CONSIDERATIONS IN ASEISMIC DESIGN OF REFINERY FRACTIONATION COLUMNS

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SUMMARY

It is intended to share the experience of determining design seismic forces for refinery fractionation columns supported on elevated stagings of height 10-20 metres considering the interaction of steel fractionation column with concrete/steel frame resting on piles or directly on ground based on the treatment of vibrations of a complex cantilever system. Due allowance has been given to the flexibility of soil-foundation system and dimensional para-meters leading to variable properties in terms of sectional area, moment of inertia, elastic modulus as well as variable damping along height. A concise and rapid procedure is presented on how to evaluate the seismic loads, bending moments and shear forces for such vessels considering the recommendations of IS:1893-1975 tabulating the analysis result of several such columns for different Indian refineries.

INTRODUCTION

The common practice is to complete the mechanical design of these slender vessels by determining the seismic forces considering the vessel rigidly fixed at the top of staging, the parameters for which are fixed much later.

Recently refineries have been located in India at Halida, Bongaigaon, and Mathura which are highly seismic active and as such aseismic design of elevated columns for these refineries has demanded special consideration and technique for analysis.

DESIGN BASIS

For the aseismic design of such complex systems, the designer is confronted with various constraints viz the soil condition, the nature and extent of hazard in case of distress of structure, the possibility and intensity of earthquake, variable properties along height in terms of sectional area, moment of inertia, elastic modulus and damping etc. As such, some basis have to be framed for the selection of material and type of support structure which very much depend on factors like the intensity of earthquake motions expected, the flexibility of the system, its ductility and influence of soil foundation interaction.

Design Seismic Coefficient

The average acceleration spectra curves have been used to arrive at the design seismic coefficient (α_h) based on IS:1893-1975.

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$\alpha_h = \beta I (F_o \frac{S_a}{g})$, where I is importance factor based on strategy, life expectancy and economic considerations and should be 2 for such refinery vessels.

Time period of the system

Time period for a complex system is evaluated as a cantilever "fig. 1". Such an assumption in design is close to actual behaviour of the system when its dimensions in plan are small and considerably less than the seismic wave length. The time period (T) is determined in two stages, first assuming the cantilever fixed at base and then the values modified for soil compressibility.

For full fixity at base, $T = \frac{1}{5}\sqrt{\frac{\Sigma G_i \cdot Y_{oi}^2}{\delta_o}}$

Study on such tall slender structures has established the influence of the flexibility of soil on time period and shear by about 10-30% depending on the type of soil, in which case,

$$T = \frac{1}{5}\sqrt{\frac{\Sigma G_i (Y_{oi} + Y'_{oi})^2}{(\delta_o + \delta'_o)}}$$

Time period of the vessel rigidly fixed at the top of staging,

$$T = C_T \sqrt{\frac{(W_t/g) h_o}{A E_s}}$$

The values of Sa/g can be directly read from the established spectra curves for the particular site against the time period and α_h calculated.

Design Seismic forces

After T and α_h established, shear and moment for the fractionation column at and above the top of the staging can be calculated as under "Ref. 1"

$$V_x = C_v \alpha_h W_t \left[\frac{5}{3}\frac{x}{h_o} - \frac{2}{3}\left(\frac{x}{h_o}\right)^2\right]$$

$$M_x = \alpha_h W_t \bar{h} \left[0.6\left(\frac{x}{h_o}\right)^{1/2} + 0.4\left(\frac{x}{h_o}\right)^4\right]$$

$$V_b = C_v \alpha_h W_t$$

$$M_b = \alpha_h W_t \bar{h}$$

Only first mode response is significant for such a cantilever system and the effect of higher modes can be safely omitted even when large amount of translational base compliance is present. The increase in moment under multi mode considerations is of the order of 10-12% over the first mode which is neutralised by the rotation of the base if founded raft.

CONCLUSION

a) While the earthquake loads for the mechanical design has to be first approximated considering the vessel fixed at the top of staging, the final design should be strictly based on correct analysis of the complex cantilever system for realistic solution and competitive design.

b) To facilitate fast computation where computer aid is not readily available, the system could be analysed for the uniform damping (lower value) and the time period, moment and shear determined.

c) The time period of the system should be properly moderated for the flexibility of the soil under base. The time period thus moderated shall be far more accurate and higher than under conditions (a) & (b) and hence economical design struck for refinery vessels.

ACKNOWLEDGEMENT

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REFERENCES

1. IS:1893-1975 Criteria for Earthquake Resistant Design of Structures, Indian Standards Institution, Delhi

2. SINHA K N & MUNSI T K D (1978) Considerations in Aseismic design of structures for Refinery columns Proc. 6 ECEE, Dubrovnik (Yugoslavia).

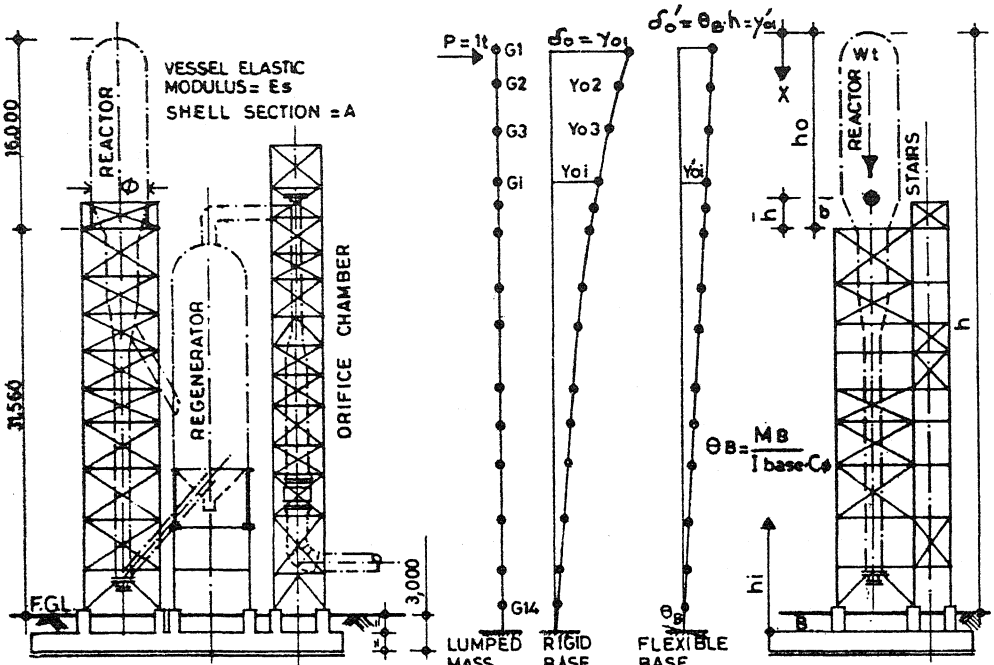
Table 2 : Values of CV and CT "Ref. 1"

K = ho/re	5	10	15	20	25	30	35	40	45	50
Cv	1.02	1.12	1.19	1.25	1.30	1.35	1.39	1.43	1.47	1.50
CT	14.4	21.2	29.6	38.4	47.2	56.0	65.0	73.8	82.8	1.8K

re = radius of gyration of column shell at base.

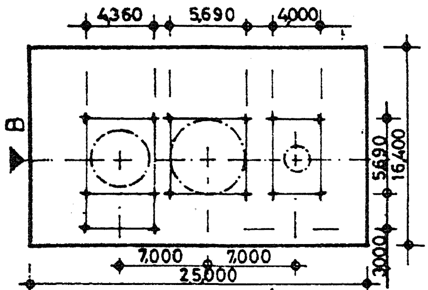
Table 3 : Results of refinery columns on elevated staging

Refinery column at	Haldia	Bongaigaon	Mathura	Mathura
ho (m)	33.5	28.0	16.0	35.0
h-ho (m)	10.2	10.0	31.5	5.0
ø (mm)	8400	3400	4536	2800
Staging base	rigid	rigid	rigid	rigid
Tb for vessel (Sec)	.30	0.389	.420	.1056
T_B for cantilever (Sec)	.60	0.550	.610	.180
$F_o \frac{S_a}{g}$ for T_b	.185	0.172	0.162	0.162
$F_o \frac{S_a}{g}$ for T_B	.148	0.145	0.098	0.162



VIEW A
Fig.1(b)

VIEW B
Fig.1(c)



PLAN
A

Fig.1(a): REACTOR - REGENRATOR FOR MATHURA REFINERY

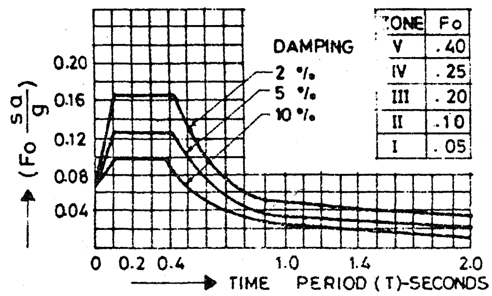


Fig.2: DESIGN ACCELERATION FOR MATHURA SITE

TABLE 1: VALUES OF β FOR SOIL FOUNDATION INTERACTION "REF. 1"

TYPE OF SOIL	PILES RESTING ON SOIL	OTHER TYPE OF PILES	RAFT	ISOLATED FOOTINGS WITH TIE BEAM	ISOLATED FOOTINGS WITHOUT TIE BEAM
N > 30	1.0	-	1.0	1.0	1.0
10 < N < 30	1.0	1.0	1.0	1.0	1.2
N < 10	1.0	1.2	1.0	1.2	1.5