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Comparative Analysis of RC & Steel Chimney with Design Wind Loads on Reinforced Concrete

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Abstract

This study deals with the comparative analysis of Reinforced Concrete (RC) & Steel chimneys. Such chimneys (with heights up to 60m) will be analyze and designed in conformity with various codes of practice. The main masses to be thought-about throughout the analysis of tall structures like chimneys are wind forces, temperature loads and seismic loads in addition to the dead loads. The design is finished with limit state ideas (which are nonetheless to be incorporated into IS 4998). The main objective of the present work is to comparative study of geometrical limitations in the analysis of self-supporting RC & steel chimney. Here we analysis and compare of steel chimney and concrete chimney with considering lateral forces and result obtained in term of Node Displacement, Support reaction and support Moment and verifies the various stresses on both kinds of stacks.

Keywords: wind load, height/Base ratio, mode shape & Frequency

1. Introduction

India has been striving to alleviate the electric power crisis, recently aggravated due to the economic boom in the country. Out of the two major sources of power, i.e. Hydro Power and Thermal Power, the latter has become more popular due to its adaptability towards larger production capability. Thermal power is obtained through burning coal, which is required to operate the steam boilers. When burnt, the coal produces polluting gases that need to be discharged at a high elevation enough to dilute the pollution and to keep it within acceptable limits at ground level. An adequately designed tall chimney serves this purpose. As the pollution norms have become stringent with time, the chimney heights have gone up progressively from 100m to 150m to 220m to 275m.In most thermal power plants, 275m tall concrete chimneys have now become the standard norm. It may be worthwhile mentioning here that a bi-product of burning of coal is fly ash, which is produced in the process line between boiler and chimney. This fly ash is extracted using electrostatic precipitators, which incidentally can be used in blended cement and as mineral admixture in concrete.

Figure 1.1 cantilever steel chimney

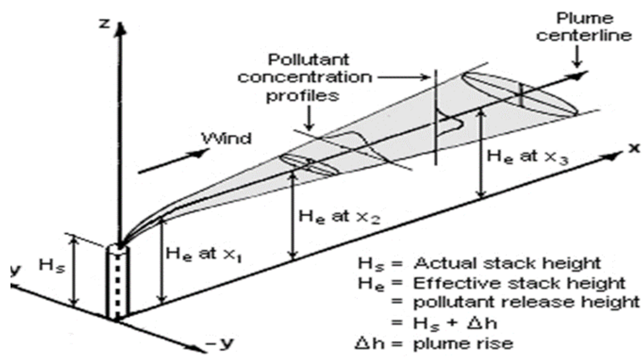

Figure 1.2 Spread of Plume

1.1 Background

Each structure is to be designed for strength, limiting deflection, and durability. The function and aesthetics of structures should keep in consideration during achieving this strength, deformation and durability. It may possible when the structural engineer had quite knowledge about architectural requirements. In case of high-rise structure, certain failures may occur due to lateral loads. The lateral loads are almost wind and earthquake, whose main horizontal force component acting on the different members of structure. The lateral force effects due to wind and earthquake loads are usually analyzed as an equivalent static load in most type of high-rise structure. These structures are designed in such a way that its every component must resist two types of loads like vertical Load due to gravity and lateral load due to earthquake and wind. The reinforced concrete chimney shell, which transfer vertical load and lateral load to the foundation. The present study is on the analysis of cantilever reinforced concrete chimney with variation in geometry and different orientation, when they are subjected to the lateral loads.

1.2 Classification of chimneys

A] Based on number of flues

1) Single flue (each boiler will have an independent chimney)
2) Multi flue (Single chimney serves more than one boiler; more flues are housed inside a common concrete windshield)

B] Based on material of construction

1) Concrete (Chimney); Reinforced/P.re-stressed
2) Steel (stack)
3) Masonry

C] Based on structural support

1) Guyed stacks (used in steel stacks for deflection control)
2) Self-supporting (cantilever structures)

D] Based on lining

1) With Lining: Lined chimneys/stacks
2) Without lining: Unlined chimneys/stacks

1.3 Scope and Objective of Work

1. To carry out computerized analysis on different types of models using ansys.
2. To identify geometry variation parameter such as height to base diameter ratio, tapering of the structure.
3. To study the effect of variation in geometry of cantilever steel chimney
4. To determine the bending stress, lateral displacement and lateral forces for the cantilever steel chimney by analysing the models for static forces.

2. Literature Review

G. Murali, B. Mohan[2] 2012- This paper studies analysis and design of three chimneys of 55m high above ground level. The chimneys were designed with three different wind speeds. The force of wind depends upon its speed and turbulence. The parametric study of static and dynamic forces, the static moment and dynamic moment and thickness of chimney shell and a comparison is made for three chimneys. The results showed that the static and dynamic moments are minimum for short chimney with lowest wind speed and more for tall chimney with greatest wind speed. Thickness of chimney is independent of wind speed, height and earthquake zone.

Rajkumar, Vishwanath. B. Patil[3] 2013- The authors discusses about the parametric study of RC chimney of varying heights, diameter, wind zones and earthquake zones, different soil conditions and for various load conditions. The response of chimney to earthquake and wind oscillations becomes more critical influencing response and design of chimney. Microsoft Visual Basic 6.0 software programming were used for the analysis is carried out using. The above cases are compared and the results were extracted. The maximum values for wind and seismic analysis were obtained and reffered for the further design. They concluded that, wind load governs the design of RC chimney. The oscillation is dependent upon the slenderness of chimney. Gust factors should be accounted in the dynamic analysis along with the wind factor. Grade of concrete should be greater than M25.

Kirtikanta Sahoo [4] May 2013- The present study investigates the effect of presence of manhole in terms of stresses, deflection and mode shapes of the chimney. These parameters are calcuted using finite element software ANSYS. From the results, it is seen that the modes shape are considerably different with the presence of manhole in the chimney. Also the chimney without manhole has higher fundamental frequency as compared to chimney with manhole. This is due to the reduction in effective stiffness causes due to the presence of manhole in the chimney.

Rinki, ShashiShekhar Singh; [5] 2016- This paper deals with the study of structural behaviour of the flare base steel stack under equivalent static load and dynamic varying wind load. The static & dynamic wind analysis is carried out by using the Staad. Pro Vi8 Ss5. The parametric study was carried out to find out static and dynamic forces, maximum deflection for flare base steel stack. The comparison is done for three different wind speeds, constant height & shell thickness. It concluded that the increment in the wind speed increases the speedStatic& dynamic wind forces 2. Maximum deflection due to static anddynamc wind force increases as compared with wind speed. Maximum deflections for wind speed due to static wind forces are less as compare to maximum deflection due to dynamic wind force for wind speed.

Hardik D. Lapsiwala[6]2014-This paper deals with the study of literature. The writer has studied different literature based upon the analysis of steel chimney under wind forces and seismic forces. By the study of previous literature, it has been concluded that the the most critical and unpredictable effect is the wind effect on chimney as compared to the earthquake load effect. Hence for the design and analysis of steel chimney, the most critical parameters are height of chimney, top and base diameter of chimney and thickness of chimney. These parameters are carefully considerd before the design of chimneys.

Rakshith B D. [7] 2015- This paper gives the design and analysis concepts of chimneys as per Indian codal provisions incorporating finite element analysis. The study was based on the effect of the presence of inspection manhole in the chimney. For this, the comparison of chimney with and without manhole is done and analysis is carried out in STAAD Pro. The emphasis was also given to the effect of geometric limitations on the design aspects of chimney. Also the parameters under study was, top to base diameter ratio of chimney and to predict the bending stress variation as a function of geometry. The conclusion of this study is that, the top to base diameter ratio and height to base diameter ratio are the two main geometric functions through the maximum bending stress and maximum moment is induced due to dynamic load in a cantilever steel chimney. The inspection manhole increases the top displacement and stress resultant resulting in the reduction of overall stiffness of chimney.

T.Saran Kumar [8] 2015- In this study, five chimney models of different heights and diameters at top and bottom, were designed and wind load was calculated. Strakes are provided at top one-third height of chimney in helical form increasing the dead load of chimney. The chimney with and without strakes are analysed and Reynolds number was calculated from finite element software ANSYS Fluent. Vortex shedding effect on five chimney models revealed that the vibration induced by wind in the tall chimneys varies with respect to height. The strakes in chimneys reduces the across wind effect on chimneys. As height increases, the Reynolds number increases which indicates the increase of turbulent flow and the provision of the strakes reduces the Reynolds number which further indicates that the flow effect is controlled.

Bhagyashree Vananje[9] 2016- This paper shows the comparison between steel chimney and R.C.C. chimney. The study mainly focuses on deciding the design criteria by carrying out the wind analysis and seismic analysis on both the chimneys i.e. steel and RCC chimney, and the comparison is made based upon the performance criteria and cost criteria. Based on the analysis the author concluded that for fire place, steel stack is more efficient as compared to RCC stack. Cost of chimney construction totally dependent upon the height of the stack, hence both RCC and steel chimney are prudent.

R.Kalaimugi [10] 2016 -This paper investigates design of steel chimney considering wind load and earthquake load. The geometrical characteristics of steel chimneys plays an important role in steel chimneys is designed considering wind load and earthquake load. Geometry of a self-supporting chimney is responsible for its stiffness; hence steel chimney plays an important role in its structural behavior under lateral dynamic loading. Analysis due to wind effect of this chimney is associated with different foundation parameters and corresponding to deformation and stress.

R. Boopathiraja [11] 2016- The 72 m high self-supporting steel chimney is considered for design and analysis. The foundation of chimney is designed. The comparison in between self-supporting chimney and guyed chimney is done based on the moment at base. It is concluded that the base moment of Guyed chimney is less as compared to self-supporting chimney, hence considered as safe for design and construction.

Linda Ann Mathew,[12] 2016- In this paper considering a steel chimney as cantilever beam with annular cross section is designed considering dead load and wind load. The chimney models with different thicknesses were modeled and analyzed in ANSYS software. The chimney can be made cost effective with lower thickness. Also chimney with lower thickness has more stability as compared to chimney with higher thickness. A couple field analysis were carried out for steel chimney with minimum thickness and compare the same with linear analysis, it was found that, the proposed chimney model for 6 mm thickness was under the safe limit. Also the maximum stress was obtained near the supports and minimum near the top of the chimney.

3. Methodology

3.1 Wind Engineering

For cantilever concrete chimney, wind is considered as major source of loads. This load can be divided into two components respectively such as,

1) Along-wind effect
2) Across -wind effect

The wind load exerted at any point on a chimney can be considered as the sum of quasi-static and a dynamic-load component. The static-load component is that force which wind will exert if it blows at a mean (time-average) steady speed and which will tend to produce a steady displacement in a structure. The dynamic component, which can cause oscillations of a structure, is generated due to the following reasons:

1) Gusts
2) Vortex shedding
3) Buffeting

3. 2 Along Wind Effects

Along wind effects are happened by the drag component of the wind force on the chimney. When wind flows on the face of the structure, a direct buffeting action is produced. To estimate such type of loads it is required to model the chimney as a cantilever, fixed to the ground. In this model the wind load is acting on the exposed face of the chimney to create predominant moments. But there is a problem that wind does not blow at a fixed rate always. So the corresponding loads should be dynamic in nature. For evaluation of along wind loads the chimney is modeled as bluff body with turbulent wind flow. In many codes including IS: 6533: 1989, equivalent static method is used for estimating these loads. In this procedure the wind pressure is determined which acts on the face of the chimney as a static wind load. Then it is amplified using gust factor to calculate the dynamic effects.

3.3 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. When chimney subjected to cyclic loading, the friction with air, friction between the particles which construct the structure, friction at the junctions of structural elements, yielding of the structural elements decrease the amplitude of motion of a vibrating structure and reduce to normal with corresponding to time. When this friction fully dissipates the structural energy during its motion, the structure is called critically damped. For designing earthquake resistant structures, it is necessary to evaluate the structural response to ground motion and calculate respective shear force, bending moments. Hence ground motion is the important factor for seismic evaluation. To estimate exact future ground motion and its corresponding response of the structure, it depends on soil-structure interaction, structural stiffness, damping etc. 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,

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

A] Response-spectrum method
This method consists of three steps such as,

1) Fundamental period
2) Horizontal seismic force
3) Determine design shears and moments

1) Fundamental period
The fundamental period of the free vibration is calculated as,
Stiffness of the flared chimney is approximately two times the prismatic chimney. Therefore, the conservative estimate of natural time period for this self-supported steel chimney will be:
2) Horizontal seismic force
The horizontal seismic force (Ah) is to be calculated according to IS 1893 (Part- 1): 2002 as follows:
3) Design shear force and moment
Either simplified method (that is, equivalent static lateral force method) or the dynamic response spectrum modal analysis method is recommended for calculating the seismic forces developed in such structures. Site spectra compatible time history analysis may also be carried out instead of response spectrum analysis.

B] Simplified Method (Equivalent Static Lateral Force Method)
The simplified method can be used for ordinary stack like structures. The design shear force, V and design bending moment M for such structures at a distance X from the top, shall be calculated by the following formulae:

C] Dynamic Response (Spectrum Modal Analysis)
The dynamic analysis using response spectrum method should be carried out for important stack-like structures. The number of mode to be considered in the analysis should be such that about 90 percent of modal mass is excited. The modes could then be combined by modal combination of corresponding response like shear, moment, etc., as suggested in IS 1893 (Part-1). The detailed dynamic analysis using time history shall be required where analysis is based on site-specific response spectrum and compatible time history of ground motion.

D] 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.

4. Conclusions

1. Chimney model with larger diameter and greater thickness has shown satisfying results.
2. The deformation is decreased by 78.86% in

model 9 as compared to M1.

3. Moreover shear stress has been reduced upto 68%.
4. Equivalent stress and strain also shown considerable drop in the value of M9.
5. For vibration analysis it is observed that as the diameter and thichkness increases the modal frequency also increases.
6. It is proved that diameter and thickness are the two governing parameters to control the shear and deformation of the chimney.

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