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Optimization of Steel Chimney

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Abstract: This paper presents the analysis process and optimization of a steel chimney in accordance with IS codes A typical chimney to be located at Sangamner, Maharashtra for an exit flue discharge of 100000 m^3/s is taken for the example. The chimney is first designed for static wind load and then the design is checked against dynamic wind load, possible resonance and seismic load. The MATLAB software which can perform for the optimization purposes. Initially, are presented the assumptions used for modeling, i.e. geometry, support conditions and loading calculations. Follows the simulation methodology at the particular software package and finally are presented the results of the analysis. In the end of each analysis are presented the results obtained by all methods and comparative reviews. An industrial chimney of 45 m height is taken for formulation of optimal design problem. This Steel Chimney is having constant outer diameter and thickness is varying from top to bottom in four steps. Outer diameter is 2 m, thickness of top segment shell is 12mm, and that of second, third and fourth segment it is 14mm, 18mm and 20mm respectively.

Keywords: Chimney, Optimization, Nonlinear Programming, Self Supported Chimney

I. INTRODUCTION

Chimneys or stacks are very important industrial structures for emission of poisonous gases to a higher elevation such that the gases do not contaminate surrounding atmosphere. These structures are tall, slender and generally with circular cross-sections. Different construction materials, such as concrete, steel or masonry, are used to build chimneys. Steel chimneys are ideally suited for process work where a short heat-up period and low thermal capacity are required. Also, steel chimneys are economical for height upto 45m. There are many standards available for designing self supporting industrial steel chimneys: Indian Standard IS 6533: 1989 (Part-1 and Part-2), Standards of International Committee on Industrial Chimneys CICIND 1999 (rev 1), etc. Geometry of a self supporting steel chimney plays an important role in its structural behaviour under lateral dynamic loading. This is because geometry is primarily responsible for the stiffness parameters of the chimney.

The design of Steel chimney can be done in two ways:

A. Self-Supporting Steel Chimneys.

When the lateral forces (wind or seismic forces) are transmitted to the foundation by the cantilever action of the chimney, then the chimney is known as self-supporting chimney. The self-supporting chimney together with the foundation remains stable under all working conditions without any additional support.

B. 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. These attached guys or stays do share these applied loads. These guys or stays ensure the stability of the guyed Steel chimney. These Steel chimneys may be provided with one, two or three sets of guys. In each set of guys, three or four or sometimes six wires are attached to the collars. When one set of guy is used, then the guys are attached to a collar at one third or one fourth of the height from the top. When more than one set of guys are used, then these are used at various heights.

II. METHODOLOGY

Optimization is an art of obtaining the best results under given circumstances. In design process, engineers have to take many technological and managerial decisions at several stages. The ultimate goal of all such decision is either to minimize the effort required or to maximize the desired benefit.

A. Formulation of Optimum Design Problem

The general three phases considered in the optimum design of any structure are:

1) Structural modeling.
2) Optimum design modeling.

3) Optimization algorithm.

In structural modeling, the problem is formulated as the determination of a set of design variables for which the objective of the design is achieved without violating the design constraints. For the optimum design modeling, Study the problem parameter in depth, so as to decide on design parameter, design variables, constraints, and the objective function. In the search for finding optimum design starts from a design or from a set of designs to proceed towards optimum. For economic design of steel chimney, optimization methodology and above parameters are discussed in the following sections.

In optimization of a design, the design objective could be simply to minimize the cost of production or to maximize the efficiency of production. An optimization algorithm is a procedure which is executed iteratively by comparing various solutions till an optimum or a satisfactory solution is found. With the advent of computers, optimization has become a part of computer-aided design activities. There are two distinct types of optimization algorithms widely used today.

In design of Steel chimney structure, the objective function is taken for minimizing the overall cost of construction. Structurally, a chimney is designed for its own weight, wind pressure or seismic forces and the temperature stresses. Its own weight cause direct compression in the section which increases towards the base. The wind pressure tends to bend the chimney as a cantilever about its base, causing compression on leeward side and tension on windward side.

Here we consider large-scale nonlinear optimization problems, i.e., problems with nonlinear objective and/or nonlinear constraints which are sufficiently smooth with hundreds to hundreds of thousands of variables. The general formulation can also include linear and box constraints as stated below: min $x\ f(x)$ subject to $lg \le g(x) \le ug\ lB \le Bx \le uB\ lx \le x \le ux$ There are two main approaches for solving NLP. It is good to understand their very distinct features. The easiest for a comparison is to look at how the inequality constraints are treated and how the solver approaches the optimal solution (the progress of the optimality measures: optimality, feasibility, complementarity). Inequality constraints are the hard part of the optimization because of their "twofold nature". If the optimal solution satisfies strictly the inequality, i.e., the optimal point is in the interior of the constraint, the inequality constraint doesn't influence the result and could be removed from the model. On the other hand, if the inequality is satisfied as an equality (is active at the solution), the constraint must be present and could be treated as an equality from the very beginning.

Most of the existing solvers (such as e04vh, e04uc, e04us) in the NAG Library are based on the activeset sequential quadratic programming method (or just SQP). Such a solver needs to solve at each iteration a quadratic approximation of the original problem and it tries to estimate which constraints needs to be kept (are active) and which can be ignored. A practical consequence is that the algorithm partly "walks along the boundary" of the feasible region given by the constraints. The iterates are thus early on feasible w.r.t. all linear constraints (and a local linearization of the nonlinear constraints) which is preserved through the iterations. The complementarity is satisfied by default and once the active set is determined correctly and optimality is within the tolerance, the solver finishes.

B. Loadings and Load Combinations

The followings loads are to be estimated while designing the Steel chimney

1) Wind load
2) Earthquake load
3) Imposed load

C. Load Combinations

As per IS: 6533 (Part 2), the following load causes are to be considered while designing the stack

1) Load case 1 = Dead load + wind load (along X direction) + Imposed load
2) Load case 2 = Dead load + wind load (along Y direction) + Imposed load
3) Load case 3 = Dead load + Imposed load + earthquake load

III. RESULT

A. Optimization for Chimney

The programs developed were applied to obtained optimal solution for 45 m height Steel Chimney. Optimal values are obtained for two cases which include segments of different heights as mentioned below and compared with conventional values.

1) *CASE (I)* 4 segments of 15m, 10m, 10 and 10m.
2) *CASE (II)* 8 segments of 7.5m, 7.5m, 5m, 5m, 5m, 5m, 5m, and 5m.

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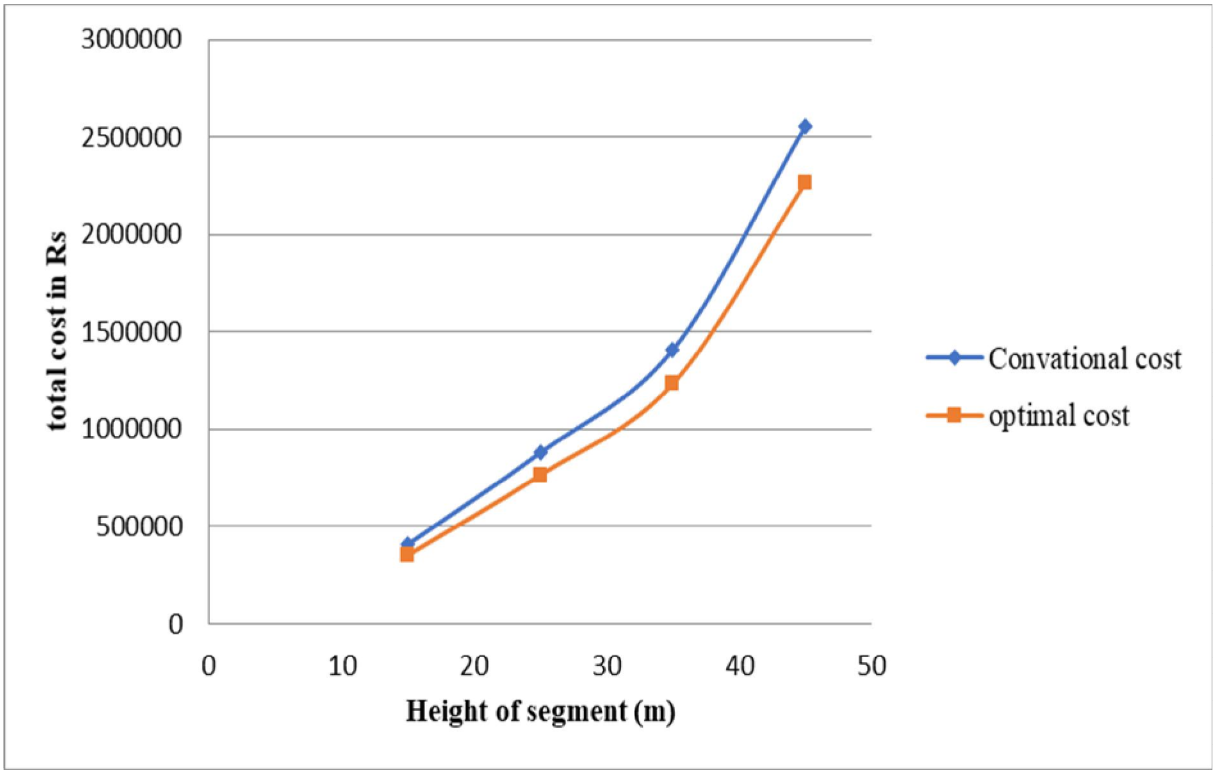
TABLE I
CASE (I) OPTIMAL VALUES FOR FOUR (4) SEGMENTS.

Sr. No	height (m)	Segment	Segment length (m)	Thickness of plate X(mm)	Area of steel (mm$^{2)}$	Weight Of steel (Kg)	Cost (Rs.)
1	15	0-15	15	18	0.145934	11455.87	1031028
2	25	15-25	10	16	0.099676	7824.579	469474.70
3	35	25-35	10	14	0.087304	6853.408	411204.50
4	45	35-45	10	12	0.749078	5880.265	352815.90



Graph 1 CASE (I) Comparison of optimum and conventional cost.

TABLE II
CASE (II) OPTIMAL VALUES BY TAKING EIGHT (8) SEGMENTS.

Sr. No	height (m)	Segment	Segment length (m)	Thickness of plate X (m)	Area of steel (m^2)	Weight of steel (Kg)	Cost (Rs.)
1	7.5	0-7.5	7.5	0.018	0.11202264	6595.333	395720
2	15	7.5-15	7.5	0.016	0.09967616	5868.434	352106
3	20	15-20	5	0.016	0.09967616	3912.289	234737.4
4	25	20-25	5	0.014	0.08730456	3426.704	205602.2
5	30	25-30	5	0.014	0.08730456	3426.704	205602.2
6	35	30-35	5	0.012	0.07490784	2940.133	176408
7	40	35-40	5	0.012	0.07490784	2940.133	176408
8	45	40-45	5	0.010	0.062486	2452.576	147154.5

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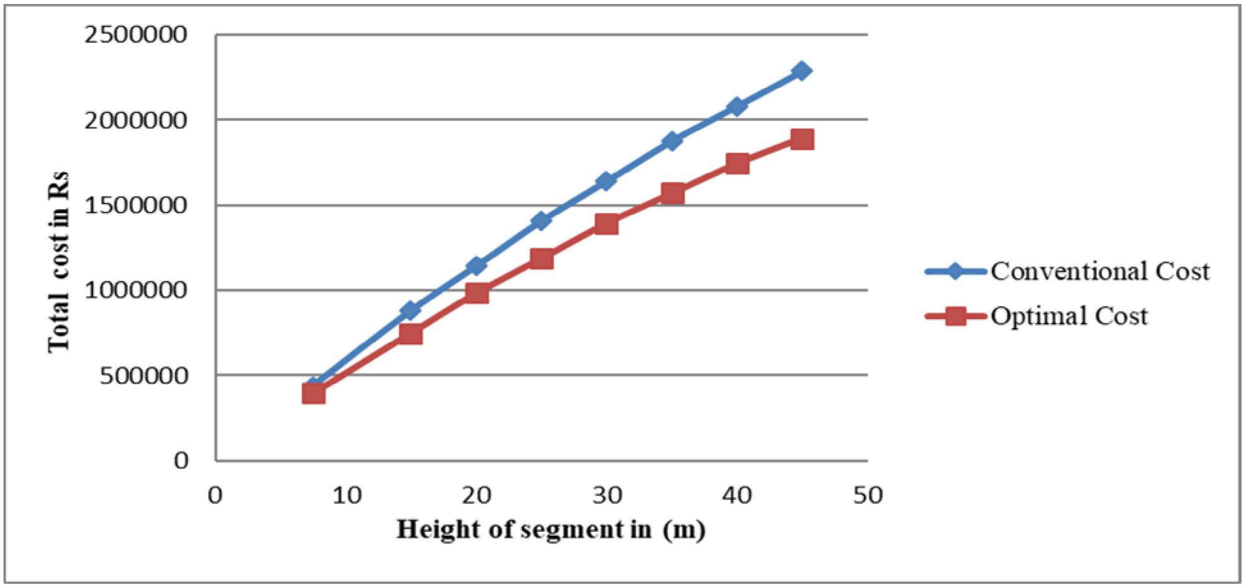

Graph 2 CASE (II) Comparisons of optimum and conventional cost.

IV. CONCLUSIONS

The work is presented for optimal design of 45m Steel chimney structure. While doing optimization two cases are considered, dividing total 45m chimney into Case (I) 4 segments, Case (II) 8 segments, Optimum values for cost, steel are then compared with the conventional values. It is revealed from the graphs plotted for each case that the optimum values are getting more precise as number of segments goes on increasing. Optimal design shows total percentage cost saving of 11% in case (I), 17% in case (II),. This shows that optimization is more cost effective as numbers of segment go on increasing.

REFERENCES

[1] Johannes C. Kloppers & Detlev G. Kroger "Cost Optimization of Cooling Tower Geometry",'Engineering Optimization'. Vol 36; No 5; Year 2004. p.p.575-584.
[2] E. Omera, R. Guettab, I. Ioslovichb, and P.O. Gutmanb, "Energy Tower combined with pumped storage and desalination: Optimal design and analysis", 'Renewable Energy 33 (2008) p.p. 597–607.
[3] F.W. Yu; K.T. Chan "Economic Benefits of Optimal Control for water-cooled Chiller Systems Serving Hotels in a Subtropical Climate", 'Energy and Buildings'. Vol 42; No 2; Year 2010. p.p.203-209.
[4] Eusiel Rubio-Castro, Medardo Serna-González, José María Ponce-Ortega, "Optimal Design of effluent-cooling Systems Using a Mathematical Programming Model" , 'International Journal of Refrigeration. Vol 34; No 1; Year 2011.p.p. 243-256
[5] R.V. Rao; V.K. Patel, " Optimization of Mechanical Draft Counter Flow wet-cooling Towers Using a Rigorous Model", 'Applied Thermal Engineering'. Vol 31; No 16; Year 2011.p.p. 3615-3628
[6] Izuru Takewaki, "Semi-explicit optimal frequency design of chimneys with geometrical constraints", 'Department of Architectural Engineering, Kyoto University, Sakyo, Kyoto 606, Japan Available online 3 May 1999.
[7] Rakshith B D, Ranjith A, Sanjith J, Chethan G " Analysis of Cantilever Steel Chimney As Per Indian Standards" Int. Journal of Engineering Research and Applications ISSN : 2248-9622, Vol. 5, Issue 5, (Part -5) May 2015.p.p.151-162.
[8] GK Verboom and H Van Koten , "Vortex excitation: Three design rules tested on 13 industrial chimneys", Journal of Wind Engineering and Industrial Aerodynamics. Vol. 98, Year 2010.p.p.145-154.
[9] A Flaga and T Lipecki , "Code approaches to vortex shedding and own model", Engineering Structures.Vol 32, Year 2010.p.p.1530-1536
[10] J. Kawecki and J. A. Zuran´ski , "Cross-wind vibrations of steel chimneys-A new case history" Journal of Wind Engineering and Industrial Aerodynamics. Vol.95. Year 2007.p.p.1166-1175.
[11] IS 6533 Part 1; 1989, "Design and Construction of Steel Chimney", Bureau of Indian Standards, New Delhi (2002).
[12] IS 6533 Part 2; 1989, "Design and Construction of Steel Chimney", Bureau of Indian Standards, New Delhi (2005).
[13] IS800-2007, Code of practice Steel structures, Bureau of Indian standard, New Delhi.