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STUDY OF DESIGN OF RCC CHIMNEY AND ANALYSIS FOR WIND LOAD AND EARTHQUAKE FORCES

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A B S T R A C T

Reinforced chimneys are used in power plants to take the hot and poisonous flue gas to a great height. Code of practice for design of reinforced concrete chimney (Third revision of IS 4998:2015) is used for the analysis. The location selected for the study is **Bellary** in **Karnataka.** Wind load and Earthquake forces are considered for this study. The analysis is done on 250m tall RCC chimney. The main focus is to study the wind analysis result and the Earthquake forces with wind zones I, II, III, IV And EQ zones II,III,IV,V. We referred IS 4998 2015, IS 875:2015, IS 1893 (part 4):2005 and IS 1893(part1):2016. The analysis is carried out for 8 models by using STAAD PRO software and MS Excel.

Keywords: RCC Chimney , Earthquake loads , Wind loads , Combined design loads , Zone factor

1. Introduction

Chimneys are tall and slender structures which are used to discharge waste/flue gases at higher elevation with sufficient exit velocity such that the gases and suspended solids (ash) are dispersed into the atmosphere over a defined spread such that their concentration, on reaching the ground is within acceptable limits specified by Pollution Control Regulatory Authorities. Now a days due to rapid industrialization, a huge demand for tall chimney structures came into existence.

1.1Objective

The main objective of this project is to study the design of RCC chimney, calculation of wind load and earthquake forces by using IS code and the comparative study of wind load and earthquake forces for different zones. Design and analysis is done considering the load combination dead load+ wind load + Earthquake forces. Different wind zones and earthquake zones are considered for this study.

1.2Methodology

The methodology includes the selection of type of chimney and finalized the dimensions of components for the selected chimney. The present study considers IS 4998 2015, IS 875:2015, IS 1893(part 4):2005 and IS 1893(part 1):2016. Modeling and analysis of chimney is done using STAAD-PRO software. In this study a 250m height RCC chimney is considered for analysis It is analyzed for Zone I Zone II Zone III & Zone IV for the same height. Lastly, the result of the analysis of RCC chimney for all the wind zone has been compared.

2. Design methodology

2.1 Preliminary Data

Height (m) : 250 m

1/3 rd height (m) : 166.6667

Diameter at 1/3 height (m)

H/D ratio : 12

Y- Increment = 10

Height- Base diameter ratio = 12

Slope (taper) or batter of the chimney = 1 in 50

Grade of concrete = M25

Table 1: Description of Wind models.

Model No.	Zones	Outer dia. at top (m)	Outer dia. at bottom (m)	Thickness of shell at top (m)	Thickness of shell at bottom(m)
1	I	20.2	20.3	0.2	0.23
2	II	20.2	20.3	0.2	0.3
3	III	20.28	20.38	0.28	0.38
4	IV	20.32	20.42	0.32	0.42

Table 2: Description of Earthquake models.

Model No.	Zones	Outer dia. at top (m)	Outer dia. at bottom (m)	Thickness of shell at top (m)	Thickness of shell at bottom(m)
1	II	20.2	20.3	0.2	0.23
2	III	20.2	20.3	0.2	0.3
3	IV	20.28	20.38	0.28	0.38
4	V	20.32	20.42	0.32	0.42

Fig. RCC Chimney

3. Calculation of Loads

Loads acting on RCC Chimney:

• Self weight

- Earthquake loads
- Wind loads

3.1 Calculation of along wind loads:

the along wind load, F(z) can be calculated for unit height of chimney at any section, Z is equal to the summation of the mean along-wind load $\overline{F}(z)$ and the fluctuating component F'(z) of along-wind load.

$$F(z) = \overline{F}(z) + F'(z)$$

Here, the mean along wind load

$$\overline{F}(z) = \overline{C}_D \, d(z) \overline{p}(z)$$

Where, $\overline{C}D$ = mean drag coefficient = 0.8

d(z) = outer diameter of chimney at height z.

The fluctuating component of along wind in N/m at height z shall be computed as

$$F'(z) = 3\frac{(G-1)}{H^2}\left(\frac{z}{H}\right)\int_0^H \overline{F}(z)\, z\, dz$$

Where, G = Gust response factor.

H = total height of the chimney above ground level in m.

$$G = 1 + g_f r_t \sqrt{B + \left(\frac{SE}{\beta}\right)}$$

where

gf = peak factor, defined as the ratio of expected peak value to root mean square value of the fluctuating load, given by:

$$\nu T = \frac{3\,600\, f_1}{\left(1 + \frac{B\beta}{SE}\right)^{1/2}}$$

Where

v = effective cycling rate

T = sample period taken as 3 600 s

*r*t = twice the turbulence intensity at the top of the chimney, given by :

*r*t = 0.622 – 0.178 log10 H

B = background factor indicating the slowly varying component of wind load fluctuations, given by:

$$B = \left\{1 + \left(\frac{H}{265}\right)^{0.63}\right\}^{-0.88}$$

E is a measure of available energy in the wind at the natural frequency, given by:

$$E = \frac{\left\{123\left(\frac{f_1}{\overline{V}(10)}\right)H^{0.21}\right\}}{\left\{1 + \left(330\frac{f_1}{\overline{V}(10)}\right)^2 H^{0.42}\right\}^{0.83}}$$

S = size reduction factor, given by:

$$S = \left\{1 + 5.78\left(\frac{f_1}{\overline{V}(10)}\right)^{1.14} H^{0.98}\right\}^{-0.88}$$

$\overline{V}(10)$ = mean hourly wind speed at 10 m height above ground level (m/s),

β= structural damping as a fraction of critical damping to be taken as 0.016 for along-wind loads, and

*f*1 = natural frequency of unlined chimney in the first mode of vibration, in Hz, as per **5.5.8**.

$$f_1 = 0.2\left(\frac{d_0}{H^2}\right)\sqrt{\frac{E_{ck}}{\rho_{ck}}}\left(\frac{t_0}{t_H}\right)^{0.3}$$

where

t0 = thickness of the shell at bottom, in m ;

*t*H = thickness of the shell at top, in m;

d0 = centerline diameter of the shell at bottom in m ;

ρck = mass density of concrete, kg/m3 ; and

Eck = dynamic modulus of elasticity of concrete, in N/m2.

3.2 Calculation of across-wind load: -

Across wind load shall be calculated as given below:

According to the IS code, across-wind loads due to vortex shedding in the first and second modes shall be considered in the design of all chimney shells when the critical wind speed

Vcr is between 0.5$V(zref\ )$ and 1.3$V(zref\ )$. Across-wind loads need not be considered outside this range. For the five models selected, the across wind effects are not considered as the critical wind speed was outside the range specified by the code.

$$M_{ac} = \left[g_{ac} S_s C_L \frac{\rho_a V_{cr}^2}{2} d_e H^2 \right] \times \left[\frac{\pi}{4(\beta_s + \beta_a)} \right]^{0.5} S_P \left\{ \frac{2L}{\left(\left(\frac{H}{d_e} \right) + C_E \right)} \right\}^{0.5}$$

where

*S*s = mode shape factor taken as 0.57 for the 1st mode and 0.18 for the 2nd mode.

CE = end effect factor taken as 3.

*g*ac = peak factor for across-wind load taken as 4.0.

*d*e = effective diameter taken as average outer diameter over top one-third height of chimney (m).

CL = RMS lift coefficient and is given by :

CL = CLo F1B

where

CLo = RMS lift coefficient modified for local turbulence and is given by:

$$C_{Lo} = -0.243 + 5.648\, I_{ref} - 18.182 \left[I_{ref} \right]^2$$

Where,

$$I_{ref} = \frac{1.0}{\ln\left(\frac{z_{ref}}{z_0} \right)}$$

zref = reference height, given by :

zref = (5/6)H

$$F_{1B} = -0.089 + 0.337 \ln\left(\frac{H}{d_e} \right)$$

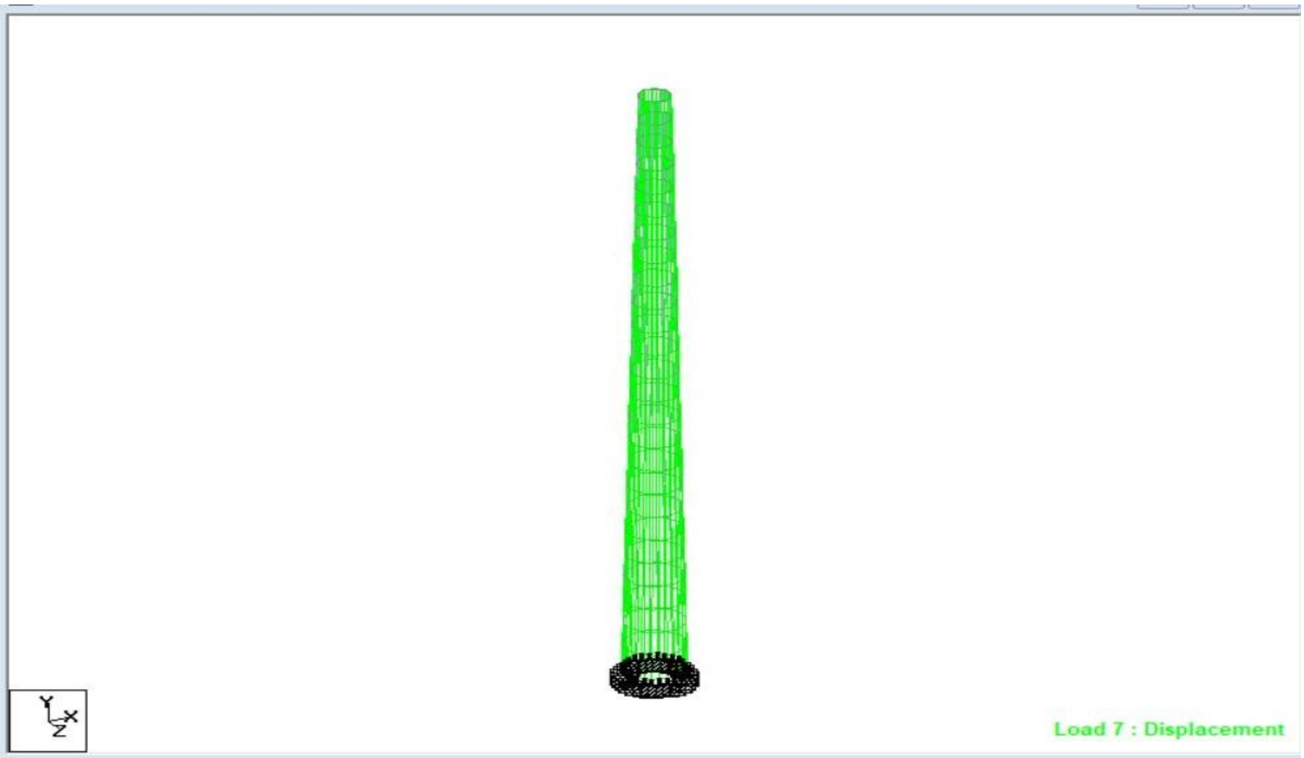
F1B shall be between 0.2 and 1.0.

$$V_{cr} = \frac{f_1 d_e}{S_t}$$

for the first mode, and

= 5 *f*2 *de* for the second mode

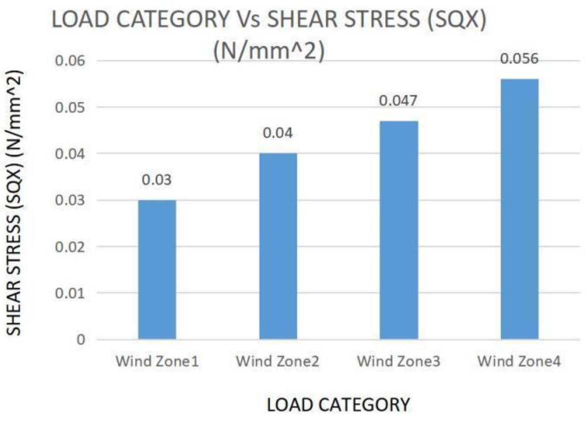
Design of Model Using STAAD Pro



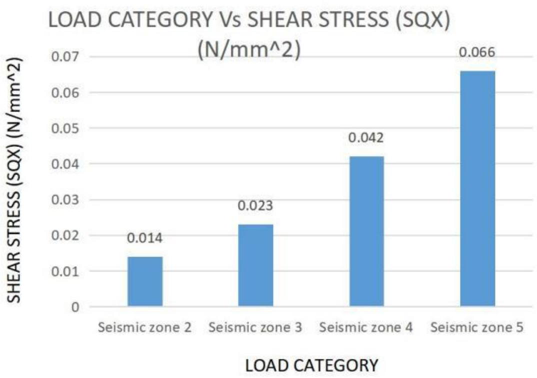
4.RESULT AND DISCUSSIONS

RESULT: The main objective of this project is to analysis the rcc chimney for different wind zones and earthquake zones by used STAAD PRO software

Shear stress of earthquake and wind.

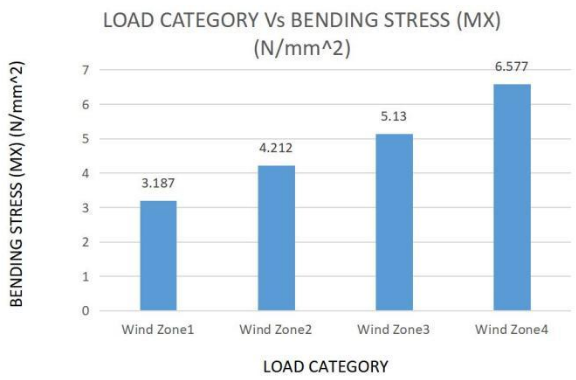


From the above graph of load category vs shear stress along x, it is observed that as the load category of wind load is increasing the shear stress along x is also increasing.

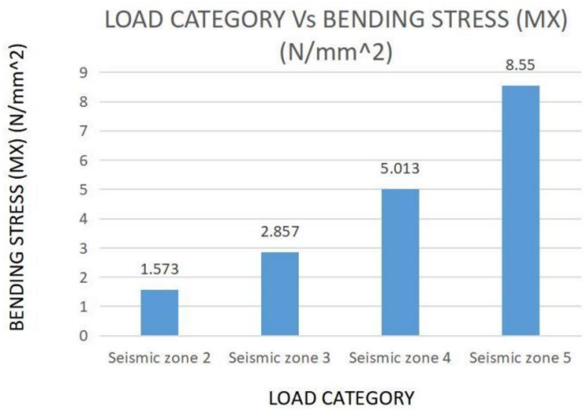


From the above graph of load category vs shear stress along x, it is observed that as the load category of earthquake load is increasing the shear stress along x is also increasing.

Bending stress for different load category of wind and earthquake



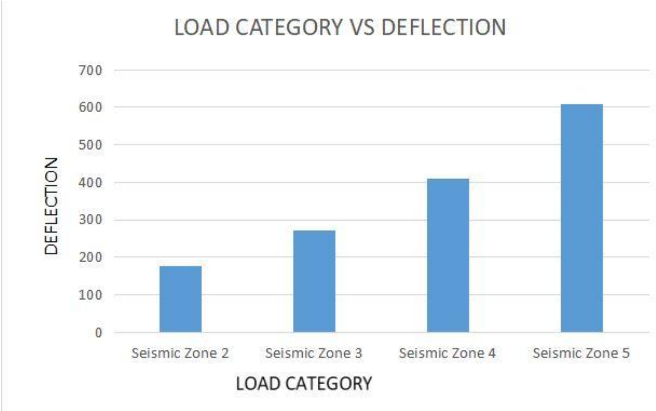
From the above graph of load category vs bending stress along x, it is observed that as the load category of wind load is increasing the bending stress along x is also increasing .



From the above graph of load category vs bending stress along x, it is observed that as the load category of wind load is increasing the bending stress along x is also increasing .

Graph For Deflection

From the above graph of load category vs deflection along x, it is observed that as the load category of wind load is increasing the deflection along x is also increasing .



From the above graph of load category vs deflection along x, it is observed that as the load category of seismic load is increasing the deflection along x is also increasing .

5.CONCLUSIONS

From this project we conclude that the following:

1. In wind load the load category is increasing, the shear force and bending moment alongx is also increasing.

2. In earthquake load the load category is increasing, the shear force and bending moment along x is also increasing.

3. The load category of wind is increasing, the thickness and deflection is also increasing.

4. The load category of earthquake is increasing, the thickness and deflection is also increasing.

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