"COMPARATIVE ANALYSIS OF A COOLING TOWER CONSIDERING LATERAL FORCES AND THERMAL EFFECT USING SAP2000"

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Abstract— Cooling tower are used as devices of heat rejection in order to eradicate high temperature from hot water and release in the atmospheric air that's the reason such towers are considered an integral part of any thermal power plants. The examination includes test and two-dimensional computational liquid elements investigation of a real industry worked cooling tower. Channel water temperature and mass stream pace of water and air are having the principle impact on the presentation of counter stream initiated draft cooling tower. In cooling tower water is made to stream down drop by drop, or structure a meagre layer over the level surface so it comes into direct contact with air moving upwards inverse way. The temperature move from the water to the air stream raises the air's temperature and its general stickiness to 100% and this air is released to the air. In like manner different boundaries, for example, range, tower trademark proportion can likewise be expanded extensively, the pressure at the external locale, variation in temperature.

This study is focused towards conducting a dynamic analysis on Cooling Tower considering parameters such as thermal effects towards the layer which exist inside tower and lateral load as wind pressure in order to check the stability of commercial structure on wires of stability, resistance towards forces, displacement and temperature using analytical tool SAP 2000.

Keywords: Nonlinear Static Analysis, Deflection Cooling Tower, Analysis, Thermal, Displacement, Forces, Moment.

Introduction

Cooling towers are the fundamental segments of numerous nuclear and thermal energy plants. The pinnacles differ in size that can be up to 200 meters tall and 100 meters in breadth having a complex exaggerated calculation with thin dividers. They might be exposed to an assortment of loading conditions, for example, dead, wind, quake, temperature and development loads. Nonetheless, the wind load is viewed as the most basic load without a tremor.

Heat is released in force generation, refrigeration, petrochemical, steel, preparing and numerous other mechanical plants. In numerous cases, this heat is released into the environment with the guide of a cooling tower. Figure 1.1 shows an illustration of the utilization of a cooling tower in a straightforward steam power plant. Warmth is released into the environment by the cooling tower by means of an auxiliary cycle with water as the interaction liquid.

The cooling tower (CT) is the main piece of mechanical hardware whose basic role is to eliminate the warmth while limiting water utilization. They are regularly utilized in force age plants to cool the condenser feed-water. In cooling tower water is made to stream down drop by drop, or structure a slim layer over the level surface so it comes into direct contact with air moving upwards inverse way. The warmth move from the water to the air stream raises the air's temperature and its overall mugginess to 100% and this air is released to the air. Accordingly, some water vanishes and it detracted from the greater part of water, which is subsequently cooled. In this way, the evaporative cooling method is utilized on account of cooling towers.

In this examination, we will perform a dynamic investigation of a tall Cooling Tower considering heat impact over the inward layer of the pinnacle and wind strain to decide its solidness as far as temperature, strength, resistivity, forces and dislodging at various temperature.

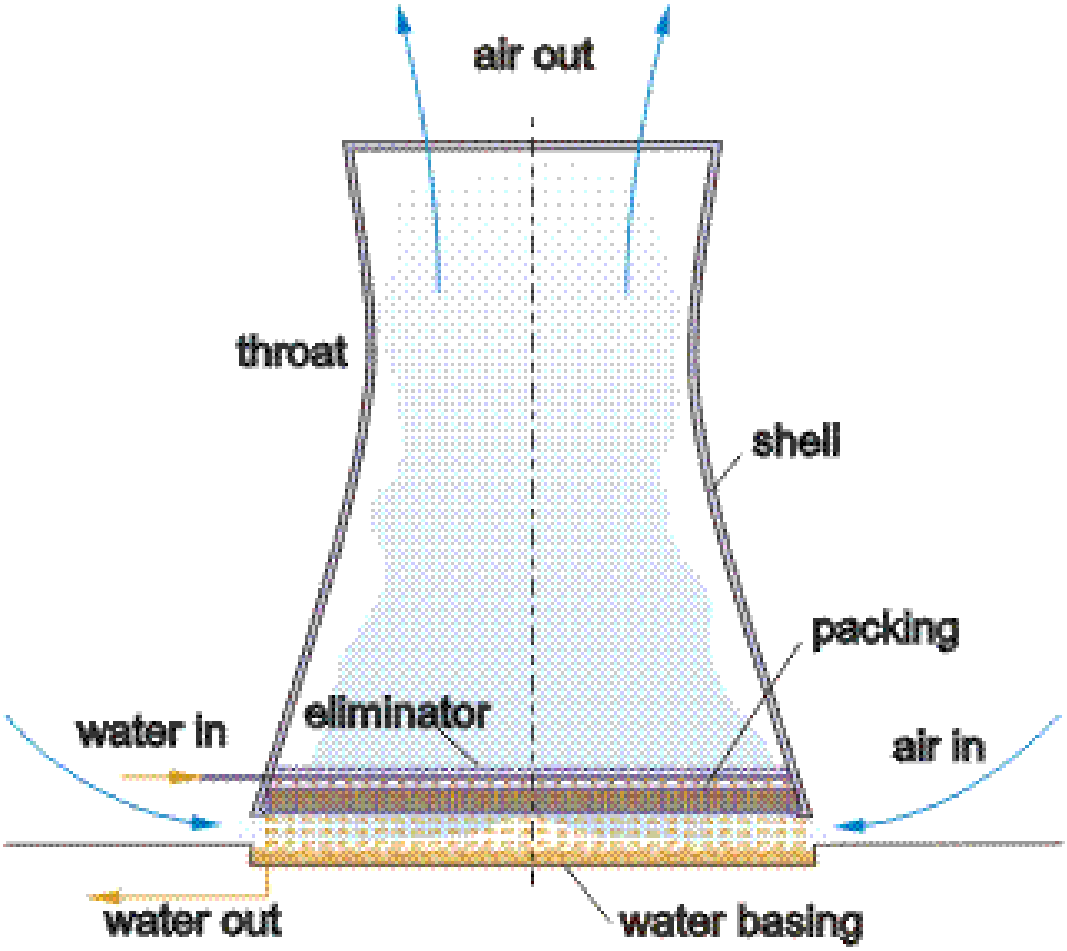

Figure 1 Cooling Tower

1.1 Applications of Cooling Tower

A cooling tower is a warmth dismissal gadget which concentrates squander warmth to the environment through the cooling of a water stream to a lower temperature. Cooling pinnacles may either utilize the dissipation of water to eliminate measure warmth and cool the working liquid to approach the wet-bulb air temperature or, on account of shut circuit dry cooling towers, depend exclusively on air to cool the working liquid to approach the dry-bulb air temperature.

Cooling towers differ in size from little rooftop top units to huge hyperboloid structures that can be up to 200 meters (660 ft) tall and 100 meters (330 ft) in measurement, or rectangular constructions that can be more than 40 meters (130 ft) tall and 80 meters (260 ft) long. The hyperboloid cooling towers are frequently connected with thermal energy stations, in spite of the fact that they are likewise used somewhat in some enormous synthetic and other mechanical plants. Albeit these enormous pinnacles are exceptionally noticeable, by far most of the cooling towers are a lot more modest, including numerous units introduced on or close to structures to release heat from air conditioning stabilizers.

- Natural gas processing plants
- Power plants
- Food processing plants
- Petrochemical plants
- Semi conductor plants
- Petroleum refineries and more

LITERATURE REVIEW

Kumar and Mathews (2018) [17] the exploration paper introduced that by expanding the mass stream pace of air the presentation of the cooling tower can be improved. All the exhibition boundaries, for example, cooling water range, viability, tower trademark proportion have expanded. The expansion in the viability of cooling tower was about 20%. At the point when the (L/G) proportion was diminished from 3.25 to 2.60. The power source temperature of cooled water is diminished to 2k. The impact of bay water temperature on the exhibition of cooling tower was examined keeping different boundaries, for example, mass stream rate, infusion stature, and fill region steady it was discovered that adequacy is decreased by 8%. The impact of water mass stream rate was likewise examined and it was discovered that by upgrading the mass stream pace of both water and air the adequacy can be expanded. Be that as it may, decreasing the mass stream pace of water lessens the yield of the cooling pinnacle and delta water temperature relies upon the plant activities.

Mondrety et. al. (2018) [7] the investigation of static underlying, dynamic (model) and seismic conduct of exaggerated cooling towers for example self-weight, static loads and ground quickening for seismic loading condition. The limit conditions considered are Top-end free and Bottom end fixed. The material utilized for the cooling tower is concrete. Three diverse cooling pinnacles will be demonstrated by utilizing SOLIDWORKS 2016 programming. The static underlying investigation is performed by putting forth a concentrated effort weight of the cooling tower i.e.: because of gravity, stress, strain and twisting because of burden is acquired for each cooling tower. The modular investigation is performed on the cooling tower by fixing it with the ground, 6 distinctive twisting modes shapes with particular frequencies are gotten as the outcome for each cooling tower. Reaction range investigation is performed to consider the seismic impact on the cooling tower, for speeding up case 0.5g, 0.6g, and 0.7g. From the modular examination table, it was presumed that as the tallness of the cooling tower increment the common recurrence will diminish.

Angalekar and Kulkarni (2018) [13] the examination paper displayed that the help of segment to the pinnacle could be displaced by indistinguishable shell parts with the objective that the item made could without a very remarkable stretch be utilized. For such a show, a lone case of the zenith with elective 'I' and 'V' supports was considered showing the lead in respect of similar plates which were indistinct from the direction where the fragment supports were thought of. For this, the breeze load over the construction was applied. The results communicated that the proportionate shells gave unclear redirected profiles to the utilization of the breeze loads, like those due to genuine sponsorships. It was seen that the 'V' supports give 73.6% more impact than

'I' reinforces by virtue of section reinforces similarly as proportionate plate system on account of the usage of wind load. The breakdown load if there ought to emerge an event of 'I' strong organization was having a 40% higher motivating force than because of 'V' type steady organizations. The construction with the plan of fortification, for instance, steel plate could uphold pretty much 35 to half more fold load than that of plain concrete.

OBJECTIVES

The Primary objectives of the study are:

1. To determine thermal effect on structural members of the tower.
2. To Analyze the cooling tower structure considering wind pressure.
3. To Analyze the structure using Analysis tool SAP2000
4. To determine the cost of construction as per S.O.R. 2019.
5. To Determine suitable width of the tower to overcome heating effect.

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. This step further dealt with presenting the application of cooling tower in various industries and its future prospects of general applications in various other industries.

Step-2:To Prepare geometrical structure of the study using analysis tool SAP2000

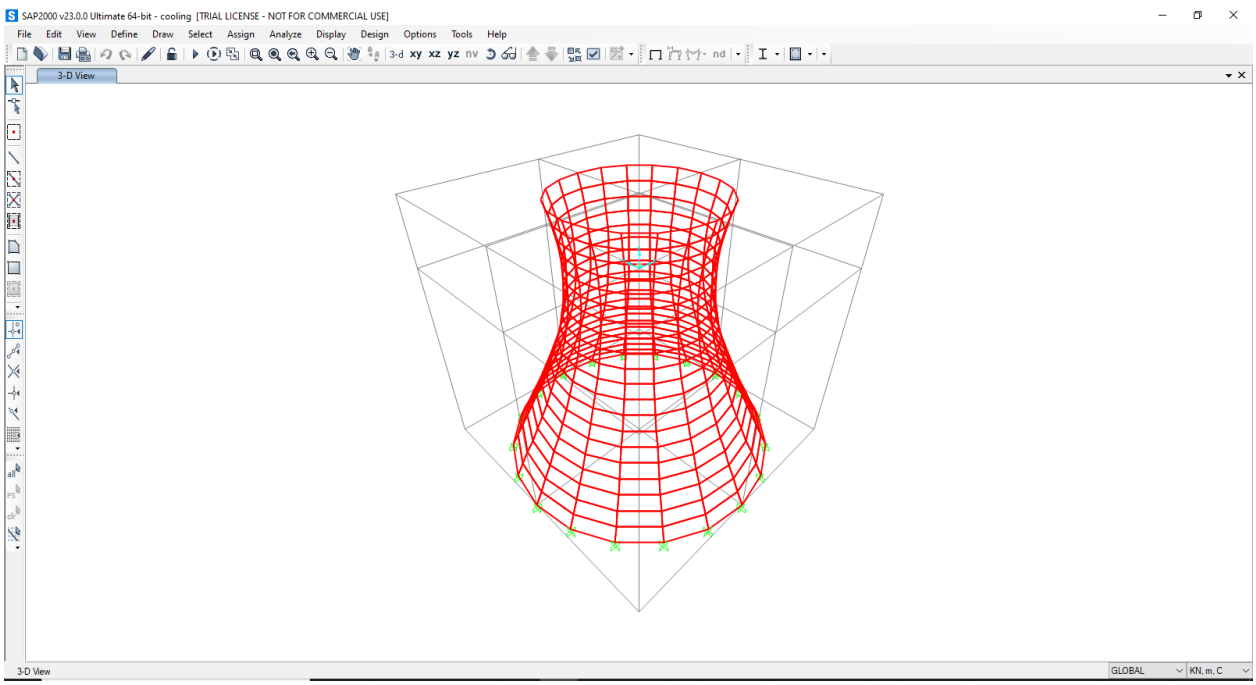

Fig 2: Modelling of Cooling Tower using SAP2000

Step-3: To Create material properties and assigning at structure.

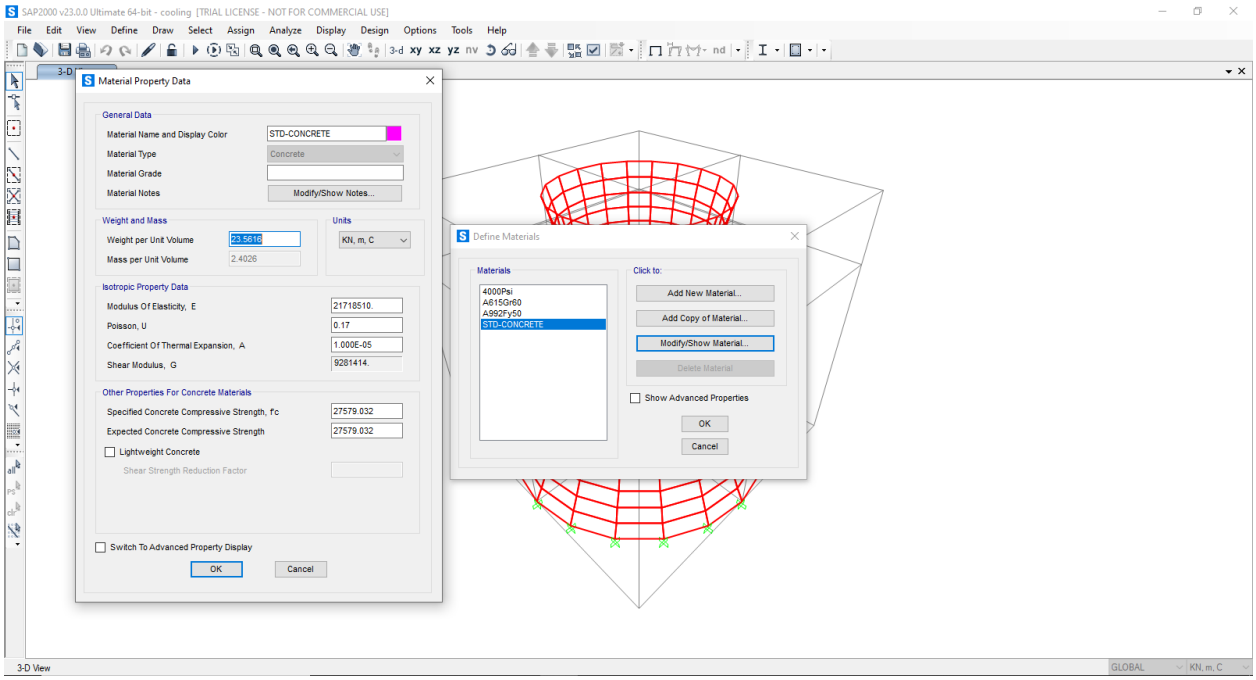

Fig 3: Assigning material and section properties

Step-3: Assigning fixed end condition at the bottom of the tower

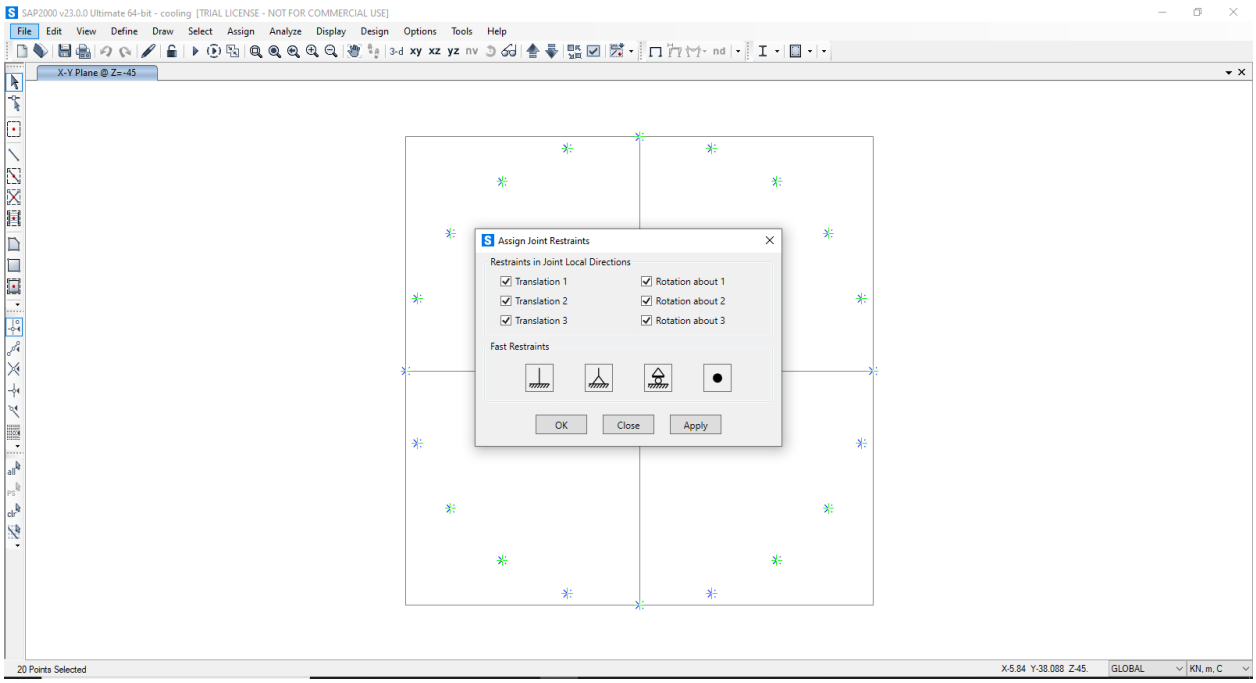

Fig 4: Assigning Support condition

Step-4: Assigning loading conditions:

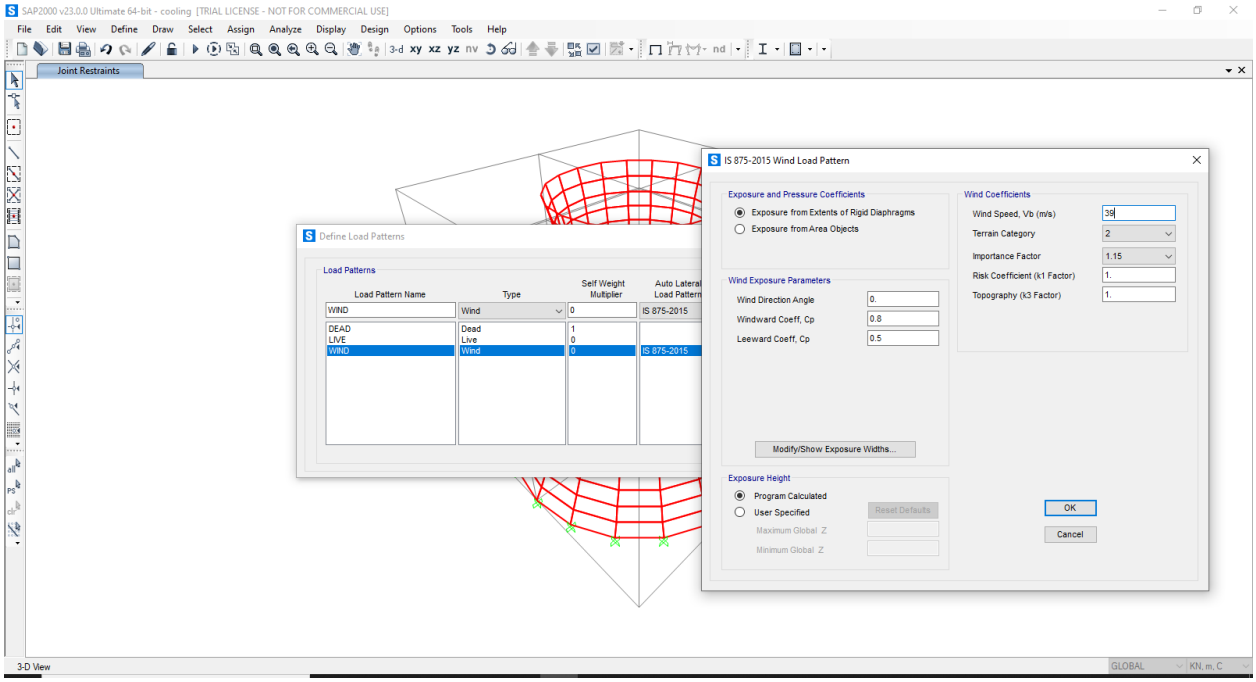

Fig 5: Loading conditions assigned

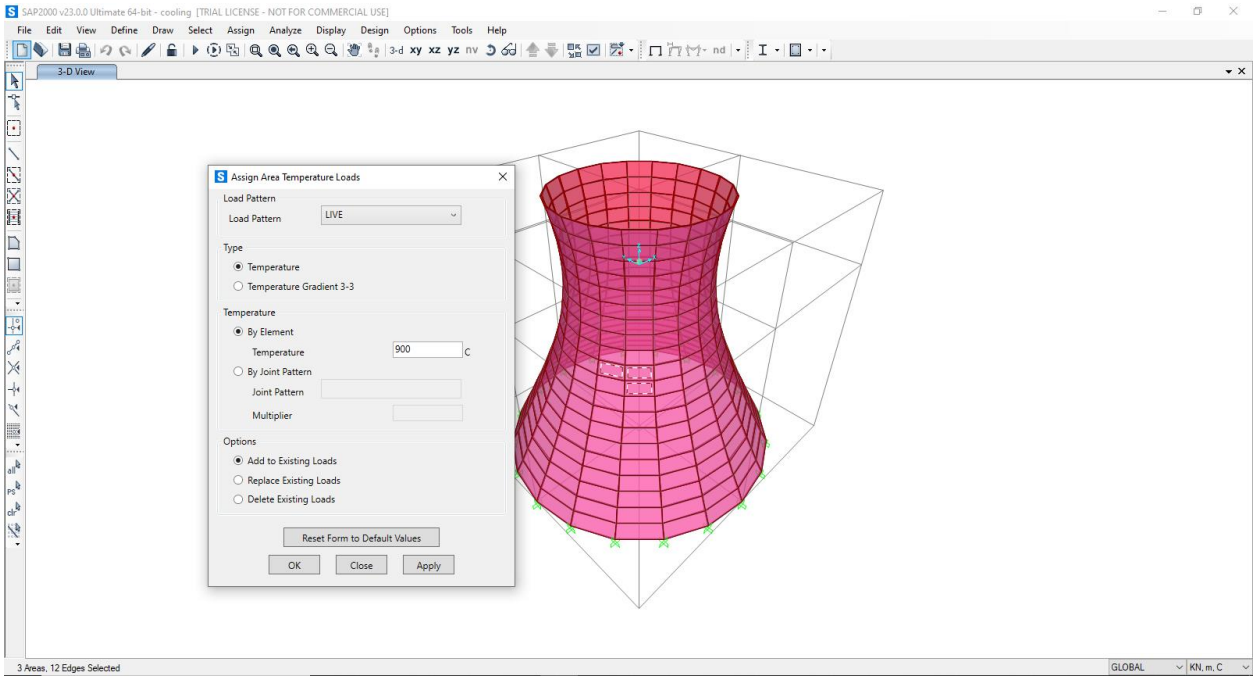

Fig 6: Temperature effect

Step-6: Assigning Load combinations as per I.S. 875-V

Table 1: Loading Combinations

Load case no.	Load cases
1	D-L
2	L-L
3	Wx
4	Wz
5	Wx -ve
6	Wz -ve
7	1.5(D-L+L-L)
8	1.5(D-L+ Wx)
9	1.5(D-L- Wx)
10	1.5(D-L+ Wz)
11	1.5 (D.L- Wz)
12	1.2(D.L+L.L+ Wx)
13	1.2 (D.L+L.L- Wx)
14	1.2 (D.L+L.L+ Wz)
15	1.2 (D.L+L.L-Wz)

Step-5: Analysis of cooling tower

In this study we are performing finite element study using analysis tool SAP2000 and observed that variation is observed at different height of the structure.

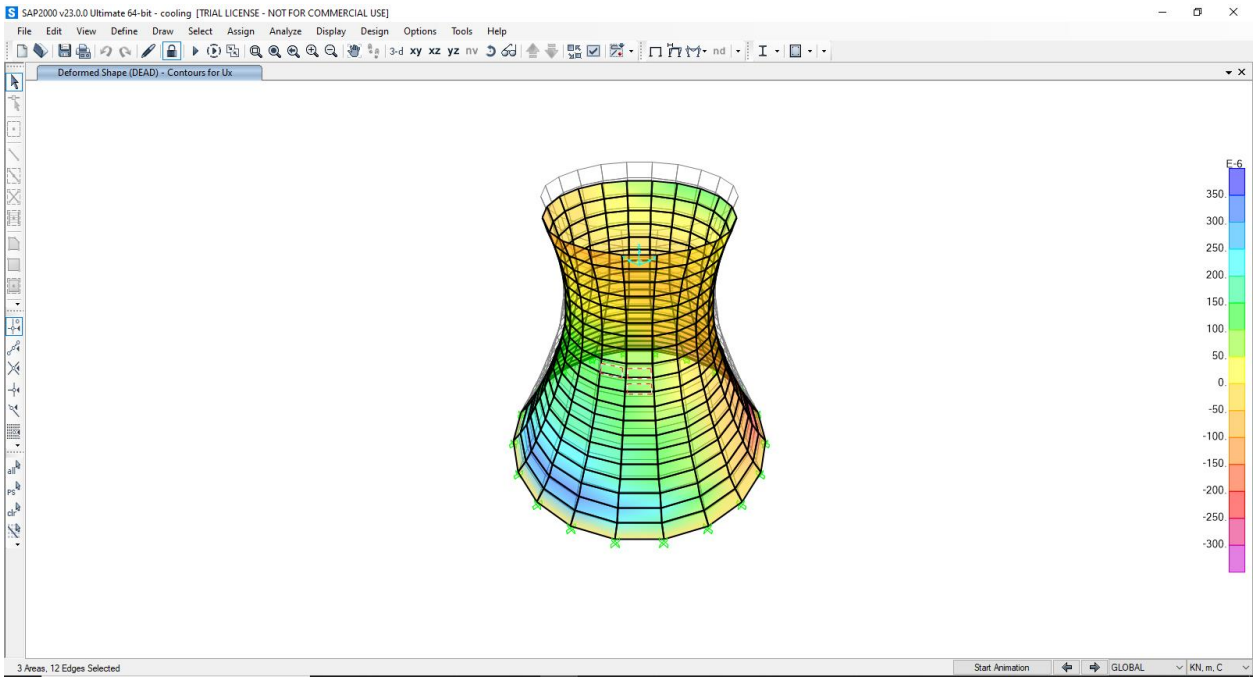

Fig 7: Analysis output

Step-6: Generating report of each case in M.S. excel for comparison.

Table 2 Geometrical Details

SR .NO.	PARAMETER	SIZES
1	AREA	25 m^2
2	TOWER HEIGHT	60 m
3	LIVE LOAD	3 Kn / m^2
4	FLOOR FINISH	2 Kn / m^2
5	Structural wall	800 mm
6	Masonry	100 mm
7	Brick lining	100 mm
8	Top ring beam	400 x 400 mm
10	Wind pressure	39 m/s
11	Thermal effect	900 ^{O}C, 100 ^{o}C & 1100 ^{o}C.
12	SOIL PROPERTY	SOFT SOIL

Table 3 Details of Material Used in the Project

SR.NO.	PARAMETER	DESCRIPTION
1	CONCRETE	M35
2	REBAR	FE 500
3	Modulus of Elasticity	1.95xE5 MPa
4	Ultimate Tensile Strength	1860 MPa
5	BRICK LINING	CLAY BRICK
6	THERMAL TEMP.	800, 900, 1000, 1100 ^{O}C

Table 4 Load Assessments and Calculations

S.No.	Load Type	As per I.S.
1	Self Load	I.S. 875-PART-1
2	Thermal Load	I.S. 875-PART-2
3	Wind pressure	I.S. 875-I:2015

ANALYSIS RESULT:

Table 5 Axial Force in KN

Storey	Max. Axial Force in KN			
	1100°	**1000°**	**900°**	**800°**
60	3025.9	3014.9	2919	2605.4
55	3025.5	3007.5	2917	2586.8
50	3025.1	3004.1	2916	2568.2
45	3024.8	3000.8	2913	2549.5
40	3024.3	2997.3	2911	2530.9
35	3023.9	2993.9	2909	2512.2
30	3023.5	2989.5	2909	2493.6
25	3023.2	2987.2	2907	2475
20	3022.9	2984.9	2906	2456.3
15	3022.6	2983.6	2905	2437.7
10	3022.3	2981.3	2904	2419
5	3022	2978	2902	2400.4
0	3021.7	2974.7	2901	2381.8

Table 6 Shear Force in KN

Storey	Max. Shear Force in KN			
	1100°	**1000°**	**900°**	**800°**
60	223.9	222.8	223	195.6
55	219.76	218.06	217	193.67
50	215.54	214.04	214	191.73
45	212.89	211.59	212	189.8
40	209.61	207.91	207	187.87
35	203.32	201.92	202	185.94
30	198.56	197.36	197	184
25	194.09	192.19	192	174.34
20	189.62	187.92	187	176.32
15	185.15	183.59	182	172.14
10	180.68	178.7	177	167.96
5	176.21	175	172	163.78
0	171.74	170.35	167	159.6

Table 7: Displacement in mm

Height of the Tower	Displacement in mm			
	800°	900°	1000°	1100°
60	50.32	91.56	106.2	112.65
55	47.21	86.07	102.1	108.54
50	44.1	80.58	97.99	104.43
45	40.99	75.09	93.91	100.32
40	37.88	69.6	89.83	96.21
35	34.77	64.11	85.75	92.1
30	31.66	58.62	81.67	87.99
25	28.55	53.13	77.59	83.88
20	25.44	47.64	73.51	79.77
15	22.33	42.15	69.43	75.66
10	19.22	36.66	65.35	71.55
5	16.11	31.17	61.27	67.44
0	0	0	0	0

Table 8 Bending Moment in KN-m

Storey	Max. Bending moment in KN-m			
	1100°	**1000°**	**900°**	**800°**
60	389.21	378.21	367.4	290.3
55	375.99	357.99	359.6	289.32
50	367.89	346.89	351.7	276.92
45	359.43	335.43	339.7	264.52
40	351.24	324.24	328	252.12
35	336.72	306.72	312.3	239.72
30	329.87	295.87	302.7	227.32
25	318.65	282.65	287.8	214.92
20	307.43	269.43	272.9	202.52
15	296.21	257.21	258	190.12
10	284.99	243.99	243.1	177.72
5	273.77	229.77	228.2	165.32
0	262.55	215.55	213.3	152.92

Table 9 Support Reaction in KN

Support reaction Fy (kN)			
1100 ºC	**1000 ºC**	**900 ºC**	**800 ºC**
9034.65	9031.34	9002.54	8703.67

Table 10: Cost analysis of the structure

S.No	Case	Qty. of concrete	Qty. of reinforcement	Concrete rate/cu.m	Reinforcement rate/kg	Cost of concrete	Cost of reinforcement
1	**Tower with 800 ºC**	1290.76	3490.32	4500	48	58,08,420	167535.36
2	**Tower with 900 ºC**	1386.45	3902.4	4500	48	62,39,025	187315.2
3	**Tower with 1000 ºC**	1580.43	4521.34	4500	48	71,11,935	217024.32
4	**Tower with 1100 ºC**	1654.98	4907.5	4500	48	74,47,410	235560

CONCLUSION

Following Conclusions are made as per the results observed in above chapter are:

1. In terms of Bending moment it is observed that as we increases the temperature moment as at 800°C value is 290.3 kN-m whereas in 1100°C it

increases to 378.21 kN-m shwing variation of 23.3 %. It can be conclude that structure is stable upto 1000°C whereas after 1000oC structure is getting week.

2. It is observed in the analysis that temperature effect plays a vital role in structural stability of the structure as there is observed a variation of more than 50% in displacement due to temperature variation, in 800°C displacement is 50.32 mm whereas in 1100°C value increases to 112.65 mm.

3. In terms of unbalance forces with increase in temperature sudden rise in stresses are observed as in 1100°C value is 223.9 KN whereas in 800°C it decreases to 195KN showing variation of 13% resulting in shear failure.

4. In terms of Axial Force variation of 35% is observed with the rise of temperature.

5. In terms of support reaction it is observed that with rise in temperature vertical pressure increases from 8703.67 KN in 800 ^{o}C to 9034.65 KN in 1100 ^{o}C.

6. In terms of cost analysis it is observed in above chapter that cost increases as we design the structure for higher thermal load. Since the requirement of Ast increases with rise in thermal load. Here it can be said that cost varies by 28.9% as we increases the temperature.

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