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Seismic and Wind Analysis of Natural Draught Cooling Tower with Change in Dimensional Ratio

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ABSTRACT

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In this study, a static linear Eigen value buckling parametric analysis is done for cooling tower shell geometries of 150 m height. The shells are subjected to wind pressures (speeds) of (47 meter per second) and seismic vibrations under zone IV to observe the trends in the critical buckling pressures/speeds at which the shell first buckles and therefore the corresponding buckling modes. The cooling tower's geometry is changed in a systematic manner along the height to obtain the relationship between applied wind speeds and seismic vibrations associated with the mode of buckling and the cooling tower's geometry. Geometrical parameter ratios of the cooling tower's dimensions are considered so as to hide a wider spectrum of the cooling tower's geometry. The critical wind speed and seismic vibrations versus height curve is observed to be similar to the Euler buckling curve. There is an assumed diameter to total height ratio of about 1.15 instead of 1.5 for any cooling tower at which the critical wind speed is maximum. The critical wind speed varies linearly with the cooling system thickness and non-linearly with all diameter ratios. A linear eigen value vibration, parametric analysis is expressed for various cooling tower shell geometries to analyse trends in the free vibration response (natural frequencies and mode shapes). The forced response of the cooling tower to various forcing frequencies of wind and seismic vibrations is analysed using the mode analysis method using Staad.pro software. The shells are subjected to increasing wind gust periods of an equivalent speed to get the trends within the forced vibration response. In a systematic ladder manner, the cooling tower geometry is changed to obtain the free and forced vibration behaviour. The natural frequencies and their corresponding for the four different modes reduce with increasing height based on the loads applied. They are generally invariant with the peak to top diameter ratio, but the bandwidth increases with increasing height to top diameter ratio. The static response frequencies and their corresponding generally increase with increasing height as well as the height to base diameter ratios. The static response frequency generally decreases with decreasing forcing frequency.. The findings can be used as a basis for further research and establishment of conceptual design guidelines when considering stability, free and forced vibration cooling tower_behaviour.

Keywords : hyperbolic cooling tower, stability, buckling, modes, critical wind pressure, speed/velocity, seismic vibrations, static response, natural frequency, mode shape

I. INTRODUCTION

With greater than ever concerns upon the problems like e.g., environmental pollution, energy shortage, associated with fossil fuel, renewable energy has been taken into particular consideration. Nowadays, the geothermal and concentrated solar thermal power plants are on the summit of scientific research agenda.

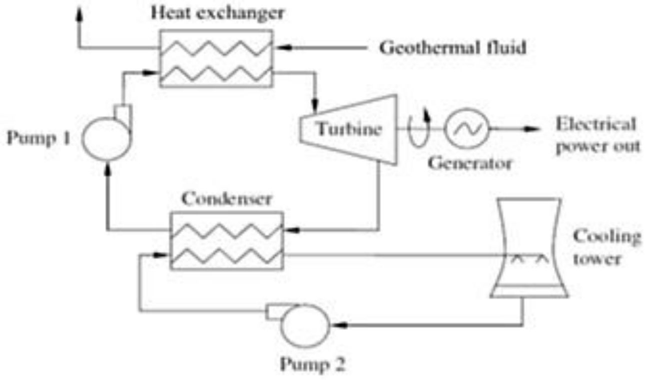


Figure 1.1 A typical binary-cycle geothermal power plant.

A typical binary-cycle geothermal power plant is illustrated in Figure 1.1. This type of geothermal electricity plant being constructed are the most common today. In Figure 1.1, the fluid from a geothermal well exchanges heat with a second working fluid in a heat exchanger. The second working fluid with a low boiling point is vapourized and then directed through a turbine to generate electricity. The vapour which exits the turbine is then cooled & condensed in a condenser through a cooling tower.

Thus, the rate of heat discharged per unit power generation for a binary-cycle geothermal plant is much higher than for other power plants, and as a result, requires larger cooling capacity of the cooling tower at the same power rating.

$$\eta th = \frac{Wnet}{Wnet+Qc}$$

Components of Cooling Tower.

Evaporative tower are having many components like:

i. Body & shape : plethora of the towers have frames basically of structural frame type that support the casings exterior enclosures, motors, fans, and other components of the frame etc.
ii. Fill: These tower to work properly are mainly filled with material like wood of artificial materials like plastic etc.convert the heat by and lower down the vaporization water and air contact present in the fill. Two type of splash are used one is film type and second is splash. continuously breaking down of smaller droplets. Plastic splash are best compared to wood splash because they observe the heat more than any other materials.. Film fill composed of thin, water spread on a plastic surface makes a thin layer film contact with the air with many different form like honeycomb etc.
iii. Basins : water basin, which is situated at or near the bottom of the tower. For the discharge of cold water, the cold water basin normally has a low point called a sump. The cold water basin is also located underneath

the entire fill at the bottom of several tower designs.

iv. Drift-eliminators: the water droplets, which float into the tower, are collected by drift eliminators.

v. Air-inlet-valves : it function is just to insert the cool air forced by the fans.

vi. Louvers: it balance the flow of natural air and balance the air flow made by fans which keeps air cool air keep moving upward and keep hot air moving downwards to turn the hot water into cool temperature.

vii. Nozzles: nozzle are the used to spray the hot water from the particular height inside the tower to fall it down. The nozzle make the water droplet is smaller the droplet it will make the water will get easily cool.

viii. Fans: In general, the term "fan" refers to a group of people who In towers, axial and centrifugal fans are used. Induced draught towers usually use propeller fans, while forced draught towers use both propeller and centrifugal fans. Depending on their size, propeller fans may have either a fixed or variable pitch.

Design of a natural draught cooling towers

Important parameters prerequisite to design of natural cooling tower.

a. Measured Parameters.

i. Wet bulb temperature of air (T_w)in °C or °K

ii. Dry bulb temperature of air (T_d)in°C or °K

iii. Inlet water temperature (T_{in}) in°C or °K

iv. Outlet water temperature (T_{out}) in°C or °K

v. Water mass flow rate / Water load (W_L) in kg/sec

vi. Enthalpy change ($\Delta H'$) i.e. air passing through tower; in kJ/kg

b. Performance Parameters.

i. Range (ΔT) where, $\Delta T = Tin - Tout$; units -°C or °K

ii. Approach ($\Delta T*$) where, $\Delta T^* = Tout - Tw$; units -°C or °K

iii. Effectiveness (Ec) where, $Ec = ((\Delta T/(\Delta T + \Delta T^*))* 100\%$

iv. Cooling capacity (Q) where, $Q = WL*Cp_{(water)}* \Delta T$ in kW

v. Performance coefficient (Ct) Value is usually taken as 5.2 or lower

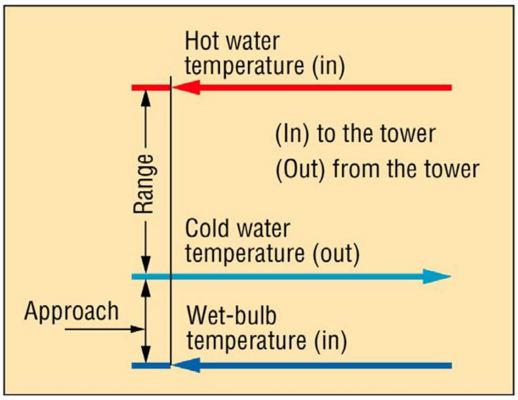


Figure 1.3 Range and Approach. [courtesy nptel Ch-3.7]

c. Design Parameters.

i. Duty coefficient D_t via formula,

$$\frac{WL}{Dt} = 0.00369 * \frac{\Delta H'}{\Delta T} * (\Delta T * +.0752\Delta H')^{0.5}$$

ii. Base area of tower A_b via formula, $D_t = \frac{19.5 * Ab * zt^{\wedge}0.5}{Ct^{\wedge}1.5}$ in m^2.

iii. Height of tower (z_t or h_t), supposed values (maximum) are used through calculations to confine to a height to diameter ratio 3:2; in case of hyperbolic natural draught towers.

iv. Diameter of tower at base $d_b = \sqrt{\frac{4 * Ab}{\pi}}$ in m.

II. NEED OF WIND LOAD CALCULATION ON NATURAL DRAUGHT COOLING TOWER

General Codal Provisions of wind loading Codal Provisions in this thesis used is IS: 875- Part - 3 - 1987 reaffirmed 2003. Basic wind speed estimates are based on peak gust velocity averaged over a three-second time interval.

For any particular location, the basic wind speed can be optimised and modification we can madejust to adding the effects to collect the design velocity acting on the structure at any ht. (V_z) on the subjected structure:

One is : Risk level, second is Terrain roughness, and the topography.

We can show it by:
Where $\mathbf{V_z = V_b \times k_l \times k_2 \times k_3 \times k_4}$

V_z = design wind speed of structure at ht. z in m per s. and K_1 = factor of probability can say risk coff.*And* k_2 *is height of* terrain under the area,k_3 = factor of the subjected topography.k_4 = fact of Importance that is acting

III. LITERTURE REVIEW

In May 2013, Bhavani Sai, I Swathi, K. S. L. Prasann, and K Srinivasa Rao's publish an article on "Design of Cooling Tower" was published in International Journal of Scientific & Engineering Research, Volume 4, Issue 5, May-2013, pp 1560-1563.This paper examines a counter-flow induced draught cooling tower and calculates parameters such as performance, effectiveness, and characteristics. A draught cooling tower provided the technical information (mechanical). Evaporation occurs in cooling towers as some of the water evaporates in the presence of cold air, causing the water to cool and condense.

In June-July 2013, Sahana.L.R and Sayeed Sulaiman, published in International Journal of Emerging Trends in Engineering and Development (IJETED), Issue 3, Volume - 4 ON "EARTH QUAKE EFFECT AND WIND PRESSURE ON COOLING TOWER". The analysis of a 124.8 m high cooling tower above ground level is the subject of this article. Finite Element Analysis was used to assess wind loads (FEM). Wind coefficient indian standard codes of 1985 with IS:875 (Part 3) - 1987 code Modal analysis will be used to calculate seismic loads for various weights of 0.3g, 0.4g, and 0.5g in compliance with IS:1893. in comparison to one that already exists.

In comparison to the RTPS reference tower, the thickness of the shell and cooling tower opening are different. The analysis was carried out using an 8-noded shell feature. The stress and strain contours, as well as the stress and strain contours being plotted and modes of deflection being mapped, are among the study' findings.

In October 2014, Tegas, NGgore, V G Sayagavi, Kiran MAdhavi and Sandeep Pattiwar publish an article (IJEAT- PP 34-39 Volume -4 Issue-1) on The effects of wind on natural draught hyperbolic cooling towers are highlighted in this article. Because of their construction, these structures are vulnerable to earthquakes and wind. Analysis & design of cooling tower is prescribed with V- shape configuration of Raker column in this work. Finite element modelling (FEM) of cooling tower shell is analysed which subdiveds shell into n numbers of plates to add wind loading conditions on each individual plate. To apply wind load Gust method and Peak wind Methods are adopted Staad.Pro is used to give a comparative result of analysis, designs and constructability. In this work, the analysis and design of a cooling tower is prescribed using a V-shaped Raker column configuration. The cooling tower shell is studied using finite element modelling (FEM), which divides the shell into n number of plates and adds wind loading conditions to each plate. Staad is used to implement the wind load Gust and Peak wind methods. Pro is used to provide a comparative analysis result.

In December 2014, Parth. R Chhaya, M. mistry, and Anuj K. Chandiwala, Published a paper in internation journal of advance engineering and research Development volume 1 issue 12 PP 47-50 on a review of wind loading on natural draught Hyperbolic cooling tower. This paper is focused on the examination and investigation of two cooling towers measuring 200 metres above ground level. A cooling tower is a system that transforms hot water into cold water by direct air contact. It is based on the temperature difference between the air inside and outside the tower.

One of the most commonly used cooling towers is the natural draught cooling tower. The Hyperbolic form of cooling tower is commonly chosen because of its strength and stability, as well as the wide available area at the base due to its shape. As per codal requirements, it should be continuously assessed for self-weight and lateral loads such as wind and earthquake loads.

A wind load analysis was conducted using the assumption that the shell base is fixed. The circumferentially distributed architecture wind pressure coefficients IS: 11504-1985 code and IS: 875 (Part 3)-1987 code were used to measure the wind loads on these cooling towers in the form of pressures.

In December 2014, Sachin Kulkarni and Prof A. V. Kulkarni presented “Static and Dynamic Analysis of Hyperbolic Cooling Tower” in the Proceedings of the 2nd International Conference on Current Trends in Engineering and Management ICCTEM -2014, Mysore, Karnataka, India, pp-9-26.” Self-weight, seismic load, and wind load are all factors in hyperbolic cooling towers. There are two existing cooling towers that have been selected. As a case study, the towers are from the Bellary thermal power station. The boundary conditions are considered at both the top (free) and bottom (restricted) ends of the spectrum (fixed).

The cooling tower's material properties include young's modulus of 31GPa, Poisson's Ratio of 0.15, and RCC job density of 25 kilonewton per cum..

8 noded shell (93 element) and 4 noded shell are used for static analysis. The ANSYS 10 (SHELL 93) factor is used to evaluate the behavioural changes in cooling towers with different tower heights and thicknesses. Seismic loads of 0.5g, 0.6g, and 0.7g with ground acceleration are carried out in compliance with indian standard codes.

In August 2015, Sunil J. Kulkarni and Ajaygiri K. Goswami, presented “Studies and Experimentation on Cooling Towers: A Review,” International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 – 0056, Volume: 02 Issue: 05, In the chemical industry, cooling towers are one of the most critical components. They are usually used to drain heat from heat sources in order to heat the power plant's sink. In industries, induced cooling towers, forced cooling towers, and natural draught cooling towers are used depending on the need. Atmospheric air is used in natural draught cooling towers. Cooling towers with induced draught. The air is sucked out. The cooling of water is caused by the humidification of the air. The efficiency of tower cooling is determined by I air and water flow speeds, and ii) water temperature.

It was also mentioned that one of the most significant losses in cooling towers is drift. Various researchers have experimented with various cooling tower shapes in order to determine their effectiveness. It gives towers aerodynamics, strength, and stability.

In December 2015, Priya Kulkarni and S. K. Kulkarni published gave an article on “Wind effect on Hyperbolic RCC Cooling Tower” in International Journal of Current Engineering and Technology; E-ISSN 2277 – 4106, P-ISSN 2347 – 5161 Vol.5, No.6 (Dec 2015), pp 3513-3517.

Many types of industrial and power plants use reinforced concrete cooling towers. The Bellary Thermal Power Station (BTPS) case study is based on current cooling towers. The thickness and measurements of the shell in the other models, cooling towers, are varied in relation to the tower used as a reference. Staad's ProV8i with boundary conditions is used to analyse the cooling towers.

The cooling towers' material properties are: I young's modulus 2.1 MPa, ii) Poisson Ratio 0.15, and iii) RCC density 25 kN/m3.Wind loads on these cooling towers calculated by IS 11504-1985 code & as per IS 875 (Part 3)-1987 code.

In June 2017, Amritha Treesa and Akshara S P, Presented “Review on Natural Draft Hyperbolic Cooling Towers,” International Research Journal of Engineering and Technology (IRJET), e-ISSN: 2395 – 0056, Volume: 04 Issue: 06, Natural draft/hyperbolic towers are double-curved thin shell concrete structures that contribute to environmental protection. It's also successful at generating electricity. These structures aid in the cooling of thermal power plants by reducing the amount of water needed, thus preventing thermal contamination of water bodies.

Natural draughts are critical in power stations because they provide cooling for a variety of applications. This generates heat and is commonly used in industries such as power plants, oil refineries, steel mills, chemical production, and manufacturing processes.

IV. METHODOLOGY

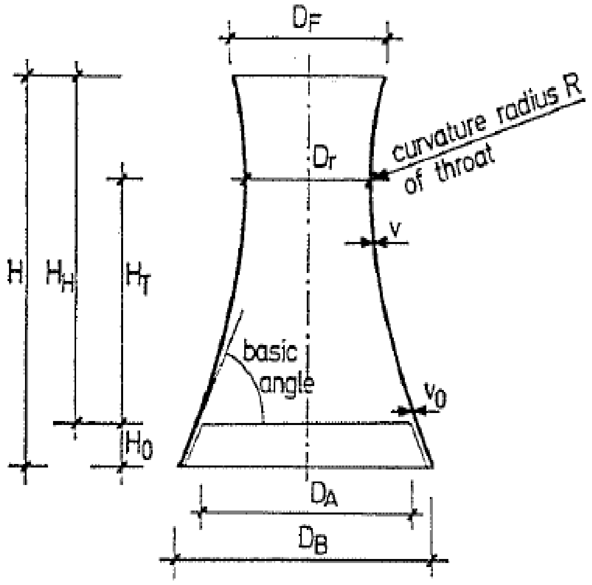


Figure 3.1 Basic details of Hyperbolic Cooling Tower.

Design of Hyperbolic Natural Draught Cooling Towers across 1500-MW power plant.

Assume the water load capacity for which the cooling tower is to be design equal to 68000 Kg/s. Under the following conditions as below;

i. Inlet water temperature (Tin) = 44.85 ℃ = 318 0K

ii. Outlet water temperature = 313 0K

iii. Dry bulb temperature of air = 301 0K

iv. Wet bulb temperature of air = 295 0K

v. Design Setup for Analysis in Staad.Pro software tool.

The structural setup was done to analyse the effects of hyperbolic structure i.e. natural draught cooling towers under wind and seismic behaviour by framing out simulation model in Staad.Pro software tool. The shell structure is having height of 150 m with 134 m as its base diameter. The building to be analysed here is completely made up of reinforced concrete; structural members includes only plate members as shell. The building is located at Ludhiana, having wind zone II & seismic zone IV.

Structural details of designed cooling tower:

a. Height of cooling towers = 150 m
b. Diameter at Base = 134 m
c. Diameter at Throat = 66 m
d. Diameter at Top = 70 m
e. Distance of Throat to Top = 25 m
f. Number of plates in vertical = 30 (5 m each)
g. Basic wind speed = 47 m/s
h. Sesmic load = As per IS: 1983- 2002 (Part – IV)

V. Results and Observations

Results and Observations

In this study, we found design of structure against seismic and normal active forces for various load cases with different possibilities on structure.

Table - 4.1. - Node displacement summary w.r.t. various load condition

			Horizontal	Vertical	Horizontal	Resultant	Rotational		
	Node	L/C	X mm	Y mm	Z mm	mm	rX rad	rY rad	rZ rad
Max X	22	12 Generated I.C.G.S. 8	21.007	-24.468	-0.000	32.249	-0.000	-0.000	-0.000
Min X	64	13 Generated I.C.G.S. 9	-21.006	-24.468	-0.000	32.248	-0.000	0.000	0.000
Max Y	64	1 Eq X	13.741	2.614	0.000	13.987	0.000	-0.000	-0.000

Min Y	22	12 Generated I.C.G.S.8	21.007	-24.468	-0.000	32.249	-0.000	-0.000	-0.000
Max Z	2524	12 Generated I.C.G.S.8	2.445	-1.700	8.266	8.786	0.001	-0.000	-0.000
Min Z	2560	12 Generated I.C.G.S.8	2.445	-1.700	-8.266	8.786	-0.001	0.000	-0.000
Max rX	2399	13 Generated I.C.G.S.9	-1.924	-6.101	-2.564	6.892	0.001	-0.000	-0.000
Min rX	2357	12 Generated I.C.G.S.8	1.924	-6.101	2.565	6.892	-0.001	-0.000	0.000
Max rY	690	11 Generated I.C.G.S.7	-2.922	-19.022	1.087	19.276	-0.000	0.000	-0.000
Min rY	690	10 Generated I.C.G.S.6	2.430	-19.391	-1.239	19.582	0.000	-0.000	-0.000
Max rZ	2374	12 Generated I.C.G.S.8	4.825	-6.918	0.000	8.434	-0.000	0.000	0.001
Min rZ	2416	13 Generated I.C.G.S.9	-4.829	-6.916	0.000	8.435	0.000	-0.000	-0.001
Max Rst	22	12 Generated I.C.G.S.8	21.007	-24.468	-0.000	32.249	-0.000	-0.000	-0.000

The above Table 4.1 showing the results of node displacement w.r.t. various load condition applied in the stepped shell structure by using staad.pro.

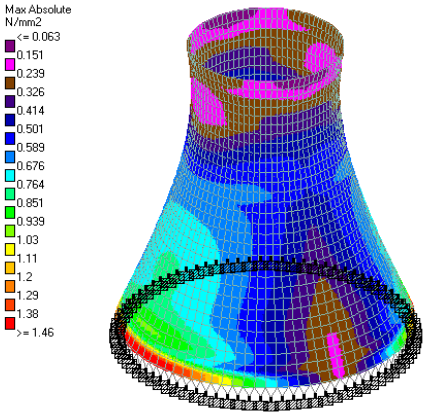


Figure – 4.1. - Contour Max Absolute stresses for cooling tower under Earthquake load.

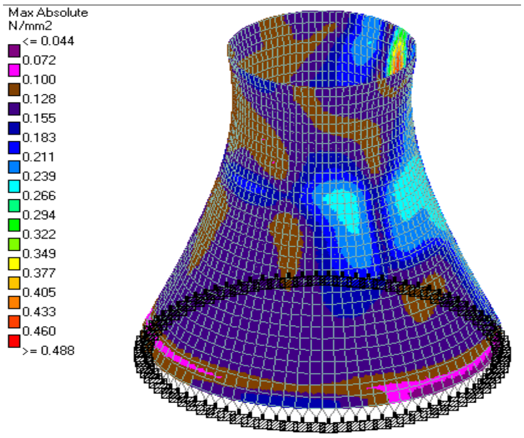
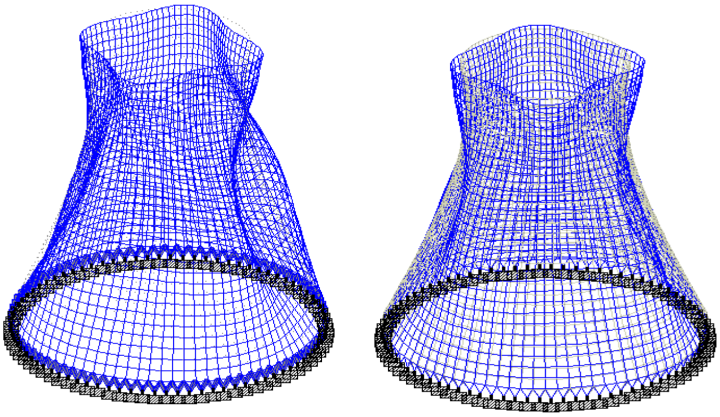
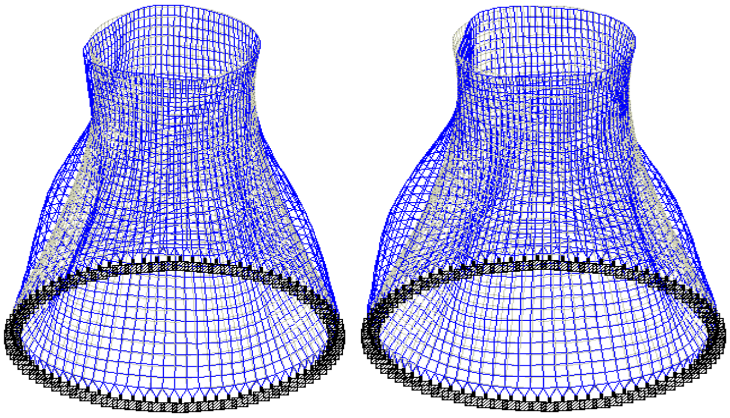


Figure – 4.2. - Contour Max Absolute stresses for cooling tower under Wind Load.



Mode Shape - 1 (b) Mode Shape - 2



Mode Shape - 3 (d) Mode Shape - 4

Figure – 4.3. - Mode Shape for cooling tower under acting load.

Calculated buckling factors for wind load case 4

MODE	BUCKLING FACTOR
1	201.86167
2	202.42676
3	236.14095
4	236.22989

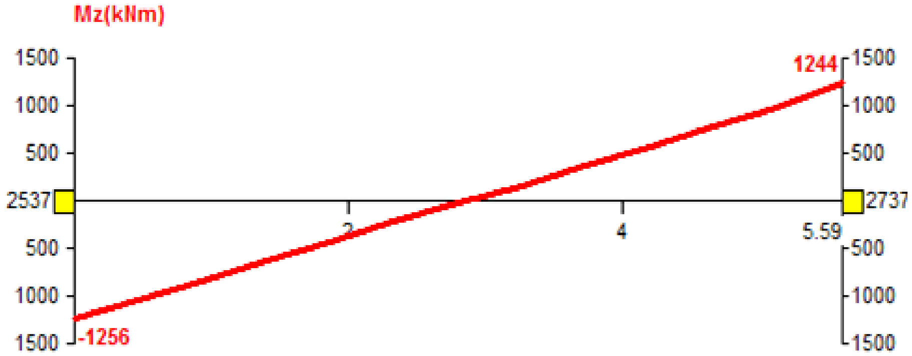


Figure – 4.4. Shows max Moment graph beam No. 2746.

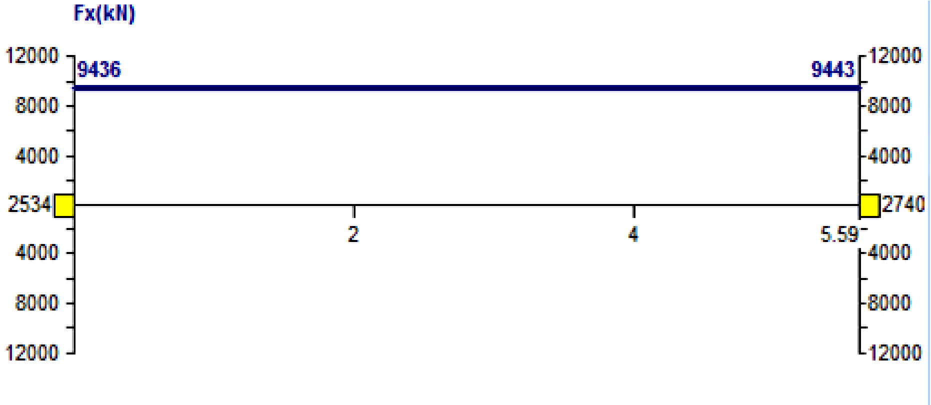


Figure – 4.5. Shows max Shear Fx graph for beam No. 2740.

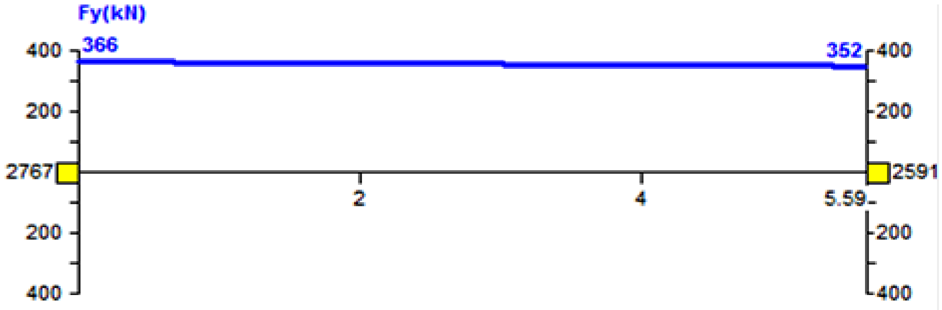


Figure – 4.6. Shows max Shear Fy graph for beam No. 2771.

In above figures and tables of results we found maximum shear forces acting on beam 2746 at node 2537thus adopting this beam for design procedure. The below table 4.4 shows the results of design. The column is designed with perimeters : M30 grade of concrete and fe415 grade of steel bars. Where the design force (pu) is 11792.8kn. and moments at initial are 1480.6, 10147.1 thus the total design moments is 1480.6

Table - 4.4. Design of column under maximum moment for beam 2746.

COLUMN_NO._2746_DESIGN_RESULTS
M30_Fe415 (Main)_Fe415 (Sec.)
LENGTH:_5.5 M   CROSS SECTION: 1.4Mx1.4M COVER: 4cm
** GUIDING-LOAD-CASE: 12_END JOINT: no2737 SHORT COLUMN

```

DESIGN AT JOINT NO_2537.
---------------------------
  CASE 1: MINIMUM ECC. ABOUT Y CONSIDERED

DESIGN_FORCES_(KNS-MET)
-----------------------
DESIG_____FORCE_(Pu)           : 11792.8

                              About Z        About Y
MOMENTS_at_initail____________              :  1480.6        10147.1
  MOMENTS DUE TO MINIMUM ECC.        :   0.00         682.23

 RATIO_of_slenderness______             :    -             -
  MOMENTS_DUE-TO-SLENDERNESS_EFFECT  :    -             -
  MOMENT_REDUCTION_FACTORS          :    -             -
  ADDITION_MOMENTS_(Maz and May)     :    -             -

  TOTAL DESIGN MOMENTS__________: 1480.59        *******
   REQD. STEEL AREA   :    43011.04 Sq.mm.
  INTERACTION RATIO: 0.99 (as per Cl. 39.6, IS456:2000)

      CASE 2: MINIMUM ECC. ABOUT Z CONSIDERED

DESIGN_FORCES_(KNS-MET)
-----------------------
DESIGNAXIALFORCE(Pu)           : 11792.8

                              About Z _____________About Y
 MOMENTinitial              :  1480.6_________10147.1
 MOMENTS DUE__TO__MINIMUm-ECC.        :  682.23           0.00

  SLENDERNESS RATIOS                :    -             -
  MOMENTS DUE TO SLENDERNESS EFFECT  :    -             -
  MOMENT REDUCTION FACTORS          :    -             -
  ADDITION MOMENTS (Maz and May)     :    -             -

  DESIGN MOMENTS_____________total _: 1480.59        *******
   REQD. STEEL AREA   :    43011.04 Sq.mm.
  INTERACTION RATIO: 0.99 (as per Cl. 39.6, IS456:2000)
    DESIGN AT JOINT NO.    2737
   CASE 1: MINIMUM ECC. ABOUT Y CONSIDERED

DESIGN FORCES (KNS-MET)
DESIGN_AXIAL_FORCE_(Pu)           : 11351.5
                              About Z        About Y
  MOMENTS_initial                 :  1503.1        9968.7
  MOMENTS_DUE_TO_MINIMUM_ECC__________  :   0.00         656.70

  SLENDERNESS_RATIOS                :    -             -
```

```
  MOMENTS_DUE-TO-SLENDERNESS EFFECT  :    -              -
  MOMENT_REDUCTION_FACTORS           :    -              -
  ADDITION-MOMENTS_(Maz and May)     :    -              -

  TOTAL DESIGN MOMENTS              : 1503.12       9968.73
   REQD. STEEL AREA   :    42080.49 Sq.mm.
  INTERACTION RATIO: 0.99 (as per Cl. 39.6, IS456:2000)

   CASE 2: MINIMUM__ECC. ABOUT_Z_CONSIDERED_

  DESIGNFORCEs(KNS-MET)
  DESIGN AXIAL FORCE (Pu)          : 11351.5
                          About Z        About Y
  MOMENTS-at-initial              :  1503.1        9968.7
  MOMENTS_DUE_TO_MINIMUM_ECC.       :  656.70          0.00

  SLENDERNESS_RATIOS                :    -              -
  MOMENTS_DUE_TO_SLENDERNESS_EFFECT  :    -              -
  MOMENT_REDUCTION_FACTORS           :    -              -
  ADDITION_MOMENTS_(Maz and May)     :    -              -

  TOTAL_DESIGN-MOMENTS              : 1503.12       9968.73
  REQD._STEEL_AREA   :    42080.49 Sq.mm.
  INTERACTION_RATIO: 0.99 (as per Cl. 39.6, IS456:2000)

CRITICAL_CONDITION : MAXIMUM AREA OF STEEL REQUIRED OF THE 4 CASES.
  REQD. STEEL_AREA   :    41764.98 Sq.mm.
  REQD. CONCRETE_AREA:  1918235.00 Sq.mm.
  MAIN_REINFORCEMENT : Provide  52 - 32 dia. (2.13%,  41820.88 Sq.mm.)
                    (Equally distributed)
  TIE REINFORCEMENT  : Provide  8 mm dia. rectangular ties @ 300 mm c/c
   SECTION CAPACITY BASED ON REINFORCEMENT REQUIRED (KNS-MET)
  ----------------------------------------------------------
  Puz :  38895.53   Muz1 :  10824.62   Muy1 :  10824.62
  INTERACTION RATIO: 1.00 (as per Cl. 39.6, IS456:2000)
  SECTION_CAPACITY_BASED_ON_REINFORCEMEN_ PROVIDED_(KNS-MET)
  ----------------------------------------------------------
  WORST LOAD CASE:    12
  END JOINT:  2737__Puz:_38912.17__ Muz :10906.10__Muy :  10906.10__IR: 0.99
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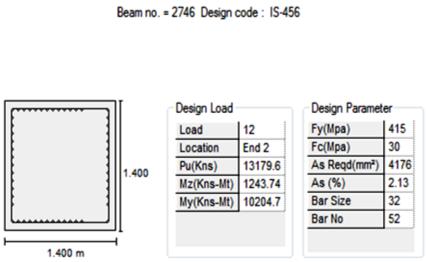

Beam no. = 2746 Design code : IS-456

Design Load

Load	12
Location	End 2
Pu(Kns)	13179.6
Mz(Kns-Mt)	1243.74
My(Kns-Mt)	10204.7

Design Parameter

Fy(Mpa)	415
Fc(Mpa)	30
As Reqd(mm²)	4176
As (%)	2.13
Bar Size	32
Bar No	52

Figure – 4.7. Column No. 2746 steel reinforcement details.

The column is designed with perimeters : M30 grade of concrete and fe415 grade of steel bars. Where the design force (pu) is 13179.6Kns. We found the required area of steel is 2.13% of sectional area that is 41764 mm2 . Thus providing 52 bars of 32 mm of diameter.

CONCLUSION

1. The natural draught cooling tower of 150mt in height designed here in this dissertation work is very efficient in handling 1500MW with single structure instead of making four low heighted cooling tower.
2. Utilization of Shell shaped structure in small thickness w.r.t general NDCT steeping of nose and throat helps in reducing dead load at base of similar height.
3. Modified structural arrangement helps in better stress distribution and restraining moment capacity due to active loading cases.
4. Active plain and Two dimensional acting load is diverged into a three dimensional component by using shell structure and Lightweight concrete.
5. Pressure forces, developed by uprising steam inside of cooling tower, counter balance maximum forces applied.
6. Load Case 8 and 12 has found as critical load case as per analysis for finding shear and stress characteristics.
7. Contour Levels of Shell structure at different modes found to be on safer side w.r.t Analysis.
8. Construction of beam at base of cooling tower imparts stability w.r.t available dead and live loads but increasing depth tends fail the structure against seismic forces.
9. Seismic loading in Seismic or wind load have minimal effect which is low in destructive as compared to regular forms of structures.

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