Dynamic Analysis of RC Chimney with different heights

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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 project aims at the detailed analysis of RC and composite Chimneys subjected to static-dynamic wind load and seismic loading using ETABS 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 100m is considered for study. Parameters like Maximum lateral displacement, maximum moments, and horizontal shear are compared.**

***Index Terms*— RC chimney, Response spectrum analysis, ETABS, Composite Chimney,**

I. INTRODUCTION

A chimney is a building that encloses the flue and works with it to create a system that vents hot gases or smoke outside. 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. Reinforced concrete (RC) is primarily used in the construction of industrial chimneys that are present today in many countries, including India. The chimney's purpose is to release flue gases into the atmosphere at a height and speed that keeps the concentration of pollutants, like sulphur dioxide, below the permissible threshold. The gases are propelled upward after exiting the top of the chimney by their own buoyancy in relation to the surrounding air and the velocity of the flue gases released. Flue gas from big power plant plants is normally around 150°C for oil-fired applications and 120°C for coal-fired applications, and it contains a sizable amount of SO2 for coal and SO2 and HCl for oil. Although these efflux temperatures are designed to prevent acid condensation at the dew point in the ductwork, downwash in the flue and heat loss from the stack lead to acid deposition within the flues themselves.

Figure 1.1. Industrial RC chimney

In order to protect the environment, chimneys must carry upward and release gaseous byproducts of combustion, chemical waste gases, and industrial exhaust air into the atmosphere. Many chimneys are built each year as a result of the increasing industrial expansion. The height of RCC chimneys has risen as a result of the recent increase in pollution. To the best of our knowledge, no modular chimney has ever been built anywhere in the world, regardless of the industry, unless the chimney is too small. It is possible to build domestic chimneys with external support. To build self-standing structures that can withstand wind load, earthquake load, dead load, and other forces acting on them, RCC chimneys must therefore be properly analyzed.

50- to 100-meter chimneys are frequently employed. Because they are inexpensive to build and maintain, RC chimneys are becoming more and more common. Steel chimneys have substantial maintenance costs, and when a chimney is taller than 30 metres, brick chimneys become too bulky and expensive. It is possible to linearly vary or maintain a constant outside diameter for chimneys. The concrete shell's thickness can be adjusted linearly or in stages. Reinforced concrete chimneys are susceptible to a variety of loads, including temperature change, wind, earthquake, and self-weight. An RC chimney is designed by first choosing the section, and then looking for stress development. Tall RCC chimney buildings must be handled differently from other types of tower structures due to their unique structural issues. Due to outdated building methods or inadequate seismic design, chimneys built during and before the late 1970s may be susceptible to damage during earthquakes. Compared to the current rules, earlier codes did not provide enough coverage for seismic details.

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 how an RC chimney's windscreen responds to seismic activity and how the structure responds to a certain wind load.

1.1 Wind Effects on Structures

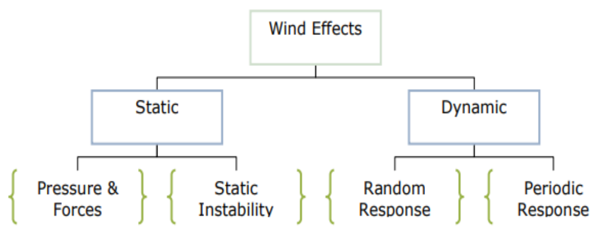
Air is moved by wind. The air is moving in a specific direction at a specific speed, and it has a specific mass (density or weight). As a result, the form's kinetic energy is expressed as

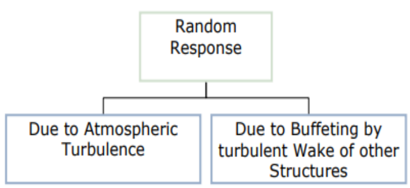
$$E = \frac{1}{2} m v^2$$

A force is applied to a stationary item when flowing air that is travelling past it collides with it in a number of ways. The wind has two sides. The first, and most advantageous, is that it can use its energy to generate power, sail boats, and lower the temperature on a hot day. The parasitic one, which is the other, loads anything that gets in its way. Engineers are concerned with the latter because the load must be supported by a structure that meets the required safety standards. Therefore, it is required that all civic and industrial constructions above ground be built to withstand wind loads. The 'equivalent static' wind should be taken into account while working with rigid constructions. However, while working with flexible wind-sensitive structures, it is crucial to take into account the structure's frequencies, integral length scale, average time, and wind energy spectrum.

The three-dimensional bodies that make up buildings and other civil engineering structures have a wide range of shapes and intricate flow patterns, which produce different pressure distributions. Because of this, the majority of 3-D studies rely entirely or mostly on experiments. In addition to the geometry of conventional structures, the peculiarities of the terrain and other nearby structures also contribute to the complexity of wind flow. Due to this, scaled models and simulated winds were used to experimentally determine the wind pressures in wind tunnels. Additionally, because buildings are never completely airtight, wind pressures can develop inside even a closed structure, reaching their highest levels in open structures. These typically increase the pressure outside, having the worst impact on both walls and roofs. Tall, thin buildings are adaptable and show a dynamic response to wind. Tall buildings vibrate in the wind as a result of the flow separation that causes turbulence in the structure itself as well as in the wind as a whole. Thus, there is a response to the wind that is both mean and variable. Tall constructions also exhibit an across-wind response because the dynamic forces act not only in the direction of the wind flow but also in a direction that is almost perpendicular to the flow (lift forces).

A mean component (time-invariant load derived from the mean wind speed) and a fluctuating component are both included in the along-wind response. The latter is further defined as the sum of its resonant and background components. It has been created to employ spectral response curves to forecast a building's along-wind fluctuating response. The issue becomes one-dimensional for structures that resemble lines, such as chimneys. This simplification, which is obviously conservative, is also employed to analyses towering buildings. Tall flexible structures also show an across-wind response, as was already mentioned. This is due to flow separation from the structure's cross section, which causes vortices to shed at a specific frequency. For circular sections, such those for chimneys and towers, which might experience resonant vibrations when the structural frequency matches the forcing frequency, the pattern of this across-wind phenomenon is comparably more regular. The response is larger in smoother flows and is strongly influenced by the wind's turbulence content. Buildings can get quite tall and develop slim proportions, in which case across-wind behaviour is significant.





II. RELATED WORK

Swati Pandey et al. (2023) evaluated the induced pressure across the chimney with different shapes: sharp-edged, chamfered, and filleted-edged. On chimneys made of M25 concrete, FSI studies were conducted. They discovered that the RCC chimney model with a filleted edge and chamfered edge has the least effect on the wind load when compared to the generic or sharp-edged RCC chimney model. The durability and structural stability of chimney constructions were proven at high wind speeds (i.e., 44 m/s). It was found that the induced pressure on the chimney construction could be precisely calculated using the CFD modelling tool. [1]

Gagandeep Singh et al. (2022) aimed at deriving standard curves with the help of which one can easily calculate the approximate wind load on a chimney in shell-completed condition. The curves have been plotted for chimneys with varied heights, top internal diameters, taper, and locations in various wind zones. These curves will determine the finalisation of the chimney's starting size and the framework that will support it. For wind analysis, utilise the codes IS 4998: 2015 and IS 875 (Part 3): 2015. They got to the conclusion that wind load increases along with the wind zone. Despite the fact that wind and height have a parabolic relationship, in very tall tapered stacks, the along wind load reduces as the diameter grows with increasing wind speed. [2]

Khaled M. Ahmida et al. (2022) investigated a chimney at the Tripoli-West power plant. Since wind was the primary source of the excitation forces operating on the chimney, information on wind velocities over a lengthy period of time was gathered from the National Centre of Meteorology in Tripoli. The maximum and average wind speeds were considered in the analysis. SolidWorks' flow simulation tool was used to model the wind flow, and the finite element analysis programme was used to run the simulations. After performing stress and deformation evaluations, the deflection at the top of the chimney was calculated and compared to standards recognized worldwide. The plant's rising surrounding population led them to the conclusion that the chimney could still need to be taller in order to protect the neighborhood's buildings from hazardous emissions. [3]

Alqama Hasan et al. (2020) analyzed the chimney of a circular section on the basis of finite element modelling using SAP2000 software. A nonlinear time history investigation was conducted on the R.C.C. chimney while accounting for two different seismic ground motions. The maximum base shear, maximum base moment, maximum top displacement, and chimney time period were taken as input ground motion from the El Centro near field and Landers Baker far field earthquake records for the nonlinear time history analysis of the R.C.C. chimney. The base was assumed to be fixed. Here, the base isolation technique included using the laminated rubber bearing as an isolator to manage the reactions. The results show that base isolation greatly minimizes seismic reactions under strong ground motion because it decouples the superstructure from the earthquake ground motion by establishing a flexible interface between the structure's foundation and base. When compared to the Landers-Baker far-field earthquake, it was discovered that the seismic responses under the El

Centro near-field earthquake were significantly higher. [4]

Prathyusha Yadav et al. (2020) reviewed the findings of a 100-m reinforced cement concrete chimney's seismic and wind analyses. In STAAD.Pro V8i SS6, the chimney was modelled with the lumped mass modelling technique. The earthquake analysis was performed in accordance with IS 1893 (Part-4):2005, whereas the wind load assessment was performed in line with IS 4998:2015. The outcomes of seismic and wind evaluations were taken into account when determining the design values. They used the limit state method and the most recent code to construct a 100-meter RCC chimney. [5]

Changdong Zhou et al. (2019) proposed a useful technique known as partitioned fragility analysis. The analytical model for the actual project, a single, 240-meter-tall reinforced concrete chimney, was created using the ABAQUS modelling application. The fragility analysis was performed to assess the damage probability of each component in various damage states while accounting for multidimensional ground vibrations. The chosen high-rise chimney construction was broken down into 17 components. Twenty ground motion recordings were selected as input motions from the Next Generation Attenuation database, and the peak ground acceleration was chosen as the intensity measure. The chimney structure's reaction to multidimensional ground motions was calculated using incremental dynamic analysis. The maximum strains of concrete and steel bars were determined to be the damage limit states of the chimney structure. The chimney construction is most fragile between the heights of 0 and 20 metres, 90 and 130 metres, and 150 and 200 metres, respectively, according to the fragility curves and surfaces generated by this research. Based on the analysis's conclusions, these weak points can be adapted to the chimney structures that are already in situ to strengthen their seismic resilience. [6]

III. RESULTS & DISCUSSION

Before doing wind load analysis and calculating horizontal shear and moments, all models are seismically loaded and their base shear and moments are determined. The following models have been examined and compared out of a total of eight:

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

3.1 Manual analysis results

First, manual analysis utilizing MS Excel sheets is done in accordance with IS standards. For seismic and wind loadings, maximum moment, horizontal shear, and natural frequency are computed.

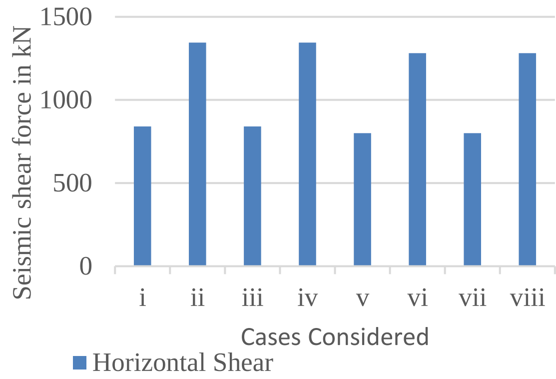


Figure 3.1. Variation of Seismic shear force

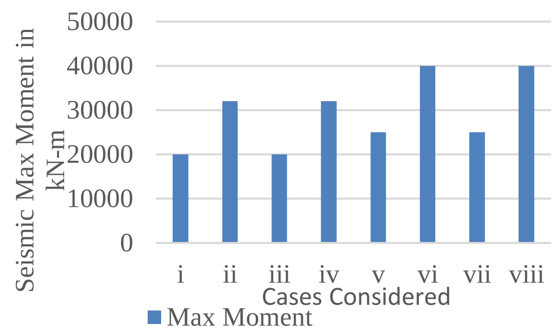


Figure 3.2. Variation of Seismic Maximum moment

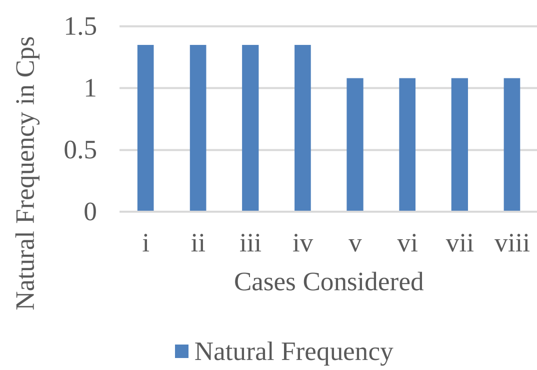


Figure 3.3. Variation of natural frequency

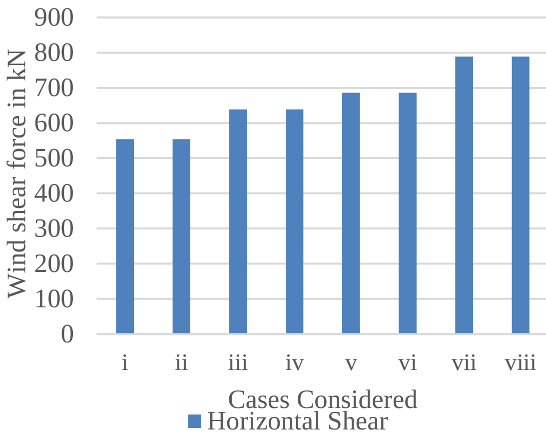


Figure 3.4. Variation of wind shear force

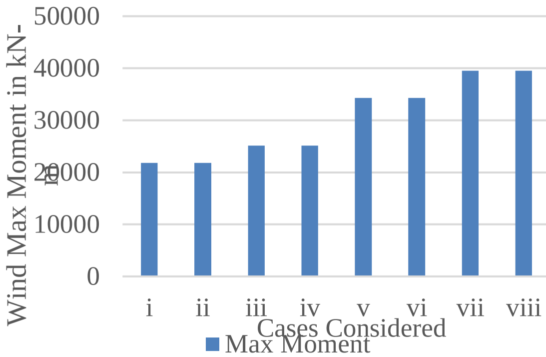


Figure 3.5. Variation of Wind Maximum moment

3.2 STAAD.Pro analysis results

All cases have been analyzed by the STAAD.Pro Connect Edition programme following manual analysis. For both seismic and wind loading, maximum lateral deflection, horizontal shear, and moments are computed.

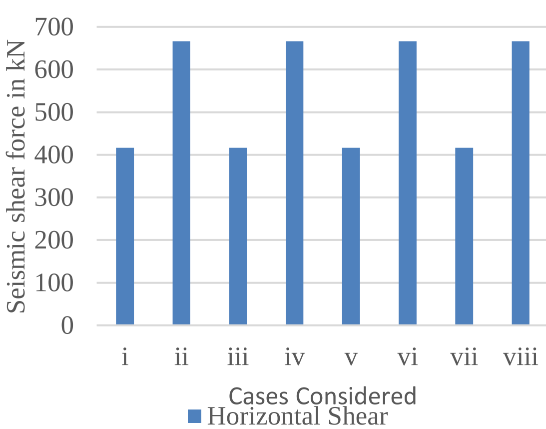


Figure 3.6. Variation of Seismic shear force

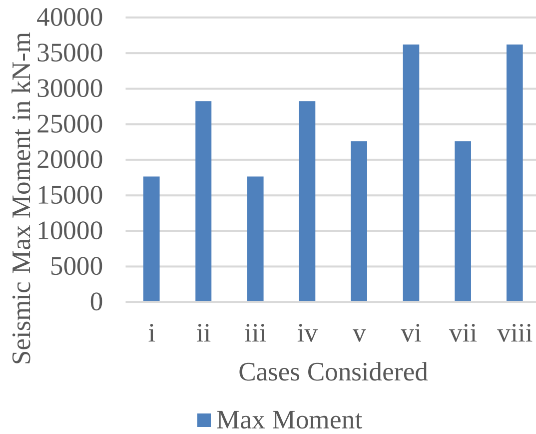


Figure 3.7. Variation of Seismic Maximum moment

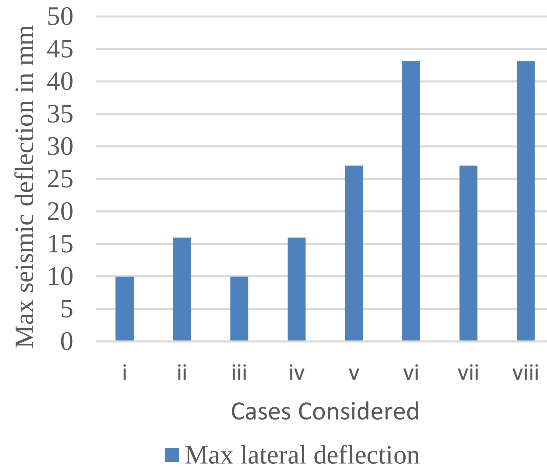


Figure 3.8. Variation of Seismic Maximum deflection

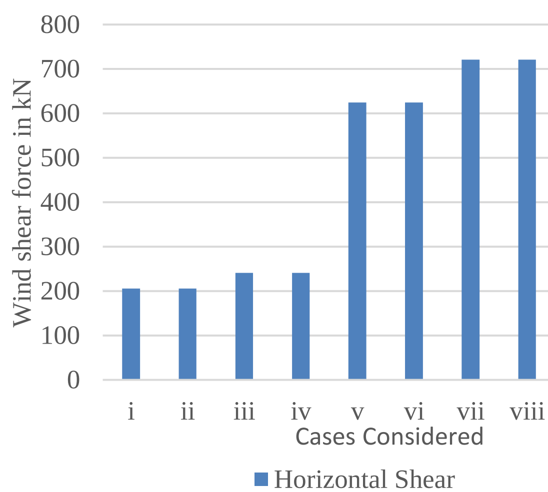


Figure 3.9. Variation of Seismic shear force

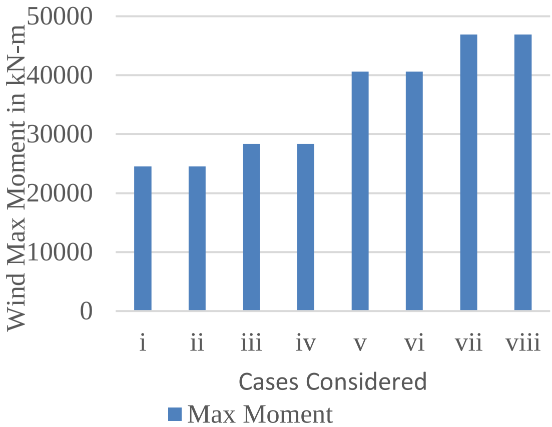


Figure 3.10. Variation of Wind Maximum moment

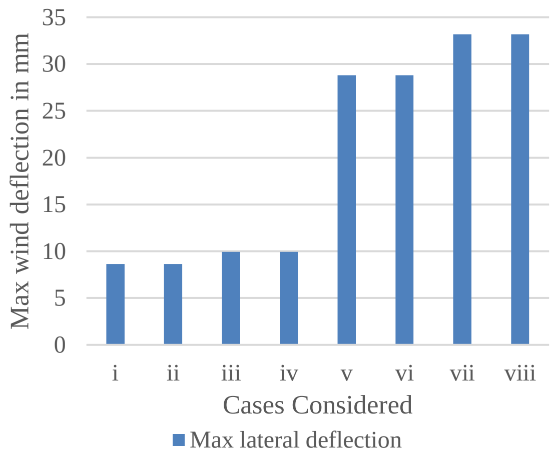


Figure 3.11. Variation of Wind Maximum deflection

IV. CONCLUSIONS

STAAD.Pro Connect version software and manual analysis have both been used to examine the performance of the R.C.C. Chimney under seismic and wind loading. From the research, we may draw the following conclusions:

- According to manual calculations, seismic horizontal shear is roughly 40–50% higher than wind horizontal shear. The STAAD.Pro analysis produced comparable outcomes.
- In seismic zone III, the seismic maximum moment is more than the wind maximum moment, which is greater when the wind speed is 47. Similar outcomes for the STAAD.Pro analysis were attained.
- Due to the longer time period, the natural frequency is lower for an 80-metre chimney and is unaffected by the seismic zone or wind speed.
- In seismic cases as opposed to wind cases, the maximum lateral deflection is greater.
- As a result, we may draw the conclusion that the critical moment and shear for the construction of a R.C.C. chimney depend on the height of the chimney, the seismic zone, and the wind speed at the site location. Therefore, it is crucial for structural designers to account for both wind and seismic loading while designing the R.C.C. chimney.
- According to the IS Code, the manual technique is more effective, however after contrasting the manual result with the STAAD.Pro result, we can say that the STAAD.Pro results are more accurate and affordable.

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