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Design and Analysis of Under Ground Water Tank Considering Different Fill Conditions Using STAAD.PRO

Deepshikha Gadekar[1], Rakesh Patel[2]

[1]P.G. Scholar, Department of Civil Engineering, S.I.R.T.S. Bhopal, Madhya Pradesh, India
[2]Professor and H.O.D., Department of Civil Engineering, S.I.R.T.S. Bhopal, Madhya Pradesh, India

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ABSTRACT

Water tanks and reservoirs are used to store liquids like water, petroleum or chemicals. For any domestic and commercial purposes, water tanks are very basic need to meet their day to day use. In this project an attempt is made to design the rectangular underground tank, the tank is to maintain atmospheric temperature and provided optimum height for easy pumping of water to overhead tank. Since it is underground water tank the lateral earth pressure and water pressure also considered for the design calculations, so the design is to be carried out as per IS code norms. This project deals with analysis and design of under ground water tank of 2lakh liter capacity. The design in this project comprises of side walls, base slab and roof slab. The analysis and design of underground water tank is done using staad.pro. For this design project limit state method is used.

Keywords : Analysis, Water Tank, Structure, Forces, Moment, Deflection.

I. INTRODUCTION

Now days, expressive constructions were taking place in hilly areas due to lack of plain ground. As a result the mountain areas have marked effect on the buildings in terms of style, material and method of construction leading to lot of structures in hilly areas. Due to sloping profile, the different levels of such structures step back towards the hill slope and may also have setback also at the same time. These structures become highly uneven and unsymmetrical, due to different version in mass and stiffness distributions on different upwards and downwards axis at each floor. Such construction in seismic prone areas attracts greater shear forces and torsion compared to usual construction.

In some parts of world, mountain area were more likely to get earthquakes; e.g. northeast area of India. In this hilly areas, usually material like, the clay, brick, stone masonry and dressed stone masonry, timber reinforced concrete, bamboo, etc., which is locally available, is used for the construction of houses. The money based growth and rapid growth of the cities with more people in hilly areas has speed up the Real Estate Development.

Reinforced Concrete Water Tanks

Reinforced concrete water tanks are constructed for storing water. The design of reinforced concrete water tank is based on IS 3370: 2009 (Parts I – IV). The design depends on the location of tanks, i.e.

overhead, on ground or underground water tanks. The tanks can be made in different shapes usually circular and rectangular shapes are mostly used. The tanks can be made of reinforced concrete or even of steel. The overhead tanks (elevated tanks) are usually elevated from the rooftop through column. In the other hand the underground tanks are rested on the foundation.

Types of RCC water tank

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

Table 1 Types of RCC water tank based on their location and shapes

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

Tank Resting on Ground

This tank are resting on ground for the storage of potable water reservoirs, aeration tank etc. In this tank internal hydrostatics pressure is acting and outside pressure is not present except the base soil pressure the weight of water from inside and soil reaction form outside.

Fig 1 RCC water tank on earth surface Underground Water Tank

Underground water tank is used for storing fluids (oil, water, gas, etc.). These tanks are subjected to water pressure from inside and earth pressure from outside. The base of tanks is subjected to water pressure from inside and soil reaction from underneath. Always these are covered at the top. These tanks should be designed for loading which gives the worst effect. The design and principles of underground tanks are the same as for tanks resting on the ground. The walls of the underground tanks are subjected to the internal water pressure and outside earth pressure. The section of the wall is designed for water pressure and earth pressure acting separately as well as acting simultaneously.

Fig 2 Underground Water Tank

Overhead Water Tank

Elevated or overhead water tank is supported on staging which may consist of masonry walls, R.C.C tower or R.C.C. column braced together. The walls are subjected to water pressure from inside. The base is subjected to the weight of water, the weight of walls and the weight of the roof. The staging has to carry a load of an entire tank with water and is also subjected to wind loads. Overhead water tanks of various shapes can be used as service reservoirs, as a balancing tank in water supply schemes and for replenishing the tanks for various purposes. Reinforced concrete water towers have distinct advantages as they are not affected by climatic changes, are leak-proof, provide greater rigidity and are adaptable for all shapes.

Fig 3 Elevated RCC water Tank

II. LITERATURE REVIEW

Wagh et al (2021) research paper presented the design of underground water tank of Rectangular shape was designed and analysed using Staad pro. Underground water tank faces different type of loads compared to other structures, they mainly face horizontal or lateral loads due to earth pressure and water pressure or any liquid pressure which was stored in the tank. The side walls of the underground water tank will face greater load at the bottom and the load linearly decreases towards the top.The analysis and design were done according to standard specifications using IS-456:2000 & SP-16, for the design of the STRUCTURAL MEMBERS. i.e., followed the LIMIT STATE method. Materials used are M20 grade concrete and Fe 415 steel unless mentioned in the particular design elements. Conclusion stated that STAAD Pro gives satisfactory results when compare with manual design also. STAAD 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. By using STAAD PRO software there is saving of 15% to 20 % of total steel in the whole structure.

Dubey et al (2021) the primary objective of the research was to investigate the behaviour of underground water tanks subjected to seismic loading and soil structure interaction and comparison of their output result to understand its behaviour. For the study existing underground water tank was used and finite element modelling of the same tank was done in ETABS17 for two different soil conditions as per IS 1893 part- 2-2014. The existing water tank situated at Solsinda, Sanwer, Indore (M.P) was considered in the investigation. Clay of high Compressibility (CL) and Silt of high

Compressibility (MH) was taken for this experiment as per IS 1893-Part- 1-2016. CL was categorized under medium or stiff soil and MH was under soft soil. Both water pressure and soil pressure are assigned as non-uniform shell loads on walls of UGT in ETABS. Walls are designed for a nonuniform load of 30 kN/m2 for water pressure and 27 kN/m2 of earth pressure. Seismic zone-3 was considered for earthquake analysis with two different soil conditions i.e. medium stiff (CL) and soft soil (MH). Classification of soil was taken from IS1893-Part 1-2016. Excel sheet was used to calculate seismic forces in terms of total base shear, total moment at base of wall and hydrodynamic pressure on wall in both X and Y direction considering impulsive and convective modes for medium and soft soil categories. Soil dynamic pressure for CL soil is 94.18 kN/m2 and 75.34 kN/m2. Results concluded that considering seismic forces is beneficial for underground water tank. On considering seismic forces the moments in walls along both X and Y at the base, exceeds moments in walls of existing tank. Although soil condition does not influence design force significantly. Shear force dominates the thickness of wall, on considering seismic forces shear forces increased which tends to redesign thickness of slab. On considering SSI effect with elastic spring at base, design forces increased as compared to seismic design with rigid base. Although SSI effect is not very much significant.

Tripathi et al (2020) the research paper presenetd seismic analysis of an Underground water tank with reinforced concrete staging structure. The structure was designed according to IS code provision to reduce Effect and minimize the consequence of seismic wave. The time-history assessment was carried out by a detailed finite element simulation of the UG water tank. For the study of nonlinear dynamic analysis, SAP 2000 software for different seismic intensity.The result of the study shows the deflected shape of tank at different condition considered as empty and full. Time history method becomes necessary to ensure safety against earthquake forces. the rectangular shape UG water tank of capacity 80000 liter. The dimension of UG tank was 6m*4m*3.5m. IS:456 2000 was been used and for seismic analysis IS:1893 2002. After providing all required structural configuration assign time history data of Nepal earthquake which was happened in 2015/04/25 (LAMJUNG, NEPAL) magnitude of (7.8). The deflected shape of UG tank by the action of time history method for different case of storage was being determined . Since time history analysis was a realistic and significantly used for the determination and design of better structure by considering factor of safety as per

IS Code. On analyzing the structure with different time history data one get different mode of deflected shape for empty tank as well as for full tank for UG reservoir.

Shinde (2018) research paper presented a comparative analysis of the computer-aided design of an underground water tank. Manual Analysis and design of the Underground Water tank by using IS code method was presented comparing with STAAD-PRO and SAP software design result, comparison of reinforcement was done and optimize results are determined. This report gives in brief, the theory behind the design of liquid retaining structure (Rectangular water tank) using working stress method. This water tank of 1,00,000-10,00,000 liters capacity was designed in computer added analysis. The deflected shape was analyzed and also the axial force of respected tank cases and develop programs for the design of water tank of flexible base and rigid base and the underground tank to avoid the tedious calculations. Comparison was made between IS code method design and various software design result to understand governing loads and carry out literature review related to underground water tank. The base deflection criteria, shell stresses and joint reaction of underground water tank structure by considering dynamic type of loading when the tank is empty and full water level conditions was presented. Results stated that the calculation of deflection in the manual design and the deflection results from STAAD and SAP software were nearly same. The shell stresses in full water condition and full empty condition was within the permissible limit that was not greater than 7000 kN/m2 and mainly the results obtained from both software's were same. If suppose tank has less dimension then unsatisfied results were obtained.

Objectives:

1. To prepare a comparative study of water tank with different water proportion as per I.S. 3370 L.S.M. as per Indian standards.
2. To determine the effect of lateral forces on a under-ground water reservoir.
3. To determine the effect of ground vibrations over the surfaces of underground water tank.
4. To prepare the modelling and analysis of the underground water tank using staad.pro

III. Methodology

Step 1: To prepare a literature survey related to our study

Literature Survey was prepared for the past study undertaken till date and shortcomings were identified on which further research needs to be executed.

Step 2: To prepare geometrical structure of the study using analysis tool Staad.pro

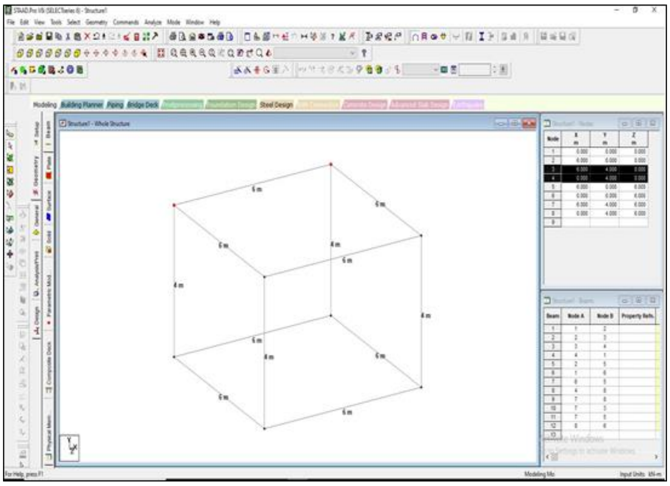


Fig 4 Plan of the Geometry

Step 3 To create material for structural sections

Step 4 To Assign and create sectional properties

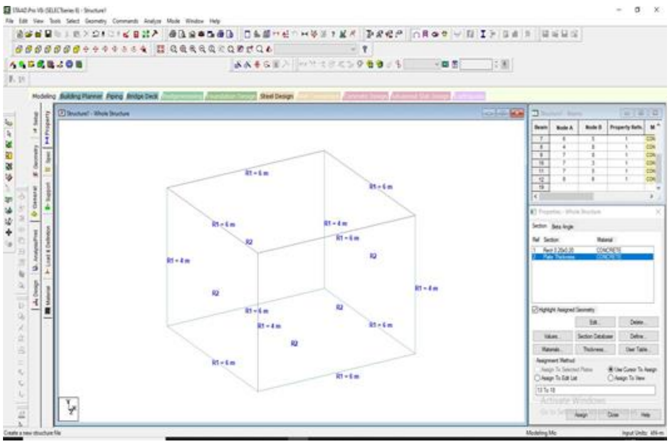


Fig 5 Section Details

Step 5: Assign supports at base beams and side walls

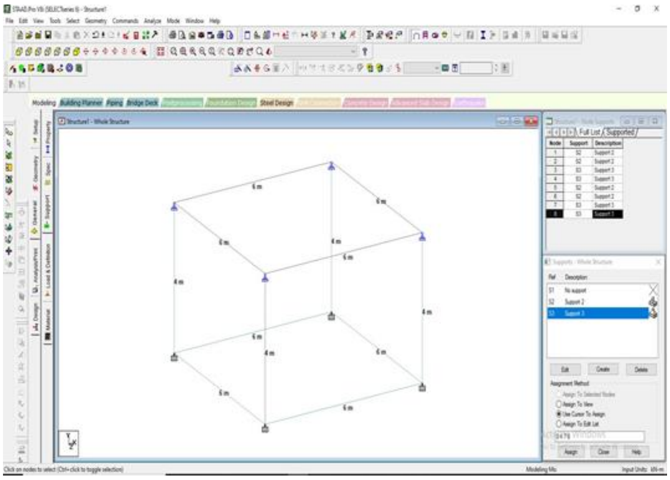


Fig 6 Support Condition Step 6: Assigning Hydrostatic Pressure (full condition)

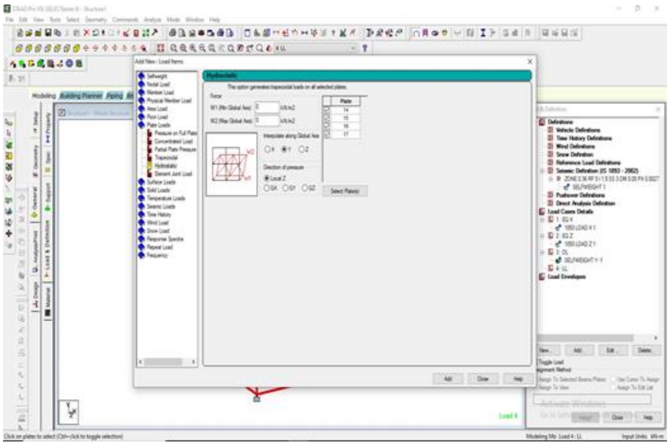


Fig 7 Hydrostatic Pressure

Step 7: Assigning Seismic force as per I.S. 1893-I:2016

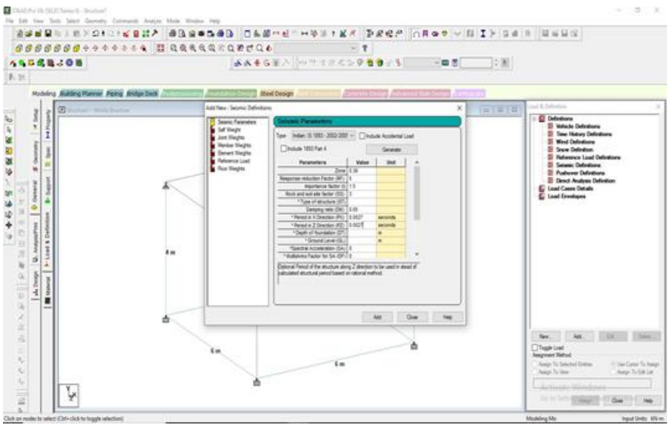


Fig 8 Assigning Seismic Load

Step 8: Assigning Backfill Condition

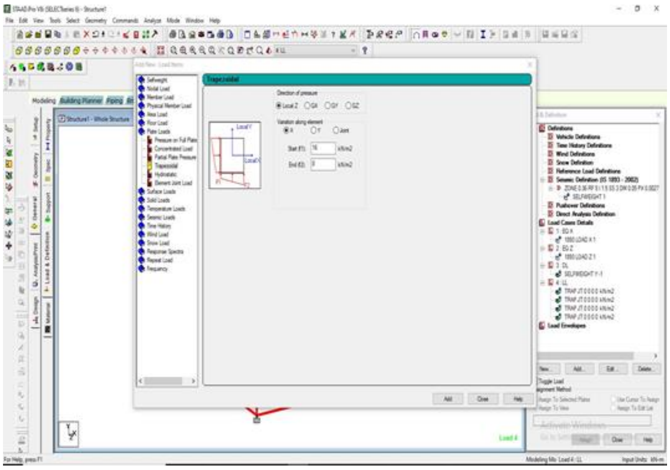


Fig 9 Backfill condition

Step 9: Analysis of structure using analysis tool Staad.pro

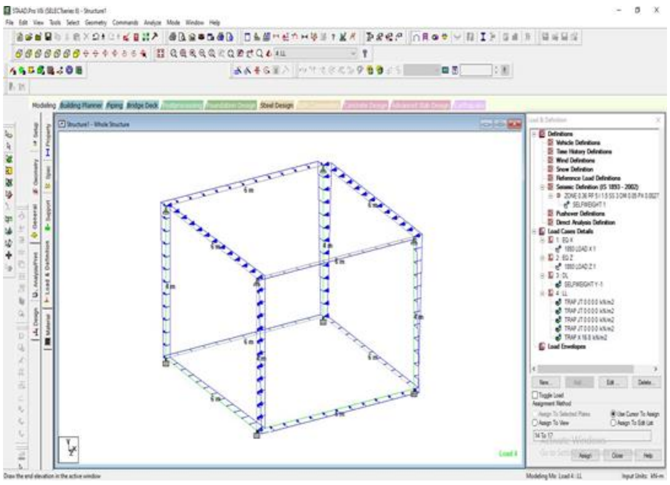


Fig 10 Analysis of the structure

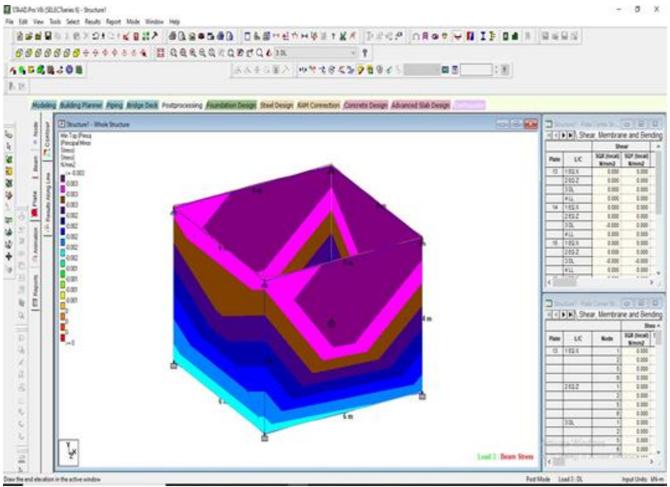


Fig 11 Stress Analysis

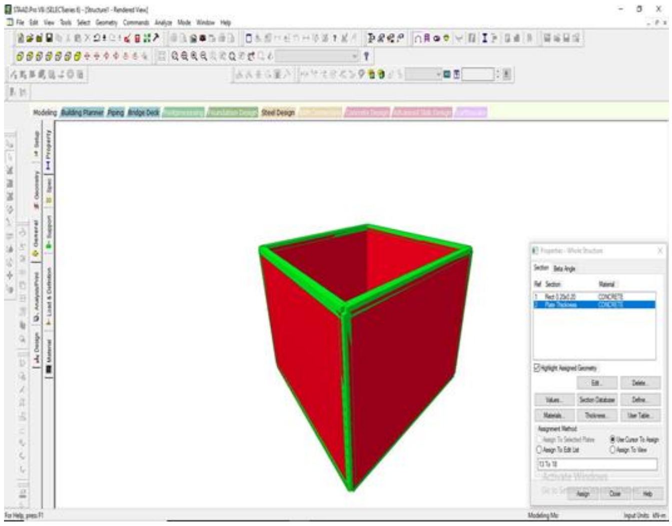


Fig 12 predefined view

Table 2 Properties of Material

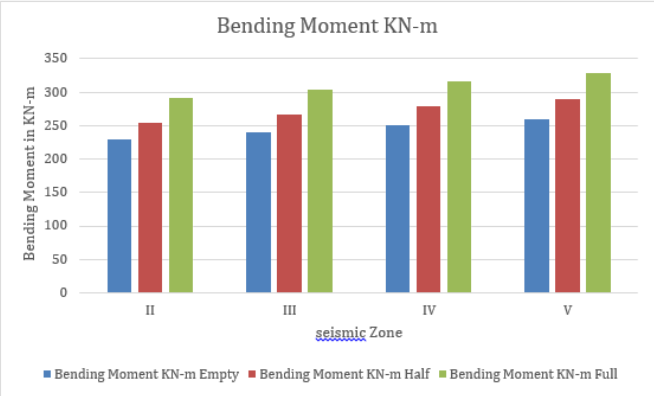
SR.NO	PARAMETER	DESCRIPTION
1	CONCRETE	M 30
2	REBAR	FE 500
3	Modulus of Elasticity	1.95xE105 MPa
4	Soil type	Medium
5	Hydraulic pressure	Tension & stress
6	Seismic load	Zone II

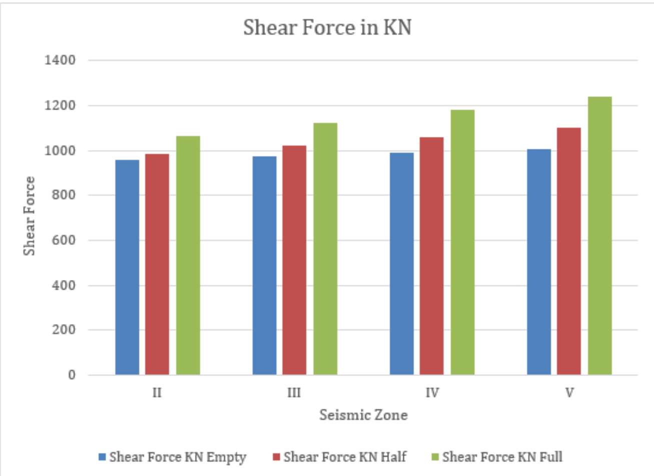
Table 3 Geometrical Structure

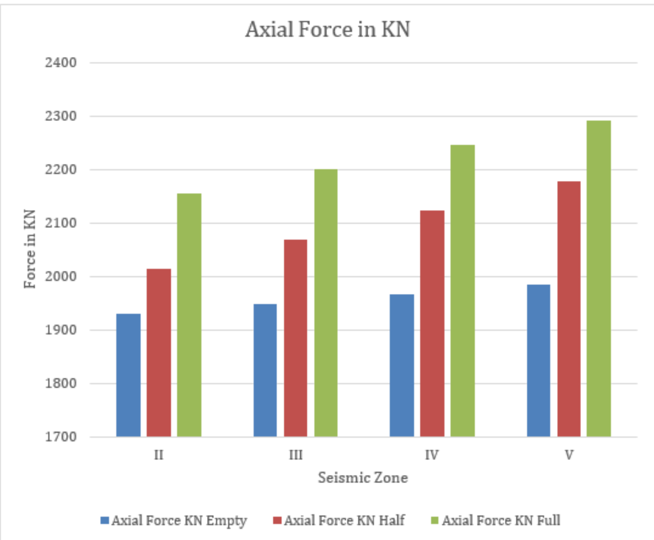
Height of the tank	**3.5 m**
Length in X direction	6 m
Length in Z direction	6 m
Area	36 m2
Backfill	Soft soil
Grade of Concrete	M30
Grade of Steel	Fe415

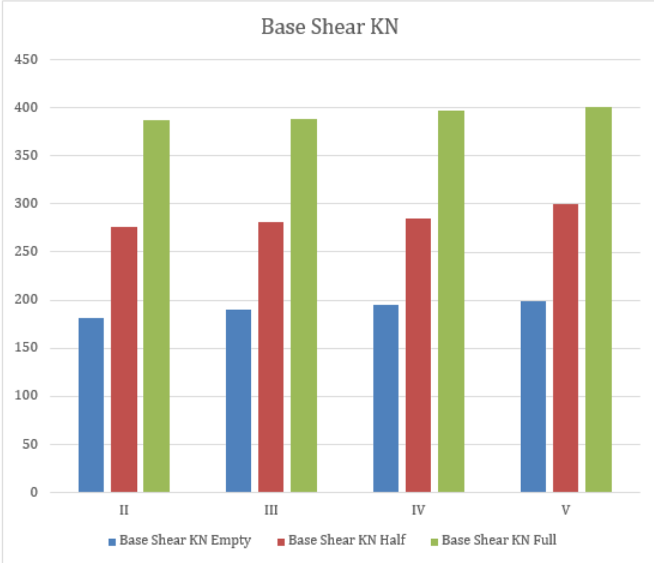
Size of column	500 mm2
Size of Beam	200 X 200 mm
Plate Thickness	200 mm
Wall Thickness	200 mm

IV. ANALYSIS RESULTS









V. CONCLUSION

- In terms of bending moment we observed that as we are comparing empty and fill a rise of 13% is observed.
- In terms of shear force a gradual rise in forces observed that fill condition is observing 8% rise in values.
- In terms of Axial force we observed that values declined by 14% in empty condition as hydraulic pressure is released.
- Support Condition: Here it is observed that support condition is showing variation of 11% as comparing empty condition with full condition.
- In terms of stresses it can be said that in all three conditions, pressure induced in side walls depending upon the hydraulic pressure and backfill condition.

VI. Future Scope

- The analyses can be extended by considering when tank is half water level condition. In this way, the behavior of different safe bearing values of soil are observed more sensitively.

- Furthermore, the analysis can be carried out by considering circular shape of underground water tank.

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