Analysis of Circular Elevated Water Tank with Slant Columns Considering Hydrostatic Load

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Abstract— The examination presents a comparative investigation of elevated water tanks exposed to dynamic stacking upheld on RC outlined structure and solid shaft structure with various limits and put in various seismic zones. History of quake uncovers that it has made various misfortunes the life of individuals in its dynamic time, and furthermore post-seismic tremor time have let individuals endure because of harms caused to the public utility administrations. Either in metropolitan or provincial territories raised water tanks frames a vital piece of the water gracefully plot, so its usefulness pre and post-seismic tremor remains similarly significant. These functions indicated that the significance of supporting framework is solid for the raised tank when contrasted with some other kind of tank. Harms caused are the aftereffects of the unsatisfactory plan of the supporting framework; some unacceptable choice of the supporting framework, and so on These structures have weighty mass gathered at the highest point of the slim supporting framework subsequently these structures are particularly defenseless against level powers because of quakes. This paper presents the dynamic investigation of raised water tanks concerning the most recent IS code distributed for fluid holding structures by Bureau of Indian Standards as per IS 1893 (Part 2): 2014. Examination of raised tanks with the diverse supporting framework, limits and seismic zones expresses that these boundaries may extensively change the seismic conduct of tanks.

Keywords: Elevated Water Tank, Sloping Columns, Hydraulic Pressure, Lateral Forces and STAAD.Pro

I. INTRODUCTION

An elevated water tank is an enormous water stockpiling compartment built to hold water flexibly at a specific stature to give adequate weight in the water dispersion framework. Fluid stockpiling tanks are utilized broadly by districts and enterprises for putting away water, inflammable fluids and different synthetic substances. Mechanical fluid tanks may contain profoundly poisonous and inflammable fluids, and these tanks ought not lose their substance during the tremor. These tanks have different sorts of help structures like RC propped outline, steel outline, RC shaft, and even stonework platform. The casing type is the most generally utilized organizing practically speaking. The primary segments of the casing kind of arranging are segments and supports. The arranging demonstrations like an extension among compartment and establishment for the exchange of burdens following up on the tank. In this way Water tanks are basic for public utility and mechanical structure.

Raised water tanks comprise of tremendous water mass at the highest point of a damages arranging which is the most basic thought for the disappointment of the tank during seismic tremors. Raised water tanks are basic and key structures, and the harm of these structures during seismic tremors may imperil drinking water flexibly, cause to flop in forestalling huge flames and generous monetary misfortune. Since the raised tanks are habitually utilized in seismic dynamic districts; henceforth; seismic conduct of them must be explored in detail. Because of the absence of information on the supporting framework, a portion of the water tanks were imploded or intensely harmed. So there is a need to zero in on the seismic security of help structure concerning the other supporting framework which is protected during the quake and furthermore to withstand more plan forces.

The frame support of elevated water tank ought to have sufficient solidarity to oppose hub burdens, second and shear power because of horizontal loads. These powers rely on the entire weight of the structure, which fluctuates with the measure of water present in the tank compartment. An examination of the dynamic conduct of such tanks must consider the movement of the water comparative with the tank just as the movement of the tank comparative with the ground. The current work expects to look at the seismic exhibition of raised water tank thinking about varieties in organizing stature for various limits.

A. Lateral Forces

Lateral loads are live loads that are applied corresponding to the ground; that is, they are level powers following up on a structure. They are not quite the same as gravity loads for instance which are vertical, descending forces.

The most common types are:

- Wind load.
- Seismic load.
- Water and earth pressure.

Wind load may not be a significant concern for small, massive, low-level buildings, but becomes more importance with height, the use of lighter materials and the use of shapes that may affect the flow of air, typically roof forms.

Significant seismic loads can be imposed on a structure during an earthquake. They are likely to be relatively instantaneous loads compared to wind loads. Buildings in areas of seismic activity need to be carefully designed to ensure they do not fail if an earthquake should occur.

Water pressure tends to exert a lateral load which increases linearly with depth and is proportional to the liquid density. Similarly, earth pressure (such as settlement) can be applied against below-ground structures such as basement walls, retaining walls, and so on.

Lateral loads such as wind load, water and earth pressure have the potential to become an uplift force (an upward pressure applied to a structure that has the potential to raise it relative to its surroundings). For more information, see Uplift force.

Structures should be designed carefully with likely lateral loads in mind. A structural element that is typically used to resist lateral loads is a shear wall. In simple terms, lateral forces could push over parallel structural panels of a building were it not for perpendicular shear walls keeping them upright. For more information see: Shear wall.

B. Need of Water Tank

Water Tanks are needed to store water for the day by day use in household works, drinking, cleaning, production line and enterprises. Water tanks are isolated into three unique classes dependent on their area and shape. The water tanks are developed utilizing cement and steel according to necessities, metal materials as chamber covered with consumption defensive materials are additionally utilized for the development of water tanks.

Water tanks are commonly moulded round or rectangular utilized for the capacity of huge amounts of water. The boundaries needed for the development of water tanks incorporate the overall plan of water tank and choice of development material.

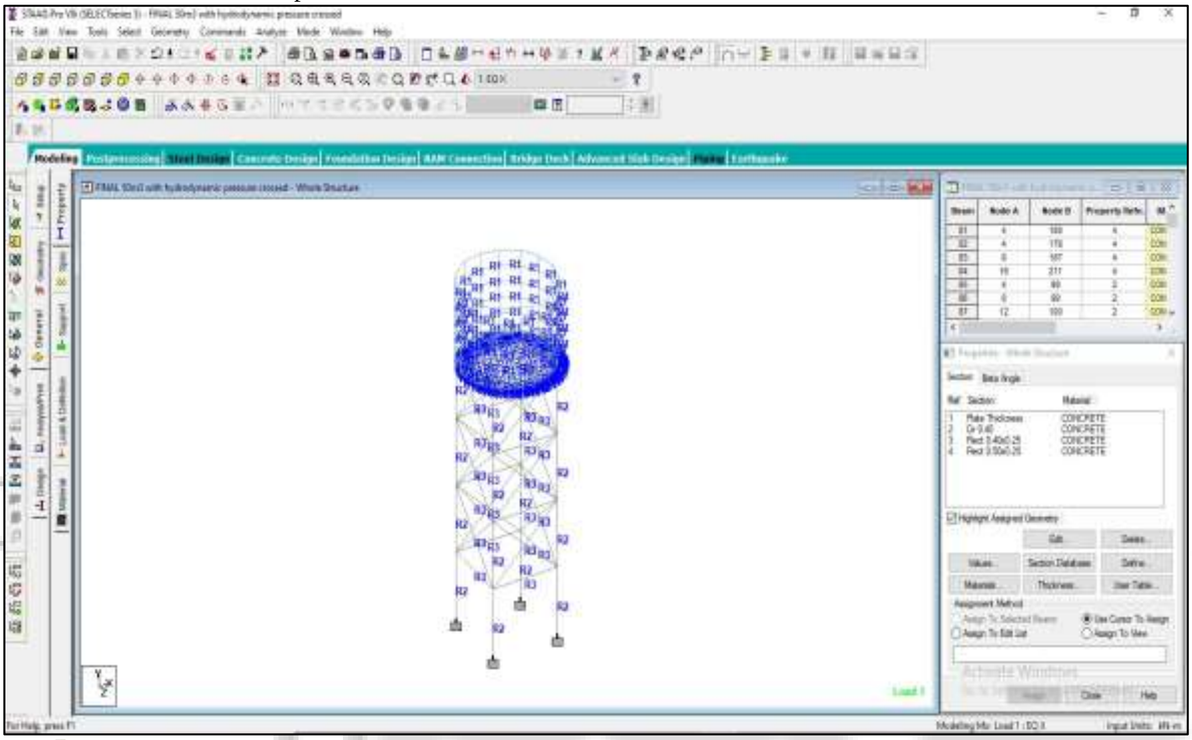

Fig. 1: Elevated Water Tank with Slant Column

C. STAAD.Pro

The analysis examination devices permit specialists to refine plans to an uncommon degree, and accordingly, numerous utilities feel testing isn't justified. In any case, while incredible steps have been made in the examination and plan of water towers, contrasts between investigation results and full-scale tests actually occur.

STAAD.Pro highlights a cutting-edge UI, perception apparatuses, amazing examination and plan motors with cutting edge limited component and static and dynamic investigation capacities. From model age, examination and plan to perception and result check, STAAD.Pro is the expert's decision for steel, solid, wood, aluminum and cold-framed steel plan of low and tall structures, ducts, petrochemical plants, burrows, extensions, heaps and considerably more. The accompanying key STAAD.Pro apparatuses help improve normally dull undertakings:

The STAAD.Pro Graphical User Interface joins Research Engineers' inventive selected page design. By choosing tabs, beginning from the highest point of the screen and heading down, you input all the vital information for making, investigating and planning a model. Using tabs limits the expectation to absorb information and guarantees you never miss a stage.

The STAAD.Pro Structure Wizard contains a library of brackets and edges. Utilize the Structure Wizard to rapidly-produce models by indicating stature, width, expansiveness and number of coves toward every path. Make any adaptable parametric structures for rehashed use. Ideal for high rises, extensions and rooftop structures.

II. PROBLEM IDENTIFICATION AND LOADING CONDITIONS

A. Material Properties

Material Properties		
Sr.no	Parameter	Description
1	Concrete	M 30
2	Rebar	FE 500
3	Modulus of Elasticity	1.95xE5 MPa
4	Ultimate Tensile Strength	1860 MPa
5	Soil Type	Medium
6	Wind Pressure	39 m/s
7	Hydralic Pressure	Tension & stress
8	Seismic Load	Zone II

Table 1: Material Properties

Geometrical Data	
Height of the tank	3.5 m
Staging height (linear)	8 m

Base diameter of tank	4.4 m
Diameter of Sphere	4.4 m
Number of Columns	4
Grade of Concrete	M30
Grade of Steel	FE415
Size of Column	500 mm2
Size of Beam	350 X 250 mm
Plate Thickness	800 mm
Wall Thickness	450 mm
Bracing	I.S.M.B. 100

Table 2: Geometrical Data

B. *Population Forecast*

Populace estimating is characterized as the technique for deciding the normal populace for a specific plan time of water flexibly framework with the assistance of the examination and investigation of future functions and accessible records.

The populace is a significant boundary that is resolved for the plan of the water arrangement of a specific zone. Water gracefully frameworks are intended for a populace expected for a specific plan period as opposed to mulling over the current populace of the region. The future period or which arrangement is made in the water flexibly conspire is known as the plan time frame.

There are a few numerical techniques that can be utilized to decide the populace for a plan period.

C. *Population Forecasting Methods*

The populace anticipating techniques require the estimations of present and past populace records to go through the computation. The nearby enumeration records of a specific territory offer the benefit of present and past populaces.

1) Arithmetic Progression
2) Geometric Progression
3) Iller Bankasi Method
4) Decreasing Rate of Growth method
5) Graphical Extension Method
6) Comparative Method
7) Ratio and Correlation method
8) Component Method
9) Logistic Method

D. *Case Study*

Bhopal is located at the heart of India and north of the upper limit of the Vindhya mountain ranges located at the Malwa Plateau. It is higher than North Indian plains and the land rises towards the Vindya range to the south. The city has uneven elevation and surrounded with small hills regions within the boundaries of the city. The major hills in Bhopal comprises of Idgah Hills and and Shyamla Hills in the northern region and Arera Hills in the central region.

Average Water Demand = Avg. water demand coefficient. (grm/Acre)*Landuse (Area (acre))

Maximum Day Demand = 2.2 * Average Day Demand

Peak Hour Demand = 3.4 * Average Day Demand Operation Storage = 25 %of Maximum Day Demand

Fire Storage = 0.63 MG per acre.

Emergency Storage = Underground (provided emergency pumping methods are available for supplying 25% maximum Day Demand).

E. *Geometrical Increase Method*

In this method, the percentage increase in the population from decade to decade is assumed to remain constant. Geometric progression method is used to find the future increment in the population. Since this method provides higher values and hence needs to be applied for a new industrial town at the beginning of the development for only few decades. The population at the end of nth decade 'Pn' can be estimated as:

Pn = P(1+IG/100)

Here, IG = Geometric Mean (%) P =Present Population

N =number of decades

Year	Population	Increment	Geometrical Increase
1991	1691	489	(489/1201) = 0.40
2001	2077	386	(386/1691) = 0.23
2021	2585	508	(508/2077) = 0.24

Table 3: Year wise Population Increment to valuate Geometrical Increase

Geometrical Mean IG = (0.18 x 0.18 x 0.40 x 0.23 x 0.24)1/4 = 0.235 i.e. 23.5%

Population in year 2021 is, P2021 = 2585 x (1+ 0.235)1 = 3193.63. Similarly for the year 2031 and 2041 can be calculated by,

P2031 = 25858 x (1+ 0.235)2 = 3944

P2041 = 25858 x (1+ 0.235)3 = 4870

As per the calculus, the adopted capacity is valued as 50 m^3

F. *Loading Conditions*

1) *Dead Loads as per IS: 875 (Part I)-1987*

Unit Load				
Loading type	Calculation	Load	Unit	Remarks
RCC Water Tank	0.8 x 25 kN/m2	20	kN/m2	-

Table 4: Dead Load

2) *Live Loads as per IS: 3370 LSM. Hydraulic Load Horizontal 10 KN/ m^2 and vertical 12.5 KN/m^2 ^{a}t phase wall.*

3) *Seismic Loads*

S.no	Parameter	Value	Remarks
1	Seismic Zone	II	0.1 intensity
2	Important Factor	1.5	Table-6(1893-I)
3	Response Reduction	5	Table 7
4	Soil Type	II	Medium

Table 5 Seismic Load as per I.S. 1893-I: 2016

III. METHODOLOGY

Following steps were considered for the analysis of the study:

1) Step 1: To prepare the literature survey related to the case study.
   Literature survey as prepared from the past research undertaken till date and shortcomings were identified on which further research needs to be executed.
2) Step 2: To prepare the geometrical structure of the study using analytical application STAAD.Pro.
3) Step 3: To create material for structural sections

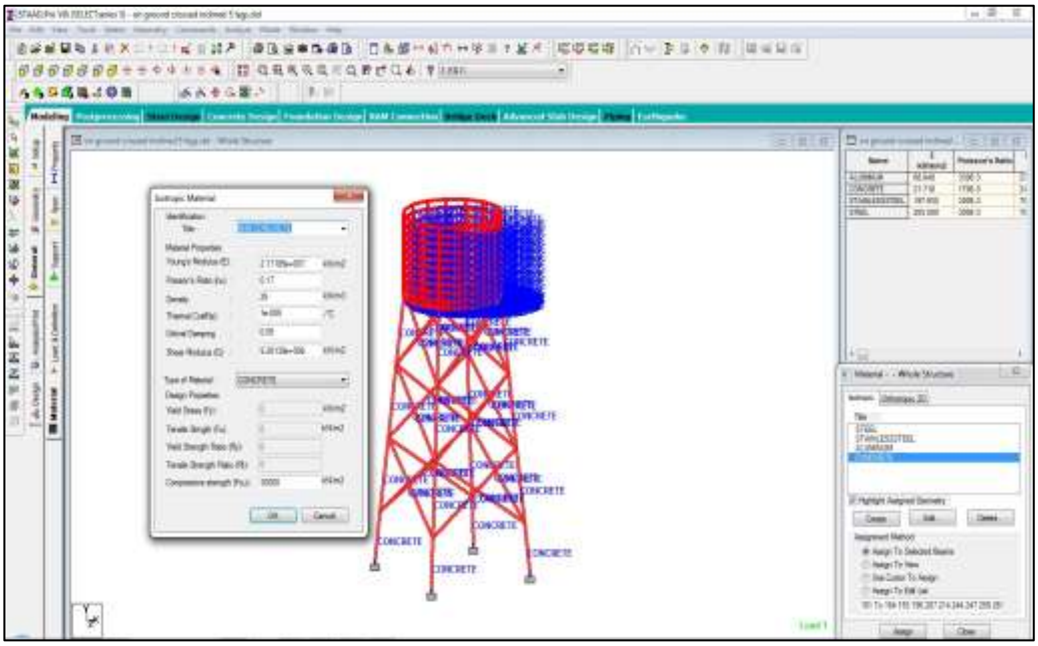

Fig. 2: Assigning Material Properties

4) Step 4: Creating section properties

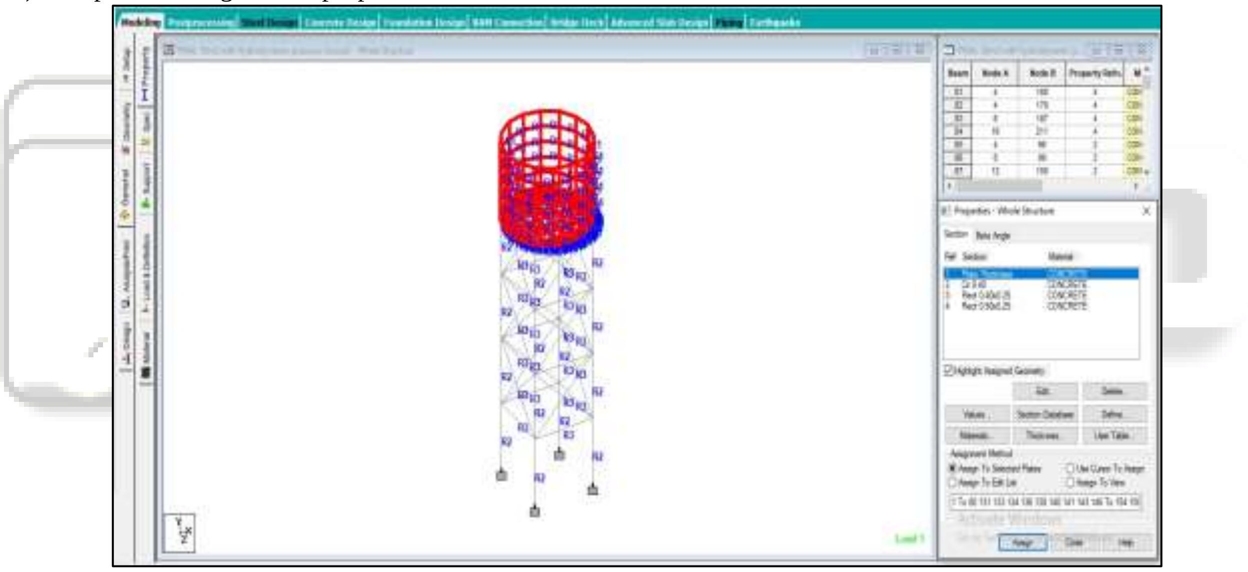

Fig. 3: Sectional Data

5) Step 5: Assign Weak spring at base beams and cylindrical surface

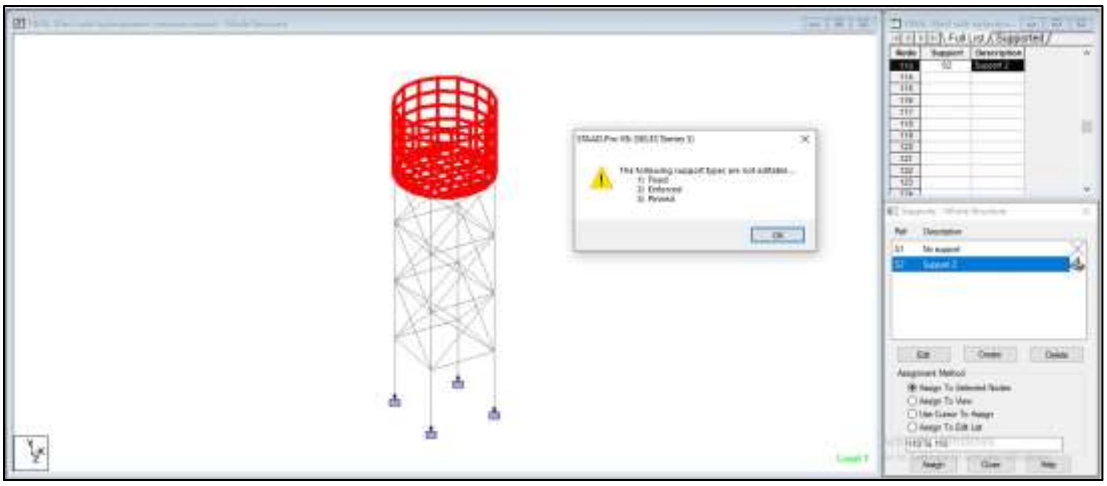

Fig. 4: Assigning Surface

6) Step 6: Assigning Hydrostatic Pressure (Full Condition)

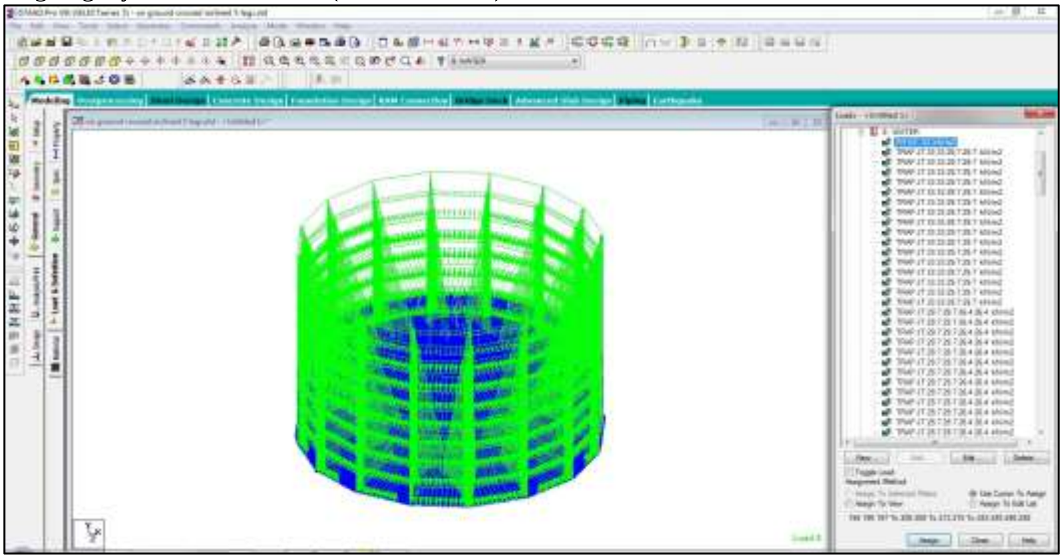

Fig. 5: Assigning Hydrostatic Load

7) Step 7: Assigning Wind Pressure as per IS 875-III: 2015 (39 m/s wind speed) and seismic load as per IS 1893-I: 2016.

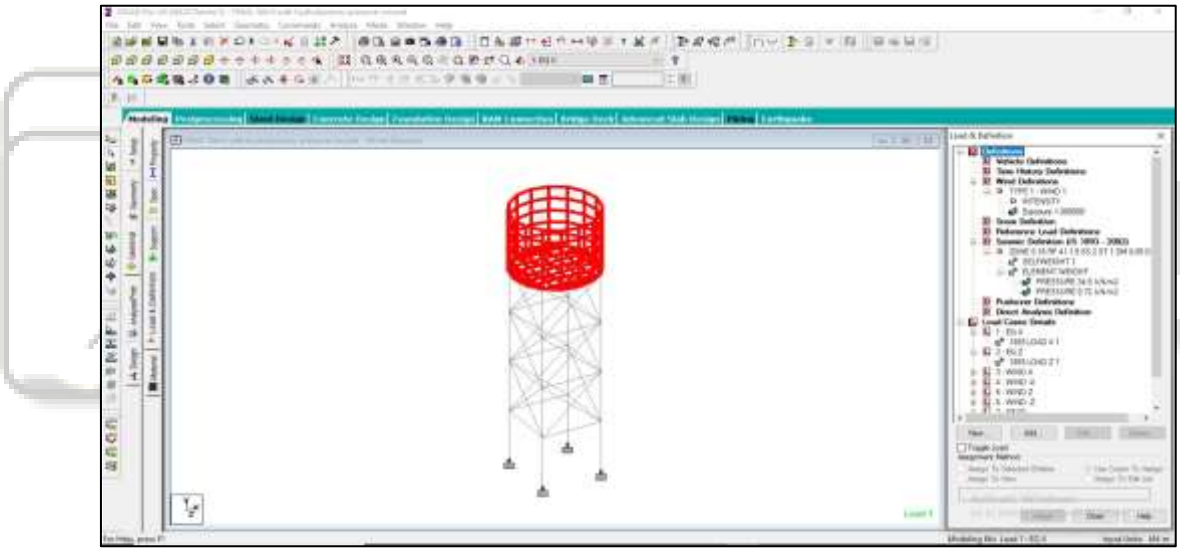

Fig. 6: Assigning Lateral Loads namely wind load and seismic load

8) Step 8: F.E.M analysis of structure using analytical application STAAD.Pro.

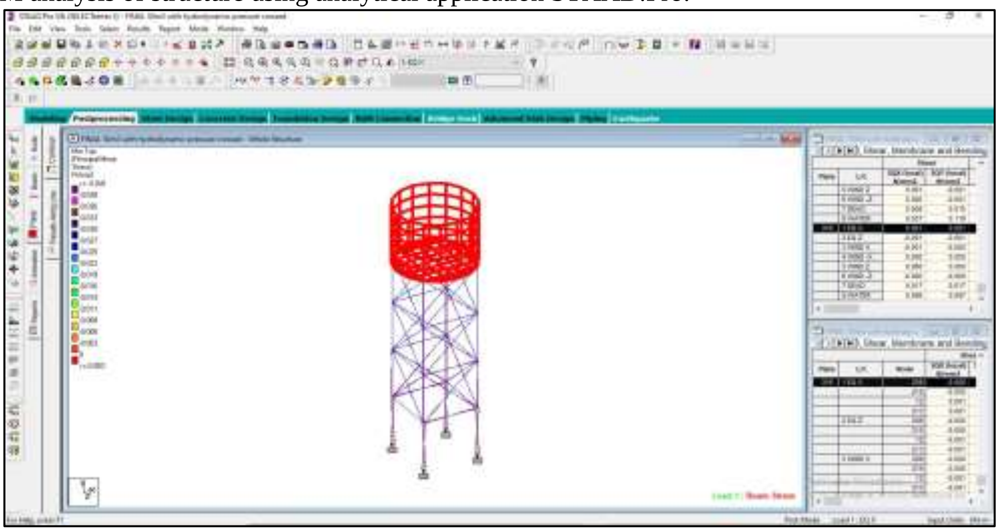

Fig. 7: Performing Analysis

9) Step 9: valuated the results using MS Excel.

IV. RESULTS AND DISCUSSION

A. Stress Analysis

1) *Maximum Forces acting on Top Ring Beam*

Maximum Forces on Top Ring Beam						
Degree	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
0	51.46	7.96	10.12	0	36.01	-7.49
2	51.46	7.96	10.12	0	36.01	-7.49
4	51.2	7.7	9.86	0	35.75	-7.75
6	50.73	7.23	9.39	0	35.28	-8.22
8	51.34	7.84	10	0	35.89	-7.61
10	51.79	8.29	10.45	0	36.34	-7.16
12	52.58	9.08	11.24	0	37.13	-6.37

Table 6: Max. Forces on Top Ring Beam

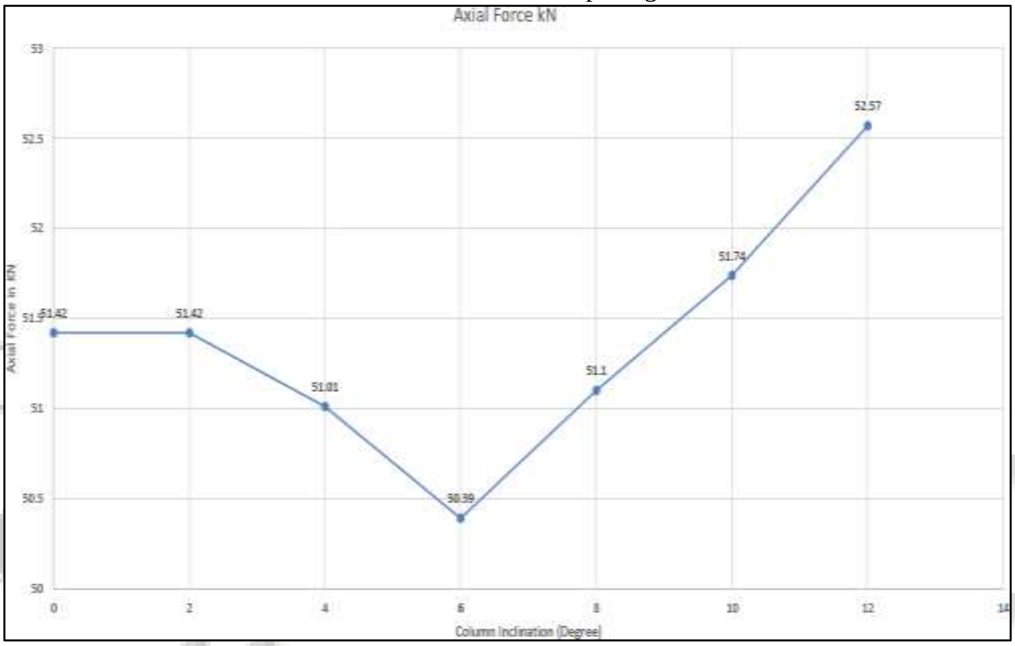

Fig. 8: Axial Force at Top Beam

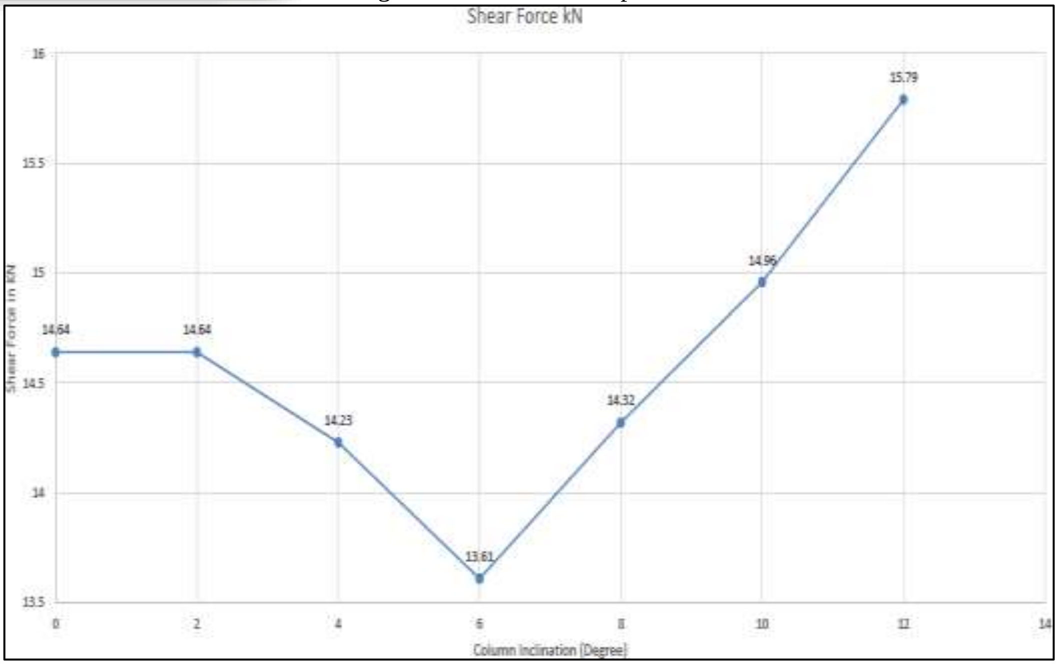

Fig. 9: Shear Force at Top Beam

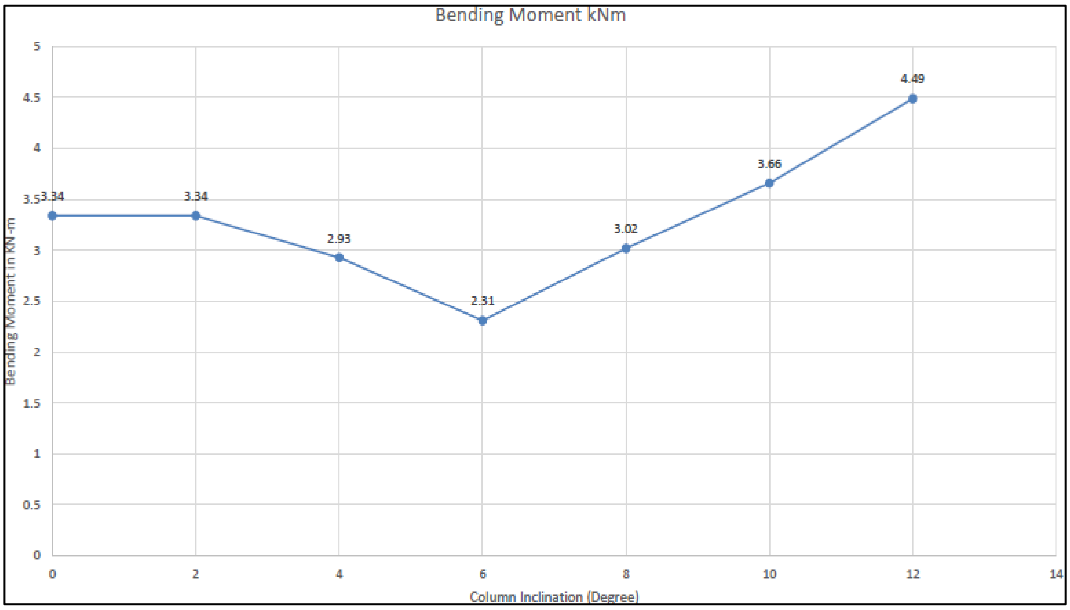

Fig. 10: Bending Moment at Top Beam

2) Maximum Stresses on Cylindrical Surface

Maximum Stresses on Cylindrical Surface								
Degree	SQX (local) N/mm2	SQY (local) N/mm2	SX (local) N/mm2	SY (local) N/mm2	SXY (local) N/mm2	Mx kNm/m	My kNm/m	Mx ykNm/m
0	0.001	-0.028	0.027	-0.01	-0.008	0.287	0.52	-0.003
2	0.001	-0.022	0.022	-0.008	-0.006	0.23	0.416	-0.003
4	-0.144	-0.052	0.113	0.023	0.022	1.608	0.858	0.135
6	0.002	-0.198	0.032	0.088	0.019	0.419	2.039	0.134
8	0.145	0.008	-0.069	-0.039	-0.035	-1.149	-0.026	-0.14
10	0.001	-0.022	0.018	-0.011	-0.005	0.186	0.365	0.014
12	-0.18	-0.059	0.131	0.028	0.031	1.909	0.918	0.186

Table 7: Maximum Stresses on Cylindrical Surface

3) Maximum Stresses on Base Surface

Maximum Stresses on Base Surface								
Degree	SQX (local) N/mm2	SQY (local) N/mm2	SX (local) N/mm2	SY (local) N/mm2	SXY (local) N/mm2	Mx kNm/m	My kNm/m	Mx ykNm/m
0	0.004	-0.035	0.003	0.008	0.002	0.242	0.541	-0.002
2	0.003	-0.028	0.003	0.007	0.002	0.193	0.433	-0.002
4	-0.159	-0.062	0.008	0.007	0.004	1.55	0.861	0.135
6	0.004	-0.227	0.001	0.014	0.004	0.38	2.053	0.137
8	0.166	0.005	-0.003	0.006	0	-1.163	0.005	-0.138
10	0.002	0.17	0.004	-0.001	0	0.007	-1.187	-0.14
12	0.003	-0.028	0.002	0.006	0.002	0.159	0.388	0.015

Table 8: Maximum Stresses on Base Shear

4) Support Reaction

Support Reactions						
Degree	Fx	Fy	Fz	Mx	My	Mz
0	-38.063	-250.43	0.04	0.081	0.017	75.853
2	-27.136	-128.77	0.023	0.045	0.467	53.459
4	0.023	128.767	-27.136	-53.459	0.467	-0.045
6	0.463	417.931	-0.463	-0.537	0	-0.537
8	0.021	148.866	-0.021	-0.052	0	-0.052
10	0.04	250.431	-38.063	-75.853	0.017	-0.081
12	-38.063	250.431	-0.04	-0.081	0.017	75.853

Table 9: Support Reaction

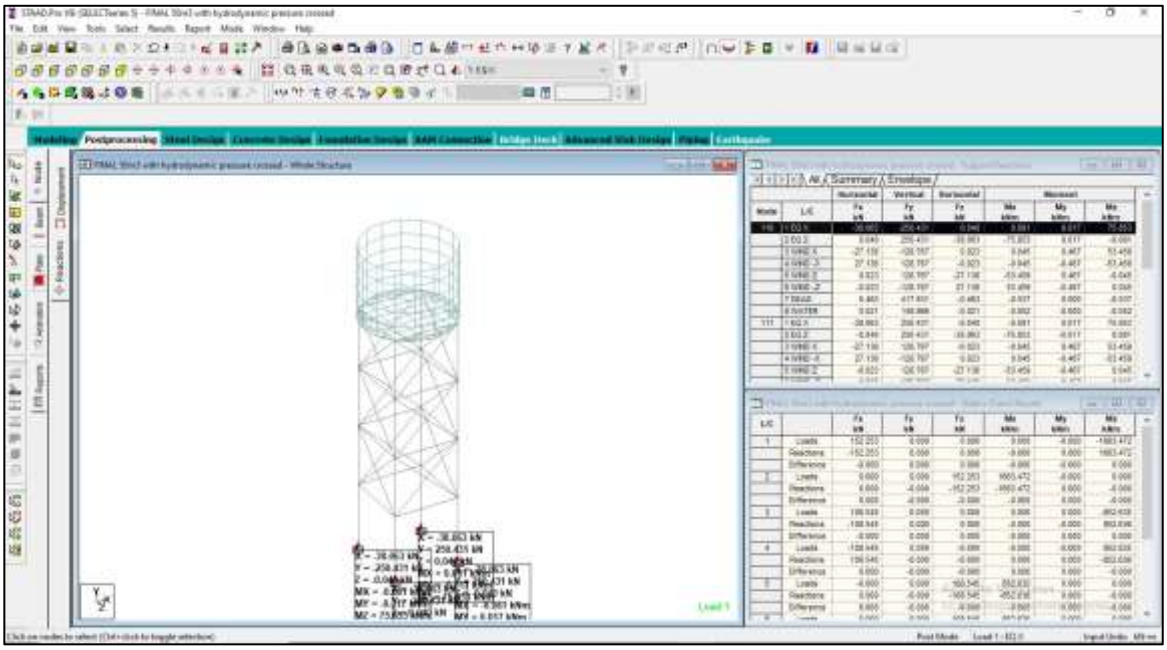

Fig. 11: Support Reaction

V. CONCLUSION AND FUTURE SCOPE

A. *Conclusion*

In the present study, finite element modelling of an elevated storage was proposed to carried out using software package Staad.Pro v8i with the capacity of 50 m3 with the top of water level at about 11.5 m above ground. The shape of the tank is considered to be circular with the aspect ratio as 0.75, 4.4m in diameter and 3.5m in height.

The fixed supports constitutes four vertical circular columns and these columns were connected through a rectangular beam at internals as 2m, 3m and 3m. The support consists of 4 vertical circular columns and the columns are connected by the rectangular beams at intervals of 2m, 3m and 3m.

Seismic Analysis as per IS 1893 Part I 2016 for zone II and basic wind speed 39 m/s as per IS 875 Part III 2015 was performed using STAAD.Pro for full water level condition.

The conclusion derived from results stated that:

1) Shear force slantly decreases from 0 degree to 8 degree by 8%, but from 10 degree it rises again up to 12 degree case.
2) In terms of moment, it was observed that there was a gradual decline in moment up to 6 degree case by 4.5% but later rises gradually.
3) In terms of Axial Force, it was observed that values continuously declines by almost 5% up to 6 degree but later present upward values.
4) In Terms of Support Reaction, it was observed that forces are properly distributed at the bottom up to 6 degree after that vibrations are observed.

B. *Future Scope*

5) In this structure we are considering seismic forces whereas in future one can select dynamic forces.
6) In this study we are considering circular elevated tank whereas in future we can consider underground tank.
7) In this study we are analyzing using staad.pro whereas in future any other analysis tool can be use.

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