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Analysis of R.C. Chimney with different wind speed using STAAD.Pro

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***ABSTRACT**: Chimneys are required to carry vertically and discharge, gaseous products of combustion, chemical waste gases, and exhaust air from and industry into the atmosphere at such a height and velocity that it doesn't harm the environment. With the rapid industrial development, large numbers of chimneys are constructed every year. Due to increased pollution over a couple of years, the height of RCC chimneys has been increased. As far as our knowledge goes none of a chimney have been constructed of modular type (configured as per need) in the world in any industry, unless the size of the chimney is too small. Domestic chimneys can be erected with external support. Therefore , The proper analysis of RCC Chimneys, are necessary so that it will create self-standing structures that will resist wind load, earthquake load Dead load and other forces acting on them. This paper aims at the detailed analysis of RC Chimneys subjected to static-dynamic wind load and seismic loading using STAAD.Pro connect edition software .Analysis is performed for two seismic zones and two different wind speed, Also height of chimney is varied and two chimney of height 60m and 80m is considered for study. Parameters like Maximum lateral displacement, maximum moments, and horizontal shear are compared.*

***KEYWORDS**: R.C. chimney, lateral deflection, STAAD.Pro, Wind shear force*

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I. INTRODUCTION

The chimneys of 50-100m are very commonly used RC chimneys becoming more and more popular because of economy in construction and maintenance. Maintenance cost of steel chimneys is high and brick chimneys become too bulky and costly when height of chimney is more than 30m. The outer diameter of chimneys may be kept constant throughout or may be linearly varied. The thickness of concrete shell may be varied in steps or linearly. Reinforced concrete chimneys are subjected to various loads such as self-weight, wind load, earthquake load and temperature variation. The design of RC chimney is carried out by selecting the section first and then checking for stress development. However, tall RCC chimney structures have different structural problems and must be treated separately from other forms of tower structures. The chimneys constructed during and before late seventies may be vulnerable to damage during earthquakes because of old construction techniques or inadequate seismic design. Previous codes do not cover sufficient seismic detailing. A chimney is a building that encloses the flue and works with it to create a system that vents hot gases or smoke into the open air. Chimneys are normally vertical or almost vertical to ensure a smooth flow of gases and to attract air into the combustion, commonly known as the stack effect or chimney effect. The majority of industrial chimneys produced today, including those in India, are made of reinforced concrete (RC).

It is regarded vital to assess the design of the previously built chimneys using current codes in order to assure their safety due to developments in design codes. This study focuses on the behaviour of the RC chimney's windshield during seismic activity and the structure's response to a certain wind load.

Figure 1. Industrial RC chimney

1.1 Load effects on Concrete Chimneys

Different kinds of loads are applied to RC concrete chimneys in both lateral and vertical directions. Aside from the structure's own weight and the pressures placed on the service platforms, the main loads that a concrete chimney typically encounters are pressure from wind loads, loads brought on by seismic activity, and temperature loads. Since concrete chimneys are often relatively tall and slender constructions, the impacts of wind on RC chimneys have a significant impact on their structural behaviour. As seismic load is a natural load that is dynamic in nature, earthquake is also a major factor for chimneys. The quasi-static approach is suggested by code rules while evaluating seismic loads.

Wind exerts a considerable pressure on the wall of RC chimney and is considered as a major source of load for RC chimneys. Wind load could further be subdivided into three components respectively such as,

1. Along-wind load
2. Across-wind load
3. Torsional effect

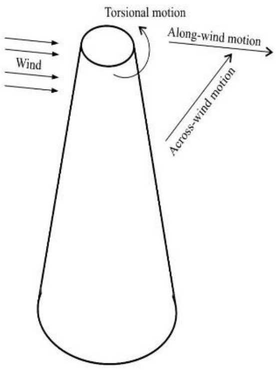

Figure 2. Schematics of wind effects with respect to its direction of flow.

II. RELATED WORK

T Saran Kumar, R. Nagavinothini (2015) presented the study of vortex shedding effect on steel chimney. Vortex shedding means at certain velocities air or fluid past a cylindrical body forms an oscillating flow, which depends on the size and shape of the body. Reynolds number used to predict fluid flow pattern fast a body is steady wer turbulent. Five models of chimneys with different heights and diameters at top and bottom, were designed as per IS 6533-1989(part 2) and wind load was calculated as per IS 875 (part 3)-1987.The study on the vortex shedding effect on different chimney models reveals that the wind induced vibration in the tall chimneys varies with respect to height. [1]

Dr. B K Raghu Prasad, Nitin Shepur, Dr. Amarnath K (2014) discussed the dynamic analysis of 150m high RCC chimney subjected to wind. Analysis has been carried out for fixed base case. They used a method given by IS 4998 (Part1): 1992 code to obtain the combined design loads. Their objective was to analyze chimneys fitted with pendulum dampers for design wind loads. They concluded that the natural frequency of the chimney decrease due to pendulum damper and mass at the chimney top. The best fitted equivalent logarithmic decrement curve damper is chosen for analysis. The displacement, velocity and acceleration decrease to the chimney with the pendulum damper. [2]

K.R.C. Reddy (2015) presented the along wind analysis of tall reinforced concrete (RC) chimneys by random vibration approach and Codal methods of India (IS 4998 (part 1)), America (ACI 307) and Australia (AS/NZS 1170.2). For the analysis based on random vibration approach, the RC chimney was modeled as multi-degree-of freedom system subjected to static load due to mean component of wind velocity and dynamic load due to fluctuating component of velocity. The fluctuating component of wind velocity at a point was considered as temporal random process. Next, the codal procedures for along-wind analysis of tall RC chimneys from Indian, American and Australian codes are reviewed. Four RC chimneys are analyzed using these methods to obtain their responses. It was found that the codal methods of along-wind analysis are simplistic, were not equipped to estimate the deflection of the chimneys and producing varied results. [3]

Alok David John et. al. (2011) aimed at providing a better understanding of the effect of interference and influence of strakes for wind load on Thermal Power Station (TPS) chimneys. Measurements of across and along vibration have been made on scale model of Panipat power station chimney, India. The aeroelastic model of the chimney has been tested in a simulated atmospheric boundary layer of height 1.0 m in the Boundary Layer Wind Tunnel at IIT Roorkee, India. The chimney model has been fabricated with FRP (fiber-reinforced plastic) at a geometric scale of 1:150 representing a chimney with height of 100 m in prototype. The wind tunnel tests for the present study have been carried out with the objective of obtaining the maximum along-wind and across-wind response of the chimney and this has been expressed in terms of bending moments. In particular, the interference effect between other nearby structures of the TPS has been investigated. Based on dimensional analysis measured values of chimney model have been converted into prototype values. Bending moment due to across-wind vibration for interference was found to be approximately double compared to that of stand-alone condition. To control across wind vibration, strakes had been mounted over the top one-third height of the chimney. It was found that there is a significant decrease in the magnitude of across as well as resultant bending moment in presence of strakes. [4]

G.Murali et. al. (2012) dealt with the study of three chimneys of 55m high above ground level. These chimneys were designed as per IS: 6533–1989 [1] and wind load was calculated as per IS: 875–1987 [2] .Three different wind speeds were considered for the design of chimneys viz., 47m/s, 50m/s & 55m/s respectively. In order to effectively analyse a chimney's response, a deep knowledge of the basic wind engineering concepts is needed. The force exerted by wind on the chimney varies with the wind speed and its associated turbulence. The study parameter of static forces, the dynamic forces, the static moment, dynamic moment and thickness of chimney shell were comrared to three chimney. The results indicated that the forces and moments of C3 is higher than the C1 and C2. The thickness of chimney is remains same even though the three different wind speed was considered. [5]

Babita Devi, Shashi Shekhar Singh (2018) dealt with the behaviour of Flare base circular steel stacks with variable height of 30m, 40m, and 50m respectively. Their study aimed was to find out the structural behaviour of Flare base steel stack under the equivalent static and dynamic wind forces. The static & dynamic wind analysis was done by using the Staad.Pro Vi8 ss5 software with assumptions as per IS 6533:1989(part1 & part2). The study parameter of static and dynamic forces, maximum deflection due to static & dynamic wind forces for flare base circular steel stacks for the different height with constant wind speed 47m/s (Location:- Agra, India) was compared. They concluded that maximum deflection was more due to dynamic wind force as compare with static wind force at their respective height. Maximum deflection difference was increasing due to static and dynamic wind force with the increase in height of steel stacks. [6]

Huang, et. al. (2004) evaluated the original design of a collapsed chimney by performing a nonlinear analysis using the analysis techniques available at that time. They also compared the analysis results with a chimney of a similar geometric properties in accordance with American design practice. The study incorporates a linear dynamic response spectrum method of analysis. The study emphasizes on the importance of limiting the maximum moment by providing multiple plastic hinges instead of providing a single hinge which is done by proper detailing of the section for the expected ductility demand. [7]

Chmielewski, et. al. (2005) studied the theoretical and natural vibration frequencies and natural modes of the 250 meters high industrial chimney with flexibility of the soil. The study also presented the experimental investigation of the free vibration response by applying two geophone sensors. A comparison was drawn between the experimental results and the theoretically obtained ones. The paper concluded that natural periods of the structure and natural modes of vibration of the chimney are considerably influenced by the flexibility of the soil underneath the chimney foundation. [8]

Elias, et. al. (2016) investigated the distributed tuned mass dampers designed effectiveness with respect to the multi-mode control of reinforced chimneys under seismic ground motion. The paper presented the chimneys under cracked and uncracked conditions having geometrically regular and irregular properties. The parametric study was carried out to realize the most adequate mass and damping ratios by placing the tuned mass damper where amplitude of the mode shape of chimney was the highest. The study resulted in reduction of peak displacement and improved seismic response control using tuned mass dampers. [9]

Objectives of investigation:

1. To analyses the R.C. chimney in two seismic zones as per IS1893:2016 and two wind zones using STAAD.Pro Connect edition Software with two different heights.
2. Dynamic Analysis using Response Spectrum method.
3. To study and compare the maximum lateral deflection, shear forces and maximum bending moments of the chimney at different zones.

III. METHODOLOGY

- To study the effects of various loading on high rise R.C. Chimney.
- Finalizing the seismic zones and wind zones along the configuration of chimney as per the requirements.
- Calculation of various loads i.e. dead load, wind load, natural frequency and wind load for R.C. Chimney.
- Analysis of 60m and 80m high R.C. Chimney using STAAD.pro Connect edition Software
- Comparison of maximum moments, base shear and maximum lateral deflection of R.C. Chimney for two different wind zones and seismic zones.

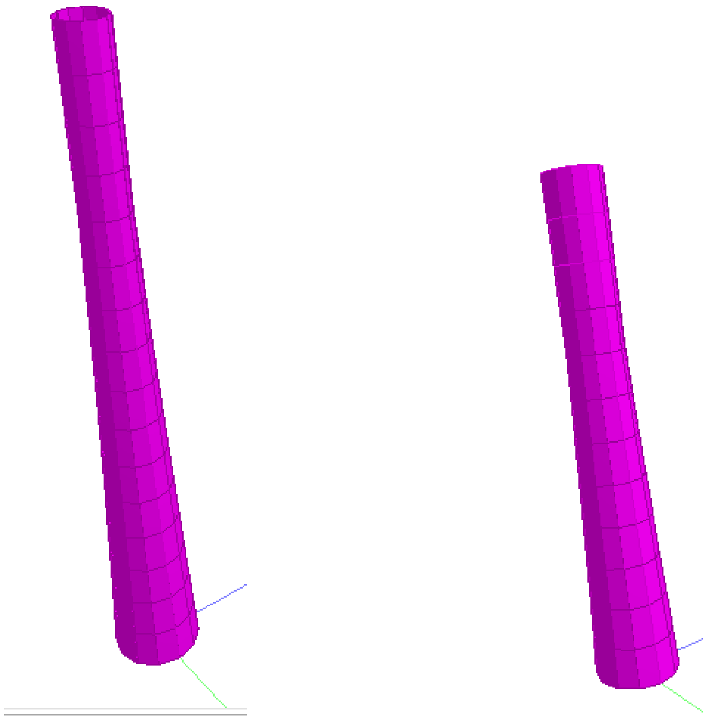

Figure 3: R.C. Chimney 80m and 60m

IV. RESULTS AND DISCUSSIONS

All models are first analysed by for seismic loading to calculate the base shear and moments of all models using STAAD.Pro connect edition software, then wind load analysis is performed and horizontal shear and moments has been calculated. Total 8 models has been analysed and compared as follows:

i. 60m height, wind speed-44m/s, seismic zone-II
ii. 60m height, wind speed-44m/s, seismic zone-III
iii. 60m height, wind speed-47m/s, seismic zone-II
iv. 60m height, wind speed-47m/s, seismic zone-III
v. 80m height, wind speed-44m/s, seismic zone-II
vi. 80m height, wind speed-44m/s, seismic zone-III
vii. 80m height, wind speed-47m/s, seismic zone-II
viii. 80m height, wind speed-47m/s, seismic zone-III

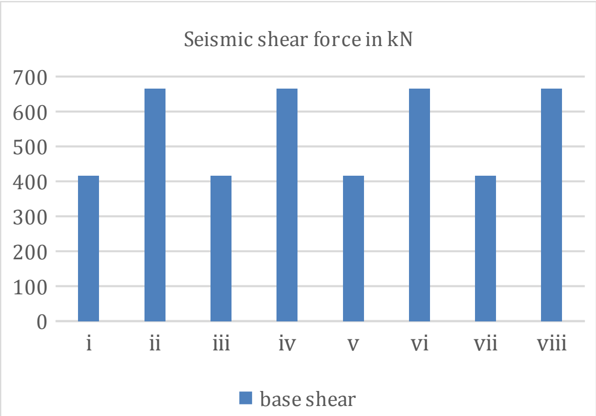

Fig. 4: Variation of Seismic shear force

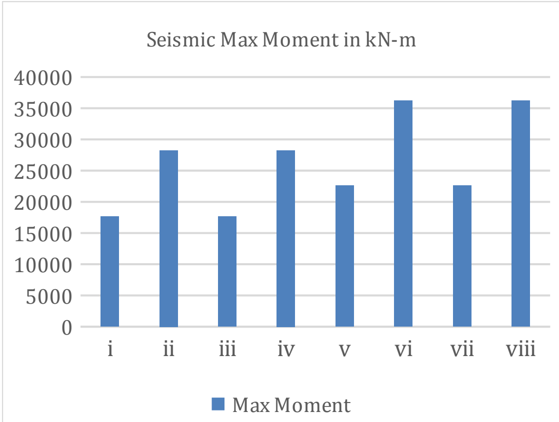

Fig. 5: Variation of Seismic Max moment

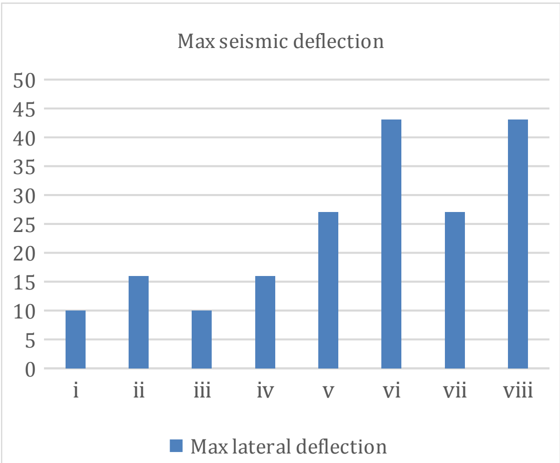

Fig. 6: Variation of Max seismic lateral deflection

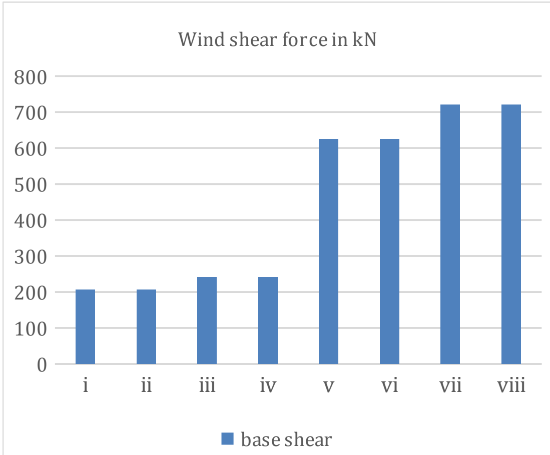

Fig. 7: Variation of Wind shear force

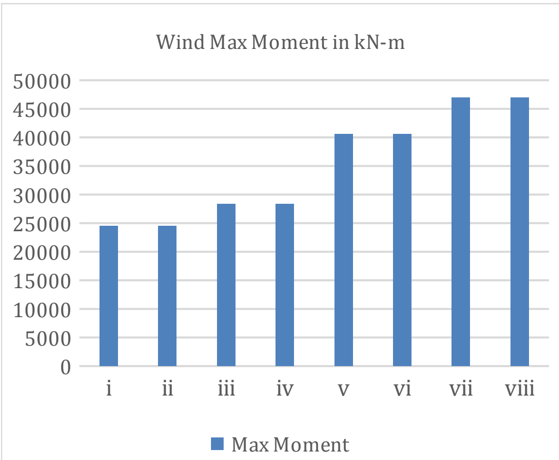

Fig. 8 Variation of Wind Max Moment

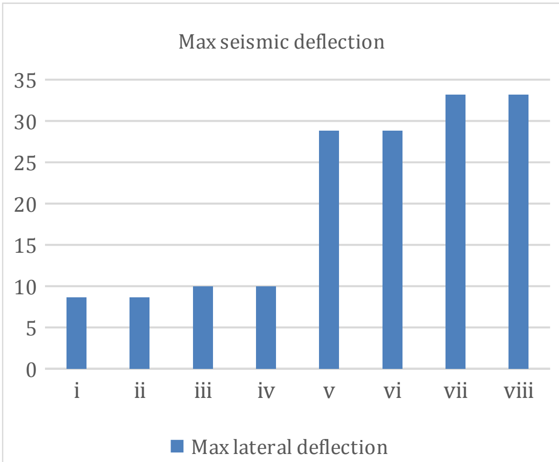

Fig. 9: Variation of Max Wind lateral deflection

V. CONCLUSION

Seismic shear force is significantly more as compared to wind shear force for wind speed 44 i.e. around 50% but its almost same for the case of wind speed 47. In all other cases wind max moment is more as compared to siemsic. Maximum lateral deflection is more in seismic lading as compared to wind loading in all cases. Thus we can conclude that for the design of R.C. chimney, critical moment and shear depends upon the height of chimney, seismic zone and wind speed of site location. So it is at most important for structural designers to design the R.C. chimney for both wind loading as well as for seismic loading.

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