INTERNATIONAL JOURNAL
OF PROFESSIONAL ENGINEERING STUDIES
Volume 9 /Issue 5 / JAN 2018

PERFORMANCE BASED SEISMIC EVALUATION OF INDUSTRIAL CHIMNEYS BY STATIC AND DYNAMIC ANALYSIS

[1] BOLEM PRIYANKA, [2] K SUNDARA KUMAR

[1]priyankabolem@gmail.com , [2]skkusuma123@gmail.com

[1]M. Tech Student, Usha Rama College of engineering and technology, Usha Rama College Road , Near Gannavaram, Ungutur Mandalam, Krishna District, Telaprolu, Krishna District, Andhra Pradesh, India, Pin Code 521109.

[2]Assistant Professor, Usha Rama College of engineering and technology, Usha Rama College of engineering and technology, Usha Rama College Road , Near Gannavaram, Ungutur Mandalam, Krishna District, Telaprolu, Krishna District, Andhra Pradesh, India, Pin Code 521109.

ABSTRACT: *The chimney is a system for venting hot flue gases or smoke from a boiler or furnace to the outside atmosphere. They are typically almost vertical to ensure that the hot flue gases flow smoothly, drawing air into the combustion through the chimney effect. It is essential to determine the wind, seismic and temperature demands of chimney structures to prevent structural problems which lead to collapse of the structure. This study focused the effect of wind load, earthquake load as well as temperature effects on reinforced concrete (RC) chimneys. Wind analysis was carried out by along wind effects by using the Simplified method and seismic analysis by time history analysis for different heights varying from 275m to 400m with three different radius-thickness ratios and for different longitudinal sections such as tapered and partially tapered by using the software ETABS V 9.7.4. Analyses were conducted to study the variation of displacement and shell stress for the wind analysis, peak displacement for the seismic analysis and temperature effects. The results indicated that as the radius-thickness ratio increases the displacement values were decreasing. The RC chimney with more height and the partially tapered section will be critical compared to fully tapered chimney for the wind, seismic and temperature effects and fully tapered chimney structure exhibiting minimum displacement.*

Keywords— RC Chimney, Wind Analysis, Seismic Analysis, Temperature effects and ETABS V 9.7.4.

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.

Tall chimneys are constructed as a result of the large-scale development of thermal power plant and industries. Tall chimneys are commonly used to discharge pollutants into the atmosphere at a higher elevation such that the pollutant which deemed harmful to the environment is kept within acceptable limits .Now a day's to reduce the air pollution the chimneys are constructed as much as tall. That is the height of the chimney has been increasing since the last few decades. Chimneys with height exceeding 150 m are considered as tall chimneys. However it is not only a matter of height but also the aspect ratio when it comes to classifying a chimney as tall . Today, Reinforced

Concrete is the dominant material used for the construction of tall chimneys . Chimneys being tall slender structures, they have different associated structural problems and must Therefore be treated separately from other forms of tower structure. In order to prevent the collapse mechanism of the chimney structure seismic as well as the wind demands must be determined accurately. For this reason, many evaluations such as nonlinear analysis of chimney structures are proposed for the accurate determination of inelastic behavior and seismic demands of the chimney.

Nonlinear dynamic analysis

Nonlinear dynamic evaluation makes use of the combination of floor motion facts with an in depth structural model, therefore is able to generating effects with extraordinarily low uncertainty. In nonlinear dynamic analyses, the distinctive structural version subjected to a floor-movement record produces estimates of element deformations for each diploma of freedom in the version and the modal responses are blended using schemes which includes the square-root-sum-of-squares.

In non-linear dynamic evaluation, the non-linear properties of the shape are taken into consideration as part of a time area analysis. This approach is the maximum rigorous, and is needed by way of a few building codes for homes of unusual configuration or of special significance. However, the calculated reaction may be very sensitive to the characteristics of the individual floor movement used as seismic input; therefore, several analyses are required the usage of distinctive floor movement facts to obtain a dependable estimation of the probabilistic distribution of structural response. Since the houses of the seismic response depend upon the intensity, or severity, of the seismic shaking, a complete evaluation calls for several nonlinear dynamic analyses at diverse degrees of intensity to symbolize different feasible earthquake scenarios. This has led to the emergence of methods just like the Incremental Dynamic Analysis.

SCOPE OF THE STUDY

- To determine the nonlinear behaviour of chimney structures without opening at section utilizing nonlinear dynamic analysis.
- To validate the result obtained from the nonlinear dynamic analysis using ETABS V9.7.4.
- To carry out the dynamics analysis for various deformation levels.

OBJECT OF THE STUDY

- To determine the effect of radius-thickness ratio of tall RC chimneys.
- To evaluate the response of chimney structures by wind analysis, seismic analysis and temperature effects for various deformation levels.
- To compare the behaviour of different chimney models

SUMMARY

The effect of earthquake and wind loads on the RCC chimney will plays a significant role in the dynamic analysis and design of the chimneys with extreme heights. The dynamic behaviour of the RC chimney will vary in wider range with respect to the height and longitudinal section of the chimney as the load exerted by the wind and earthquake on the chimney are dynamically sound and effective and tending the chimney to undergo peak displacement and acceleration. Because of its slenderness chimneys are the structures supposed to retain the critical loads by seismic and wind effects This project presents the study of along wind load and earthquake load effects on RC chimneys in zone V (basic wind speed 44 m/sec).

seismic analysis is carried out by time history analysis as per IS 1893(part 4):2005 and wind analysis by along wind effects by gust factor method as per draft code CED 38(7892):2013 (third revision of IS 4998(part 1:1992) for different heights varying from 150 to 300m and for different longitudinal sections such as uniform, tapered and uniform-tapered by using the software ETABS V 9.7.4. This study presents the resulting peak displacement and acceleration for the wind analysis, and the joint displacements and base shear for the seismic analysis, period and frequency with respect to mode by time history analysis. The RC chimney with more height and uniform section will be critical compared to other types and best suitable section will be uniform tapered for both seismic and wind load effects exhibiting minimum displacement.

II. LITERATURE REVIEW

Anurag Jain[1], Behnam Arya[2], Charles Goddard[3] and Jon Galsworthy[4] et al,.(2009)

This paper presents the results of a nonlinear dynamic analysis to evaluate the structural performance of a pile and mat foundation system supporting a 350 feet tall concrete chimney stack for hurricane force wind loads. Wind tunnel testing was conducted to develop wind load time histories along the height of the chimney. A geotechnical investigation was performed to determine the nonlinear characteristics of the pile behavior under lateral and vertical loads. A global nonlinear computer model of the chimney and foundation system was developed to determine the performance of the chimney's foundation under the wind load time histories.

The concrete windshield, pile cap and individual piles were modeled in the computer simulation. Two levels of wind speed were considered (a) a 157 mph wind speed (3-second gust, at a height of 10m in Exposure C, 150-year return period) and (b) a 225 mph wind speed (3-second gust, at a height of 10 m in Exposure C, 10,000-year return period),for the analysis. Results of nonlinear dynamic time history analysis are presented in this paper. the major conclusions that were determined from this study are: 1. Our analysis showed that for a 157 mph wind speed pile axial forces remain below the threshold where permanent pile settlement is expected. Therefore, no settlement is expected at this level of loading and the pile foundation should remain fully functional. 2. For wind speed of 225 mph, the maximum axial force in 35 piles exceeds the ultimate pile capacity. 3. The downward pile-tip displacement for a wind speed of 225 mph causes relatively large permanent settlement of the pile cap resulting in permanent displacement (tilting) of the concrete pile cap. At this level of vertical pile tip displacement localized damage of the pile cap or piles may occur. 4. Our analysis showed that the lateral pile-head force due to wind loading remains well below the threshold that causes significant lateral displacement of piles. The maximum lateral pile displacement remains in the linear range of pile behavior and does not result in any permanent deformation. 5. A comparison between the static-linear analysis and dynamic-nonlinear analysis showed that the maximum moment at the base of the chimney for dynamic-nonlinear analysis was 22% less than the base moment obtained from the static-linear analysis. While the initial analysis conducted with the ACI 307-98 provisions indicated that the pile foundation system would overload, the detailed analysis presented herein indicated otherwise. Therefore, performing a nonlinear dynamic analysis using wind load history can potentially result in a reduction of force demand on the foundation systems of tall industrial chimneys

Remyasree A R[1], Megha Vijayan[2] et and all,.(2016)

The chimney is a system for venting hot flue gases or smoke from a boiler or furnace to the outside atmosphere. They are typically almost vertical to ensure that the hot flue gases flow smoothly, drawing air into the combustion through the chimney effect. It is essential to determine the wind, seismic and temperature demands of chimney structures to prevent structural problems which lead to collapse of the structure. This study focused the effect of wind load, earthquake load as well as temperature effects on reinforced concrete (RC) chimneys. Wind analysis was carried out by along wind effects by using the Simplified method and seismic analysis by time history analysis for different heights varying from 275m to 400m with three different radius-thickness ratios and for different longitudinal sections such as tapered and partially tapered by using the software ETABS V 9.7.4.. Analyses were conducted to study the variation of displacement and shell stress for the wind analysis,peak displacement for the seismic analysis and temperature effects. The results indicated that as the radius-thickness ratio increases the displacement values were decreasing. The RC chimney with more height and the partially tapered section will be critical compared to fully tapered chimney for the wind, seismic and temperature effects and fully tapered chimney structure exhibiting minimum displacement.

The major conclusions drawn from the analysis such as wind analysis and seismic analysis. The displacement of chimneys of different height decreases with increase of radius thickness ratio. The chimney which is tapering from bottom to top has lesser displacement value than that of the chimney which is tapering from the bottom and becomes uniform at a height of one-third from the top of the structure. The displacement of chimney structure is increases with the height. Shell stress in chimneys decreases with increase of radius thickness ratio Fully tapered chimney structure has lesser shell stress value than that of partially tapered chimney.

III.METHODOLOGY

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. If a modeled chimney is analyzed as in a projected beam embedded at the la base and free at its upper end, considering the behaviour of the lineal elastic material, capable of deforming only by the effects of flexion and shear, and that it also has geometric properties (area, inertia, etc.) which vary with height, differential equations will be obtained of the movement that apply both to free and forced vibrations that cannot be resolved exactly.

Wind Load Calculation

According to IS 875 (part 3):1987 basic windspeed can be calculated,

$V_z = V_b * K_1 * K_2 * K_3$

Where , V_z= design wind speed at any height z m/s

K_1= probability factor (risk coefficient)

K_2= terrain, height and structure size factor

K_3= topography factor.

DRAG

Drag

The drag force on a single stationary bluff body is,

$$F_d = 0.5\ C_d\ A\ \rho_a\ \bar{U}^2$$

Where F_d = drag force, N

C_d = Drag coefficient

A = area of section normal to wind direction, m^2

The value of drag coefficient depends on Reynolds number, shape and aspect ratio of a structure.

EXPERIMENTAL ASSESSMENT

Experimental evaluations are expensive tests that are typically done by placing a (scaled) model of the structure on a shake-table that simulates the earth shaking and observing its behavior. Such kinds of experiments were first performed more than a century ago. Still only recently has it become possible to perform 1:1 scale testing on full structures.

IV. STRUCTURE MODELLING

A single flue reinforced concrete chimney is considered for the analysis situated in seismic zone V. The flue gas emission point will be 220 m above the finished floor level. The liner is essentially constructed from structural steel and shall be hung from the liner support platform near the chimney top. The liners are provided with resin bonded wool type thermal insulation; there will be several internal platforms of structural steel provided along the height of the chimney. Except for the roof platform, all the other internal platforms will have steel grillage of beams covered with galvanized gratings; internal platforms are provided for enabling access to various elevations of the chimney and provide restraint to the steel liners. External concrete platforms are supported by the chimney shell.

The chimney roof shall however comprise of a reinforced concrete slab supported over a grid of structural beams. The roof slab shall be protected by layer of acid resistant tiles. The grade level slab shall be of reinforced concrete. An internal structural steel staircase supported from the floor at the bottom with a guide support from shell is considered up to the support platform. There shall be rack and pinion elevator. It is known by test that downwash can be avoided if efflux velocity is greater than 1.5 times the wind speed for this reason, the chimney flue at top is based on minimum exit velocity between 15 to 25m/sec, and the Indian code IS: 4998 gives an empirical formula to calculate the chimney height.

The external profile of the chimney shell is derived from the structural consideration of the super structure and the foundation. The top portion to the extent possible is kept cylindrical followed by linear slopes. The diameter of the chimney shell at the top is kept minimum possible allowing for accommodation of the flue, staircase and the elevator. The bottom diameter of chimney is normally governed by structural requirements, for single flue chimney an outside batter of 1 in 50 or 60 and a ratio of height to base diameter in the range of 12 to 15 is provided.

Single flue of structural steel is provided to discharge the flue gases and is hung from the liner support platform near the chimney top. The shell rests on R.C.C. mat foundation of circular shape.

PROBLEM STATEMENT

1. Height of chimney - 30 m
2. Outer dia at bottom – 20.250 m
3. Outer dia at top – 10.250m
4. Thickness of shell at bottom - 0.25 m
5. Thickness of shell at top - 0.25 m
6. Grade of concrete – M40
7. THROAT dia of outer dia -- 8.25 mts
8. Exit velocity of gas at top - 25.0 m/sec
9. Flue gas volume from the flue 340 cum/sec

10. Maximum flue gas temperature 135 degree centigrade.

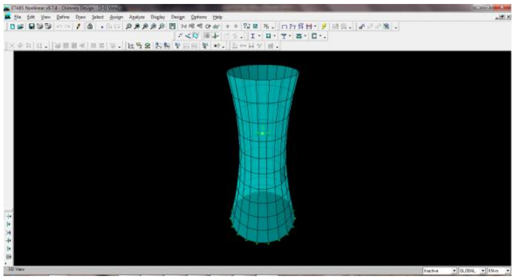
11. Seismic Zone - V

12. Basic wind Speed - 44 m/sec (for Hyderabad)

13. Foundation Type - RCC circular mat.

STAGES OF CHIMNEY CONSTRUCTION

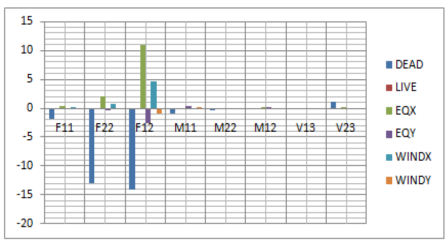
CHIMNEY MODEL IN ETABS



V. RESULTS AND DISSCUSIONS

AREA ELEMENT FORCES

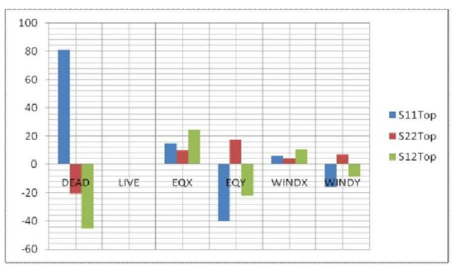
Area Elm	Joint	Output Case	F11	F22	F12	M11	M22	M12	V13	V23
1	1	DEAD	-1.92	-12.9	-14.16	-0.93	-0.32	-0.12	-0.03	1.2
1	1	LIVE	0	0	0	0	0	0	0	0
1	1	EQX	0.36	1.99	10.97	-0.14	-0.02	0.2	0.07	0.1
1	1	EQY	-0.21	-0.35	-2.51	0.41	-0.2	0.13	0.02	-0.17
1	1	WINDX	0.15	0.82	4.59	-0.06	-0.01	0.08	0.03	0.04
1	1	WINDY	-0.09	-0.16	-0.98	0.16	-0.08	0.05	0.01	-0.07



AREA ELEMENT STRESS

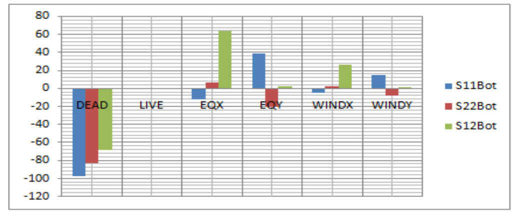
AT TOP

AreaObj	AreaElm	Joint	Output Case	S11Top	S22Top	S12Top
R1	1	1	DEAD	81.39	-20.69	-45.48
R1	1	1	LIVE	0	0	0
R1	1	1	EQX	14.99	9.84	24.72
R1	1	1	EQY	-39.99	17.51	-22.44
R1	1	1	WINDX	6.08	4.06	10.48
R1	1	1	WINDY	-15.86	6.86	-8.89



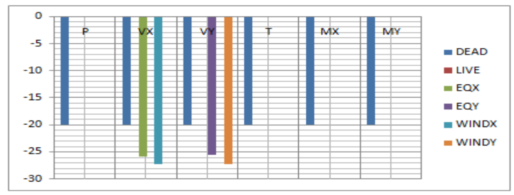
AT BOTTOM

AreaObj	AreaElm	Joint	OutputCase	S11Bot	S22Bot	S12Bot
R1	1	1	DEAD	-96.77	-82.48	-67.82
R1	1	1	LIVE	0	0	0
R1	1	1	EQX	-12.1	6.05	63
R1	1	1	EQY	38.34	-20.34	2.37
R1	1	1	WINDX	-4.89	2.47	26.27
R1	1	1	WINDY	15.17	-8.16	1.06



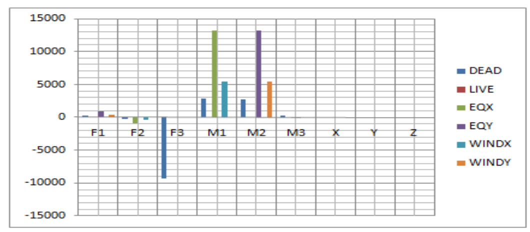
STOREY SHEAR

Story	Load	Loc	P	VX	VY	T	MX	MY
STORY11	DEAD	Top	-20	-20	-20	-20	-20	-20
STORY11	LIVE	Top	0	0	0	0	0	0
STORY11	EQX	Top	0	-25.75	0	0	0	0
STORY11	EQY	Top	0	0	-25.56	0	0	0
STORY11	WINDX	Top	0	-27.16	0	0	0	0
STORY11	WINDY	Top	0	0	-27.16	0	0	0



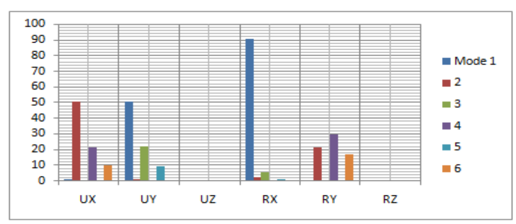
SECTION CUT FORCES

Section	Load	F1	F2	F3	M1	M2	M3	X	Y	Z
SCUT1	DEAD	200	-200	-9323.31	2865.261	2719.331	200	0	0	-17
SCUT1	LIVE	0	0	0	0	0	0	0	0	-17
SCUT1	EQX	0	-958.92	0	13252.43	0	-20.589	0	0	-17
SCUT1	EQY	957.7	0	0	0	13228.51	-3.258	0	0	-17
SCUT1	WINDX	0	-432.84	0	5402.455	0	0	0	0	-17
SCUT1	WINDY	432.84	0	0	0	5402.455	0	0	0	-17



MODEL PARTICIPATING MASS RATIO

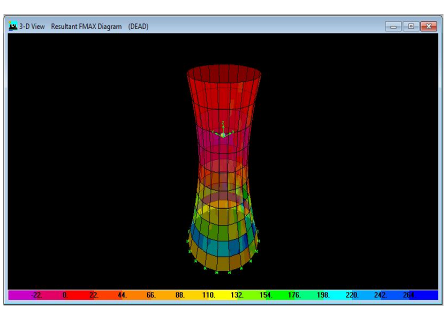
Mode	Period	UX	UY	UZ	RX	RY	RZ
1	2.108463	1.2705	50.6451	0	90.5523	0.5286	0
2	2.092203	50.8601	1.2758	0	2.2751	21.2362	0.0001
3	0.416656	0.5538	22.0779	0	5.7277	0.7614	0
4	0.414616	21.7564	0.5458	0	0.1399	30.0124	0.0007
5	0.15668	0.2364	9.4256	0	0.8652	0.4021	0
6	0.15597	9.7056	0.2435	0	0.0222	16.5226	0.0164

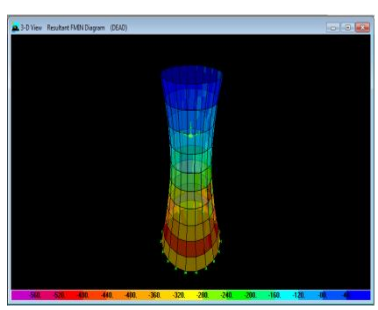


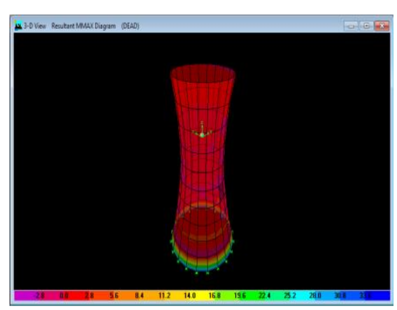
Shell stress / forces contours for shells

FORCES

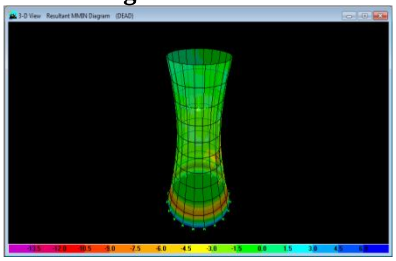
F max Diagram **F min Diagram** **M max Diagram**



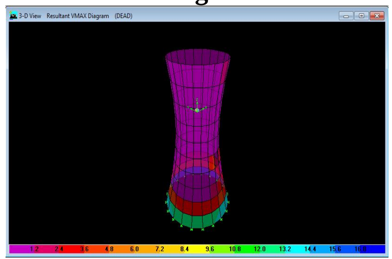




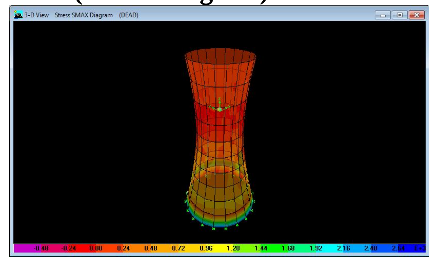
M min Diagram



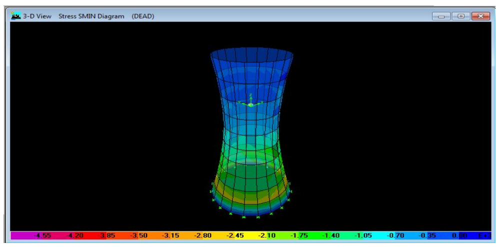
V max Diagram



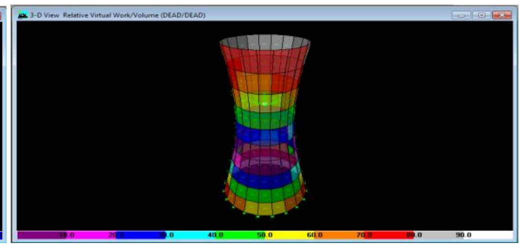
STRESS (S max Diagram)



S min Diagram



Virtual Work/Volume Diagram



VI. CONCLUSIONS

1) When the chimney is analyzed by the three effects (flexion, shear and rotational inertia), the number of elements to be discrete no longer influences the estimated responses because the height of the element is controlled by the shear if h/D < 2, and by flexion if h/D > 2, h the height of the element.
2) To estimate the fundamental period of vibration, considering only the effect of flexion, the consistent masses criterion is more accurate.
3) For the Chimney area element forces are more in case of Earth quack load in X-direction and story shear values are negative.
4) Since it is very laborious job finding a factor to transform dimensional response values to real response values considering all effects (flexion, shear and rotational inertia), good results can be obtained in the analysis of steel and reinforced concrete industrial chimneys modeling the structure employing the following considerations: Consistent masses criterion, effect of flexion, and discrete in elements.
5) It is possible to carry out an analysis of a chimney parametrically, finding a factor that will transform these a dimensional values into real responses of the structure.

6) Through our problem it was conclude that the seismic effect will cause more damages to the structure which will stabilize when it will analysis and constructed based on the stress condition which is highlighted in the diagrams.

REFERANCES

[1]. Arya A. S. y Paul, D. K. (1977), “Earthquake Response of Tall Chimneys”. Proceedings World Conference on Earthquake Engineering. New Delhi.

[2]. Astroza I., M y Asfura, A. (1972), Análisis Dinámico de Chimeneas de Inercia Variable. Comparación entre Modelo Continuo y Discreto. Memoria de Título (Ingeniería Civil) Sección Ingeniería Sísmica. Departamento de Geofísica Sismología y Geodesia, Facultad de Ciencias Físicas y Matemáticas Universidad de Chile, Santiago, Chile. Pp 208

[3]. Cancino, C. H. (1984), Diseño Sísmico de Chimeneas Industriales, Memoria de Título (Ingeniería Civil) Departamento de Ingeniería Civil, Facultad de Ciencias Físicas y Matemáticas Universidad de Chile. Pp 150.

[4]. Carrión P. L. y Dünner D. R. (1999), Análisis y Diseño Sísmico de Chimeneas Industriales, Memoria de Título (Ingeniería Civil) Departamento de Ingeniería Civil, Facultad de Ciencias Físicas y Matemáticas Universidadde Central de Chile. Pp 329.

[5]. FernándezDávila G., V. I. y Rivera F., J. (1988), "Planteamiento de Normas para el Análisis Sísmico de

[6]. Chimeneas", Séptimo Congreso Nacional de Ingeniería Civil, Departamento de Ancash., Perú, Pp 383396. FernándezDávila G., V. I. y Rivera, J. (1990), "Diseño Sísmico de Estructuras Continuas con Distribución Variable de Masa y Rigidez", Octavo Congreso Nacional de Ingeniería Civil, Departamento de Piura. Perú Pp 383396.

[7]. FernándezDávila G., V. I. (1992), Análisis Dinámico de Chimeneas Empleando el Criterio de Masas Consistentes, Proyecto semestral, Asignatura ICE3722, Dinámica de Estructuras, Pontificia Universidad Católica de Chile. SantiagoChile.

[8]. Husid, R; Asfura, A.; Astroza, M. (1974), "Vibraciones de Chimeneas de Inercia Variable", XVI, Jornadas de Ingeniería estructural. Buenos Aires Argentina. Vol. III, Pp. III28, III38

BIBLIOGRAPHY

Ms B.Priyanka was born in Krishna, AP on May 10,1993.She was graduated from the RAJIV GANDHI KNOWLEDGE AND TECHNOLOGIES(AP IIIT).Her special fields of interest included **Structures and Designing**. Presently she is studying in USHA RAMA COLLEGE OF ENGINEERING AND TECHNOLOGY, Telaprolu.

Mr. K SUNDARA KUMAR, Faculty of Civil Engineering & Head, USHA RAMA COLLEGE OF ENGINEERING AND TECHNOLOGY .Mr K.Sundara Kumar obtained B.Tech from JNTUK College of Engineering and M.Tech degree from IIT Madras in Civil Engineering with Environmental Engineering as specilization.He got 20 years experience in teaching, research and industry. He had published more than 50 research publications in various International journals.