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To Design and Analysis of Staad Based Chimney Design and Air Flow Observation

M. Tech. Scholar Shivraj Patidar, Prof. Sourabh Dashore
Department of Civil Engineering,
Sanghvi Institute of Management & Science,
Indore,MP,India

Abstract- It has been observed that most of the existing studies have focused on the load considerations for design of tall chimneys. To make a further contribution to this study, this paper presents the load parameters considered for the design of RCC chimney and focuses on one of the structural parameters of RCC chimneys viz. the effects of number of supports to the flue. A brief review on the types of supports is presented in this paper and analysis is carried out for different kinds of supports to the flue. The comparison of results is plotted. The software STAAD Pro and MS Excel sheets have been used for design.

Keywords- Analysis of chimney, Multiflue chimney, Parametric analysis, Steel flue supports, Tall RCC chimneys.

I. INTRODUCTION

During the past few years industrial chimneys have undergone considerable developments, not only in their structural conception, modeling and method of analysis, but also in the materials employed and the methods of construction. In this sense the outstanding increase in height should be highlighted as a consequence of a better control of environment pollution in populated areas.

With the increment in height the seismic action and wind have become important for working out actuating stresses on this particular type of continuous structures, making it necessary, for this reason, to study the vibratory nature by carrying out a dynamic analysis[1].

Fig 1. Industrial Chimneys.

1. 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[2].

II. DISCRETING THE STRUCTURE

Due to the complexity that means trying out one of the four particular solutions that the differential equation presents governing the movement of a continuous element like a chimney type, (see Figure.3), it was decided to solve the problem by discretization the structure.

For this purpose, two discretion criteria were used lumped masses criterion and consistent masses criterion. The simplest method to consider the properties of a dynamic system is to concentrate the mass of the structure on the nodes that define transfer displacements that is why it is called lumped masses criterion.

On the other hand, the consistent masses criterion (Mc), unlike the lumped masses criterion which depends upon the rigidity to bend, cross section of element, form factor, shear module; also, unlike the lumped masses criterion, it considers coupling between rotational and translation degrees of freedom. Therefore, the matrix of consistent masses corresponds to a full matrix that includes the effects of flexion, shear and rotational inertia[3].

III. LITERATURE REVIEW

1. T Subramani P.Shanmugam, "Seismic Analysis and Design Of Industrial Chimneys By Using Staad Pro":

Our project describes a simplified method that allow obtaining the fundamental period of vibration, lateral displacement, shear force and bending moment through a set of equations, obtaining for all cases studied an error below 10%. The results obtained in this study were applied to a total of 9 real chimneys (4 of steel and 5 of reinforced concrete) built in Chile, with the objective of calibrating founded expressions.

2. Aneet Khombe, Anand Bagali , Md Imran G , Irayya A chimney is a means by which waste gases are discharged at a high elevation **R , Sachin R Kulkarni, "Seismic Analysis And Design Of RCC Chimney"**: 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.

3. Mr. Kaluram S. Langhe, Mr.Vijaykumar. R.Rathi, "Analysis of Self Supported Reinforced Concrete Chimney with Geometry Variation":
Any structure needs to be withstand for two issues, strength and stability. Structure requires a support system that has sufficient strength to bear loads and stability to transmit it safely to the ground. The report shows an analysis of self-supported reinforced concrete chimney subjected to lateral loads like earthquake and wind loads by considering the variation in geometry. The previous investigations concluded that, height to diameter ratio and thickness of concrete shell are able to resist maximum part of lateral load on reinforced concrete chimney.

IV. DESIGN CRITERIA AND GAS FLOW ANALYSIS

1. Introduction:
As large scale industrial developments are taking place all around the world, a large number of tall chimneys would be required to be constructed every year.The primary function of chimney is to discharge poisonous gases to a higher elevation such that the gases do not contaminate the surrounding atmosphere.

Due to increasing demand for air pollution, height of chimney has been increasing since the last few decades, However chimneys being tall slender structures generally with circular cross sections, they have different associated structural problems and must therefore be treated separately from other forms of tower structures[4].

2. Functions Of Chimney:
so that after dilution due to atmospheric turbulence, their concentration and that of their entrained solid particles is within the acceptable limits on reaching the ground.

A chimney achieves simultaneous reduction in concentration of a number of pollutants such as sulphur dioxide, fly ash etc and being highly reliable it does not require a standby. While these are the distinct merits, it is well to remember that a chimney is not the complete solution to the problem of pollution control [5].

3. Material And Methods:
Staad pro is the software which has been chosen to perform this work. Since was founded in 1970, it has changed the work of academic researchers, allowing them to produce groundbreaking technical research reliably, faster and more cost-effectively than ever.

In classrooms around the world, CFD solutions have helped generations of students prepare to tackle real-world engineering challenges. CFD student version it's free, so it grant students the privilege to experience with a wide range of tools in order to deep on simulation and modelling globe. Moreover, there are a huge amount of manuals and scientific works that let all students understand easier CFD software [6].

4. Meshing Generation:
After doing the geometry, it is proceeding meshing operation. The mesh influences the accuracy, convergence and speed of the solution. It is a fundamental part of the analysis because of doing a correct mesh, guarantee nearly real results [7].

4. Objectives
- To analyses the chimney in four Temperature zones as per IS: (part 5) 2004 and wind zones as per IS (part 3): 1987 manually and using STAAD PRO software also.
- To study and compare the maximum shear forces and maximum bending moments of the chimney at different zones.
- Assess the geometry limitations imposed by IS 6533:1989 (part 1&2) for designing self-supporting RCC chimney.

4. Scope:
- Self-supporting flared RCC chimney is considered for the present study.

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- Chimneys are considered to be fixed at their support. Soil flexibility is not considered in the present study
- Chimney considered here is of single-flue type
- Only Temperature loads are taken into consideration for design of the chimney.

5. Analysis Of Rcc Chimney:
Loads Acting on RCC Chimney:

- Self-weight of chimney
- Weight of lining
- Temperature loads

6.Need For Study:
Typically the most critical section in the chimney is the bottom portion of the chimney, where huge openings are provided for the flue duct entry. Around the openings the beam column arrangement with extensive reinforcement is provided to take care of the increase in stresses due to presence of openings. Hence extensive studies is required to suggest viable alternatives [8].

V. METHODOLOGY

The methodology adopted to achieve the objectives of this research work is presented in Chart-1

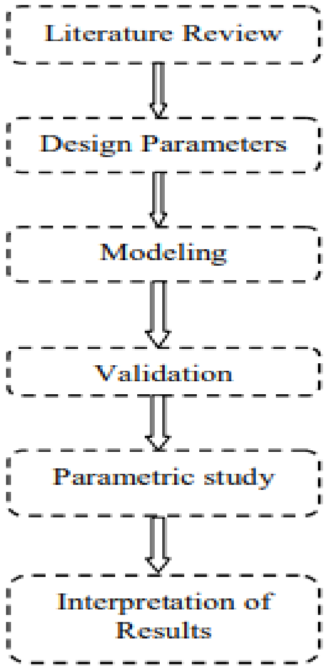

Fig 2. Methodology.

1. Design Advantages:
The design concept significantly simplifies construction of a chimney, which offers a number of distinct advantages over a conventional chimney design with a separate flue.

1.1 A shorter construction time: Building of the chimney consists of construction of the concrete column only. When a slip form is used for construction, time to build the column may be reduced to less than 2 months for a typical 200 meter high chimney. Since no additional supports for a flue need to be incorporated in the concrete shell, the design is further simplified, aiding reliability of the construction process.

1.2 Lower maintenance: Due to the simplification of the design, there are fewer items to maintain. Together with the chimney flue, flue supports, insulation, expansion joints are eliminated.

1.3 Greater suitability for seismic regions: Elimination of the internal flue removes a large mass from the chimney. A steel liner in a typical 200 meter high chimney would weigh about 500 tons, while a borosilicate glass block lining on the concrete shell would only weigh about 80 tons sharply reducing the horizontal loads induced by earthquake movements. Even when the concrete would be loaded beyond its tensile force and develop small cracks, the chimney would be kept gas tight by the lining system (i).

1.4 Flexibility in operating conditions: Borosilicate glass is one of the few materials that is completely resistant to sulfuric and hydrochloric acid without limitation for temperature or concentration. A power station may therefore choose to run at full wet stack operation or full by-pass and switch between the two.

The borosilicate glass block lining system consists of borosilicate glass blocks of a closed cellular structure, cut to a typical size of 6"x9"x2". Cutting the blocks leaves a roughened surface structure that aids in reduction of the condensate film thickness. This reduction of the condensate film thickness reduces the chance of re-entrainment of droplets into the gas stream, allowing higher wet flue gas velocities (ii). 6. Lower cost: All advantages mentioned earlier will result in a chimney that requires lower initial investment costs and lower maintenance cost during its service life.

2. Temperature Effects:
Chimney structures are vertical cantilevered shells pierced by openings where necessary and subjected to large temperature gradients. The principle specialized problems concerning chimneys arise from the thermal and corrosive effects of the elevated temperatures and differential temperature movements between concrete and the insulating materials.

High temperature flue gases give rise to insulation and movement problems, while low temperature gases induces difficulties due to acid condensation. These effects necessitate the protection of the concrete from elevated temperatures and differential temperature movements

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between concrete and the insulating materials. Temperature gradient induced vertical and circumferential stresses can be determined after establishing the magnitude of the thermal gradient. The concrete shell of a chimney has to withstand the effects of a thermal gradient prevailing across its thickness. As a result of such temperature gradient, vertical and circumferential stresses are developed whose values can be determined after establishing the magnitude of the thermal gradient under steady state conditions.

As per the CICIND Model code for chimneys, the effects of temperature differences between the inner and outer faces of the concrete shell should be calculated for the steady state heat flow. The characteristic value of the flue gas temperature should be determined from the given operational conditions and controls. The characteristic value of the ambient temperature should be taken as the regional average minimum temperature for the two coolest months of the year. Temperatures may be for simplicity be calculated as for plane walls in case of chimneys.

VI. RESULT AND ANALYSIS

1. RCC Chimney:

The exterior outline of the chimney shell is derived from the structural consideration of the great structure and the base. The top portion to the extent possible is reserved cylindrical monitored by linear slopes.

The diameter of the chimney shell at the top is set aside least possible allowing for accommodation of the flue, staircase and elevator. The bottommost diameter of chimney is ordinarily governed by structural requirements, for single flue chimney an outside batter in the range of 1 in 40 to 1 in 80, a ratio of height to base diameter in the range of 10 to 12 and a ratio of top to base diameter in the range of 0.2 to 0.8 is provided. Single flue of structural steel is provided to discharge the flue gases from the top of the chimney. The shell rests on R.C.C. mat foundation of circular shape.

2. Design Define:

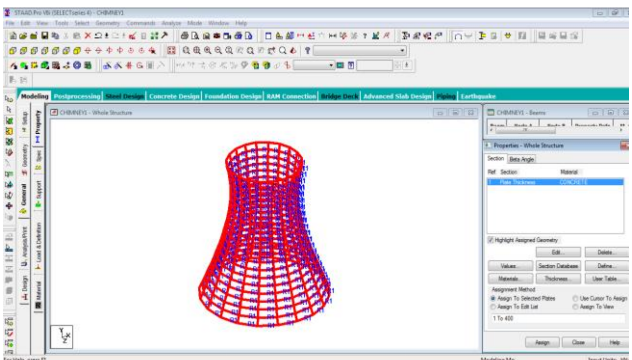


Fig 3. Reaction force.

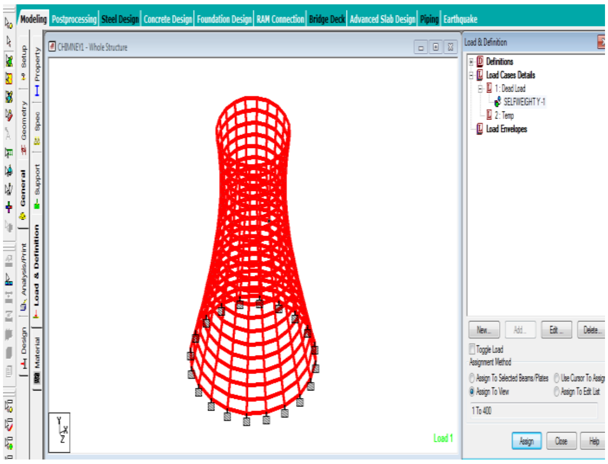


Fig 4. Define support.

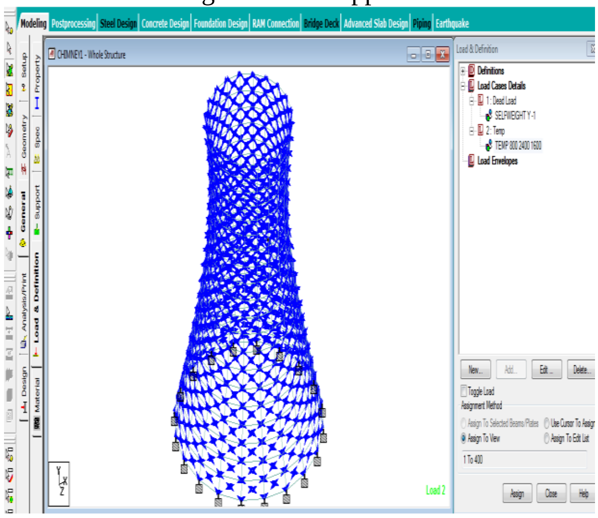


Fig 5. Define temperature distribution.

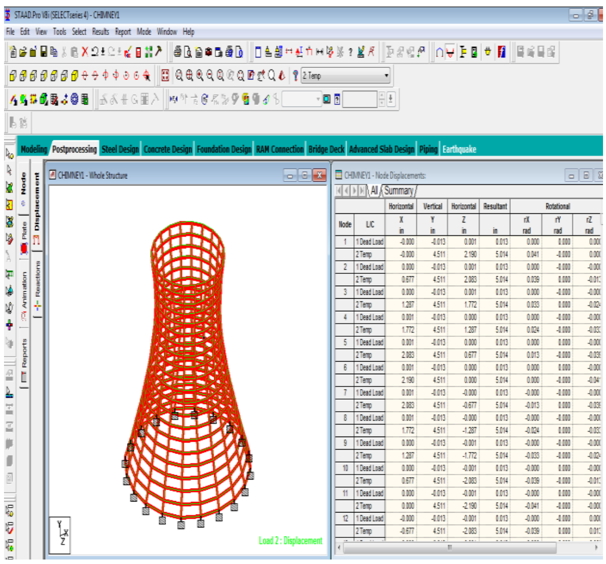


Fig 6. Node across reaction force distribution.

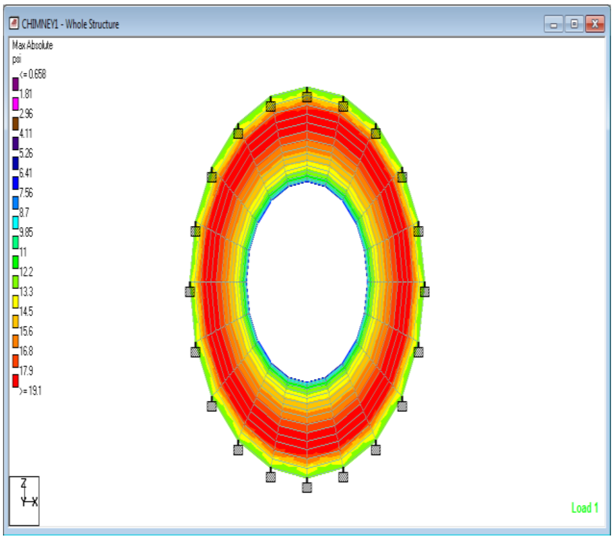


Fig 7. Top view temperature distribution.

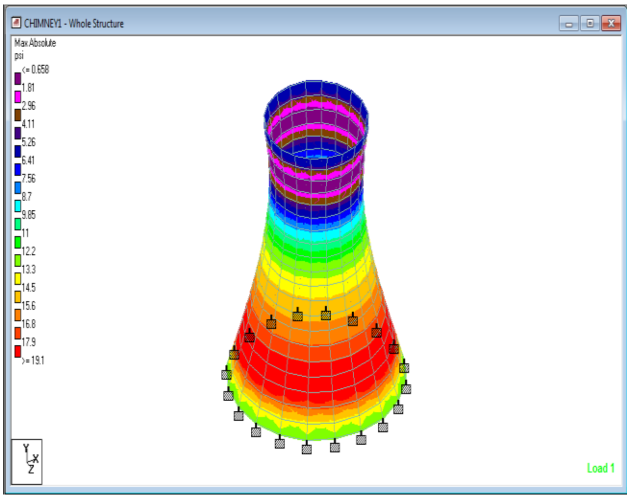


Fig 8. Side view temperature distribution.

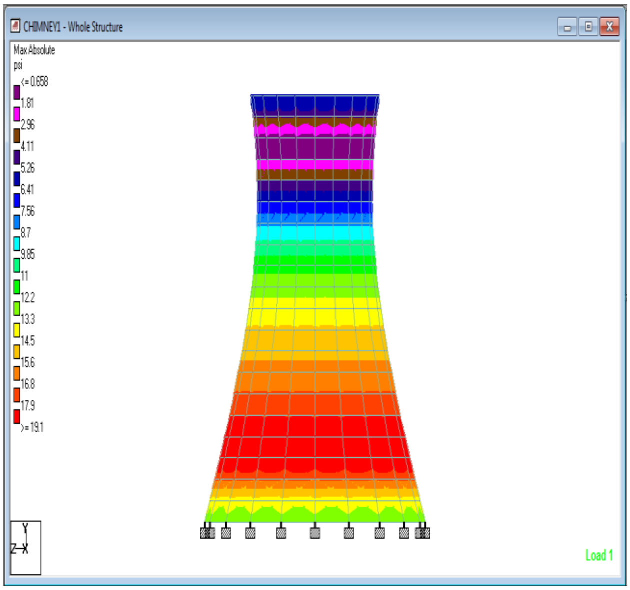


Fig 9. Side view stress distribution.

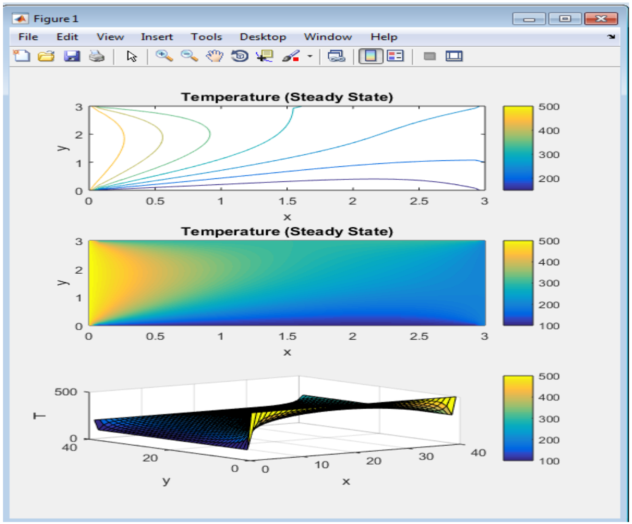
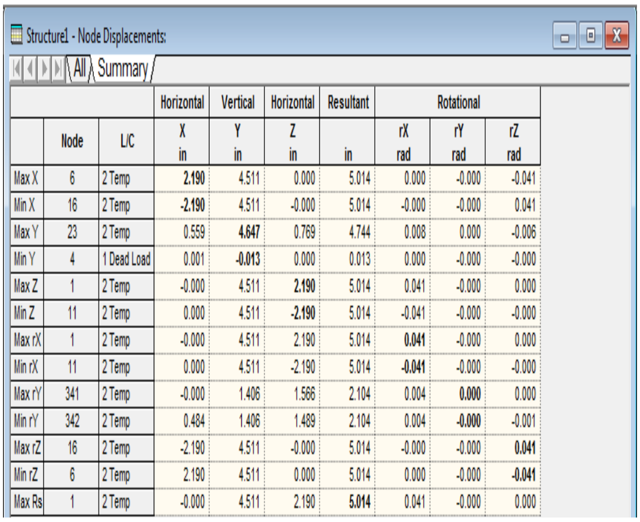


Fig 10. Stable heat transfer.

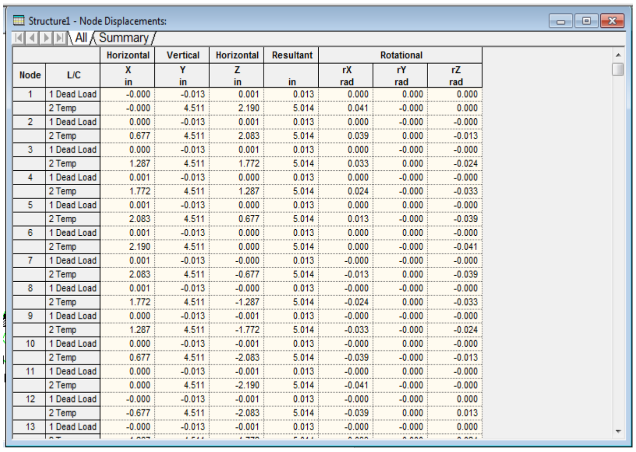


Structure1 - Node Displacements:

All Summary

	Node	L/C	Horizontal X in	Vertical Y in	Horizontal Z in	Resultant in	Rotational rX rad	rY rad	rZ rad
Max X	6	2 Temp	2.190	4.511	0.000	5.014	0.000	-0.000	-0.041
Min X	16	2 Temp	-2.190	4.511	-0.000	5.014	-0.000	-0.000	0.041
Max Y	23	2 Temp	0.559	4.647	0.769	4.744	0.008	0.000	-0.006
Min Y	4	1 Dead Load	0.001	-0.013	0.000	0.013	0.000	-0.000	-0.000
Max Z	1	2 Temp	-0.000	4.511	2.190	5.014	0.041	-0.000	0.000
Min Z	11	2 Temp	0.000	4.511	-2.190	5.014	-0.041	-0.000	-0.000
Max rX	1	2 Temp	-0.000	4.511	2.190	5.014	0.041	-0.000	0.000
Min rX	11	2 Temp	0.000	4.511	-2.190	5.014	-0.041	-0.000	-0.000
Max rY	341	2 Temp	-0.000	1.406	1.566	2.104	0.004	0.000	0.000
Min rY	342	2 Temp	0.484	1.406	1.489	2.104	0.004	-0.000	-0.001
Max rZ	16	2 Temp	-2.190	4.511	-0.000	5.014	-0.000	-0.000	0.041
Min rZ	6	2 Temp	2.190	4.511	0.000	5.014	0.000	-0.000	-0.041
Max Rs	1	2 Temp	-0.000	4.511	2.190	5.014	0.041	-0.000	0.000

Fig 11. Load Based Deflection generation.



Structure1 - Node Displacements:

All Summary

Node	L/C	Horizontal X in	Vertical Y in	Horizontal Z in	Resultant in	Rotational rX rad	rY rad	rZ rad
1	1 Dead Load	-0.000	-0.013	0.001	0.013	0.000	0.000	0.000
	2 Temp	-0.000	4.511	2.190	5.014	0.041	-0.000	0.000
2	1 Dead Load	0.000	-0.013	0.001	0.013	0.000	-0.000	-0.000
	2 Temp	0.677	4.511	2.083	5.014	0.039	0.000	-0.013
3	1 Dead Load	0.000	-0.013	0.001	0.013	0.000	-0.000	-0.000
	2 Temp	1.287	4.511	1.772	5.014	0.033	0.000	-0.024
4	1 Dead Load	0.001	-0.013	0.000	0.013	0.000	-0.000	-0.000
	2 Temp	1.772	4.511	1.287	5.014	0.024	-0.000	-0.033
5	1 Dead Load	0.001	-0.013	0.000	0.013	0.000	0.000	-0.000
	2 Temp	2.083	4.511	0.677	5.014	0.013	-0.000	-0.039
6	1 Dead Load	0.001	-0.013	0.000	0.013	0.000	0.000	-0.000
	2 Temp	2.190	4.511	0.000	5.014	0.000	-0.000	-0.041
7	1 Dead Load	0.001	-0.013	-0.000	0.013	-0.000	-0.000	-0.000
	2 Temp	2.083	4.511	-0.677	5.014	-0.013	0.000	-0.039
8	1 Dead Load	0.001	-0.013	-0.000	0.013	-0.000	-0.000	-0.000
	2 Temp	1.772	4.511	-1.287	5.014	-0.024	0.000	-0.033
9	1 Dead Load	0.000	-0.013	-0.001	0.013	-0.000	-0.000	-0.000
	2 Temp	1.287	4.511	-1.772	5.014	-0.033	-0.000	-0.024
10	1 Dead Load	0.000	-0.013	-0.001	0.013	-0.000	0.000	-0.000
	2 Temp	0.677	4.511	-2.083	5.014	-0.039	-0.000	-0.013
11	1 Dead Load	0.000	-0.013	-0.001	0.013	-0.000	0.000	-0.000
	2 Temp	0.000	4.511	-2.190	5.014	-0.041	-0.000	-0.000
12	1 Dead Load	-0.000	-0.013	-0.001	0.013	-0.000	-0.000	0.000
	2 Temp	-0.677	4.511	-2.083	5.014	-0.039	0.000	0.013
13	1 Dead Load	-0.000	-0.013	-0.001	0.013	-0.000	-0.000	0.000

Fig 12. Rotational Force.

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Structure1 - Plate Corner Stress:

Shear, Membrane and Bending

			Membrane			Bending Moment		
Plate	L/C	Node	SX (local) psi	SY (local) psi	SXY (local) psi	Mx lb-in/in	My lb-in/in	Mxy lb-in/in
1	1 Dead Load	1	7.532	-2.189	-0.261	43.460	177.129	14.551
		2	7.532	-2.189	0.261	43.467	177.130	-14.554
		22	3.805	-2.489	0.220	21.188	72.236	-15.378
		21	3.805	-2.489	-0.220	21.185	72.236	15.382
	2 Temp	1	11600.757	262.148	-696.452	-1.15241E6	27946.507	81693.611
		2	11600.725	262.091	696.418	-1.15239E6	27946.091	-81694.527
		22	-2584.738	-508.725	544.340	-1.29022E6	-504.59229E	-86103.630
		21	-2584.713	-508.670	-544.339	-1.29021E6	-504.58575E	86109.192
2	1 Dead Load	2	7.532	-2.189	-0.261	43.465	177.130	14.554
		3	7.532	-2.189	0.261	43.462	177.131	-14.551
		23	3.805	-2.489	0.220	21.185	72.236	-15.381
		22	3.805	-2.489	-0.220	21.188	72.235	15.380
	2 Temp	2	11600.747	262.121	-696.440	-1.15240E6	27946.247	81694.221
		3	11600.760	262.138	696.451	-1.15240E6	27946.444	-81693.260
		23	-2584.701	-508.675	544.327	-1.29021E6	-504.58966E	-86106.293
		22	-2584.708	-508.694	-544.327	-1.29022E6	-504.59219E	86107.231
3	1 Dead Load	3	7.532	-2.189	-0.261	43.461	177.130	14.553
		4	7.532	-2.189	0.261	43.459	177.129	-14.552
		24	3.805	-2.489	0.220	21.183	72.237	-15.380
		23	3.805	-2.489	-0.220	21.183	72.236	15.380
	2 Temp	3	11600.734	262.099	-696.418	-1.15240E6	27946.390	81694.672
		4	11600.752	262.136	696.430	-1.15240E6	27947.334	-81694.664
		24	-2584.717	-508.676	544.338	-1.29021E6	-504.58923E	-86106.354
		23	-2584.735	-508.711	-544.349	-1.29022E6	-504.59061E	86106.812
4	1 Dead Load	4	7.532	-2.189	-0.261	43.460	177.131	14.552

Fig 13. Bending Effects.

VII. CONCLUSIONS

- All graphs show that, as the deflection of chimney decreases, the base shear force increases. Also for the same, time period gets increases.
- The result shows that as the tapering ratio increases, the deflection of chimney get reduces as shown in scale.
- As compared to load analysis, the seismic forces are observed more for R.C.C. chimney.

The modelling of chimney (superstructure) involves accurate analysis, design involves various parameters which should be carried out with standard code of practices. The industrial chimney is greatly influenced by dynamic loadings.

A Structure which provides ventilation for hot flue gases or smoke from a boiler, stove, furnace or fireplace to the outside atmosphere is known as chimney. Chimneys may be found in buildings, steam locomotives and ships. During the last few decades the use of reinforced concrete chimneys in place of brick masonry and steel chimneys have become very popular due to their low cost and durability.

Composite material like reinforced concrete is eminently suited for chimney stacks. The height of a chimney influences its ability to transfer flue gases to the external environmental via stack effect. The maintenance of steel chimneys are minimum in the case of concrete stacks. The thickness of the concrete shell generally varying from 120 to 300 mm is considerably smaller than that required in the case of brick chimneys.

Concrete stacks with lesser maintenance costs are architecturally superior to masonry and steel chimneys. Chimneys are generally provided in the industries to discharge pollutants into the atmosphere at certain heights and velocities so that the pollutants do not harm the environment. The heights of the chimneys are increased to lessen the atmospheric pollution.

FUTURE SCOPE

The changes in the dimensions may have the influence on the dynamic properties of chimneys. Chimneys are the structures which are built to greater heights as tall slender structures. In early days, as household vents and over the years; they are popularly known as chimneys. C

himneys or stacks are used as a medium to transfer highly contaminated polluted gases to atmosphere at greater heights. Over the years due to development of large scale industries, a large number of tall slender chimneys are required to be designed every year. Chimneys are answerable for industrial growth in any country and changes in the various parameters in any country and changes in the various parameters or dimensions such as increasing the height of the chimneys is more independent on the structural analysis such as response to earthquake is become more critical criteria.

Diameter of the top the chimney and height of the chimney, exit velocity at the top, dispersion of gases are within the allowable limits. Mainly bottom diameter is also controlling by the various structural requirements of the both the concrete shell and foundation base of the chimney. For the development of large scale industries all over the country, enormous numbers of tall structures all over the design every year and proper care is to be taken for the design of chimneys.

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