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Analysis of Self Supported Steel Chimney as Per Indian Standard

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***Abstract**: Most of the Industrial chimneys are tall structures with circular cross-sections. Such slender, lightly damped structures are prone to wind-exited vibration. Geometry of a self supporting steel chimney plays an important role in its structural behaviour under lateral dynamic loading. This is because geometry is primarily responsible for the stiffness parameters of the chimney. However, basic dimensions of industrial self supporting self supporting steel chimney such as height, diameter at exit, etc., are generally derived from the associated environmental conditions. Manholes are provided at the bottom of the chimney for inspection purpose of the chimney. The presence of manhole reduces the cross section area and hence the stiffness of the chimney. In the present study investigates the stresses, deflection and mode shapes of the chimney due to the presence of an inspection manhole. Maximum Von Mises stress, top deflection and mode shapes were calculated using finite element software ANSYS. The results show that, the due to the presence of manhole, the stresses are increased by approximately 1.5 times for the chimney and frequency is decreased by approximately 1.12 times.*

***Key words:** steel chimney, Dynamic wind load, Static wind load, Von mises stress, Deflection, Mode*

I. Introduction

This paper deals with the analysis of self-supported-steel chimneys. Tall steel chimneys are presently planned in compliance with various codes of practice (IS 6533[1, 2], CICIND[3] etc.). The chimney is considered as cantilever column with tubular cross section for analysis. Wind loads, temperature loads, seismic loads and dead loads are considered for design purpose. But apart from these loads, wind load is considered as most vital load due to height of the structure. The effect of wind can be divided into two components: (a) along-wind effect (b) across-wind effect. But the across-wind effect is most critical and unpredictable. The bottom portion of the chimney is constructed as conical flare for better stability and for easy entrance of flue gases. Design forces in a chimney is very sensitive to its geometrical parameters such as base and top diameter of the chimney, height of the flare, height of the chimney and thickness of the chimney shell. Height of the chimney is governed by environmental conditions. As per recommendations of the Ministry of Environment and Forests[5], Govt. of India, height of a self-supporting steel chimney should be as follows:

$$h = \max \begin{cases} 14Q^{0.3} \\ 6\text{m} + \textit{Tallest Building heigh in location} \\ 30\text{m} \end{cases}$$

Where Q= total SO_2 emission from the plant in kg/hr and h = height of the steel chimney in m.
As per IS-1653 Part-1: 1989[1], height of steel chimney is also a function of environmental conditions as follows:

$$h = \left[\frac{AMFD}{8\,CV}\right]^{\frac{3}{4}}$$

Where A = coefficient of temperature gradient of atmosphere responsible for horizontal and vertical mixing of plume, M = estimated mass rate of emission of pollutants in g/s, F = dimensionless coefficient of rate of precipitation, C = maximum permissible ground level concentration of pollutant in mg/m^3, gases, m^3/s, D = diameter of stack at the exit of the chimney in m. V = estimated volume rates of emission of total flueme.
Also, inside diameter of the chimney shell at top as per IS 6533 (Part 1): 1989 is given by:

$$D = \sqrt{\frac{4\,Q_t}{\pi\,V_{exit}}}$$

Where D = inside diameter of the chimney at top in m, Q_t = Quantity of the gas in m3/s, and Vexit = Velocity of the flue gas at exit point of chimney in m/s. However, the diameter shall be so chosen that velocity of the flue gas at exit point of chimney will not exceed 30m/s, under any circumstances.

As per IS 6533 (Part 2): 19892 there are some limitations for the proportions of the basic dimensions from structural engineering considerations as follows

a. Minimum outside diameter of the unlined chimney at the top should be one twentieth of the height of the cylindrical portion of the chimney.
b. Minimum outside diameter of the unlined flared chimney at the base should be 1.6 times the outside diameter of the chimney at top

With these parameters, the basic dimensions of the Chimney are
checked to understand the code limitations. A lot of 66 of chimneys are considered for the present study.

II. Analysis Of The Selected Chimneys

2.1 Effect of Geometry

From the discussions in the previous section it is apparent that topto-base diameter ratio and height-to-base diameter ratio are the two essential factors that characterize the geometry of a self-supporting chimney. For the selected Chimneys top-to-base diameter ratio and height-to-base diameter ratio varies with constant thickness and flared base diameter. Fig. 1 presents the different parameters of the selected chimneys according to code limitations. This figure shows that the selected chimneys cover wide range of geometry**.**

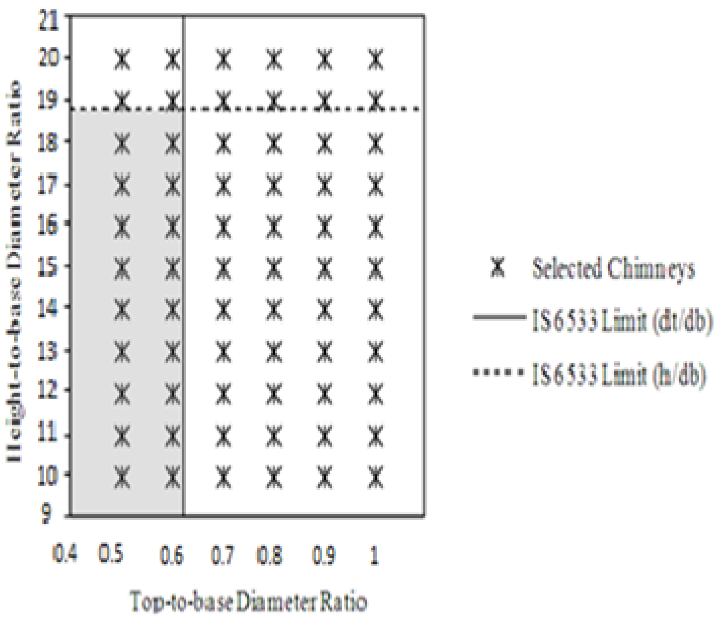
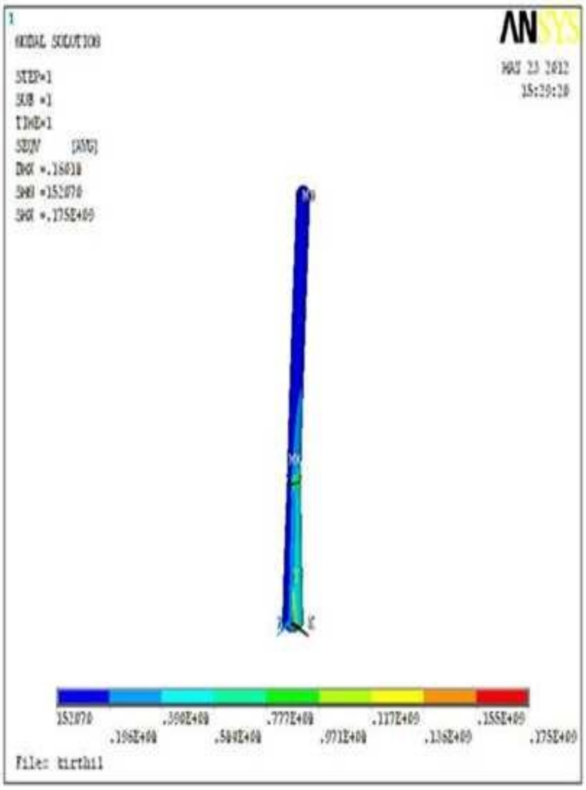


Figure :- Geometrical Parameters Distribution

2.2 Effect of manhole

Manholes are generally provided at the bottom of the chimney for maintenance and inspection purpose. The standard dimension of the manhole is 500mmx800mm according to Indian standard IS 6533 (Part-2):1989. These manholes are at generally located at minimum suitable distance from the base of the chimney. Two chimney models, one with the manhole and other without manhole, are analyzed using finite element software ANSYS for static wind load. Fig 2 (a&b) presents the Von-Mises stress for chimney model with manhole and without it. Fig 3(a&b) presents the displacement response of the two chimneys under static wind force. These two figures show that higher deflection is occurred at the top of the chimney with manhole as compared to chimney without manhole. Fig 4(a&b) presents the fundamental mode shape of the chimney models. Chimney without manhole is found to have higher fundamental frequency compared to the chimney with manhole.

Table-1 represents the difference in the parameters due to the presence of inspection man hole in the chimney**.**



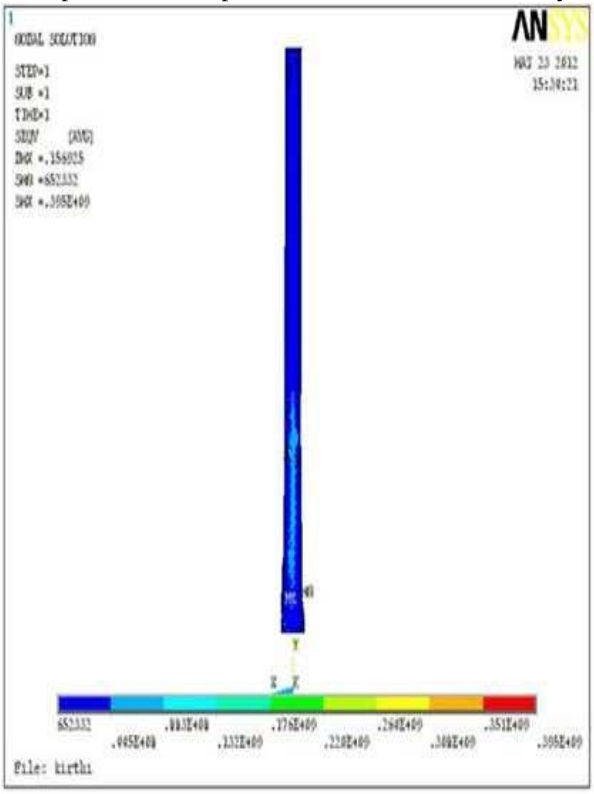
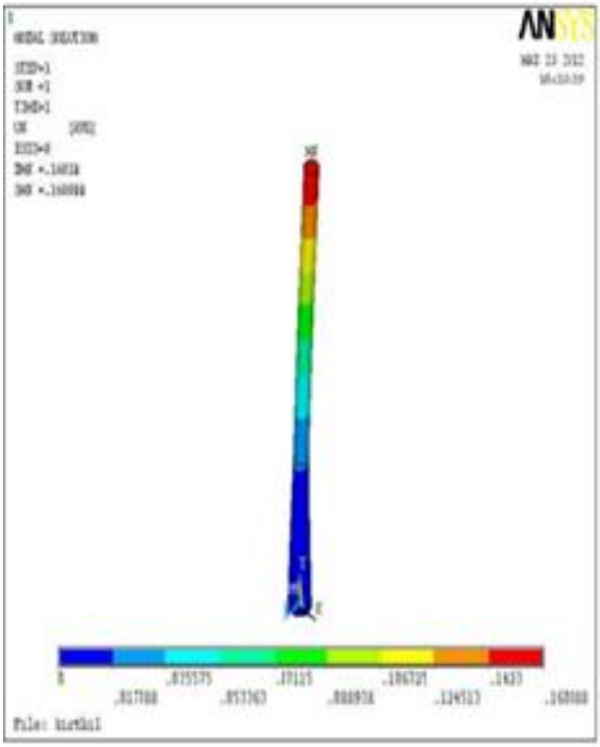


Figure 1 **Figure 1**

Comparison of Von- Mises Stress
Figure1 without man hole Figure2 With man hole



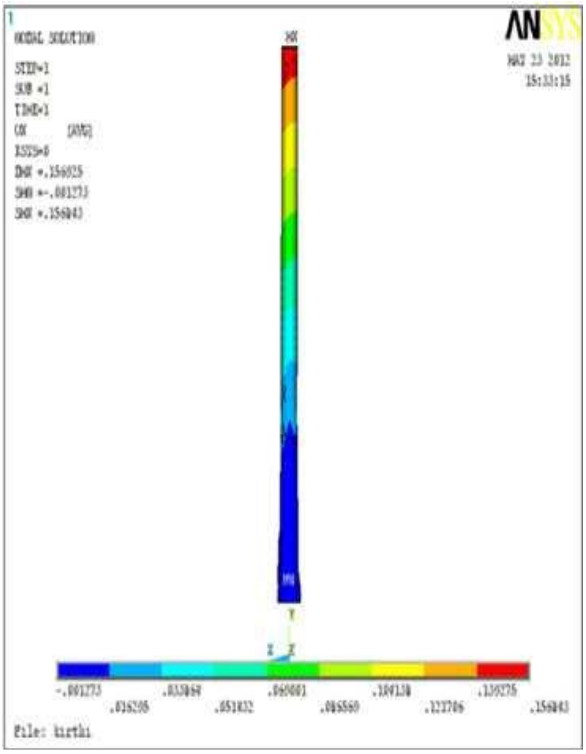
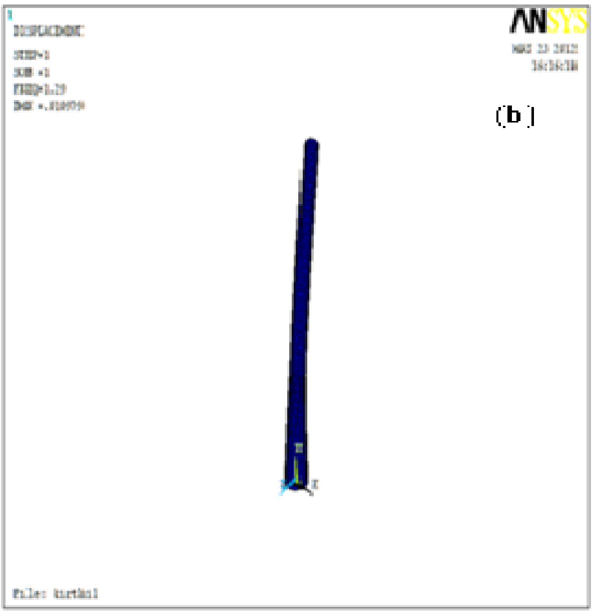


Figure 3 **Figure 2**

Comparison of top deflection in chimney
Figure3 Without man hole Figure4 With man hole



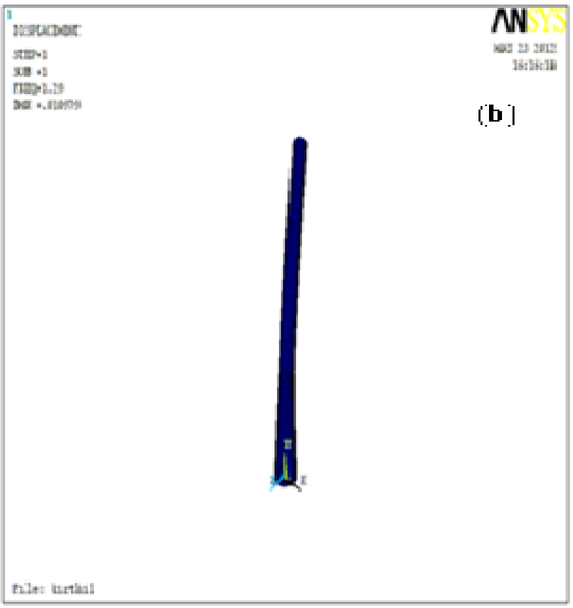


Figure 5 **Figure 6**

Comparison of mod shape in chimney Figure5 Without man hole Figure6 With man hole

III. Results And Discussions

In fig.1, it shows about the geometrical parameters which affect the design consideration. The shaded portion in the figure represents the region acceptable by the design code IS 6533 (Part 2): 1989. According to code, base diameter should be 1.6 times the top diameter of the chimney. From this relation it is obtained that the maximum limit for top-to-base diameter ratio should be 0.625. Similarly another limitation is minimum top diameter of the chimney should be one twentieth of the height of the cylindrical portion of the chimney. Hence the height-to base diameter ratio as per the code limitation is obtained as 18.75.

TABLE1

COMPARISON OF DESIGN PARAMETERS

	Without man hole	With manhole	% Difference
Top displacement(m)	0.160	0.157	2
Max. von Mises stress(MPa)	175	395	-56
Fundamental frequency(cps)	1.29	1.29	12

IV. Conclusions

The purpose of this paper was to verify the basis of design code limitations with regard to the basic dimensions of self-supporting unlined flared steel chimney and the effect of inspection manhole on the behaviour. It is established from these analyses that maximum moment and the maximum bending stress due to dynamic wind load in a self-supporting steel chimney are continuous functions of the geometry but it does not support the code limitations as mentioned previously. The results show that the maximum stress in the chimney with manhole is increased by 55.6% as compared to the maximum stress in the chimney without manhole. The top deflection is marginally equal. The mode shapes of the chimney are observed to be significantly different due to the presence of manhole. Chimney without manhole is found to have higher fundamental frequency compared to the chimney with manhole. This is because manhole reduces the effective stiffness of a chimney as evident from the modal analysis results.

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