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Effect of Geometric Parameter on Steel Chimney

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Abstract: Analysis of self-supporting steel flared unlined chimney is presented in this paper. Chimneys have become an essential part of industrial growth and to plays important role in reducing the environmental hazard caused by the large scale industries. These are tall and slender structures. The chimney's functioning is based on the natural draft or stack effect, we know that, the density of the gases diminishes with rise in its temperature, because of this when the flue gases gets inside the chimney, the buoyancy forces of air comes into action and help in lifting the flue gases out of the chimneys. We have studied the behavior of steel chimney when subjected to different wind loads in a specific seismic zone. The geometric parameter such as height to base diameter ratio is kept varying. Also the effect of providing manhole opening to the steel chimney has been studied. The loads on chimney were calculated manually and the analysis is performed using Staad Pro.
***Keywords**: Chimney, Geometric, Parameters, Slender, Staad Pro.*

I. INTRODUCTION

From last few years industrial chimneys experienced considerable advancements in structural modelling as well as in materials used for its construction. Industrial chimney are emitting various noxious gases, smoke and ashes. The main intent of chimney is to let off highly toxic gases to greater altitude with sufficient velocity since they are not tolerable at ground level.

Chimneys are accountable for industrial surge in any developing nation and in diversified geometric parameters such as height, diameter, shape of the structure, etc. chimney can be of concrete, masonry and steel. They can be self-supported or guyed structures. From internally they can be classified as lined or unlined chimney. These are slender structures given that they are having incredible height are constantly susceptible to great wind loads as well as to occasional seismic loads. Hence, it is vital to study the behavior of industrial chimney under such conditions.

The erroneous design and construction of chimney may affect its neighborhood as poisonous gases are culpable for numerous diseases and will lead to casualties. Hence, safety measures and economical plan are also crucial criteria in the designing of industrial chimney.

The objective of our project is to have a comparative study of the effect of wind load on industrial steel chimney using STAAD Pro Vi8. Various self-supporting steel flared unlined chimneys are analyzed for the prevailing wind forces and earthquake loads and bending moments which are calculated using IS 6533 (part1 &2): 1989 and are also plotted. Different height-to-base diameter ratio are considered for our project. Maximum bending moments for all the chimneys were calculated manually for the wind intensities and using MS-Excel sheets and are plotted.

Fig.1 Industrial chimney

II. METHODOLOGY

A. Assumptions while Designing Chimney

1) The wind pressure varies with the height. It is zero (0) at ground and increase as the height increases. For designing it is assumed that the wind pressure is uniform and acts throughout the height of the structure.
2) The calculation purpose of static wind. It is assumed that the load (projected area multiplied by the wind pressure) is acting at the centre of pressure.
3) Base of the stack is perfectly stiff and the effect of the stool plate and gussets on the stresses and the deflection in the stack is not considered. It is applicable for manual calculations only.
4) There are no extra lateral movements from duct transferred to the stack and suitable arrangement has to be provided to absorb this movement from the duct.
5) Earthquake causes abrupt ground motions, which are complex and uneven in character, changing in amplitude and period each for a small duration. Therefore resonance of the type as envisioned under steady-state sinusoidal excitations will not occur.
6) Earthquake is not possibly to occur simultaneously with maximum wind, flood or sea waves.

B. Loadings and Load Combinations

The following loads are to be considered while designing the steel chimney:

1) *Self-weight of Chimney:* Weight of the (access ladder + platform + rain cap + helical strake + etc.) is assumed to be 20% of the self-weight of chimney shell.
2) *Wind load:* As per IS 875 (Part 3): 1987 basic wind speed is to be calculated as,

$$\boxed{\mathbf{V_z = V_b \times K_1 \times K_2 \times K_3}}$$

Where,
V_z = Design wind speed m/s,
V_b = Basic wind speed m/s,
K_1 = Probability factor (risk coefficient),
K_2 = Height, terrain and structure size factor,
K_3 = Topography factor.
Static force = C x Pz x area of segment
Design wind pressure (Pz) = 0.6 x Vz
Shape factor for steel (C) = 0.7

3) *Earthquake Load*

By, Response Spectrum Method
This method steps such as,

a) Fundamental period
b) Horizontal seismic force

The fundamental period of free vibration is calculated as follows:

$$\boxed{\mathbf{T = C_t\,(\sqrt{(W_t \times h) / (E_s \times A \times g)})}}$$

Where,
C_t = coefficient depending on slenderness ratio,
W_t = Total weight of the structure i.e. contents above the base and weight of lining,
A = Cross-sectional area at the base of structural shell,
E_s = modulus of elasticity of material of structural shell,
g = acceleration due to gravity,
h = height above the base.

Stiffness of the flared chimney is approximately two times the prismatic chimney.
For, Horizontal seismic force,

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The horizontal seismic force (A_h) is calculated according to IS 1893 Part 1: 2002 as follows:

$$\boxed{A_h = (Z/2) \times (S_a/g) \times (I/R)}$$

Where
Z = Zone Factor
I = Importance factor
R = Response reduction factor. The ratio should be more than 1.0
$S_{a/g}$ = Spectral acceleration coefficient.

C. Description of Chimneys for Selected wind and Seismic Load

In the present paper, analysis of steel chimney with height 50 m, 70 m, 90 m; for seismic zone II is performed. The basic wind velocity is kept as 39 m/s, 44 m/sec and 47 m/s acting on chimney. The chimney is divided into number of sections along height for calculation purposes. The wind load and moment at base were calculated manually and bending stress at different location of the chimney were obtained using Staad PRO. Validation of the results obtained in the present study was done by comparing the results available in the Wind & earthquake analysis of self-supported steel chimney: Project by: Satish Kumar (M. Tech. Student) & Babita Saini (Associate Prof.) [1] and it was found that the results were in conformity.

III. RESULTS AND DISCUSSION

A. Results after analysing steel chimney in Staad PRO

1) *For V_b=39m/s:* The maximum stress were obtained for lower basic wind speed of 39 m/s and the stress obtained are as follows

The figure 2 shows the maximum stresses in chimney subjected to basic wind speed of 39 m/s for different height to base diameter ratio. The stresses obtained for chimney having h/D = 12 are *11667.70* KN/m^2, *18467.10* KN/m^2 and *19884.50* KN/m^2 for 50 m, 70 m and 90 m height respectively; for chimney having h/D = 15 are *19164.17* KN/m^2, *21272.60* KN/m^2 and *23437.55* KN/m^2 for 50 m, 70 m and 90 m height respectively; for chimney having h/D = 18 are *24549.40* KN/m^2, *25189.20* KN/m^2 and *28101.42* KN/m^2 for 50 m, 70 m and 90 m height respectively.

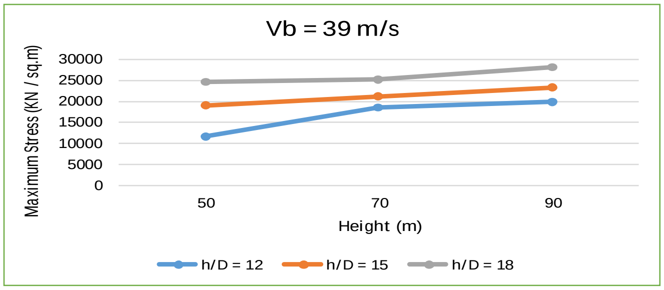

Fig.2 Maximum Stress for V_b = 39m/s

2) *For V_b=44m/s:* The maximum stress were obtained for lower basic wind speed of 44 m/s and the stress obtained are as follows

The figure 3 shows the maximum stresses in chimney subjected to basic wind speed of 44 m/s for different height to base diameter ratio. The stresses obtained for chimney having h/D = 12 are *14821.52* KN/m^2, *23504.50* KN/m^2 and *25310.72* KN/m^2 for 50 m, 70 m and 90 m height respectively; for chimney having h/D = 15 are *24279.33* KN/m^2, *27075.85* KN/m^2 and *29984.95* KN/m^2 for 50 m, 70 m and 90 m height respectively; for chimney having h/D = 18 are *27737.14* KN/m^2, *30647.27* KN/m^2 and *34659.18* KN/m^2 for 50 m, 70 m and 90 m height respectively.

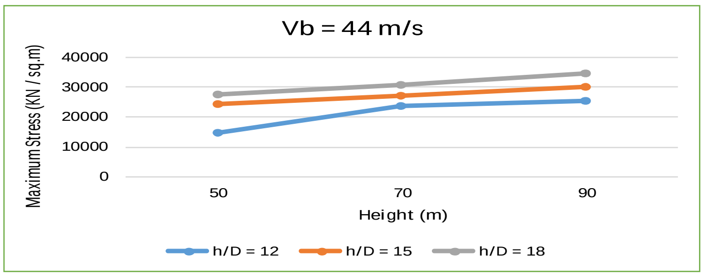

Fig.3 Maximum Stress for V_b = 44m/s

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3) For V_b=47m/s: The maximum stress were obtained for lower basic wind speed of 47 m/s and the stress obtained are as follows The figure 4 shows the maximum stresses in chimney subjected to basic wind speed of 47 m/s for different height to base diameter ratio. The stresses obtained for chimney having h/D = 12 are *24713.81* KN/m^2, *26526.94* KN/m^2 and *28566.42* KN/m^2 for 50 m, 70 m and 90 m height respectively; for chimney having h/D = 15 are *27348.46* KN/m^2, *30557.89* KN/m^2 and *33913.42* KN/m^2 for 50 m, 70 m and 90 m height respectively; for chimney having h/D = 18 are *29983.14* KN/m^2, *35699.77* KN/m^2 and *40370.54* KN/m^2 for 50 m, 70 m and 90 m height respectively.

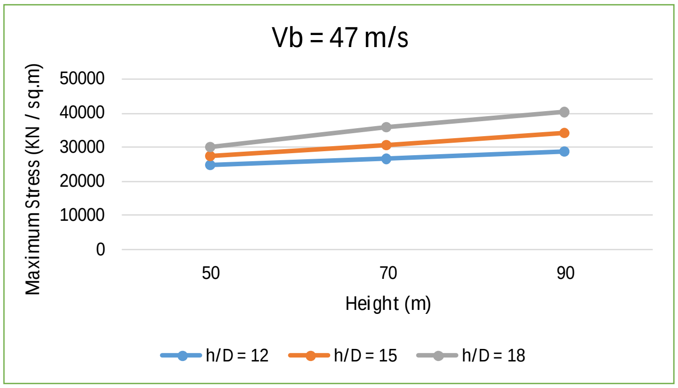

Fig.4 Maximum Stress for V_b = 47m/s

It can be observed that, figure 2, 3 and 4 shows same trend in the chart i.e. as the as the height increases the stress increases in the chimney also as the height to base diameter ratio increases the stress in the chimney increases.

B. Effect Of Inspection Manhole On The Behaviour Of Self-Supporting Steel Chimney

Manholes are mostly provided near the base of the chimney but above the flared portion for maintenance and inspection purpose. For inspection manhole, maximum stresses were calculated using STAAD PRO. The dimension of the manhole were designed by manual calculation for 50 m, 70 m, and 90 m high steel chimney having height to base diameter ratio as 15.

Six steel chimney models, three with manhole and three without manhole, were analysed using STAAD PRO for wind load as it plays important factor while designing as compared to seismic load.

Using Staad PRO the stresses are found out to be *24279.33* KN/m^2, *27075.85* KN/m^2, and *29984.95* KN/m^2 for 50 m, 70 m, and 90 m chimney respectively. As it can be observed from figure 5, that the maximum stresses occurred at the base of the chimney over a large portion so it can be concluded that the chimney without manhole has the chances of failure at its base.

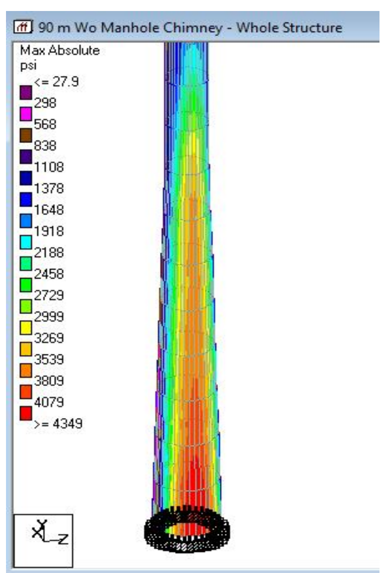

Fig.5 Maximum Stress for 90m w/o manhole chimney

Using Staad PRO the stresses are found out to be *38014.72* KN/m^2, *42451.77* KN/m^2, and *48824.46* KN/m^2 for 50 m, 70 m, and 90 m manhole chimney respectively. As it can be observed from figure 6, that the maximum stresses occurred at the sides of the manhole opening over a small portion so it can be concluded that the chimney with manhole in spite of carrying more stress than chimney's without manhole will not fail at its base.

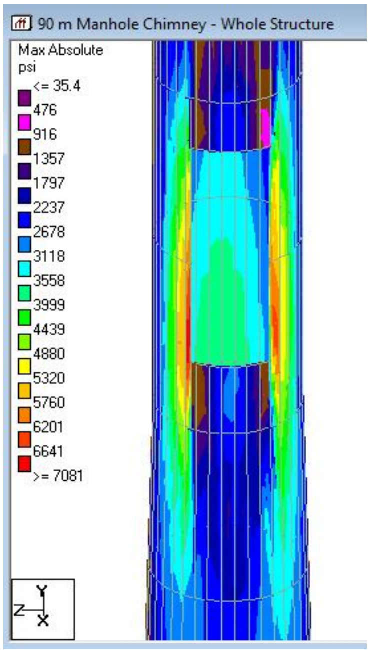

Fig.6 Maximum Stress for 90m with manhole chimney

TABLE I
Maximum Stresses For With and Without Manhole Chimney Comparison

Height (m)	Maximum Stresses (KN/m^2)	
	Manhole Chimney	Without Manhole Chimney
50	24279.33	38014.72
70	27075.84	42451.77
90	29984.45	48824.46

The below figure 7, represents the maximum stress for chimney without manhole as well as for chimney with manhole with varying height of 50 m, 70 m, and 90 m all having same height to base diameter ratio as 15. It can be observed from the chart that there is more bending stress in chimney with manhole about 56 % to 63% as compared to chimney without manhole. For 50 m, 70 m and 90 m high chimney with manhole the increase in stresses was found to be *56.57* %, *56.58* % and *62.68* % when compared to chimney without manhole.

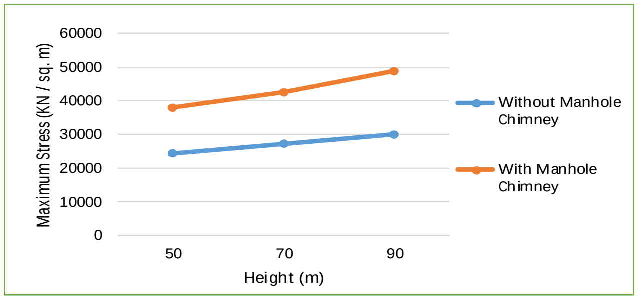

Fig.7 Stress chart for with and w/o manhole chimney

IV. CONCLUSION

A. Future Scope

1) Analysis considering geometric parameter of different top to base diameter ratio and its effect on the bending stress of the steel chimney can be done.
2) Effect of seismic load considering different seismic zones can also be studied.
3) Across-wind wind can be analysed through computational fluid dynamics using finite element software ANSYS.
4) The present study considers only self-supporting steel chimney. This study can be further extended to concrete chimney as well as guyed steel chimney.

C. Conclusion

1) For high wind intensity and low risk earthquake zone, wind loads were more prominent. Hence, chimney must be analysed for wind forces.
2) It was observed from the result obtained from manual calculation and software developed in STAAD PRO, for maximum moment are similar.
3) The maximum bending stress due to wind load in a self-supporting steel chimney are continuous function of the geometry height to base diameter ratio as it is observed that as the ratio increases the stresses in the steel chimney also increases.
4) There is maximum bending stresses in case of chimney with inspection manhole as compared to chimney with no inspection manhole. This is because manhole decreases the effective rigidity of a chimney. Therefore, it is important to consider manhole opening in the analysis and design of self-supporting steel chimney.

REFERENCES

[1] K. Sachidanandam., R. Vijaya Sarathy., 2016; Analytical Behaviour of Steel Chimney subjected to Dynamic Loading. International Journal of Innovative Research in Science, Engineering and Technology.
[2] Sagar, S., Basavaraj, G., 2015; Performance based seismic evaluation of industrial chimney by static and dynamics analysis. International Research Journal of Engineering and Technology.
[3] Praveen K., Dr. Ajay S., 2016; Analysis of self-supporting steel chimney. IJARIIE.
[4] Santhi K., Sridhar P., 2017; Analysis of self-supported steel chimney; International Journal for Research in Applied Science & Engineering Technology.
[5] Satish K., Babita Saini., 2016; Wind and Earthquake Analysis of Self-supported Steel Chimney; Department of Civil Engineering, National Institute of Technology, Kurukshetra.
[6] Jain, S.K. and Singh, B.P; 1992; IS code provision for seismic design of tall chimneys. International Journal of Structure.
[7] Kiran, N.R., 2001. Analysis and Design of Reinforced Concrete Chimneys. Bachelor of Technology major project, Department of Civil Engineering, Indian Institute of Technology Madras.
[8] Kumar, R. and Patil, B.V., 2013. Analysis of Self Supporting Chimney. International Journal of Innovative Technology and Exploring Engineering.
[9] Rakshith, B.D., Ranjith, A., Sanjith, J. and Chethan, G., 2015. Analysis of Cantilever steel chimney as per Indian Standards. International Journal of Engineering Research and Applications.
[10] Reddy, K.R.C, Jaiswal, O.R. and Godbole P.N., 2011. Wind and Earthquake Analysis of Tall RC Chimneys. Journal of Earth Sciences and Engineering.
[11] Shaikh, M.G. and Khan, H.A.M.I., 2009. Governing loads for design of a tall RCC chimney. Journal of Mechanical and Civil Engineering (lOSRJMCE).
[12] Rohini, V., Padmavathi, B., Reddy, S.K. and Srikanth, S.; 2012. Study of wind load effects on tall RC chimneys. International Journal of Advanced Engineering Technology.
[13] Kirtikanta Sahoo, Pradip Sarka, Robin Davis; Analysis of Self-supported chimney Steel Chimney with the Effects of Manhole and Geometrical Properties, International Journal of Scientific and Engineering Research.
[14] IS 6533 (Part 1) 1989: DESIGN AND CONSTRUCTION OF STEEL CHIMNEY – MECHANICAL ASPECT; Published by Bureau of India Standard, New Delhi.
[15] IS 6533 (Part 2) 1989: DESIGN AND CONSTRUCTION OF STEEL CHIMNEY – STRUCTURAL ASPECT; Published by Bureau of India Standard, New Delhi.
[16] IS 875 (Part 3) 1987: DESIGN LOADS (OTHER THAN EARTHQUAKE) FOR BUILDINGS AND STRUCTURES – WIND LOADS; Published by Bureau of India Standard, New Delhi.
[17] IS 1893 (Part 1) 2002: CRITERIA FOR EARTHQUAKE RESISTANT DESIGN OF STRUCTURES – GENERAL PROVISIONS AND BUILDINGS; Published by Bureau of India Standard, New Delhi.