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STUDY OF SELF SUPPORTED STEEL CHIMNEY AS PER IS CODE

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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.

A total of 66 numbers self supporting steel flared unlined chimneys with different top-to-base diameter ratio and height-to-base diameter ratio were considered for this study. The thickness of the chimney was kept constant for all the cases. 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) using MathCAD software. Also the results were verified with the finite element analysis using commercial software ANSYS. Basic wind speed of 210 km/h which corresponds to costal Orissa area is considered for these calculations. Maximum base moments and associated steel stresses were plotted as a function of top-to-base diameter ratio and height-to-base diameter ratio. The results obtained from this analysis do not agree with the code criteria.

INTRODUCTION

Chimneys or stacks are very important industrial structures for emission of poisonous gases to a higher 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 upto 45m. Fig. 1 shows a photograph of self-supporting steel chimneys located in an industrial plant.

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:

i) Minimum outside diameter of the unlined chimney at the top should be one twentieth of the height of the cylindrical portion of the chimney.

ii) Minimum outside diameter of the unlined flared chimney at the base should be 1.6 times 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.

LITERATURE REVIEW

A literature review is carried out on the design and analysis of steel chimney with special interest on the geometrical limitations. Although a number of literatures are available on the design and analysis of steel chimney there are only two published literature found that deals with the geometrical aspects of steel chimney.

This section presents a brief report on the literatures reviewed as part of this project.

Menon and Rao (1997) reviews the international code procedures to evaluate the across wind response of RC chimneys. The disparities in the codal estimates of across wind moments as well as the load factor specifications are examined in this paper through reliability approach. This paper recommends that it is necessary to design for the across wind loading at certain conditions. Chmielewski, *et. al*. (2005) studied about natural frequencies and natural modes of 250 m high- multi-flue industrial RC chimney with the flexibility of soil. This paper used finite element method for analysis. Also, experimental work to investigate the free vibration response is carried out by using two geophone sensors and experimental results are compared with analytical results. The results show that the soil flexibility under the foundation influences the natural modes and natural periods of the chimney by considerable margin.

Ciesielski, *et. al*. (1996) observed cross vibration on a steel chimney arising out of aerodynamic phenomenon. This paper shows that specially designed turbulizers, mechanical dampers can reduce this cross vibrations considerably.

Ciesielski, *et. al*. (1992) gives information on vortex excitation response of towers and steel chimney due to cross wind. A model is proposed to calculate maximum displacement of the chimney at top due to cross wind and the results are reported to match closely with the observed maximum top displacement.

Flaga and Lipecki (2010) analysed the lateral response of steel and concrete chimneys of circular cross-sections due to vortex excitation. A mathematical model of vortex shedding is proposed for calculating maximum displacement of the chimney at top due to vortex shedding.

Gaczek and Kawecki (1996) explained about the cross-wind response of steel chimneys with spoilers. 3-start helical strake system with strakes of pitch 5D is explained in this paper. Also, it is reported that the top displacement of a chimney depends on the parameter of excitation.

Galemann and Ruscheweyh (1992) presented the experimental work on measurements of wind induced vibrations of a steel chimney. For the along-wind vibration, the aerodynamic admission function has been developed from the vertical coherence of the wind speed as well as from the dynamic response directly. It is shown that the interaction effect between the strouhal frequency and the natural frequency of the chimney should produce a new exciting frequency which is lower than the strouhal frequency.

Hirsch and Ruscheweyh (1975) also analysed a steel chimney which is collapsed due to wind- induced vibrations. The analysis considered cross-wind oscillations of steel stacks of given structural data (such as natural frequencies and log decrements). Hydraulic automotive shock- absorber to prevent vortex-induced oscillations is also demonstrated in this paper.

Kareem and Hseih (1986) carried out the reliability analysis of concrete chimneys under wind loading. In this paper, safety criteria are taken into consideration. Excessive deflection at the top of the chimney and exceedence of the ultimate moment capacity of the chimney cross-section at any level were taken as failure criterion. Formulation for wind-induced load effects, in the both along-wind and across-wind directions, is presented according to the probabilistic structural dynamics. Covariance integration method is used to formulate a special description of fluctuating wind load effects on chimneys. Load effects and structural resistance parameters are treated as random variables. These random variables are divided into three categories such as, wind environment and meteorological data, parameters reflecting wind-structure interactions and structural properties.

Kawecki and Zuranski (2007) measured the damping properties of the steel chimney due to cross-wind vibrations and also compared different approaches to the calculation of relative amplitude of vibration at small scruton number. They also gave importance to climatic conditions during vibrations. They also presented better description of cross-wind vibrations according to the Eurocode and CICIND model code.

Ogendo, *et. al*. (1983) presented a theoretical analysis that shows that for a large class of steel chimney designs a resilient damping layer at the base can help to achieve a sufficiently high overall damping level to inhibit significant vortex-induced vibrations. Also, it is concluded from full-scale experiments that the system damping level can be increased by a factor of up to 3.

Pallares, *et*. *al*. (2006) discusses about the seismic behaviour of an unreinforced masonry chimney. A 3D finite element non-linear analysis is carried out incorporating cracking and crushing phenomena to obtain lateral displacements, crack pattern and failure mode. Also the maximum earthquake in terms of peak ground motion that the chimney can withstand is obtained.

Research Objectives

Based on the literature review presented in the previous section the objective of the present studyis defined as follows:

- Assess the geometry limitations imposed by IS 6533:1989 for designing self supportingsteel chimney.

SCOPE

i) Self-supporting flared steel chimney is considered for the present study

ii) Chimneys are considered to be fixed at their support. Soil flexibility is not consideredin the present study

iii) All chimneys considered here are of single-flue type

iv) Uniform thickness is considered over the full height of the chimney.

v) Only wind load and seismic load are taken into consideration for design of thechimney.

RESULTS AND DISCUSSION

The objective of this chapter was to check the basis of design code limitations with regard to the basic dimensions of a self supporting unlined flared steel chimney. Two parameters: (i) top-to-base diameter ratio and (ii) height-to-base diameter ratio were considered for this study. A numbers chimneys with different dimensions analysed for dynamic wind load. A total of 66 numbers self supporting steel flared unlined chimneys were analysed for dynamic wind load due to pulsation of thrust caused by wind velocity. It is found from these analyses that maximum moment and the maximum bending stress due to dynamic wind load in a self supporting steel chimney are continuous function of the geometry (top-to-base diameter ratio and height-to-base diameter ratio). 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 ofthe chimney.Last part of this chapter presents the effect of inspection manhole on a self supporting steel chimney. This results show that manhole increases the von-mises stress resultant and top displacement in a chimney. This is because manhole reduces the effective stiffness of a chimney as evident from the modal analysis results.

CONCLUSION

The main objective of the present study was to explain the importance of geometrical limitations in the design of self supported steel chimney. A detailed literature review is carried out as part of the present study on wind engineering, design and analysis of steel chimney as well as concrete chimney. Estimation of wind effects (along wind & across wind), vortex shedding, vibration analysis, and gust factor are studied. There is no published literature found on the effect of geometry on the design of self supporting steel chimney. Design of a self supporting steel chimney as per IS 6533 (Part-1 and 2): 1989 is discussed through example calculations. A study is carried out to understand the logic behind geometrical limitations given in Indian Standard IS 6533 (Part-1 and 2): 1989. The relation between geometrical parameters and corresponding moments and shear is developed by using MathCAD software. Two parameters: (i) top-to-base diameter ratio and (ii) height-to-base diameter ratio were considered for this study. A numbers chimneys with different dimensions analysed for dynamic wind load. A total of 66 numbers self supporting steel flared unlined chimneys were analysed for dynamic wind load due to pulsation of thrust caused by wind velocity.

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