RCC chimney for 800Mw thermal power plant

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Abstract. A Chimney is an industrial structure used to ventilate hot flue gases from the furnace to the outside living atmosphere. The Chimneys are typically vertical, or as near as possible to vertical, to ensure that the gases flow smoothly. As a result of the procedure of chimney is ability to handle Dead load, Wind load, Earthquake load and Temperature load. In this research, achimney is starting from basic calculations to analytical calculations. A Chimney analysis for the thermal power plant, the location was taken as Vijayawada, (AP). Where as the basic wind speed and seismic zone were considered only in that particular location. Analysis was about how to calculate the height, calculating area and volumer the thermal plant generates 800MW power. Analysis was calculated by using Indian code IS 4998-2015 in manual and software. STAAD Pro and ANSYS are the softwares used for the validation.

Keywords: Chimney, Wind loads, STAAD Pro, ANSYS, Manual work.

1. Introduction

Chimneys are typically vertical, or as near as possible to vertical, to ensure that the gases flow smoothly. Often chimneys were used in industries, factories and kitchens. Chimneys are available in steel, RCC, Brick, etc. The chimneys are used as teleporting the gasses to the external environment. Additionally, the dispersion of pollutants at higher altitudes can reduce their impact on the immediate surroundings. The dispersion of pollutants over a greater area can reduce their concentrations and facilitate compliance with regulatory limits. In this research, the chimney was designed at thermal power plant which is located in Vijayawada, Krishna district, AP. The Chimneys are ability to handle dead load, wind load, earthquake load, and temperature loads. Apart from that wind loads are more significant loads than other loads. A chimney teleports the flue gas from the thermal power plant which is inside the chimney, planned as liner structure but in this research, no liner structure planned inside the chimney.

Generally the Thermal power plants contain power generators based on the capacity of power produced by generator. Similarly in this research the thermal power plant named Dr. Narla tata Rao thermal power plant (V.T.P.S) in Vijayawada is containing power generator with 1760Mw capacity. In that 1760Mw capacity, six generators are with 210Mw capacity and one generator is with 500Mw capacity. Recently the government-sanctioned 800Mw generator to V.T.P.S because of the extension power a chimney is required for increasing to ventilate the Flue gases[1]. Consequently in this research chimney was designed by the power plant with 800Mw capacity.
According to the location, it plays a main role for any construction, because of that main role of location every structural engineer upload with site details. Usually the chimneys are typically vertical, or as near as possible to vertical at higher altitudes with the wind gusts. Similarly in this research, for the reason of wind gusts the location was planned beside the Krishna river at Vijayawada [2]. Generally, the gust of winds beside the river is higher than the other areas. As per the IS 875-part 3, Vijayawada is Zone-II, the basic wind speed of this location is 50m/s based on this basic wind speed wind load was designed.

Additionally, earthquake load was also calculated by the consideration of site parameters. Based on this Vijayawada location is in Zone-III. In this site the soil type is in medium-hard type. From the dimensions of the structure remaining details are added.

2. Thermal Power Plant:
Thermal power plants are generated power by using coal at a particular temperature. The burning coal will heat the water and with that water vapor the turbine will rotate. For 1MW of power plant 378kgs of coal was required. In this research of chimney, 800MW power plant of thermal plants generate both in steam and SO2. Steam will treat the plant itself with a cooling tower but SO2 is hard to treat so that harmful flue air is not good for outside atmosphere. So by using this chimney, the hot flue gases is teleporting from the furnace to the outside atmosphere which is harmful to humans [3].

2.1. Chimney:
A chimney is a part of a thermal power plant. Chimneys are made up of RCC, Steel, Brick, etc. Chimneys are transporting items because they teleport the gas through them. Chimneys are also used in factories, industries, home kitchens etc. According to this research, chimneys are taken from thermal power plants.

2.2. About SO2:
Coal contains 0.5% of Sulphur, when the coal is heated the Sulphur reacts with oxygen that reaction gives Sulphur Dioxide (SO2). 

\[ S + O_2 \rightarrow SO_2 \]  

(Note 1: Sulphur atomic number (32) oxygen (16) but one Sulphur requires twice of the oxygen as per above reactions.)

3. Properties:
Height, area, and volume have differed from these chimney structures. These are general properties of the chimney

3.1. Height:
Chimney height calculation based on the discharge (Q) of flue gas. Discharge per hour was decided by the height of the chimney. For 800MW power plant calculating Sulphur dioxide is discharge per hour is the main purpose of the height [4].

\[ H = 14 \times (Q)^{0.3} \]  

3.1.1. Discharge:
Coal required for 800MW can be found for the as 1.1 Sulphur content in coal is calculated. EQ(3)

\[ S + O_2 \rightarrow SO_2 \]  

\[ 32 + (2\times16) \rightarrow 64 \]
Therefore, the coal contains 0.5% of Sulphur. After that Sulphur content multiply by two oxygens then Sulphur Dioxide discharge was calculated.

3.2. Area:
The area of the chimney is easy to calculate. Chimney looks like a cone shaped but opens at the top area. So chimney is a hallow section so the inside area is not required because of that inside area subtracted like $A = [A_1 - A_2]$.

$$
A_1 = \pi * [R_1^2 + r_1^2 + (R_1 + r_1) * \sqrt{(R_1 - r_1)^2 + H^2}]
$$

$$
A_2 = \pi * [R_2^2 + r_2^2 + (R_2 + r_2) * \sqrt{(R_2 - r_2)^2 + H^2}]
$$

(4)

3.3. Volume:
Same as area, volume is also calculated whether it is a frustum of cone type model. To generate the integration formula is required. This volume is for solids so it subtract with thickness both the values $V = [V_1 - V_2]$.

$$
V_1 = \frac{\pi}{3} * H * [R_1^2 + r_1^2 + (R_1 + r_1)]
$$

$$
V_2 = \frac{\pi}{3} * H * [R_2^2 + r_2^2 + (R_2 + r_2)]
$$

(5)

(Note 2: don’t subtract directly from full cone area or volume because diameter issues are generated automatically.)

4. Loads:
Dead load, wind load, earthquake load and temperature loads are the design of the chimney but there are no particular load for the chimney. Wind load is shows more effect on the chimney and the temperature load is depending on the industry. According to this research, it is on the thermal power plant. So, temperatures in this thermal power plant are not heavier than another industry [5]. Load calculated are as per the IS 4998-2015 in this research.

4.1. Dead Load:
Dead load known as self-weight, for calculating the Dead load, the IS875-part1 is used that followed by the IS4998-2015.

For that volume and densities are multiplied from (2.3) volume was taken and density of concrete taken as 2500 (because the structure is made up of RCC).

4.2. Wind load:
Wind load was caused by wind gust. Wind load occurs in the opposite direction to the chimney which is in circular and vertical structure so wind load is more significant than another load on the chimney. As the location in Vijayawada which is beside the river where the wind load is heavy to the chimney, then it is a challenge to the structure strength. For the tall chimney, the structure needs to resist with two types of wind loads, along with the wind load and avoid the failure of structures.

4.2.1. Design wind speed ($V_d$):
This wind speed is mandatory to calculate the wind load in the across direction of wind. For the design load, basic wind speed of the location was required, basic wind speed $V_b$, risk coefficient $K_1$, height factor $K_2$, topography factor $K_3$, and important factor $K_4$. Design wind speed is differed from height because of terrain roughness.

4.2.1.1. Basic wind speed $V_b$: 
Basic wind speed varies for every location, in this research location taken at Vijayawada, its basic wind speed is 50m/s as following IS 875 -PART 3

4.2.1.2. Risk coefficient $K_1$, Height factor $K_2$, Topography factor $K_3$, and Important factor $K_4$:
These factors and coefficients are directly taken from IS 875-part 3. $K_1$=1.56, $K_3$=1, $K_4$=1.15, But the terrain roughness is different from different height. For the reason of that design wind speed also varying at different heights.

4.2.1.2.1. Height factor $K_2$:
This factor was calculated by using the direction of the wind and the height of the structures. $z$ is the height for calculating roughness, $z_0$ is the aerodynamic factor in equivalent mannar is taken as constant $(0.002m)^2$. From (2.1) height is calculated in that every 5m(mode height) terrain roughness was calculated.

$$K_2 = 0.1432 \times \ln\left(\frac{z}{z_0}\right) \times z_0^{0.0706} \tag{6}$$

With that factors and coefficients design wind speed was calculated by the formula

$$V_z = V_b K_1 K_2 K_3 K_4 \tag{7}$$

4.2.2. Wind pressure $P(z)$:
This is the Design wind pressure due to periodic mean of wind speed, it is used to calculate the mean along with the wind load. There is a difference in IS 875-part3 and IS 4998-2015. That difference is air mass density directly multiplied by 0.5 in IS 875 part3 but IS 4998-22015 gave like below formula.

$$V_2 = \frac{1}{2} \rho_a [V_z] \tag{8}$$

(Note 3: $\rho_a$=1.2 Kg/m$^3$ taken in IS 4998-2015)

4.2.3. Along with the wind load:
The wind flow direction wind contacts the structure throughout the circular circumference. This wind load rises when the height is increasing. For Every 10m rising is different from each. $F_z$ is Along the wind load symbol [6].

$$F_z = F_z \tag{9}$$

Thus the sum of mean along with the wind load and fluctuation of the wind load shown in the above formula

(Note 4: From the IS 4998-2015 $V_c$ value is within the limits of 0.5V($c$) to 1.3 V($c$) Across the wind load was not required. For this chimney $V_c$ is within the limit.)

4.2.3.1. Mean along with the wind load $F_z$
The mean along wind load is the multiplication for drag coefficient $C(d)$, periodic wind pressure $P(z)$, and diameter of chimney $d(z)$

$$F_z = C(d) \times P \times d(z) \tag{10}$$

(Note 5: outside diameter is changing bone place to another in this research every 5m conceded as a mode. So, diameter founded for every 5m)

4.2.3.2. Fluctuations of along the wind load $F_z^1$:
Wind load is not a constant load it varies from time to time and height to height. To balance the fluctuations this load was added to the mean load. That load design will satisfy the structures.
Important factor was the fluctuations gust factor ($G$)[3]. Gust factor is the sudden impacts of wind one after another, that gust of wind tested by the strength and natural frequency of the chimney.

$$G = 1 + g_{f} r_{t} \sqrt{B + \frac{SE}{\beta}}$$  \hspace{1cm} (12)

For calculating gust factor balance intensity $r_{t}$, size factor $S$, energy and frequency was required finally critical damping $\beta$ also needed in IS 4998-2015 directly $\beta = 0.016$ given.

4.2.3.3. Natural frequency of chimney $f$:

The Chimney naturally possesses its frequency which is the natural frequency of chimney.

$$f_{1} = 0.2 \times \frac{d_{0}}{H^{2}} \times \sqrt{\frac{E_{c}}{\rho_{c}c}} \times (t/t_{0})^{0.3}$$ \hspace{1cm} (13)

Use of the frequency shows the limit of the displacements the chimney undergoes any of the vibrations and if the vibration is more than natural frequency then chimney will collapse. So, the gust factor considers the natural frequency to design the wind load along with it.

5. Earthquake load:

In this research, location area Vijayawada is not an earthquake zone. But chimney is a tall structure it needs seismic analysis[6]. So equivalent static method followed in this research by using IS 1893 part-1 2016.

5.1. Seismic coefficient method:

1. Earthquake loads always depend on chimney location zones.
2. Chimneys natural period $Z$ also play a major role.
3. Type of soil is considering the problems.
4. By using the soil type average spectral acceleration ($S_{a}/g$).
5. The factor of importance ‘I’ is also required.
6. Chimney decided the reduction response factors ‘R’.
7. Design of Horizontal load accelerations $A_{h}= (S_{a}/g) \times (\frac{z}{2}) \times (I/R)$  \hspace{1cm} (14)
8. Calculating base shear of the $V_{h}= A_{h} \times W$.  \hspace{1cm} (15)
9. Design Lateral loads tables $Q_{i}= V_{h} \times (W_{i} \times h_{i})/\sum_{j=1}^{n}(W_{j} \times h_{j})$  \hspace{1cm} (16)

6. Temperature loads:

Thermal power plants producing electricity by burning coal, that coal burned at a certain temperature that could be calculated. For design temperature load calculating the heat drop across the chimney is concrete shell [7].

$$\text{Heat drop } T_{c} = \frac{t_{d_{c}}}{c_{d_{c}}} \times \frac{T_{i} - T_{0}}{\frac{1}{k_{i}} + \frac{t_{d_{c}}}{c_{d_{c}}} + \frac{d_{c_{i}}}{k_{o_{d_{c}}}}}$$ \hspace{1cm} (17)

This head drops changes throughout the chimney with different heights. At Bottom of the chimney temperature is high while going to the top of the chimney it will reduce.

6.1. Stress developed by temperature:

Due to the temperature concrete and steel both undergoes stresses. For calculating the stress which is created inside the chimney vertical and circumferential.
Vertical stress

For concrete $f'_{ctv} = \sigma_{te} x C x T_x x E_c$ (18)

For steel $f'_{stv} = \sigma_{te} x (C-1+\gamma_2) x T_x x E_s$

Circumferential stresses

For concrete $f'_{cvc} = \sigma_{te} x C x T_x x E_c$ (19)

For steel $f'_{svv} = \sigma_{te} x (\gamma_2-1-C^1) x T_x x E_s$

These are the maximum stresses of both vertically and circumferentially due to temperature developed by the power plant.

7. Strength design of circular chimney:
Design strength is the bearing limit of the structure. It is the maximum limit with the factor of safety, while the maximum limit was crossed then the structure was collapsed[8]. This is common strength of Concrete and Steel (R.C.C). This is also known as the ultimate strength of the structure.

$$f_c = \frac{0.67e_{cu}f_{ck}}{\gamma_c} \left(2\left(\frac{e}{e_{cu}}\right)^2 - \left(\frac{e}{e_{cu}}\right)^2\right) N/Sq.mm \quad (20)$$

$e_{cu}$=maximum strain in compressive of concrete.

$e_{sf}$=short term load factor $=\frac{0.95-0.1\frac{P_u}{P_{umax}}}{0.85}$

$f_{ck}$=Characteristic compressive strength of concrete.

$\gamma_c=1.5$

8. Results:
8.1.Property:
8.1.1. Height:
Height of chimney calculation followed by (2.1).

$$H = 14 \times (Q)^{0.3}$$

For 1MW generator burn 378.0062Kgs of coal to generate power. But in this research 800MW Generator burns 3,02,400Kgs of coal. Every coal contains 5% of Sulphur present. In 3,02,400 Kg that 5% is 1512, so there is 1512 Sulphur generating per hour[9]. After the Sulphur burned it reacts with oxygen, thus the Sulphur comes up with multiplication to two oxygens than 3024Kg/hr is the discharge of the So2 based on EQ (21)

$$H = 14 \times (3024)^{0.3} = 154.98 \text{ m.} \approx 155 \text{ m}$$

8.1.2. Area of chimney:
$A_1$= Outer diameter considered for this area. $A_2$= Eliminate the assumed thickness for the inside area. Only making for hollow structure this operation happened. EQ(22)

$$A_1 = \pi \times [(R_1^2+R_1^2+R_1+R_1)\times\sqrt{(R_1-R_1)^2+H^2}] = 138573.5895m^2$$

$$A_2 = \pi \times [(R_2^2+R_2^2+R_2+R_2)\times\sqrt{(R_2-R_2)^2+H^2}] = 12901.2788m^2$$

$$A = [A_1-A_2] = 138573.5895-12901.2788=10672.3107m^2$$
8.1.3. Volume of chimney:
Volume is calculating by the following of 3.3 and EQ(23)

\[ V_1 = \frac{\pi}{3}H\left(R_1^2 + r_1^2 + (R_1 + r_1)^2\right) = 45,773.00496 \text{m}^3. \]
\[ V_2 = \frac{\pi}{3}H\left(R_2^2 + r_2^2 + (R_2 + r_2)^2\right) = 42,283.21912 \text{m}^3. \]
\[ V = [V_1 - V_2] = 45,773.00496 - 42,283.21912 = 3489.78583 \text{m}^3. \]

8.2. Load Design:
8.2.1. Dead load:
Volume multiplied by Density of Reinforced concrete.

\[ DL = 3489.7853 \times 25 = 87,244.6325 \text{KN}. \]

8.2.2. Wind load:
Wind loads are more severe than other loads because the chimney is a larger structure towards the sky. While going away from the surface wind effect randomly increased[7]. So, the perfection of the wind load was needed.

\[ V_z = V_b \times K_1 \times K_2 \times K_3 \times K_4 \]

\[ V_b \] is the basic wind speed in the selected location. The current research location in Vijayawada even it is in zone II the basic wind speed 50m/s. \( K_2 \) height factor makes the difference of the wind load at different heights \( z_0 \) is the 0.02 aerodynamic factor for all terrine areas shown in table 1

\[ K_2 = 0.1432 \times \left[ \ln\left(\frac{z}{z_0}\right) \right] \times z_0^{0.0706} \]

Table 1. TerrionRoughness

| No. of. Story | Height of Story | z   | \( K_2 \)  |
|--------------|----------------|-----|------------|
| 1            | 5              | 5   | 0.59609    |
| 2            | 5              | 10  | 0.67092    |
| 3            | 5              | 15  | 0.71469    |
| 4            | 5              | 20  | 0.74575    |
| 5            | 5              | 25  | 0.76984    |
| 6            | 5              | 30  | 0.78953    |
| 7            | 5              | 35  | 0.80617    |
| 8            | 5              | 40  | 0.82058    |
| 9            | 5              | 45  | 0.8333     |
| 10           | 5              | 50  | 0.84467    |
| 11           | 5              | 55  | 0.85496    |
| 12           | 5              | 60  | 0.86436    |
| 13           | 5              | 65  | 0.873      |
| 14           | 5              | 70  | 0.881      |
| 15           | 5              | 75  | 0.88845    |
| 16           | 5              | 80  | 0.89541    |
| 17           | 5              | 85  | 0.90196    |
| 18           | 5              | 90  | 0.90813    |
| 19           | 5              | 95  | 0.91397    |
| 20           | 5              | 100 | 0.91951    |
| 21           | 5              | 105 | 0.92477    |
| 22           | 5              | 110 | 0.92979    |
| 23           | 5              | 115 | 0.93459    |
| 24           | 5              | 120 | 0.93919    |
| 25           | 5              | 125 | 0.9436     |
| 26           | 5              | 130 | 0.94783    |
8.2.3. Design wind loads

Design wind speed is following with \( V_b x K_1 x K_2 x K_3 x K_4 \) readings given in table followed by the IS 4998-2015. Calculated values shown in table 2 [8].

Followed by design wind pressure \( \bar{P}_g = \frac{1}{2} \rho_a |V_g| \) then

Along the wind load is \( F_z = \bar{F}_z + F_z^1 \)

Natural frequency: \( f_1 = 0.2 x \frac{\rho_0}{\rho_a} x \sqrt{\frac{E_c}{\mu_c} x (\rho_0/\mu_0) 0.3} = 0.498 \) Hz

| No. of modes | Height of Story | \( z \) | \( V_Z \) | \( \bar{P}_g \) | \( \bar{F}_z \) | \( F_z^1 \) | \( F_z \) N/m² |
|-------------|----------------|-----|-------|-------|-------|-------|-------|
| 1           | 5              | 5   | 53.46925 | 1715.376 | 8632.216 | 977.6473 | 9609.863 |
| 2           | 5              | 10  | 60.18161 | 2173.096 | 11440.3 | 2591.357 | 14031.65 |
| 3           | 5              | 15  | 64.10809 | 2465.908 | 13554.54 | 4605.386 | 18159.93 |
| 4           | 5              | 20  | 66.89398 | 2684.882 | 15381.78 | 6968.294 | 22350.07 |
| 5           | 5              | 25  | 69.05487 | 2861.145 | 17056.12 | 9658.51 | 26714.63 |
| 6           | 5              | 30  | 70.82046 | 3009.322 | 18638.38 | 12665.41 | 31303.8 |
| 7           | 5              | 35  | 72.31324 | 3137.522 | 20161.11 | 15983.52 | 36144.63 |
| 8           | 5              | 40  | 73.60634 | 3250.736 | 21643.61 | 19610.09 | 41253.7 |
| 9           | 5              | 45  | 74.74694 | 3352.263 | 23098.17 | 23543.99 | 46642.16 |
| 10          | 5              | 50  | 75.76724 | 3444.405 | 24533.05 | 27785.07 | 52318.12 |
| 11          | 5              | 55  | 76.69021 | 3528.833 | 25954 | 32333.81 | 58287.81 |
| 12          | 5              | 60  | 77.53282 | 3606.803 | 27365.16 | 37191.12 | 64556.28 |
| 13          | 5              | 65  | 78.30795 | 3679.281 | 28769.6 | 42358.16 | 71127.77 |
| 14          | 5              | 70  | 79.0256  | 3747.027 | 30169.61 | 47836.32 | 78005.93 |
| 15          | 5              | 75  | 79.69372 | 3810.653 | 31566.96 | 53627.06 | 85194.02 |
| 16          | 5              | 80  | 80.3187  | 3870.657 | 32963.01 | 59731.96 | 92694.97 |
| 17          | 5              | 85  | 80.90579 | 3927.448 | 34358.83 | 66152.65 | 100511.5 |
| 18          | 5              | 90  | 81.4593  | 3981.371 | 35755.28 | 72890.78 | 108646.1 |
| 19          | 5              | 95  | 81.98288 | 4032.716 | 37153.02 | 79948.01 | 117101 |
| 20          | 5              | 100 | 82.4796  | 4081.731 | 38552.61 | 87326.02 | 125878.6 |
| 21          | 5              | 105 | 82.95208 | 4128.629 | 39954.47 | 95026.48 | 134980.9 |
| 22          | 5              | 110 | 83.40258 | 4173.594 | 41358.97 | 103051 | 144410 |
| 23          | 5              | 115 | 83.83304 | 4216.787 | 42766.39 | 111401.3 | 154167.7 |
| 24          | 5              | 120 | 84.24519 | 4258.351 | 44176.95 | 120079 | 164255.9 |
| 25          | 5              | 125 | 84.6405  | 4298.409 | 45590.86 | 129085.6 | 174676.5 |
| 26          | 5              | 130 | 85.02031 | 4337.072 | 47008.26 | 138422.8 | 185431 |
| 27          | 5              | 135 | 85.38578 | 4374.439 | 48429.28 | 148092 | 196521.3 |
| 28          | 5              | 140 | 85.73796 | 4410.599 | 49854 | 158094.9 | 207948.9 |
| 29          | 5              | 145 | 86.07778 | 4445.631 | 51282.5 | 168433 | 219715.5 |
| 30          | 5              | 150 | 86.40608 | 4479.607 | 52714.86 | 179107.7 | 231822.5 |
| 31          | 5              | 155 | 86.72362 | 4512.591 | 54151.1 | 190120.5 | 244271.6 |

Load 105120.5
Wind Graph representation: This figure 1 shows how the attitude of wind load increases height randomly by following table 2.

![Wind Graph representation](Diagram)

**Figure 1. Wind Graph representation**

8.3. Earthquake load

The equivalent static method, lateral loads are calculated by the following method table 3, figure 2.

\[ Q_i = V_h x \left( \frac{W_i x h_i}{\sum_{j=1}^{n} (W_j x h_j)} \right) \]

| hi   | wi   | wihi^2 | wihi^2/wihi^2 | \{wihi^2/wihi^2\} vb |
|------|------|--------|---------------|---------------------|
| 155  | 61664.78794 | 1481496530 | 0.122460335 | 693.0806779 |
| 150  | 59352.72617 | 1335436339 | 0.110387017 | 624.7501118 |
| 145  | 57084.79707 | 1200207858 | 0.099209046 | 561.4868878 |
| 140  | 54861.00664 | 1075275613 | 0.08888216  | 503.0404967 |
| 135  | 52681.33689 | 960117364.8 | 0.079363193 | 449.1666234 |
| 130  | 50545.80581 | 854224118.2 | 0.070610069 | 399.6271465 |
| 125  | 48454.40741 | 757100115.7 | 0.06258181  | 354.1901386 |
| 120  | 46407.14168 | 668262840.1 | 0.055238531 | 312.6298664 |
| 115  | 44404.00862 | 587243014   | 0.048541441 | 274.7267901 |
| 110  | 42445.00824 | 513584599.7 | 0.042452845 | 240.2675641 |
| 105  | 40530.14054 | 446844799.4 | 0.036936141 | 209.0450367 |
| 100  | 38659.4055  | 386594055   | 0.031955821 | 180.8582499 |
| 95   | 36832.80315 | 332416048.4 | 0.027477473 | 155.5124399 |
| 90   | 35050.3346  | 283907701.1 | 0.023467778 | 132.8190366 |
| 85   | 33311.99646 | 240679174.4 | 0.019894513 | 112.5956639 |
| 80   | 31617.79212 | 202353869.6 | 0.016726548 | 94.66613943 |
| 75   | 29967.72046 | 168568427.6 | 0.013933847 | 78.86047499 |
| 70   | 28361.78148 | 138972729.2 | 0.01148747  | 65.01487612 |
| 65   | 26799.97517 | 113229895.1 | 0.00935957  | 52.97174231 |
| 60   | 25282.30153 | 91016285.51 | 0.007523396 | 42.57966969 |
| 55   | 23808.76057 | 72021500.72 | 0.005953289 | 33.69343736 |
| 50   | 22379.35228 | 55948380.7  | 0.004624687 | 26.17403472 |
Figure 2. The lateral loads acting on the Chimney

8.4. Temperature load
Temperature effect on total chimney without liner is calculated by this formula in table 4

\[ \text{Heat drop } T_x = \frac{T_i - T_0}{c + \frac{1}{K_1 + \frac{K_2}{C_c \cdot c + K_3}}} \]

Table 4. Temperature drop

| \(d_{CO}\) | \(d_i\) | \(d_c\) | \(t\) | \(C_c\) | \(T_i\) | \(T_0\) | \(K_1\) | \(K_2\) | \(T_x\) |
|-----------|--------|--------|-----|-------|--------|--------|--------|--------|------|
| 14.70968  | 14.20968 | 14.45968 | 0.5 | 1.73  | 320    | 284    | 20     | 68     | 204.5794 |
| 14.41935  | 13.91935 | 14.16935 | 0.5 | 1.73  | 320    | 284    | 20     | 68     | 204.5056 |
| 14.12903  | 13.62903 | 13.87903 | 0.5 | 1.73  | 320    | 284    | 20     | 68     | 204.4287 |
| 13.83871  | 13.33871 | 13.58871 | 0.5 | 1.73  | 320    | 284    | 20     | 68     | 204.3486 |
| 13.54839  | 13.04839 | 13.29839 | 0.5 | 1.73  | 320    | 284    | 20     | 68     | 204.2649 |
| 13.25806  | 12.75806 | 13.00806 | 0.5 | 1.73  | 320    | 284    | 20     | 68     | 204.1776 |
| 12.96774  | 12.46774 | 12.71774 | 0.5 | 1.73  | 320    | 284    | 20     | 68     | 204.0862 |
| 12.67742  | 12.17742 | 12.42742 | 0.5 | 1.73  | 320    | 284    | 20     | 68     | 203.9905 |
| 12.3871   | 11.8871  | 12.1371  | 0.5 | 1.73  | 320    | 284    | 20     | 68     | 203.8903 |
| 12.09677  | 11.59677 | 11.84677 | 0.5 | 1.73  | 320    | 284    | 20     | 68     | 203.7852 |
| 11.80645  | 11.30645 | 11.55645 | 0.5 | 1.73  | 320    | 284    | 20     | 68     | 203.6748 |
| 11.51613  | 11.01613 | 11.26613 | 0.5 | 1.73  | 320    | 284    | 20     | 68     | 203.5587 |
| 11.22581  | 10.72581 | 10.97581 | 0.5 | 1.73  | 320    | 284    | 20     | 68     | 203.4364 |
8.5. Design for axial and uni-axial load:
All values taken based on the IS4998- 2015 code book. From table 5

| TX  | c   | c'   | α_w | E_s | E_c | f_{stv} | f_{ctv} | f_{cts} | f_{ctv} |
|-----|-----|------|-----|-----|-----|---------|---------|---------|---------|
| 204.57 | 1.89E | 3.79E | 0.00001 | 2.00E+ | 3.35E+ | 9.57E+ | 1.52E+ | 3.04E+ | 9.57E+ |
| 94   | 04  | 04   | 17   | 05   | 10  | 02      | 04      | 04      | 02      |
| 204.50 | 1.89E | 3.79E | 0.00001 | 2.00E+ | 3.35E+ | 9.57E+ | 1.52E+ | 3.03E+ | 9.57E+ |
| 56   | 04  | 04   | 17   | 05   | 10  | 02      | 04      | 04      | 02      |
| 204.42 | 1.89E | 3.79E | 0.00001 | 2.00E+ | 3.35E+ | 9.57E+ | 1.52E+ | 3.03E+ | 9.57E+ |

Figure 3. Temperature drop
|   |   |   |   |   |   |   |
|---|---|---|---|---|---|---|
| 87 | 04 | 04 | 17 | 05 | 10 | 02 |
| 204.34 | 1.89E | 3.79E | 0.00001 | 2.00E+ | 3.35E+ | 9.56E+ |
| 86 | 04 | 04 | 17 | 05 | 10 | 02 |
| 204.26 | 1.89E | 3.79E | 0.00001 | 2.00E+ | 3.35E+ | 9.56E+ |
| 49 | 04 | 04 | 17 | 05 | 10 | 02 |
| 204.17 | 1.89E | 3.79E | 0.00001 | 2.00E+ | 3.35E+ | 9.56E+ |
| 76 | 04 | 04 | 17 | 05 | 10 | 02 |
| 204.08 | 1.89E | 3.79E | 0.00001 | 2.00E+ | 3.35E+ | 9.56E+ |
| 62 | 04 | 04 | 17 | 05 | 10 | 02 |
| 203.99 | 1.89E | 3.79E | 0.00001 | 2.00E+ | 3.35E+ | 9.56E+ |
| 05 | 04 | 04 | 17 | 05 | 10 | 02 |
| 203.89 | 1.89E | 3.79E | 0.00001 | 2.00E+ | 3.35E+ | 9.56E+ |
| 3 | 04 | 04 | 17 | 05 | 10 | 02 |
| 203.78 | 1.89E | 3.79E | 0.00001 | 2.00E+ | 3.35E+ | 9.56E+ |
| 52 | 04 | 04 | 17 | 05 | 10 | 02 |
| 203.67 | 1.89E | 3.79E | 0.00001 | 2.00E+ | 3.35E+ | 9.56E+ |
| 48 | 04 | 04 | 17 | 05 | 10 | 02 |
| 203.55 | 1.89E | 3.79E | 0.00001 | 2.00E+ | 3.35E+ | 9.56E+ |
| 87 | 04 | 04 | 17 | 05 | 10 | 02 |
| 203.43 | 1.89E | 3.79E | 0.00001 | 2.00E+ | 3.35E+ | 9.56E+ |
| 64 | 04 | 04 | 17 | 05 | 10 | 02 |
| 203.30 | 1.89E | 3.79E | 0.00001 | 2.00E+ | 3.35E+ | 9.56E+ |
| 75 | 04 | 04 | 17 | 05 | 10 | 02 |
| 203.17 | 1.89E | 3.79E | 0.00001 | 2.00E+ | 3.35E+ | 9.56E+ |
| 14 | 04 | 04 | 17 | 05 | 10 | 02 |
| 203.02 | 1.89E | 3.79E | 0.00001 | 2.00E+ | 3.35E+ | 9.56E+ |
| 75 | 04 | 04 | 17 | 05 | 10 | 02 |
| 202.87 | 1.89E | 3.79E | 0.00001 | 2.00E+ | 3.35E+ | 9.56E+ |
| 51 | 04 | 04 | 17 | 05 | 10 | 02 |
| 202.71 | 1.89E | 3.79E | 0.00001 | 2.00E+ | 3.35E+ | 9.56E+ |
| 34 | 04 | 04 | 17 | 05 | 10 | 02 |
| 202.54 | 1.89E | 3.79E | 0.00001 | 2.00E+ | 3.35E+ | 9.56E+ |
| 15 | 04 | 04 | 17 | 05 | 10 | 02 |
| 202.35 | 1.89E | 3.79E | 0.00001 | 2.00E+ | 3.35E+ | 9.56E+ |
| 85 | 04 | 04 | 17 | 05 | 10 | 02 |
| 202.16 | 1.89E | 3.79E | 0.00001 | 2.00E+ | 3.35E+ | 9.56E+ |
| 32 | 04 | 04 | 17 | 05 | 10 | 02 |
| 201.95 | 1.89E | 3.79E | 0.00001 | 2.00E+ | 3.35E+ | 9.56E+ |
| 43 | 04 | 04 | 17 | 05 | 10 | 02 |
| 201.73 | 1.89E | 3.79E | 0.00001 | 2.00E+ | 3.35E+ | 9.56E+ |
| 04 | 04 | 17 | 05 | 10 | 02 |
| 201.48 | 1.89E | 3.79E | 0.00001 | 2.00E+ | 3.35E+ | 9.56E+ |
| 98 | 04 | 04 | 17 | 05 | 10 | 02 |
| 201.23 | 1.89E | 3.79E | 0.00001 | 2.00E+ | 3.35E+ | 9.56E+ |
| 05 | 04 | 04 | 17 | 05 | 10 | 02 |
| 200.95 | 1.89E | 3.79E | 0.00001 | 2.00E+ | 3.35E+ | 9.56E+ |
| 03 | 04 | 04 | 17 | 05 | 10 | 02 |
| 200.64 | 1.89E | 3.79E | 0.00001 | 2.00E+ | 3.35E+ | 9.56E+ |
| 66 | 04 | 04 | 17 | 05 | 10 | 02 |
| 200.31 | 1.89E | 3.79E | 0.00001 | 2.00E+ | 3.35E+ | 9.56E+ |
| 63 | 04 | 04 | 17 | 05 | 10 | 02 |
### 8.6. Design strength

Design strength with a factor of safety.

\[
f_c = \frac{0.67 \epsilon_y f_{ck}}{Y_c} \left( 2 \left( \frac{\epsilon}{\epsilon_{y}} \right)^2 - \left( \frac{\epsilon}{\epsilon_{cu}} \right)^2 \right) = 14.70333 \text{N/Sq.mm}
\]

\[
\epsilon = 0.00173
\]

\[
\epsilon_{cu} = 0.002
\]

\[
f_{ck} = 30
\]

\[
\epsilon_s f = \frac{0.95 - 0.1 \frac{P_{u}-P_{max}}{P_{u}}}{0.85} = \frac{[0.95 - 0.1(1.22072*10^{-4})]}{0.85} = 1.117632621
\]

\[
Y_c = 1.5
\]

---

### 8.7. Validation with software’s

STAAD Pro and ANSYS are used in this research

#### 8.7.1. STAAD Pro

Software used for the analysis of the chimney that shows different deflections in different load combination[10]

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![Figure 4. DL+WL X+TL](image)

![Figure 5. DL+EL X+TL](image)
After that plate stress also shown min-max top plate stress fig shown.

8.7.2 ANSYS

It shows the direction of wind load acting. The direction of the chimney and also the deflection effect of the chimney [11].
9. Conclusion
1. This research of chimneys is for VTPS newly proposed 800MW generator.
2. This chimney design strength $f_c = 14.70333$N/Sq.mm.
3. Maximum displacement $\delta = 2.32798$ mm.
4. This research calculations are successfully done by both numerical design and software analysis.
5. This Chimney design is analyzed by Staad pro and simulated by Ansys software.

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