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SEISMIC ANALYSIS AND DESIGN OF RCC CHIMNEY

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Abstract- *Chimneys are characterizing landmarks of power plants and industrial setups. Chimneys are required to carry vertically and discharge, gaseous products of combustion, chemical waste gases, and exhaust air from and industry to the atmosphere. Rapid growth of industrialization and increasing need for air pollution control has made RC chimneys a common structure in the modern scenario. With large scale industrialization, number of chimneys and stacks being constructed is increasing year by year. In many industries chimneys are required to leave hot waste gasses at greater height. 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 to 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. The Present paper deals with the study of Seismic Analysis and design of Industrial chimney. The Existing chimney is chosen from Raichur Thermal power station [RTPS]. Existing chimney of 220m height was analyzed in STAAD Pro software with varying heights. The chimney heights are varied and behavioral changes due to static and seismic loads are observed. Plate element, line element was chosen from STAAD pro software for modeling of chimney. Seismic analysis is carried out for different earthquake zones (i.e. Zone II, Zone III, Zone IV).*
Maximum Displacements, Maximum shear forces, Maximum bending moments, stresses are obtained from the analysis. Maximum Displacement v/s height of chimney, Maximum shear force v/s height of chimney, maximum bending moment v/s height of chimney is plotted graphically.

Keywords *– Chimney, Design, Displacements, Modeling, Stresses, Static, Seismic*

I. INTRODUCTION

Chimneys or stacks are the essential industrial structures which are used for the emission of toxic gases or smokes from a boiler, stove, fireplace or Furnaces to a larger elevation such that the gases should not pollute the surrounding environment. These are generally tall, slender in nature & consist of cylindrical or circular cross-sections. There are different types of construction materials, such as concrete, steel, brick masonry, are used in construction of chimneys. Steel chimneys are suited for process works where there is a short term heat-up period and inadequate thermal capacity. Also steel chimneys are more economical up to a height of 35m - 40m. Usually chimneys are almost vertical in view in order to ensure that the hot gases should flow out smoothly. Chimneys are often tall to increase their draw of air for the Combustion and to dispose the pollutants in flue gases over a greater area In order to decrease the pollution concentration according to regulatory or other limits. Figure below shows image of self-supporting RC chimneys.

A. Function of Chimney

A chimney is a means by which dispose gases are released at a high enough Elevation so that after weakening due to atmospheric disturbance, their concentration and that of their entrained solid particulates is within satisfactory limits on reaching the ground. A chimney achieves simultaneously reduction in concentration of a number of pollutants (SO_2, Fly ash, etc) and being highly reliable it doesn't require any standby. While these are its clear merits, it is well to remember that a chimney is not the complete solution to the problem of pollution control.

C. Technical Details of Raichur Thermal Power station [RTPS]

1) Location – RTPS (Raichur Thermal Power Station) Stage III units 5 & 6 RC Multiflue Chimney
2) Place – Shaktinagar, Raichur
3) Height of chimney – 220m
4) Bottom diameter –17m
5) Top diameter –13.1m
6) Thickness of shell –0.25m

Earthquake load for the chimney has been calculated as per IS: 1893 Part-1 2002. Accordingly the relevant parameters are as follows:

Zone factor (Z) considered = 0.1, 0.16, 0.24

Seismic zones considered = II, III, IV

Importance factor (I) = 1.5 AS per IS 1893 (Part IV) – 2005 –Page No. - 8 Table No.-2

Reduction factor (R) = 3 As per IS 1893 (Part IV) – 2005 – Page No. – 9 Table No. - 3

Soil type considered– soft soil.

D. Statement of Problem

1) To Analyze and design the existing chimney (220m height) using Staad pro software for static and seismic Analysis.
2) To Analyze and design the existing chimney and obtaining displacement, SF, BM, and thus studying various parameters by varying height and shell thickness.
3) To Study the behavior of existing chimney for earthquake loading.

E. Objectives of the present Study

1) To Study the linear static analysis (i.e. self weight) of existing chimney with varying heights (CH 1, CH 2, CH 3).
2) To Study the comparison between chimneys for displacement with varying heights.
3) To Study comparison of shear force and bending moment of existing chimney for manual and software results for earthquake loading
4) To Study the comparison between shear force and bending moments for selected earthquake zones (i.e. Zone II, Zone III, and Zone IV).
5) To Study optimum height of chimney for static and seismic analysis.

F. Methodology

Based on the objectives of present study following methodology has been set for present work.

- Static Analysis – Dead Load or Self-Weight.
- Dynamic Analysis – Seismic Analysis.
- STAAD PRO software.
- Element used for modeling- Line element, 4 noded plate element, 20 noded line element.
- IS 1893 part-I (2002) – Criteria for Earthquake Resistant Design of Structures, Part 1: General Provisions and Buildings.
- IS 1893 part-IV (2005) – CRITERIA FOR EARTHQUAKE RESISTANT DESIGN OF STRUCTURES. PART 4 INDUSTRIAL. STRUCTURES.

Table – 1 Chimney at different Heights

Sl no	Chimney Notations		Chimney Height (m)	CHIMNEY Discription
1	Chimney 1	CH 1	209	5% Decrease in dimension of existing chimney
2	Chimney 2	CH 2	220	Existing chimney (RTPS)
3	Chimney 3	CH 3	231	5% Increase in dimension of existing chimney

II. INTRODUCTION TO STAAD PRO SOFTWARE

STAAD or (STAAD Pro) is a structural analysis and design computer program originally developed by Research Engineers International at Yorba Linda, CA in year 1997. In late 2005, Research Engineers International was bought by Bentley Systems.
An older version called Staad-III for windows is used by Iowa State University for educational purposes for civil and structural engineers. Initially it was used for DOS Window system. The commercial version STAAD Pro is one of the most widely used structural analysis and design software. It supports several steel, concrete and timber design codes. It can make use of various forms of analysis from the traditional 1st order static analysis, 2nd order p-delta analysis,

geometric non linear analysis or a buckling analysis. It can also make use of various forms of dynamic analysis from modal extraction to time history and response spectrum analysis.
In recent years it has become part of integrated structural analysis and design solutions mainly using an exposed API called Open STAAD to access and drive the program using a VB macro system included in the application or other by including Open STAAD functionality in applications that themselves include suitable programmable macro systems. Additionally STAAD Pro has added direct links to applications such as RAM Connection and STAAD. Foundation to provide engineers working with those applications which handle design post processing not handled by STAAD Pro itself. Another form of integration supported by STAAD Pro is the analysis schema of the CIM steel Integration Standard, version 2 commonly known as CIS/2 and used by a number modeling and analysis applications.

A. DETAILS OF EXISTING RC CHIMNEY USED FOR THE ANALYSIS

- Location of chimney- Raichur Thermal power Station (RTPS)
- Zone - zone II
- Height of chimney - 220m
- Top outer diameter -13.1m
- Top inner diameter -12.5m
- Bottom outer diameter -17m
- Bottom inner diameter -15.6m
- Shell thickness -0.25m
- Size of column- 0.45x0.25m
- Size of beam- 0.45x0.25m
- Importance factor- 1.5
- Reduction factor- 3
- Damping ratio -5%

III. SEISMIC DESIGN CALCULATIONS FOR EXISTING CHIMNEY-220m [MANUAL CALCULATION]

Particulars	ZONE II	ZONE III	ZONE IV
Area of C/S	18.307m^2	18.307m^2	18.307m^2
M.I (Moment of Inertia)	634.691m^4	634.691m^4	634.691m^4
Total weight of chimney	97598.91kN	97598.91kN	97598.91kN
α r	0.00477	0.00477	0.00477
Time period [T] sec	4.123sec	4.123sec	4.123sec

Fig 1- Chimney model

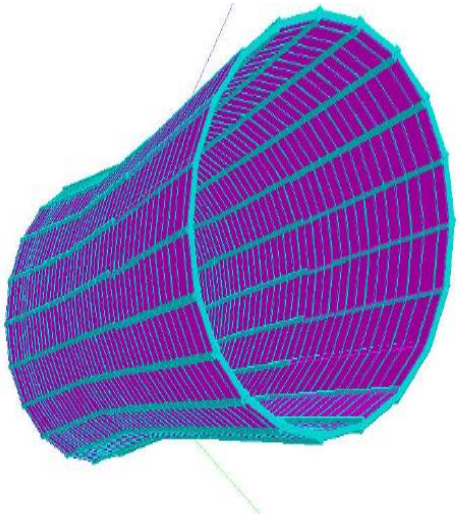


Fig-2 Chimney 3D Model

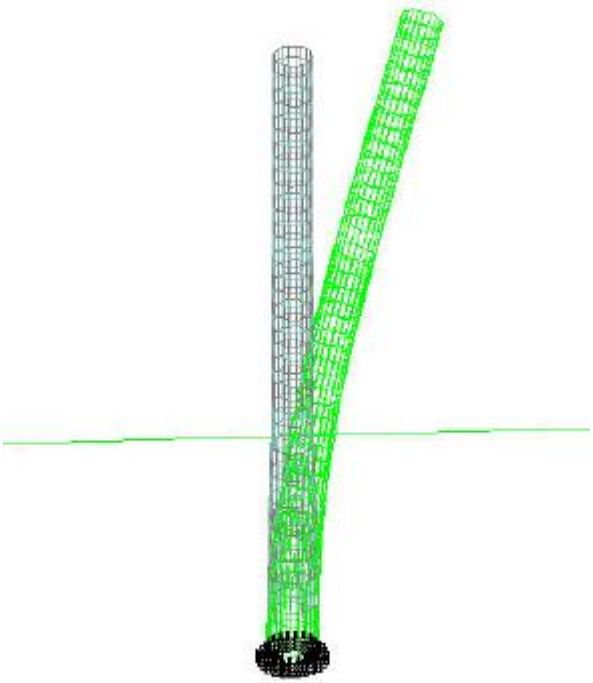


Fig-3 Displacement of Chimney

Fig-4 Shear force

Fig-5 Bending Moment

Fig- 6 Top Combination stress

Fig-7 Bottom Combination stress

Fig-8 Max Principal Major Stress at top

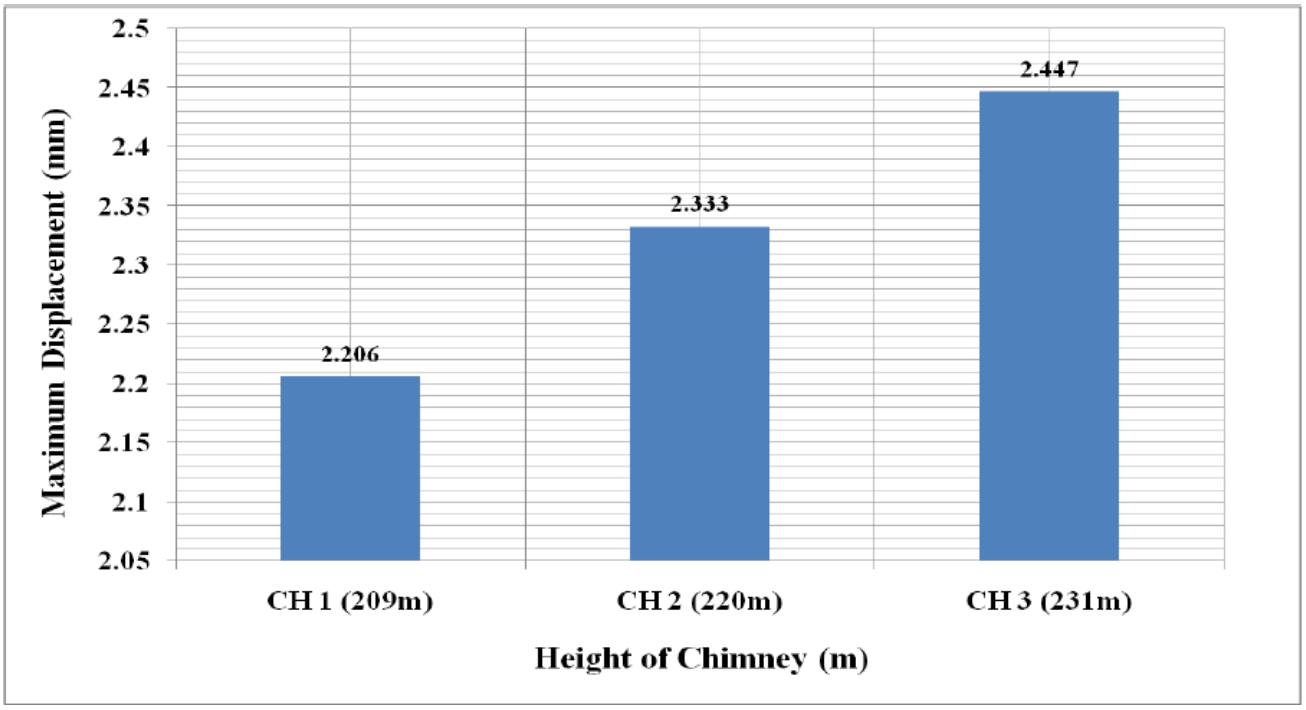
Fig-9 Max Principal Major Stress at Bottom

IV. TABULATION & RESULTS

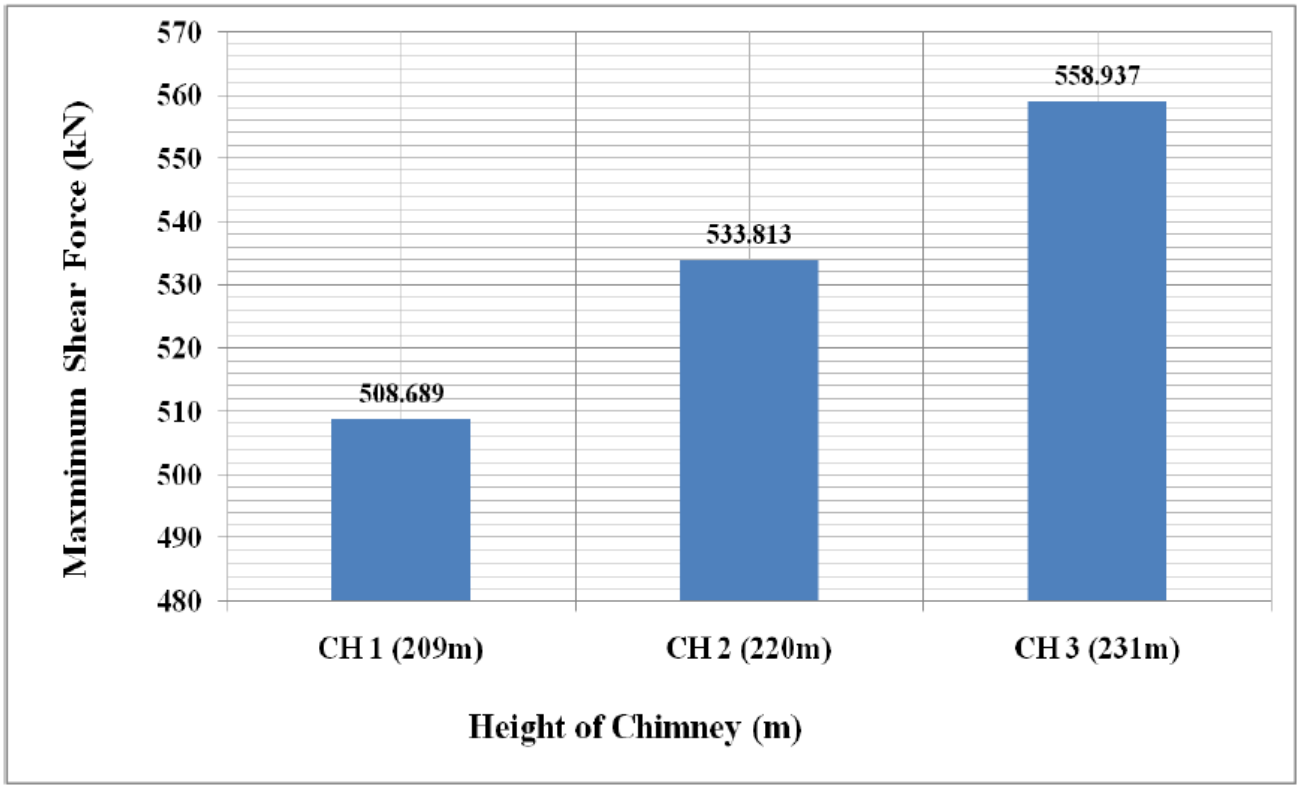
- Static Analysis

Table -2 Static Analysis results for different heights of chimney

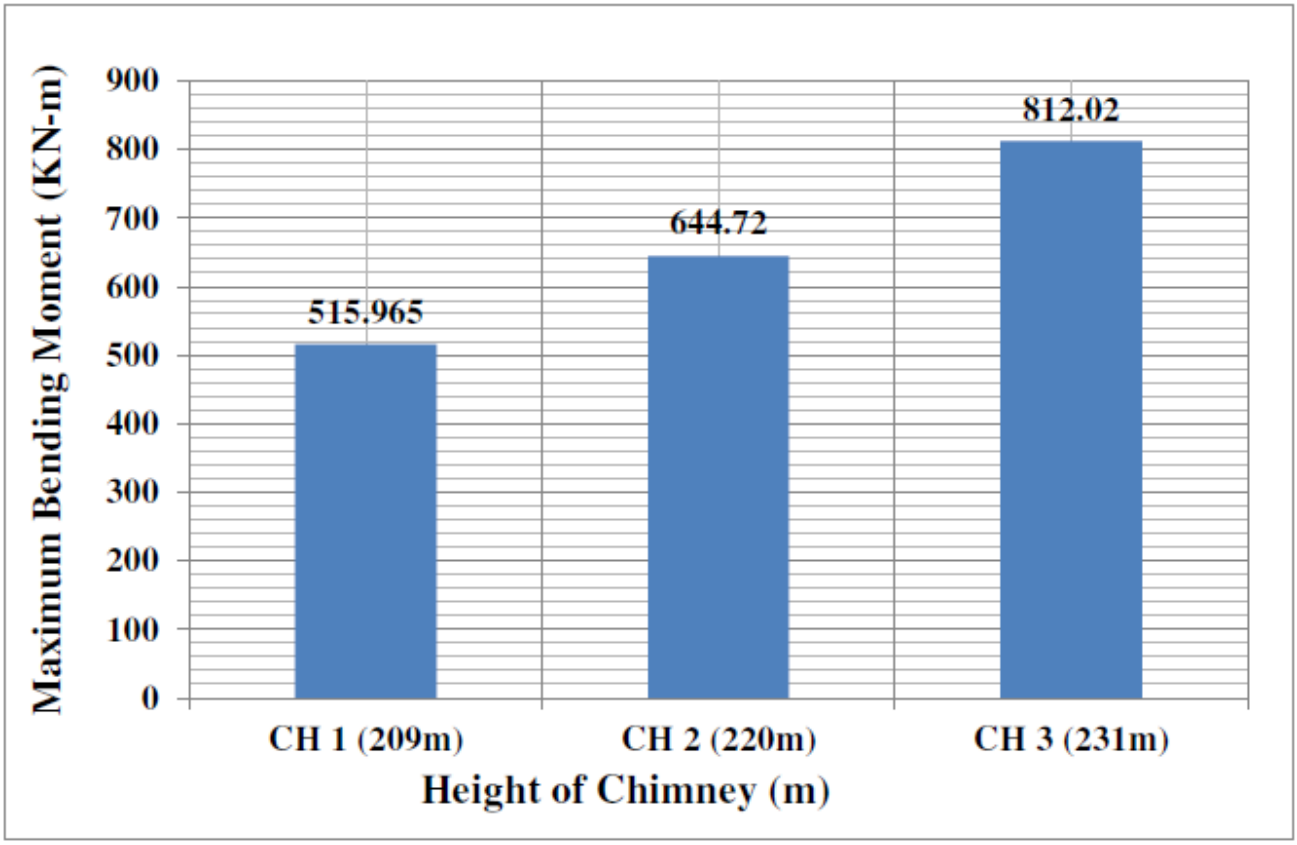
SL.NO.	CHIMNEY	DISPLACEMENT in mm	MAXIMUM SHEAR FORCE in kN	MAXIMUM BENDING MOMENT in kN-m
1	CH 1 (209m)	2.206	508.689	515.965
2	CH 2 (220m)	2.333	533.813	644.72
3	CH 3 (231m)	2.447	558.937	812.02



Graph 1-Graphical Representation of Maximum Displacement v/s Chimney height for static analysis



Graph 2-Graphical Representation of Maximum Shear v/s Chimney height Force for static analysis



Graph-3 Graphical Representation of Maximum Bending moment v/s Chimney height for static analysis

- **Seismic Analysis**

SEISMIC ANALYSIS [Software Results]

Table -3 Seismic results for different heights of chimney's

			ZONE II		ZONE III		ZONE IV	
SL.NO.	CHIMNEY	DISPLACEMENT in 'mm'	SF (MAX)	BM (MAX)	SF (MAX)	BM (MAX)	SF (MAX)	BM (MAX)
1	CH 1 (209m)	4.126	1045.083	15487.75	1214.314	20148.96	1439.955	31953.75
2	CH 2 (220m)	4.253	1101.239	21848.30	1281.551	29642.38	1521.968	63842.64
3	CH 3 (231m)	4.367	1157.580	33988.73	1349.085	52946.29	1604.425	89382.93

A. Comparison between Manual calculation and software readings for existing chimney CH 2 (220m)

MAXIMUM SHEAR FORCE in 'kN'

Table -4 Maximum Shear force values for different zones

SL.NO	ZONE	MANUAL READINGS	SOFTWARE READINGS
1	ZONE II	614.19	1045.083
2	ZONE III	1228.48	1214.314
3	ZONE IV	1535.03	1521.968

MAXIMUM BENDING MOMENT in 'kN-m'

Table -5 Maximum Bending moment values for different zones

Sl no	ZONE	MANUAL READINGS	SOFTWARE READINGS
1	ZONE II	23847.42	21848.30
2	ZONE III	24832.60	29642.38
3	ZONE IV	59593.54	63842.64

V. SUMMARY & CONCLUSIONS

The Analysis and Design of Industrial chimney has always been a challenging task to any structural Engineer. In this present paper, analysis and design of existing chimney of 220m height chosen from Raichur thermal power station (RTPS) has been analyzed using STTAD-pro software. Static and seismic analysis has been carried out using –Line element, Plate element and Node element. Maximum displacement values, Maximum shear force, Maximum bending moment values are obtained from the analysis. The chimney heights are varied and the behavioral changes are observed. Seismic analysis is carried out for different earthquake zones and values are compared with manual calculations.

Following conclusions could be drawn from present study

Static Analysis

1) On Comparing all chimneys (CH 1, CH 2, CH 3) in static analysis (self weight of chimney), displacement value gradually increases with increase in height of chimney. (Refer graph no-1)

2) The shear force values obtained from static analysis gradually increased upon increasing height of chimney. (Refer graph no-2)

3) The bending moment values obtained from static analysis increased upon increasing height of chimney, the bending moment region shifts from bottom to middle portion of chimney. (Refer graph no-3)

Seismic analysis

1) On comparing all chimneys (CH 1, CH 2, and CH 3) for seismic load. Maximum Displacement and shear force, bending moment values increased with increase in height of chimney.

2) The Shear force and bending moment values obtained from seismic analysis for zone II matched with manual calculation for existing chimney (CH 2).

3) The Maximum displacement values, SF & BM values increases for increasing heights of chimney for different seismic zones. As zones are changed from zone II to Zone IV the behavior of chimney changes with all factors. The optimality can be found with low stress and displacement values by finding out proper shell thickness and height.

4) The proper convergence study must be carried out in order to find optimum height of chimney, which depends upon proper selection of elements used for modeling of chimney.

5) The stresses, displacements induced in chimney must be carried out and validate in order to find optimum height of chimney with least stress distribution.

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