Analysis of Self supporting Steel Stacks with Variable Geometrical Configuration under the seismic loading for different shapes

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Abstract— The present study deals with seismic behavior in zone IV for the different shapes of steel stacks with variable heights of 30m, 40m, and 50m. This work is carried out with sole objective to find which shape of steel stack is more stable under the seismic loading condition in terms of fundamental frequency and maximum deflection. The Seismic analysis is done by using the 'Staad Pro Vi8 ss5' software on the different shapes with some assumptions as per IS 6533:1989(part-1&II).

Keywords— Steel stacks, Seismic analysis, Maximum deflection, Fundamental frequency, Response spectrum.

INTRODUCTION

Stacks or chimney are very important industrial structures for emitting harmful gases to a higher elevation in atmosphere such that the gases do not contaminate nearby atmosphere. Failure of steel stacks is prime issue in most of industries. The cause behind the failure is analyzed by the seismic analysis of stacks. Total 9 stacks with different shape (simple circular, flare base and tapered) with Variable heights (30, 40,50m) were proposed for Seismic analysis as mentioned in Table-1. The analysis is done by using Staad Pro Vi8 ss5.

ANALYSIS OF STEEL STACKS:

Seismic effects include the effect of dynamic force exerted on steel stacks during earthquake. In the current work Response spectrum method is used to analyze the selected stacks.

A. *Geometry for flare base and tapered steel stacks:*

Basic geometry of steel stacks is governed by top diameter (D_t), base diameter (D_b) and effective height (H_e). Following IS code are used for the analysis of steel stacks.

a) IS 6533 (part-1):1989, "Indian standard code of practice for design and construction of steel chimney –code of practice-Mechanical aspects."
b) IS 6533 (part-2):1989, "Indian standard code of practice for design and construction of steel chimney –code of practice-Structural aspects."
c) IS 1893(part-4):2005 for the Seismic analysis.

Minimum top diameter of unlined chimney should be one twentieth of effective Height of chimney/stacks and minimum outside diameter at base should be equal to 1.6 times the top diameter of stack. (As per IS 6533(part2):1989(reaffirmed in 2003) cl.7.2.4 (b) &(c).

Table: 1 Geometry of Flare base and tapered steel stacks (Effective height H_e only for Flare base)

Total Height of stack (Meters) (H)	Effective Height (H_e) (2/3xH) (meter)	Top Diameter (constant) (H/30) (m)	Varying top to bottom diameters ratio (D_b/D_t) ratio (m)
			1.6
H	H_e	D_t	D_b
30	20	1	1.6
40	26.67	1.33	2.128
50	33.34	1.66	2.656

PROBLEM -STATEMENT

Analyze the behavior of self-supporting circular; flare base, Tapered steel stacks with variable geometric configurations for the seismic response as per Indian standard code of practice.

A. *Details of selected stacks:*

- Type: self-supported unlined industrial circular steel stacks with constant shell thickness as IS 6533 Part-1.
- Total 9 steel stacks (3 stacks of different heights, shapes and each stack with variable diameters)
- Selected heights of steel stacks are 30m, 40m, 50m.
- Top diameter for each stack is taken as minimum h/30 as per provision in IS 6533:1989.
- Variation in base diameter for each stack for fixed value of top diameter will be in following incremental ratio (ratio D_b/D_t) : 1.6
- Base condition : Rigid support at base
- Thickness of stack shell=16mm (constant for all stacks)
- Material : Stainless steel
- Location of stack :Agra
- Seismic zone :zone IV …(IS 1893:2005)
- Materials for steel stack are conforming to IS2062:2006.

RESULTS:

Seismic analysis results are tabulated in terms of Fundamental frequency and maximum deflection in table-2(for SCSC), Table-3(for FBSC), Table-4(TSC) and Table-5(maximum deflection). Fig-1, Fig-2 and Fig-3 shows the seismic behaviour, graphical representation of fundamental frequency and maximum deflections in SCSC, FBSC, TSC respectively which are as follows:

A. *Seismic response for circular steel stacks:*

The fundamental time period increase with increment in height of steel stack. The frequency for the simple circular steel stacks decrease with the increment in height for the seismic loading as mentioned in the table-2.

Table: 2 Seismic response for simple circular steel stack (SCSC)

Height (m)	Top Diameter (m)	Bottom Diameter (m)	Modes	Fundamental Time Period (T) sec	Fundamental Frequency (f) (cycle/sec)
30	1	1	1	0.44844	2.230
40	1	1		0.79461	1.258
50	1	1		1.26307	0.792

B. Seismic response for flare base steel stacks:

The fundamental time period increase with increment in height of steel stack. The frequency for the flare base steel stacks decrease with the increment in height for the seismic loading as mentioned in the table-3.

Table: 3 Seismic response of Flare base steel stacks (FBSC)

Height (m)	Top Diameter (m)	Bottom Diameter (m)	Modes	Fundamental Time Period (T) sec	Fundamental Frequency (f) (cycle/sec)
30	1.00	1.600	1	0.33214	3.011
40	1.33	2.128		0.43840	2.281
50	1.66	2.656		0.55652	1.797

C. Seismic response for Tapered steel stacks:

The fundamental time period increase with increment in height of steel stack. The frequency for the tapered steel stacks decrease with the increment in height for the seismic loading as mentioned in the table-4.

Table: 4 Seismic response of Tapered steel stacks (TSC)

Height (m)	Top Diameter (m)	Bottom Diameter (m)	Modes	Fundamental Time Period (T) sec	Fundamental Frequency (f) (cycle/sec)
30	1	1.6	1	0.267	3.747
40	1.33	2.128		0.357	2.803
50	1.66	2.656		0.447	2.238

D. Fundamental frequency due to Seismic response:

The fundamental frequency decreases with the increment in height of steel stack for all shapes. Fundamental frequency is more in tapered shape steel stacks as compare to simple circular and flare base steel stack for the 1st mode.

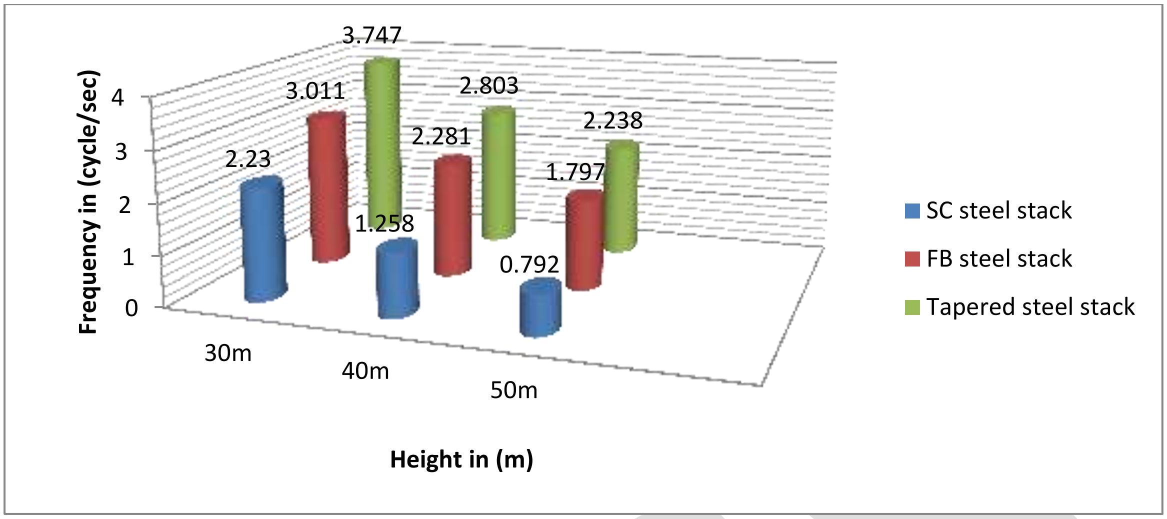

Fig-1 Fundamental frequencies in different shapes of steel stacks with variable heights

E. Max. Deflection due to Seismic response:

Maximum deflection increases with the increment in height of steel stack for all shapes. Tapered steel stacks are having less deflection as compare with simple circular and flare base stacks as per table-5 and Fig-2.

Table 5 Maximum Deflection (mm) Due to Seismic Response of steel stacks

Height	**Simple circular steel stacks in (mm)**	**Flare base steel stacks in (mm)**	**Tapered steel stacks in (mm)**
30m	3.394	2.168	1.415
40m	8.009	3.609	2.606
50m	12.729	5.963	4.086

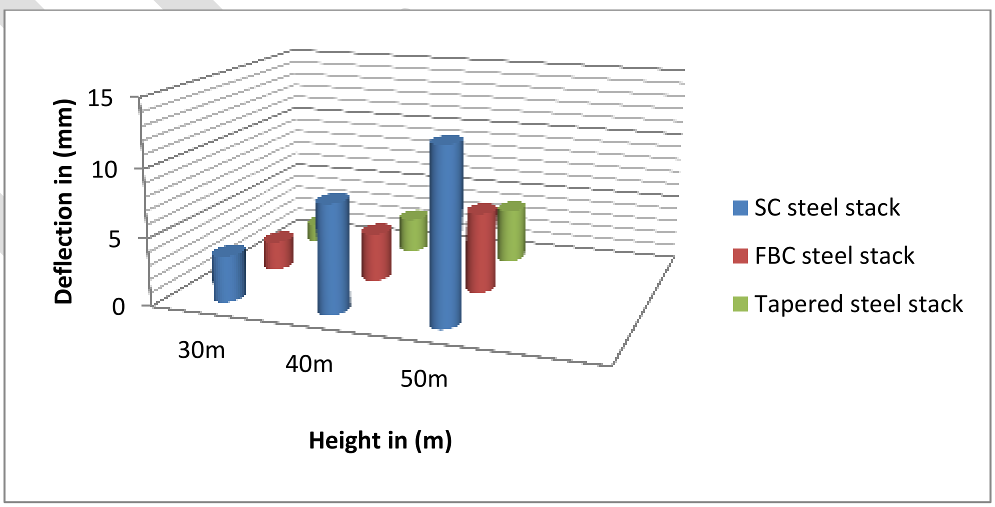

Fig-2 Maximum Deflection due to Seismic response with variable Heights (Different shapes) for 1st mode

CONCLUSION:

Following conclusions are obtained from all above graphical representations:

1. Fundamental frequency in tapered shape steel stacks(30,40,50m) is (40.49,55.12,64.61%) less than as compare with simple circular steel stacks of (30,40,50m).and (19.64,18.62,19.71%) less than as compare to flare base steel stacks of 30,40,50m.
2. Maximum deflection in Simple circular shape steel stacks(30,40,50m) is (58.31,67.46,67.90%) more than as compare with tapered steel stacks of (30,40,50m).and (34.73,27.79,31.48%) more in flare base steel stacks as compare with tapered steel stacks of 30,40,550m.
3. Tapered shape of steel stack is more stable under the seismic loading condition.

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