FINITE ELEMENT OF STEEL (ANALYSIS OF SELF SUPPORTED STEEL CHIMNEY AS PER INDIAN STANDARD)

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ABSTRACT

Most of the industrial steel 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 steel chimney, such as height, diameter at exit, etc., are generally derived from the associated environmental conditions. To ensure a desired failure mode design code (IS-6533: 1989 Part 2) imposes several criteria on the geometry (top-to-base diameter ratio and height-to base diameter ratio) of steel chimneys. The objective of the present study is to justify the code criteria with regard to basic dimensions of industrial steel chimney. Maximum bending moment and stress for all the chimneys were calculated for dynamic wind load as per the procedure given in IS 6533: 1989 (Part 2). Maximum base moments and associated steel stresses were plotted as a function of top-to-base diameter ratio and height-to-base diameter ratio.

I. INTRODUCTION

Chimneys or stacks are very important industrial structures for emission of poisonous gases to ahigher elevation such that the gases do not contaminate surrounding atmosphere. These structures are tall, slender and generally with circular cross-sections. Different construction materials, such as concrete, steel or masonry, are used to build chimneys. Steel chimneys are ideally suited for process work where a short heat-up period and low thermal capacity are required. Also, steel chimneys are economical for height up to 45m. There are many standards available for designing self-supporting industrial steel chimneys: Indian Standard IS 6533: 1989 (Part-1 and Part-2), Standards of International Committee on Industrial Chimneys CICIND 1999 (rev 1), etc. 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, the basic geometrical parameters of the steel chimney (*e.g.*, overall height, diameter at exit, etc.) are associated with the corresponding environmental conditions. On top of that design code (IS-6533: 1989 Part 2) imposes several criteria on the geometry of steel chimneys to ensure a desired failure mode. Two important IS-6533: 1989 recommended geometry limitations for designing self-supporting steel chimneys are as follows:

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

Present study attempts to justify these limitations imposed by the deign codes through finite element analyses of steel chimneys with various geometrical configurations.

II. LITERATURE SURVEY

Self-supporting steel chimneys experience various loads in vertical and lateral directions. Important loads that a steel chimney often experiences are wind loads, earthquake loads, and temperature loads apart from self-weight, loads from the attachments, imposed loads on the service platforms.

Wind Effects: -For self-supporting steel chimney, wind is considered as major source of loads. This load can be divided into two components respectively such as,

- Along-wind effect
- Across -wind effect

The dynamic component, which can cause oscillations of a structure, is generated due to the following reasons:

- Gusts
- Vortex shedding
- Buffeting

Seismic Effects: - Due to seismic action, an additional load is acted on the chimney. It is considered as vulnerable because chimney is tall and slender structure. Seismic force is estimated as cyclic in nature for a short period of time. For analysis purpose, chimney is behaved like a cantilever beam with flexural deformations. Analysis is carried out by following one of the methods according to the IS codal provision,

- Response-spectrum method (first mode)
- Modal-analysis technique (using response spectrum)
- Time-history response analysis.

Temperature Effects: -The shell of the chimney should withstand the effects of thermal gradient. Due to thermal gradient vertical and circumferential stress are developed and this values estimated by the magnitude of the thermal gradient under steady state condition.

Design Aspects: - The design aspects include design, construction, maintenance and inspection of steel stacks. This also includes lining materials, draft calculations, consideration for dispersion of pollutants into atmosphere and ash disposal. The sizing of stack depends upon many factors, broadly it can be said that a stack is sized such that it can be exhaust a given quantity of flue gases at a suitable elevation and with such a velocity that the ground level concentration (GLC) of pollutants, after atmospheric dispersion, is within the limits prescribed in pollution regulatory standards, while the stack retains structural integrity. Thus, while handling a given quantity of flue gases, the major factors which influence attack dimensions are:

- Draft requirements
- Environmental regulations
- Structural considerations
- Compositions of flue gas are specific weight, quantity of dust data above the aggressiveness of gases.

In order to minimize loss of heat from a stack and to maintain the temperature of the steel shell above the acid due point level external insulations may be fitted. The amount of insulation required to maintain the temperature of flue gases above he acid dew point depends upon

- Effective of insulation
- The velocity of the gases
- The inlet temperature of the flue gases

According to Indian standard code IS: 14164-2008, industrial application and finishing of

Thermal insulation materials at temperatures above -800 C and up to 7500 C, code of practice deals with the material selection for selection for insulation and method of application.

III. SUMMARY

The main objective of the present study was to explain the importance of geometrical limitations in the design of self-supported steel chimney. Estimation of wind effects (along wind & across wind), vibration analysis, and gust factor are studied. Design of a self-supporting steel chimney as per IS 6533 (Part-1 and 2): 1989 will be discussed through example calculations. A study will be carried out to understand the logic behind geometrical limitations given in Indian Standard IS 6533 (Part-1 and 2): 1989. Two parameters:

- Top-to-base diameter ratio
- Height-to-base diameter ratio

Were considered for this study. A numbers chimney with different dimensions analysed for dynamic wind load. Many numbers self-supporting steel flared unlined chimneys were analysed for dynamic wind load due to pulsation of thrust caused by wind velocity. To explain the effect of inspection manhole on the behaviour of self-supporting steel

Chimney, two chimney models one with the manhole and other without manhole are taken into consideration.

IV. SCOPE AND CONCLUSION

This study does not support the IS 6533 (Part-2): 1989 criteria for minimum top diameter to the height ratio of the chimney and minimum base diameter to the top diameter of the chimney. Inspection manhole increases the von-misses stress resultant and top displacement in a self-supporting steel chimney. This is because manhole reduces the effective stiffness of a chimney as evident from the modal analysis results. Therefore, it is important to consider manhole opening in the analysis and design of self-supporting steel chimney.

- The effect of across-wind can be analysed through computational fluid dynamics using finite element software ANSYS.
- This study can be further extended to guyed steel chimney as well as concrete chimney.

REFERENCES

[1] IS 1893 Part 4; 2005, "Criteria for Earthquake Resistant Design of Structures," Bureau of Indian Standards, New Delhi 2002.
[2] IS 6533 Part 1; 1989, "Design and Construction of Steel Chimney,"Bureau of Indian Standards, New Delhi 2002.
[3] IS 6533 Part 2; 1989, "Design and Construction of Steel Chimney," Bureau of Indian Standards, New Delhi 2005.
[4] A Kareem and J Hseih, "Reliability analysis of concrete chimneys under wind loading," Journal of Wind Engineering and Industrial Aerodynamics. 25, pp. 93-112, 1986.
[5] CICIND, "Model code for steel chimneys (Revision 1-December 1999)," Amendment A,March 2002.
[6] D Menon and PS Rao, "Uncertainties in codal recommendations for across-wind load analysis of R/C chimneys," Journal of Wind Engineering and Industrial Aerodynamics.72, pp. 455-468, 1997.
[7] DE Newland (1981), "Factors in the design of resilient seating's for steel chimneys and masts," Soc. Environmental engineers conference on structural methods of controlling wind excited vibration, Loughborough.
[8] DJ Johns, J Britton and G Stoppard, "On increasing the structural damping of a steel chimney," Int. J. Earth. Engg & Struct. Dyn. 1, pp. 93-100, 1972.
[9] FJ Pallare´s, A Aguero and M Martın, "Seismic behaviour of industrial masonry chimneys", International Journal of Solids and Structures. 43, pp. 2076–2090, 2006.
[10] G Hirsch and H Ruscheweyh, "Full-scale measurements on steel chimney stack," Journal of Industrial Aerodynamics. 1, pp. 341-347, 1975.
[11] GK Verboom and H Van Koten , "Vortex excitation: Three design rules tested on 13 industrial chimneys," Journal of Wind Engineering and Industrial Aerodynamics. 98, pp.145-154, 2010.
[12] SO Hasen, "Vortex-induced vibrations of line-like structures", CICIND Report,1(15), pp.15-23, 1998.
[13] M Hortmanns and L Marengo, "Comparison of two actual methods for the evaluation of the vortex-excitation response", In: Proc 10th ICWE, errata, 1999.