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A Review on Analysis of Tall Rcc Chimney

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ABSTRACT:
This paper presents a review on the various analysis that has been done on a tall reinforced concrete chimney under wind load as well as earthquake load. Three dimensional soil structure interactions, dynamic analysis, effect of wind load and earthquake analysis has been done on the structure. Various parametric studies have been done for finding out the effect of each factor. Four soil types are considered for the analysis namely loose sand, medium sand dense sand and rock. All the values assumed and loads taken are as per the codal provision.

KEYWORDS: Soil structure interaction, wind load, earthquake analysis, annular raft foundation.

INTRODUCTION

Chimneys are tall vertical structures that help to clear the gases or smoke produced from kitchen, fireplace or furnace. Tall chimneys are provided in power plants or industries. They help to release the toxic substances into a particular height. Theses chimneys are constructed tapered with a decreasing cross sectional area.

The working of chimney is similar to the working of a tunnel system. The most common material used for the construction of chimney is reinforced concrete. It helps to resist the wind load acts on it. Reinforced concrete chimneys are mainly classified into single flue chimney and multi flue chimney. Many of the single flue chimneys are used at cement factories, power plants and oil refineries whereas multi flue chimneys are used in brick chimneys.

Wind force is the main force which influences on the chimney. The design of chimney also deals with considering the effect of earthquake according to the zones where they are located. The temperature of chimney designed thermal power stations are 150° C to 180° C whereas for oil refineries, it ranges from 800° C to 1000° C. Lining is provided to protect the shell from the effect of corrosion, abrasion and temperature of these gases. Most of the lining is done by using fire clay bricks which can withstand a temperature of 1200° C. The foundation of chimney is mainly of solid raft or annular ring. The ideal foundation for the chimney is circular but according to the construction ease, economy etc we are used to provide other shapes also.

SOIL STRUCTURE INTERACTION

Soil structure interaction can be defined as an interaction which arises between ground and structure. Both the soil and structure plays a vital role in soil structure interaction. While designing a structure we usually consider certain load, load combination etc. although, without a proper study regarding soil type the analysis become incomplete. Because, the stability of structure is mainly depending upon certain factors, soil-structure interaction is one among them.

The paper "THREE DIMENSIONAL SOIL STRUCTURE INTERACTION ANALYSIS OF ANNULAR RAFT FOUNDATION OF TALL RC CHIMNEY UNDER WIND LOAD" deals with the analysis of tall RC chimney with annular raft foundation. It is subjected to wind load and 3D Soil Structure Interaction also considered. The researchers had taken different values of height, slenderness ratio for the parametric study of chimney and external diameter to thickness ratio for the parametric study of annular raft. There were four soil types selected to study the importance o soil structure interaction. It is assumed that the chimney is located in the terrain category two. Wind speed is taken as 50m/s as per the codal provision. Analysis had been done using ANSYS software.

To study the importance of soil structure interaction, four types of soil were considered. They are loose sand, medium sand, dense sand and rock. The study shows that the variation of tangential moment and radial moment in raft is same in case of along wind and across wind loads. The value of tangential moment in raft is always maximum at the inner edge of the raft for loose sand. In remaining cases, the value of tangential moment is maximum at the windshield location in the raft. It is found that the radial moment is high at the windshield location of leeward side of entire shaft.

It is noted that the settlement increases as the soil type changes from rock to loose sand. There occurs a maximum settlement at the inner edge of the leeward side of chimney non uniformly. More settlement is in case of loose sand and medium sand. As the foundation behaves like rigid while interacting with dense sand and rock, there will not experiences much deformations on the soil. It is obtained that both tangential and radial moments are higher for chimneys with maximum height, which implies that the height of chimney increases the difference in moments.

The paper "WIND LOAD ANALYSIS OF TALL CHIMNEYS WITH PILED RAFT FOUNDATION CONSIDERING THE FLEXIBILITY OF SOIL" presents the analysis of tall reinforced concrete chimneys with different elevations and base diameters. It is assumed that the behavior of chimney was linear elastic. Tall RC chimney of uniform thickness with annular piled raft foundation is considered for the analysis.

It is taken as the diameter of shaft of the chimney at the ground level is 50% lesser than the overall diameter of raft of the chimney. For all chimneys at a depth of 30m the soil type was assumed as bed rock. The study was conducted using the finite element software ANSYS.

The figure given below shows the plan view of piled raft foundation of chimney with height to depth ratio 12.

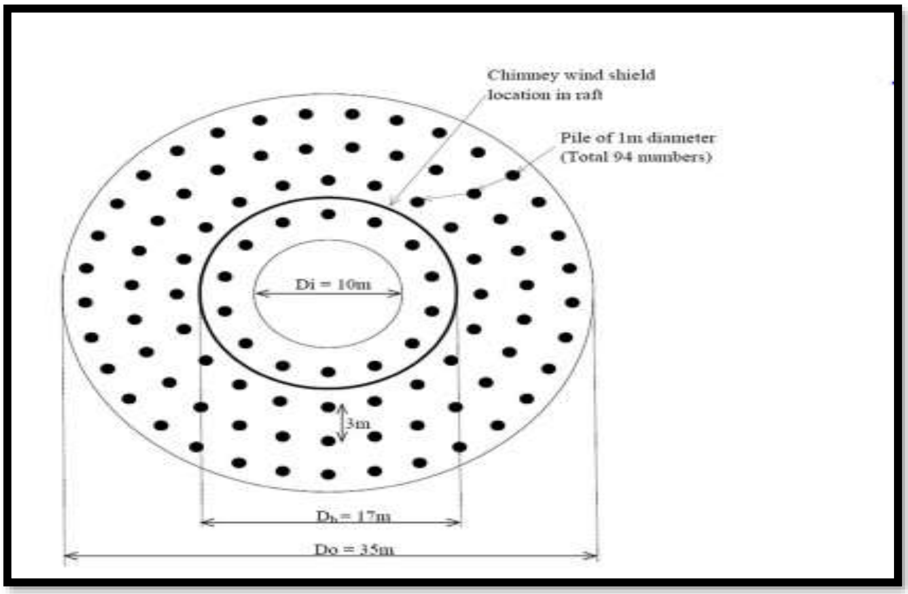

Fig 1. Plan view of 200m height chimney with piled raft foundation

For modeling the soil, elastic continuum approach was taken on. Wind load is calculated as per IS 4998(Part 1) - 1992(2003) and is applied as point load at a particular intervals of height. Two methods are used for the estimation of along wind load and across wind load. They are simplified method and random response method.

In simplified method, the drag force per unit height at any level of chimney is calculated by using the equation,

$$F_z = P_z C_D d_z$$

Where P_z is the design wind pressure at z height, C_D is the drag coefficient of chimney and d_z is the diameter of chimney at z height.

In random response method, the drag force is calculated by,

$$F_z = F_{zm} + F_{zi}$$

Where F_{zm} is the wind load due to hourly mean wind speed(HMW) at z height

$$F_{zm} = 0.6 v_z^2 C_D d_z$$

Vz is the HMW speed and F_{zi} is the wind load due to fluctuating component of wind at z height.

$$F_{zi} = \frac{3(G-1)}{H^2} \frac{z}{H} \int_0^H F_{zm} z d_z$$

$$G = 1 + g_f r \sqrt{B + \frac{SE}{\beta}}$$

G is the gust factor, gf is the peak factor, r is the twice of turbulence intensity, B is the background factor indicating the wind load fluctuation, E is the available energy, S is the size reduction factor and β is the coefficient of damping of the structure.

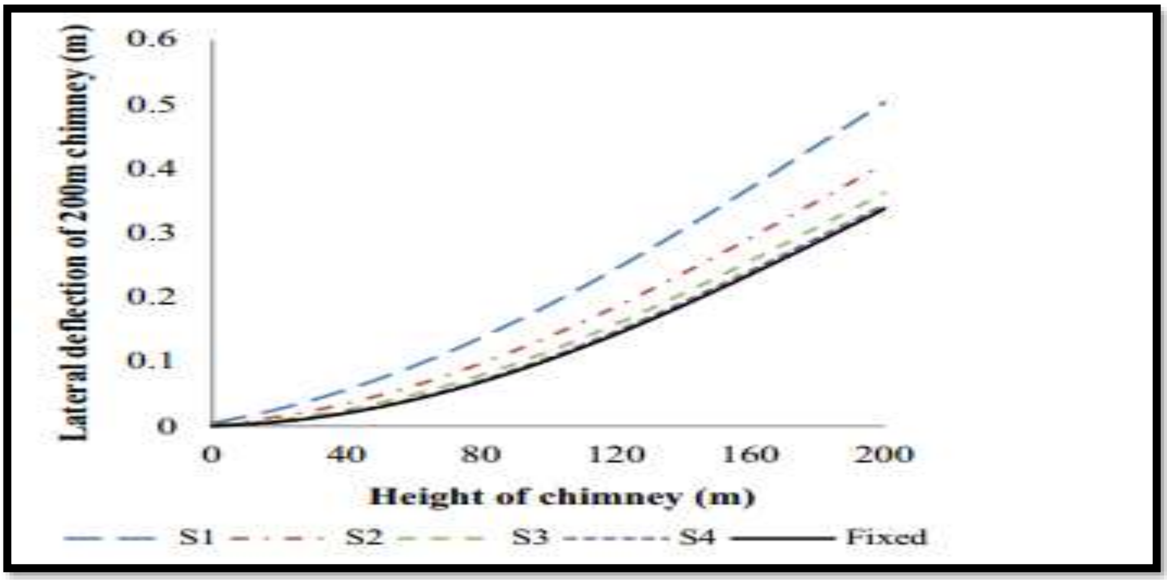

Fig 2: Lateral deflection of 200m height chimney with different soil type, flexible base and fixed base.

The graph shows the lateral deflection of a chimney with 200m height. Their selected different soil conditions with flexible base and fixed base for comparing. From the graph it is clear that as the height increases lateral deflection also increases. The results obtained from the study are fundamental natural frequency obtained from chimney with fixed base is higher. The variation of fundamental natural frequency with flexible base that of rigid base is more for chimney with minimum height and resting on loose type sand.

On the analysis of lateral deflection, the deflection of chimney increases with the flexibility of soil. Another fact found out from the study is that, after the analysis, the maximum deflection is experienced at the tip of the chimney in all cases. The variation of tangential moment increases with flexibility of soil and seen until H/20 from the base. The variation of radial moment is more for chimneys with lower elevation under flexible raft on loose sand. The variation of base moment increases with the stiffness and is maximum for fixed base chimneys than flexible based chimneys. The study concludes that the chimney with skin friction piles in loose sand is not suitable for construction works and they are not suggested in practical cases.

In the paper "ANALYSIS OF FOUNDATION OF TALL RC CHIMNEY INCORPORATING THE FLEXIBILITY OF SOIL" deals with the 3D finite element analysis of chimneys with annular raft foundation and piled annular raft foundation. Here the flexibility of soil considered for the analysis. The selected case for analysis was soil subjected to across wind load case.

The analysis has been done on ANSYS and the behavior of soil has been assumed as linear elastic. The settlement and bending moment of both structures were studied and compared in this paper. Different types of soil conditions were considered for the study. They are loose sand, medium sand, dense sand and rock. Soil stratum is considered bed rock up to a depth of 30 m from the ground level. Terrain category 2 and a wind speed of 50m/s is selected for the analysis. The figure given below shows the finite element model of integrated chimney piled raft soil system.

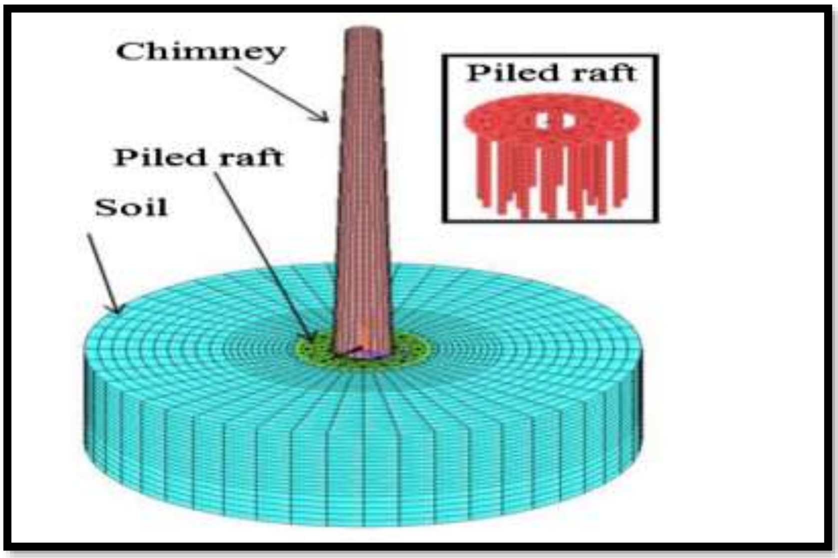

Fig 3: Finite element model of integrated chimney piled raft soil system

From the analysis it is clear that as the stiffness decreases, the tangential bending moment increases and it is maximum at the inner edge of the raft. It s gradually decreases to the outer edge of raft. This has been for soil types loose and medium since the raft is rigid. Tangential moment is maximum at wind shield shell location and it is for soil type's dense sand and rock.

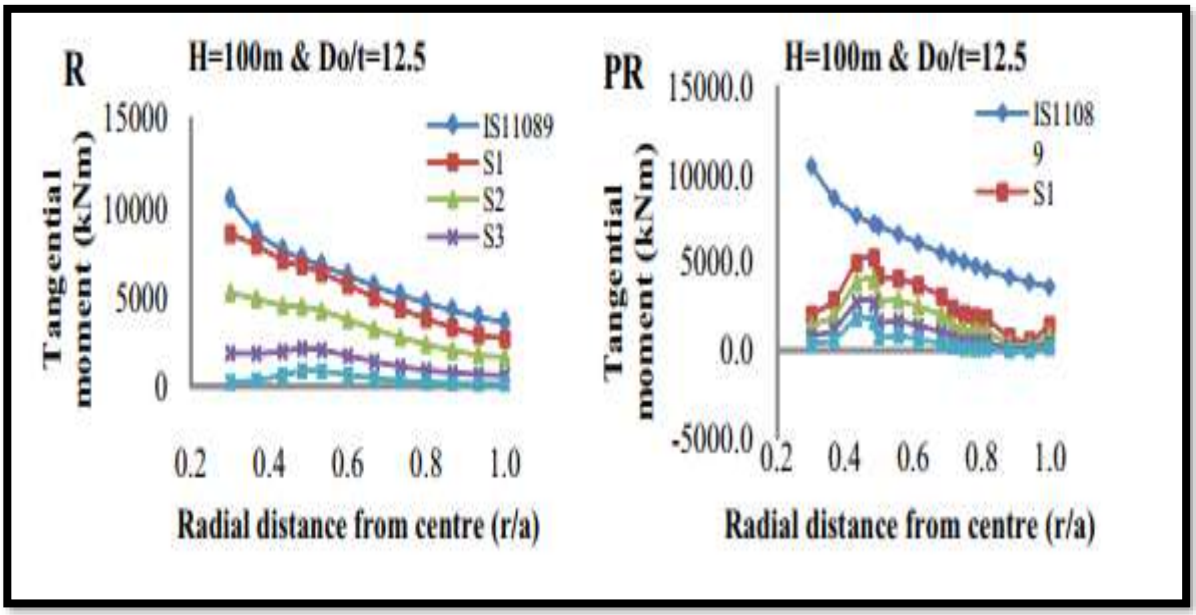

Fig 4: Tangential moment of chimney with height 100m.

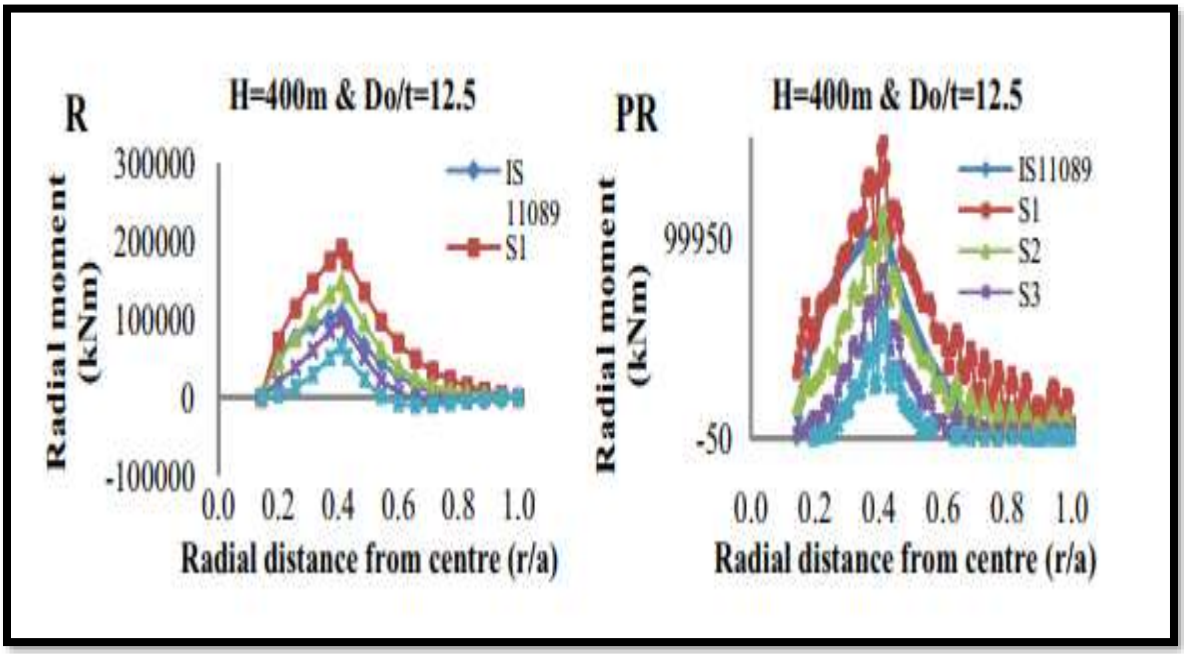

Fig 5: radial moment of chimney with height 100m.

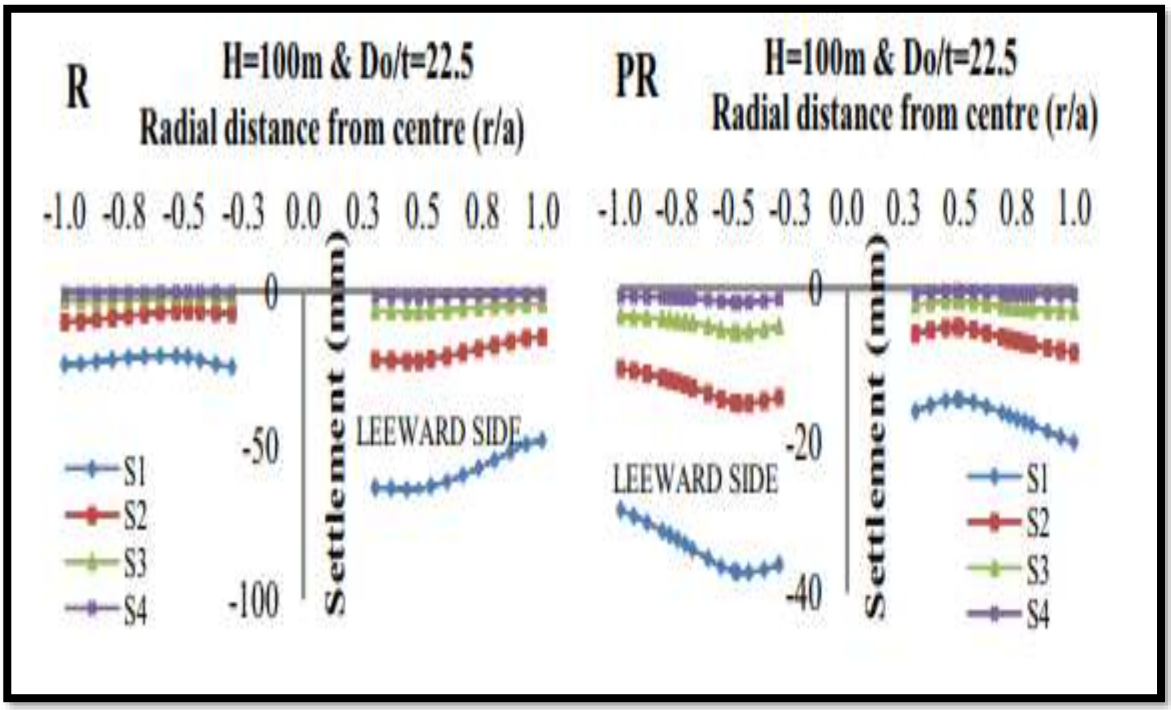

Fig 6: settlement of chimney in mm.

The radial moment is peak at wind shield shell location in the raft. As the stiffness of soil increases, the radial moment decreases. The settlement of raft decreases as the soil type varies from loose sand to rock. The settlement pattern is non uniform and is maximum at the inner edge of leeward side of raft. It is varies from the inner edge to the wind shield location.

For rock type soil the deformation is negligible. The raft acts like rigid when it came into contact with the rock type soil. The study concludes that piled raft foundations are suitable for loose sand and medium sand.

DYNAMIC ANALYSIS

Dynamic analysis is a part of structural analysis and it can be referred as the calculation of the response of a building structure to earthquakes. There are two types of dynamic analysis. One is linear and the other is non linear.

In linear dynamic analysis, the soil structure interaction will calculate with respect to time. Generally, linear procedures will apply if the structures are expected to remain elastic in nature. The performance objective of the structure implies greater inelastic demands, the uncertainty with linear procedures increases to a point that requires a high level of conservatism in demand assumptions and acceptability criteria to avoid unintended performance. Therefore, procedures integrated with inelastic analysis can minimize the uncertainty of the overall analysis.

Similar as linear analysis, soil-structure interaction plays another role in nonlinear dynamic analysis which utilizes the combination of ground motion data with a detailed structural model, therefore it gets a capability to produce a result with relatively low uncertainty. In nonlinear dynamic analyses, the detailed structural model subjected to a ground-motion record produces estimates of component deformations for each degree of freedom in the model and the modal responses are combined using schemes such as the square-root-sum-of-squares. In non-linear dynamic analysis, the non-linear properties of the structure are considered as part of a time domain analysis.

The study “NON LINEAR DYNAMIC ANALYSIS OF RCC CHIMNEY” deals with the analysis of nonlinear behaviour of RC chimneys. It is assumed that the RC chimney is located in zone II with a basic wind speed of 33m/s and the soil stratum is hard. Time history analysis is used to find out the effect of seismicity. Gust factor method is used to find out the effect of wind loads. It has been done for different heights and longitudinal sections like uniform, tapered and uniform tapered. Analysis has been done using SAP 2000. The figure given below shows the displacement v/s height graph.

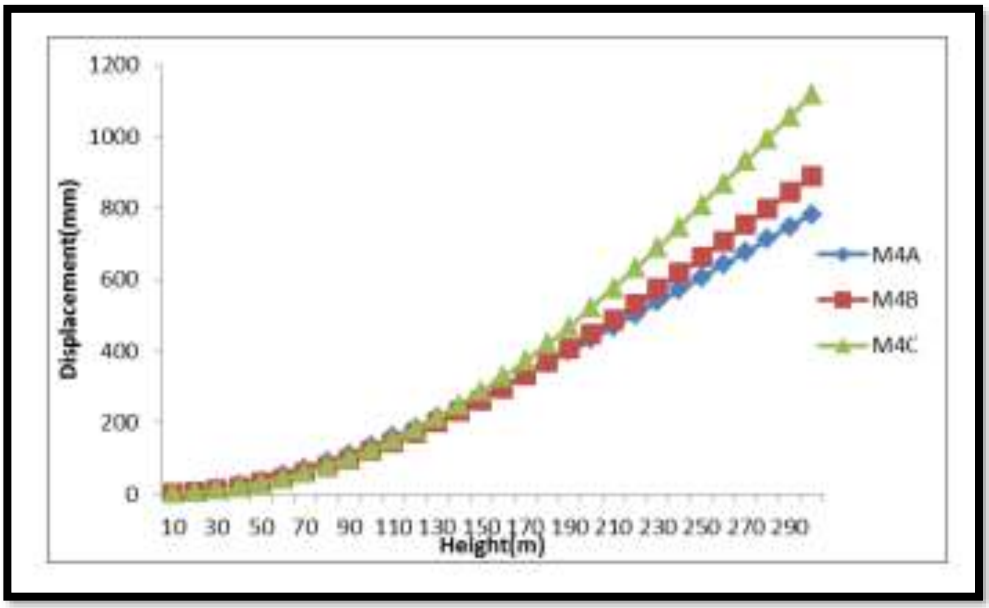

Fig 7: Displacement v/s height graph

The result of this study includes the peak displacement, acceleration, joint displacement, base shear, period and frequency corresponding to each mode. From wind analysis it is found that the uniform tapered section has more displacement. As the height of chimney increases the displacement also increases.

The purpose of paper “DYNAMIC ANALYSIS OF RC CHIMNEYS” is to analyze the displacement and base shear of RC chimney subjected to seismic loads. Seismic analysis is carried out using response spectrum method. Along with this, free vibration analysis has been carried out to find out the fundamental natural frequency and mode shapes. The analysis has been done using SAP 2000.

A chimney with fixed support is considered for the analysis and their experiences a cantilever action on the elements of chimney. The diameter of tapered chimney is varying from top to bottom and shown as increasing from the top to bottom. The figure below shows the 3D view of chimney along with the view obtained from the modal analysis.

Fig 8: 3D view and view after modal analysis of tapered chimney

They had been taken 16 models with 4 different shell thickness for analysis. Modal analysis is performed for determining the mode shapes of the structure. Along with this response spectrum analysis has been performed to identify the effect of earthquake load acts on the structure.

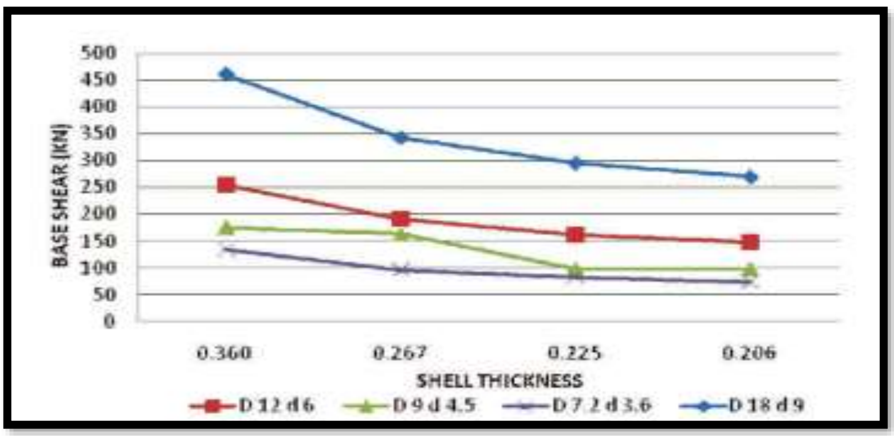

Fig 9: Shell thickness v/s base shear

It is noticed from the response spectrum analysis that, as the shell thickness decreases the displacement increases and the base shear decreases. Also it is found that there is no variation in the fundamental natural frequency of structure as the shell thickness varies.

"ANALYSIS OF SELF SUPPORTING CHIMNEY" is a paper deals with the dynamic analysis of a self supporting chimney. This paper also contains the parametric study of chimney with different diameter, height, wind zone, earthquake zone, soil type and load conditions. Earthquake zones selected were zone II with hard soil and zone V with soft soil. Wind speed varies from 33m/s to 55m/s. The chimney has an internal temperature of 100 degree Celsius. Microsoft Visual Basic 6.0 is programming software which is used for the analysis. The analysis includes both seismic and wind analysis. The results acquired from the analysis compared to each other. The effect of along and across wind load were considered.

Earthquake loads, fundamental time period, horizontal seismic forces etc were calculated using IS 1893 (Part 1): 2002. Wind loads are calculated using IS 875 (Part 3): 1987. Analysis has been done using random response analysis with the help of IS 4998 (Part 1): 1992. Methodology adopted for the analysis of chimney is expressed as a flow chart.

Form 1 in the software used to find out the geometrical properties of the structure such as area of concrete, area of lining, moment of inertia, weight etc of concrete. Form 2 calculates the shear force, bending moment, stresses in concrete and reinforcement. Form 3 calculates the horizontal forces induced due to the effect of static wind force, corresponding bending moments and relative stresses.

Form 4 is used to find out the design horizontal forces due to the effect of across wind load and the combined effect of across and along wind load. Form 5 determines the stresses due to the combination of dead load and wind load or earthquake load. Also form 6 determines the stresses due to the combination of wind load and temperature. Form 7 is used to analyze the various load combinations as per IS 4998 (Part 1): 1992. Figure 10 shows the flow chart explaining the methodology.

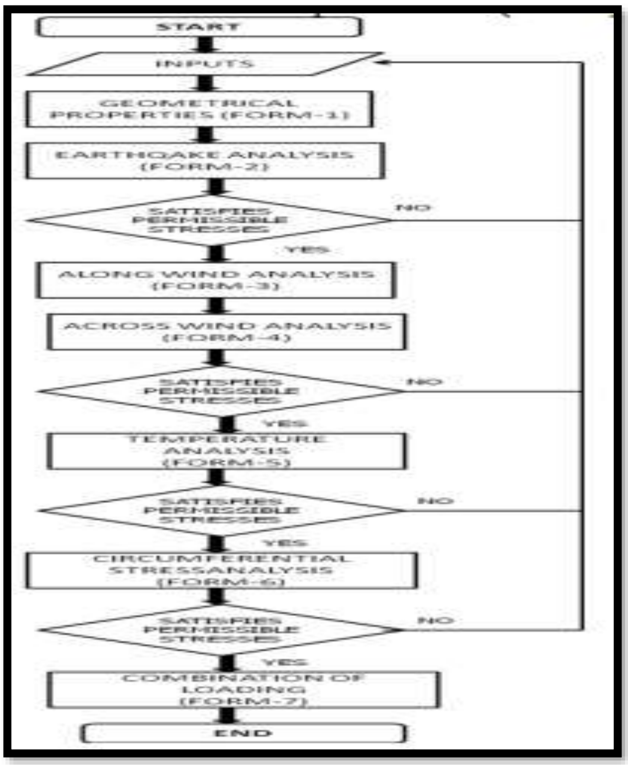

Fig 10. Methodology of analysis.

The study concludes that the oscillation depends on the wind speed, slenderness ratio. As the height varies the other data's of chimney remains constant. As the height increases, the stress also increases. Analysis results give the stresses developed in the chimney due to the critical earthquake zone at a minimum wind speed of 33m/s.

CONCLUSION

The above studies give the following findings;

- The moments experienced on the structure such as tangential and radial are higher for chimney with maximum height.
- Settlement is more in case of loose sand and medium sand than dense sand and rock.
- The fundamental natural frequency is higher for chimney with fixed base than flexible base.
- Maximum deflection is experienced at the top most portion of the chimney.
- Also it increases with the flexibility of soil.

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