Comparative Analysis Of Steel Chimney Subjected Dynamic Seismeic Load And Wind Load

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Abstract- *A chimney is a structure that provides ventilation for hot flue gases or smoke from a boiler, stove, furnace or fireplace to the outside atmosphere. Chimneys are typically vertical, or as near as possible to vertical, to ensure that the gases flow smoothly, drawing air into the combustion. The height of a chimney influences its ability to transfer flue gases to the external environment via stack effect. Additionally, the dispersion of pollutants at higher altitudes can reduce their impact on the immediate surroundings. Industrial Chimneys are tall and slender structures with circular cross-sections. The project based on the analysis and design concepts of chimneys as per Indian codes provisions incorporation was also made through finite element analysis. Different types of steel chimney models are made by varying its height, diameter and geometry. All the models are prepared in the STAAD-Pro Software. The main objective of this study is to perform vibration analysis of steel chimney for dynamic wind loads using different critical velocity.*

Keywords- Steel Chimney, WIND Analysis.,STAAD-Pro

I. INTRODUCTION

1.1General

Chimneys are tall and slender structures with uniform or tapering circular cross-sections that are installed for releasing hot flue gases or smokes produced in any industrial furnaces, boilers or fireplaces into the higher heights of the atmosphere. Chimneys are designed as tall vertical structures in such a way that they release unwanted harmful gases smoothly by drawing air into the combustion, which is referred as the “Stack Effect”. Steel chimneys are classified on the basis of their supports and shape. Based on support they are classified as cable stayed or guyed chimneys and self-supporting chimneys. Self-supporting chimneys are widely used in the industrial areas..

Figure 1.1 Industrial Steel Chimneys (Ref: www.vedomosti.ru)

Geometry of a self-supporting steel chimney plays an important role in its structural behavior under lateral dynamic loading. However, the basic geometrical parameters of the steel chimney (e.g., overall height, diameter at exit, etc.) are associated with the corresponding environmental conditions. Steel chimneys to ensure a desired failure mode.

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

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

1.2Necessity of the work

The undertaken work is important because dynamic analysis of steel chimneys has always been a critically important phenomenon. Steel chimneys are very important structural components in any industry and their analysis and design along with regular maintenance is a crucial factor in the modern industrial age. The main aim to undertake this work is to perform vibration analysis for different critical velocity using STAAD-Pro software.

1.3Objectives of Study

1. To analyze with guyed or without guyed steel chimney in various earth quake zones as per IS code

1893-2000 & static wind zones as per IS 875 (part-3)1987 by using STAAD PRO.

2. The effect of static seismic force can be analyzed by seismic coefficient method by STAAD PRO.
3. To determine maximum stresses, maximum bending moment & deflection of chimney at 3 different basic wind speed.(i.e. 47m/s,39m/s,55m/s)

To compare maximum stresses, maximum bending moment & deflection with guyed & without guyed chimney

II. THEORITICAL CONTENT

2.1 General

This Chapter consists of information regarding steel chimney such as types, geometry etc. and various codal provisions, STAAD-Prosoftware theory.

2.2 Classification of Chimney

On the basis of types of construction of the shaft, the chimney are classified into two types, namely, self-supporting and guyed. The chimney may be lined either over the entire or part height depending upon the temperature and aggressiveness of the flue gases.

2.2.1 Guyed steel chimneys

In high steel chimneys, the mild steel wire ropes or guys are attached to transmit the lateral forces. Such steel chimneys are known as *guyed steel chimneys.* In guyed steel chimneys, all the externally applied loads (wind, seismic force, etc.) are not totally carried by the chimney shell..

2.2.2 Self-Supporting Steel Chimney

Self-supporting steel stack resist all external loads acting on it by acting as a vertical cantilever structure. Several static and dynamic loads act on the stack xternally and create actions that tend to laterally displace, deflect or overturn the stack.

Advantages

In case of steel structures, steel has a high strength/weight ratio. Thus, the dead weight of steel structures is relatively small. This property makes steel a very attractive structural material for construction of high rise stack like structures.

2.3 Geometric Profiles of Steel Chimneys

Profile of a steel stack can be circular tapering or conical near base and cylindrical up to the top. IS 6533(part2):1989 deals with the circular chimneys that are having conical flare portion up to one third of the effective height of the stack from the bottom and then continued .

2.4 Geometric parameters of Steel Chimney

IS 6533(Part2):1989 defines the structural aspects for steel chimneys and also gives recommendations for basic dimensioning of steel chimneys. The basic geometrical parameters of the steel chimney are associated with the corresponding environmental conditions. Also Indian standard design code (IS-6533 (Part 2): 1989) defines many criteria for the geometry of stack like structures to ensure a desired failure mode. **Clear Diameter of The Stack (D)** : It is the nominal diameter of the stack for unlined chimneys

1. **Height of The Stack (H):** It is the total height of the stack from base to top.
2. **Top Diameter (D_t)**: It is the outer diameter of the stack at the top .according to codal provisions this diameter has to be minimum one twentieth of the height of the stack for unlined steel chimneys. This is one the basis of the undertaken work.
3. **Base Diameter (D_b):** It is the outer diameter at the base of the stack .minimum dimensions of base diameter should be 1.6 times the dimension of the top diameter. Which means the ratio of base diameter and top diameter should be minimum 1.6

III. METHODOLOGY

3.1 General

Following methodology is adopted for this research. It includes modelling in Ansys, Study of code for wind zone and earthquake zone, validation and results **Flowchart 1** Methodology

3.2 Wind load

Wind load is considered as the most influential load acting on the steel chimneys .this load is divided into two parts as static wind load and dynamic wind load. From various literatures reviews dynamic wind load is found to be the governing load for the analysis and design of the chimneys.

I) Along-wind effect
ii) Across -wind effect

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 structure. The dynamic component, which can cause oscillations of a structure, is generated due to the following reasons:

I) Gustsii) Vortex sheddingiii) Buffeting

3.2.1 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.

3.2.2 Static wind effect

A static force called as drag force, obstructs an air stream on a bluff body like chimney. The distribution of wind pressure depends upon the shape and direction of wind incidence. Due to this a circumferential bending occurs and it is more significant for larger diameter chimney. Also drag force creates along-wind shear forces and bending moments.

3.3 Standard Codes Used in the Analysis

3.3.1IS 875 (Part-3):1987

"Code of Practice for Design Loads (Other Than Earthquake) For Buildings and Structures" This part covers

a. Wind loads to be considered when designing buildings, structures and components.

3.3. IS 6533 (Part-1): 1989

Indian standard design and construction of steel chimneys-code of practice (Mechanical aspects). This includes

a. Determination of inside diameter.

b. Determination of stack height based on pollution norms and dispersion of gases into the atmosphere.

3.3.3IS 6533 (Part-2): 1989

This is Indian Standard Code of practice for design and construction of steel chimneys (structural aspect). This includes

a. Material of construction for bolts, plates, rivets and welding

b. Loadings and load combinations

3.4 Assumptions in the Analysis

The undertaken research work is analytical and does not involve design of the steel chimneys. Therefore selection of steel stack configurations and their modeling needs certain basic assumptions. They are listed as follows:

1. Location of the stack is topographically planar and velocity of wind at the location is uniform.
2. For the purpose of calculations, it is assumed that the static wind load is acting at the center of pressure.
3. The base of the stack is perfectly rigid and acts as a perfect cantilever.
4. Seismic loads and dynamic wind loads are not simultaneously acting on the structure.
5. There are no additional lateral movements from the duct transferred to the stack
6. material of the stack is perfectly homogeneous and uniform throughout the height of the stack
7. Along wind effects are more prominent than the across wind effects.

3.6 Static wind load:

Static wind load is calculated as per the procedure given in IS 875:Part3.

Basic wind speed = V_b m/s

Design wind speed $V_z = V_b \times K_1 \times K_2 \times K_3$

Where, K_1 = probability factor (risk coefficient)

K_2 = terrain, height and structure size factor,

K_3 = topography factor

Wind pressure = $0.6\ V_z^2$ (wind pressures at specified intervals of the stack heights are estimated)

3.8 Problem Statement

1.	Height of the chimney	60 m
2.	Outer diameter of chimney at bottom	5.455m
3.	Outer diameter of chimney at top	3.273 m
4.	Thickness of shell at bottom	0.15 m
5.	Thickness of shell at top	0.15 m
6.	Thickness of air gap	0.08 m
7.	Thickness of fire brick lining	0.1m
8.	Grade of concrete	M25
9.	Height to base diameter ratio	11
10.	Top diameter to base diameter ratio	0.6
11.	Basic wind speed(Delhi,Mumbai,Kolkta)	47,44,50m/s
12.	Structural steel	78.5kN/m3

13. Live load 5kN/m3
14. Terrain category 2
15. Class of structure C
16. Risk coefficient k1 1
17. Topography factor k3 1
18. Zone factor 0.16
19. Seismic zone III
20. Importance factor (I) 1.5
21. Reduction factor (R) 3

- K2 factor taken from IS code 875(part-3):1987 from Table -2
- Earthquake load for the chimney has been calculated as per IS 1893(par 4) : 2005

For Guyed rope:-
Height-30.063m
Length -10
diameter-20mm

5.7 Design

Basic dimensions of chimney
Total height of chimney 60
Height of the flare = 1/3H=1/3x60=20m

1) Computation of wind pressure
Divide the entire chimney into section 10m height.

The design wind speed at any height z is given by
Vz = Vb. K1. K2. K3
Where , Vb – basic wind speed at the site
K1 –probability factor = 1
K3- topography factor=1
K2- terrain, height and structure size factory
Vz = 47 x 1 x 1 x K2
Wind pressure Pz = 0.6 V_z^2
Chimney adopting shape factor of 0.7

IV. MODELLING AND ANALYSIS

4.1 General

This chapter deals with the static and dynamic analysis of self-supporting short circular industrial chimneys. Total 9models of steel chimneys are analyzed for static and dynamic wind loadings.

Model No.1 –60 m Steel Chimney WITH WIRE (Terrain Category – 1I)
Model No.2 –60 m Steel Chimney WITHOUT WIRE (Terrain Category – 1I)

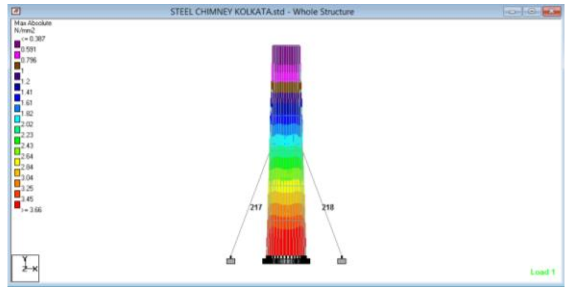


Figure 4.1 max absolute stress guyed rope

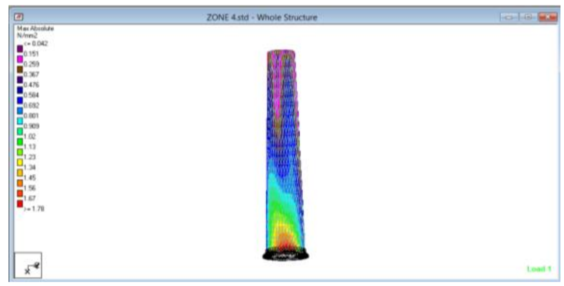
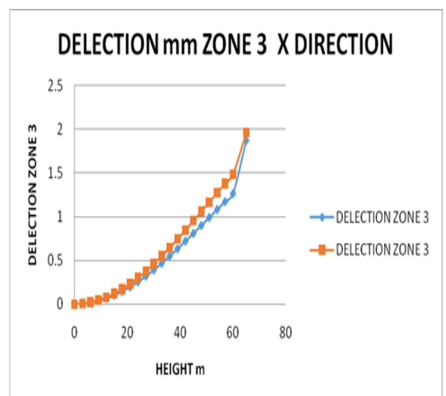


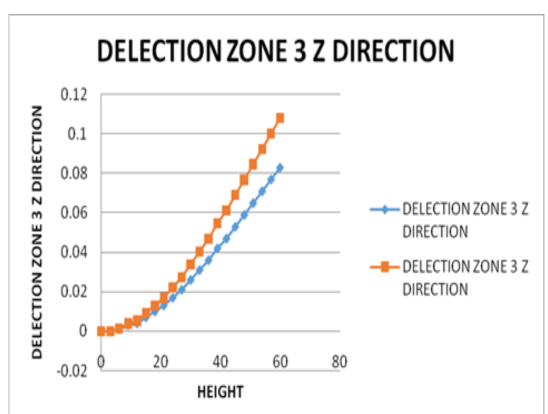
Figure 4.2 max absolute zone 4 guyed rope

V. RESULT & DISCUSSION



deflection zone 3 x

In above graph the max. Deflection is 1.48 in without gyed rope zone 3x.

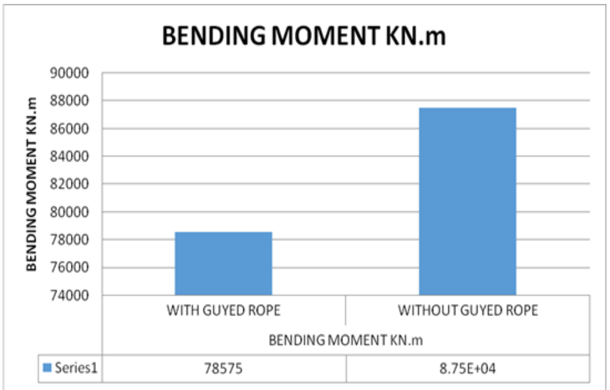


deflection one 3 z

In above graph the max. Deflection is 0.11 in without gyed rope zone 3z.

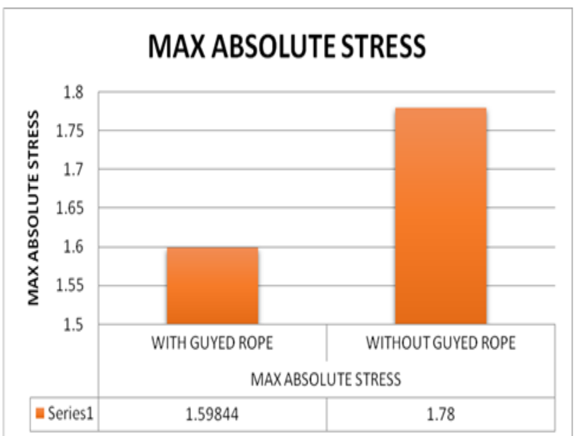
SEISMEIC GRAPH:

Bending moment



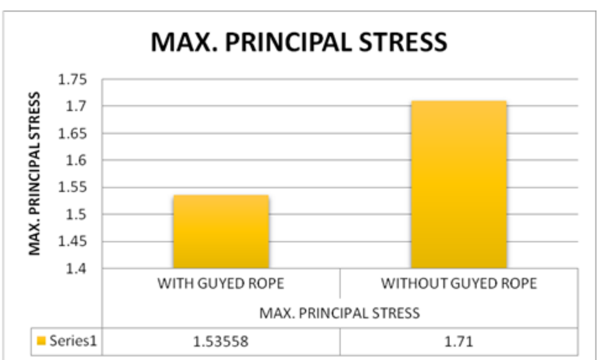
bending moment

In above graph the max. Bending moment is 87500 in without guyed rope zone



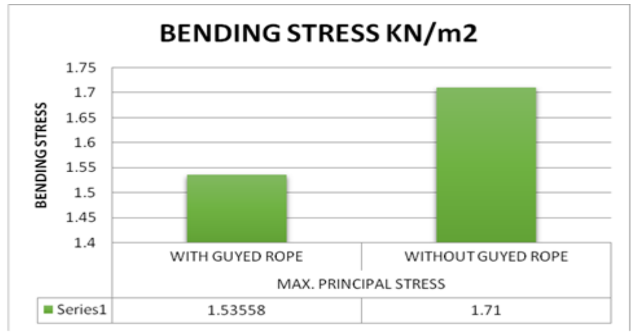
max absolutemoment

In above graph the max. Absolutemoment is 1.78 in without guyed rope zone



max principal stress

In above graph the max. Principal stress is 1.71 in without guyed rope zone.



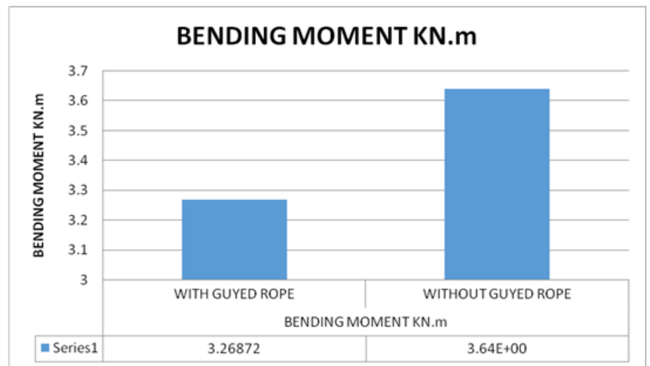
bending stress

In above graph the max. Bending stress is 1.71 in without guyed rope zone.

- **WIND LOAD**

1. Mumbai

bending moment



bending moment

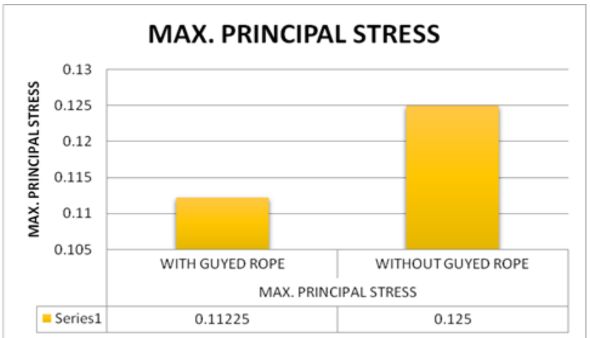
In above graph the max. Bending moment is 3.6 in without guyed rope zone.

Max. Absolute Stress

Max. Absolute Stress

In above graph the max. Absolute stress is 3.66 in without guyed rope zone 3x.

Max. Principal Stress

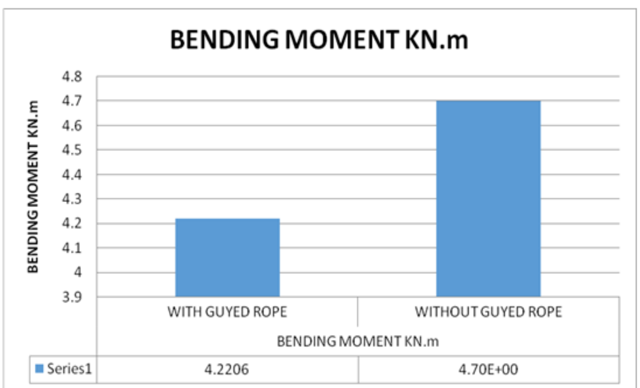


Max. Principal Stress

In above graph the max. Absolute stress is 0.125 in without guyed rope zone 3x.

2.Delhi

bending moment



bending moment

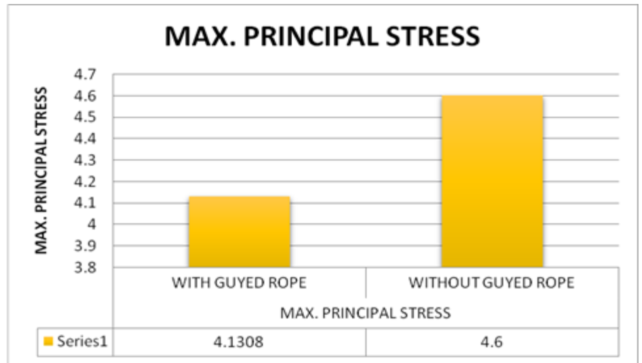
In above graph the max. Bending moment is 4.7 in without guyed rope zone.

Max. Absolute Stress

Max. Absolute Stress

In above graph the max. absolute stress is 4.5 in without guyed rope zone.

Max. Principal Stress

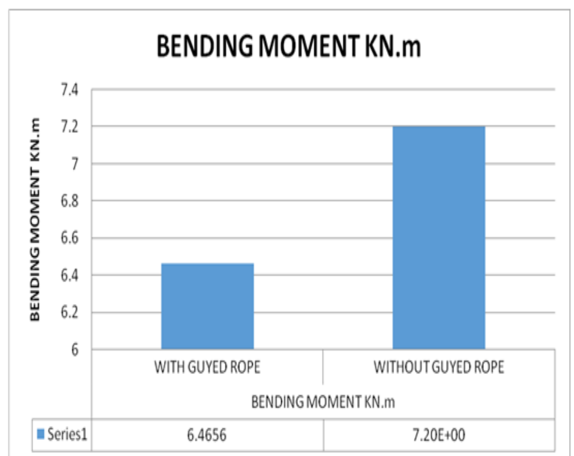


Max. Principal Stress

In above graph the max. Principal stress is 4.6 in without guyed rope zone.

3.Kolkata

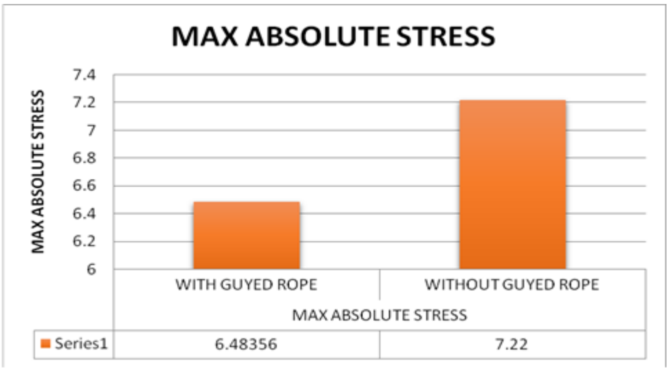
bending moment



bending moment

In above graph the max. Bending moment is 7.2 in without guyed rope zone.

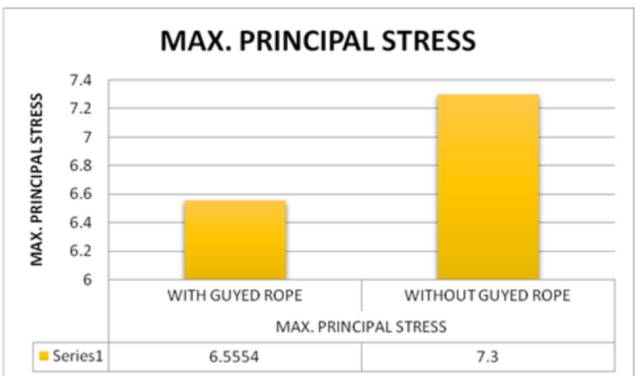
bending stress



Max. Absolute Stress

In above graph the max. absolute stress is 7.22 in without guyed rope zone.

Max. Principal Stress



Max. Principal Stress

In above graph the max. principal stress is 7.3 in without guyed rope zone.

V. CONCLUSIONS

Following conclusions are drawn as per the results obtained from analysis with and without opening.

1) The results obtained from analysis in STAAD-PRO for response of chimney are compared with that obtained from IS Code, provisions and other software. Here it can be safely said that STAAD-PRO is an efficient tool for analysis of chimney.
2) The wind speed is calculated for mumbai, kolkata and delhi region as per IS 875 and for earthquake analysis zone 3 and zone 4
3) The comparison is made with guyed wire and without guyed wire for height of 60 m
4) For dynamic analysis shear force and bending moment values decreases as the height of chimney increases from top to bottom.
5) Finite element analysis gives a non-zero shear at the top due to finite size of the top element. The shear at top from finite element analysis will be less if more elements are taken.
7) The deflection, drift ,bending stresses and shear stresses decreased as guyed wires are provided .All the readings are decreased by 15-20% by use of guyed wire. Hence it can be concluded that for tall chimney guyed wires should be used
8) The stress concentration for guyed wire is more as compaired to that of without guyed wire.

VI. FUTURE SCOPE

With the rapid industrialization construction of chimney is inevitable. Earthquakes are also increasing in number as the result of large changes undergoing in mother earth. A seismic risk is increasing day by day and calls for earthquake resistant construction. These earthquakes are not only harmful to building, bridges, water tank but also chimneys, which are overlooked as compared to other structures. Not enough work done on this subject. This work is only a stepping-stone to create awareness regarding the seismic response of tall chimneys. A lot of work is still required to be done. In light of this the future scope of present work is as follows-

a) Compare the dynamic response of steelchimney with some other material like FRC.
b) Study the effect of impact of falling of chimney on the surrounding structures (Interference effect on chimney).
c) Study the change in seismic behavior of chimney when supported by pile foundation and raft foundation that is taking into account soil structure interaction.
d) Study the seismic response of chimneys based on conditional time history.

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