.534 | -88.013 | 30.139 |
| MIN | -10.132 | -345.781 | -3.334 | -19.588 | -0.422 | -735.006 | -272.2 | -27.547 |

| Base slab | SQX kN/m2 | SQY kN/m2 | MX kN-m/m | MY kN-m/m | MXY kN-m/m | SX kN/m2 | SY kN/m2 | SXY kN/m2 |
|---|---|---|---|---|---|---|---|---|
| MAX | 181.439 | 232.738 | 44.496 | 44.514 | 29.414 | 162.964 | 163.283 | 7.582 |
| MIN | -229.409 | -326.318 | -49.096 | -49.994 | -27.466 | -262.179 | -264.467 | -14.075 |

- *Rectangular Fully Underground Tank*

| Wall | SQX kN/m2 | SQY kN/m2 | MX kN-m/m | MY kN-m/m | MXY kN-m/m | SX kN/m2 | SY kN/m2 | SXY kN/m2 |
|---|---|---|---|---|---|---|---|---|
| MAX | 260.927 | 380.314 | 24.306 | 76.541 | 17.452 | 304.225 | 283.934 | 149.495 |
| MIN | -260.927 | -352.026 | -43.619 | -47.678 | -17.452 | -245.263 | -492.574 | -149.495 |

| Base Slab | SQX kN/m2 | SQY kN/m2 | MX kN-m/m | MY kN-m/m | MXY kN-m/m | SX kN/m2 | SY kN/m2 | SXY kN/m2 |
|---|---|---|---|---|---|---|---|---|
| MAX | 328.198 | 326.872 | 79.158 | 78.847 | 28.741 | 339.066 | 341.644 | 71.696 |
| MIN | -328.198 | -326.619 | -48.339 | -51.019 | -28.741 | -357.898 | -358.136 | -71.696 |

- *Circular Partially Underground Tank*

| Wall | SQX kN/m2 | SQY kN/m2 | MX kN-m/m | MY kN-m/m | MXY kN-m/m | SX kN/m2 | SY kN/m2 | SXY kN/m2 |
|---|---|---|---|---|---|---|---|---|
| MAX | 10.835 | 196.699 | 4.962 | 28.834 | 0.229 | 674.534 | -88.086 | 22.016 |
| MIN | -7.412 | -204.157 | -3.334 | -19.588 | -0.309 | -55.34 | -263.075 | -20.111 |

| Base Slab | SQX kN/m2 | SQY kN/m2 | MX kN-m/m | MY kN-m/m | MXY kN-m/m | SX kN/m2 | SY kN/m2 | SXY kN/m2 |
|---|---|---|---|---|---|---|---|---|
| MAX | 132.649 | 169.857 | 32.269 | 32.284 | 21.534 | 162.964 | 163.283 | 7.582 |
| MIN | -167.394 | -237.952 | -36.352 | -37.001 | -20.111 | -151.881 | -153.529 | -8.462 |

- *Rectangular Partially Underground Tank*

| Wall | SQX kN/m2 | SQY kN/m2 | MX kN-m/m | MY kN-m/m | MXY kN-m/m | SX kN/m2 | SY kN/m2 | SXY kN/m2 |
|---|---|---|---|---|---|---|---|---|
| MAX | 260.927 | 117.901 | 19.186 | 47.424 | 17.452 | 304.225 | 129.348 | 149.495 |
| MIN | -260.927 | -352.026 | -43.619 | -47.678 | -17.452 | -155.585 | -492.574 | -149.495 |

| Base Slab | SQX kN/m2 | SQY kN/m2 | MX kN-m/m | MY kN-m/m | MXY kN-m/m | SX kN/m2 | SY kN/m2 | SXY kN/m2 |
|---|---|---|---|---|---|---|---|---|
| MAX | 217.376 | 215.9 | 41.245 | 40.504 | 23.799 | 339.066 | 341.644 | 59.901 |
| MIN | -217.377 | -215.64 | -37.045 | -38.981 | -23.799 | -115.917 | -115.616 | -59.901 |

- *Circular Tank Rest on Ground*

| Wall | SQX kN/m2 | SQY kN/m2 | MX kN-m/m | MY kN-m/m | MXY kN-m/m | SX kN/m2 | SY kN/m2 | SXY kN/m2 |
|---|---|---|---|---|---|---|---|---|
| MAX | 153.664 | 64.161 | 12.572 | 39.069 | 15.339 | 515.663 | 851.024 | 1050.41 |
| MIN | -153.664 | -530.244 | -32.539 | -170.724 | -15.339 | -431.045 | -2271.49 | -1050.41 |

- *Rectangular Tank Rest on Ground*

| Wall | SQX kN/m2 | SQY kN/m2 | MX kN-m/m | MY kN-m/m | MXY kN-m/m | SX kN/m2 | SY kN/m2 | SXY kN/m2 |
|---|---|---|---|---|---|---|---|---|
| MAX | 217.376 | 215.9 | 41.245 | 40.504 | 23.799 | 339.066 | 341.644 | 59.901 |
| MIN | -217.377 | -215.64 | -37.045 | -38.981 | -23.799 | -115.917 | -115.616 | -59.901 |

## 6. Conclusion

When it's required to hold a lot of water, tanks that are lying on the ground are typically circular or rectangular. The basic design of the tank, as well as the selection of the construction materials and coatings, are among the characteristics of water tanks. This study demonstrated the significance of the aforementioned design criterion in the safe and cost-effective design of various above-ground water tank types, shedding light on a precise and practical tank optimization technique.

- Used IS-456:2000 for the design of the STRUCTURAL MEMBERS. i.e., followed the LIMIT STATE method.
- STAAD Pro gives satisfactory results when compare with manual design also.
- SATAAD PRO analysis and design is always beneficial over the conventional method of analysis and design of water tank.
- Manual analysis and design requires lengthy and complicated procedure while STAAD PRO requires less time & easy design &analysis process.
- As compared to rectangular tanks circular tanks are more economical.

## 7. Future Scope

By taking into account conditions where the tank has half its water level, the analyses can be expanded. This makes it easier to observe how different safe carrying values of soil behave. Additionally, the analysis can be performed by taking into account the ground water tank's resting circular shape.

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