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K. G. Bhatia
Structural Dynamics, Corporate R & D, BHEL, Hyderabad, India

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K. G. Bhatia

Laboratory Manager, Structural Dynamics, Corporate R & D, BHEL, Hyderabad, India

SYNOPSIS: The Design Office practice for the analysis and design of frame foundation generally ignores the soil structure interaction effects on the response of the frame foundation. A 210 MW T.G. frame foundation is analysed using various standard approaches as well as using 3-D finite element analysis. The analysis is carried out for fixed base as well as for elastic base conditions. Linear and rotational soil springs are considered to include the effect of base elasticity. The results of the analysis are presented. The analysis reveals that the soil structure interaction effects are significant both on the dynamic response parameters as well as on the strength parameters.

INTRODUCTION:

A 210 MW T.G. frame foundation is considered for the analysis. The total weight of the machine is of the order of 990 tons. The total rotor weights are of the order of 103 tons. The foundation size is 31 Mtrs. X 10 Mtrs. The height of the frame foundation above the bottom raft is 14.6 Mtrs. The thickness of the bottom raft is 3 Mtrs. The frame foundation consists of 6 transverse frames. Fig.(1) gives schematic view of 210 MW T.G. foundation. Fig. (2) gives the top deck plan and Fig. (3) gives the plan at the top of raft.

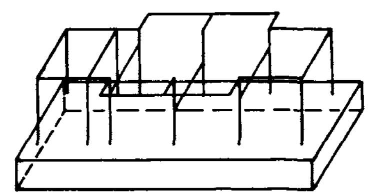

FIG. 1 3 D SCHEMATIC VIEW OF TG. FOUNDATION.

METHODS OF ANALYSIS:

The frame foundation is analysed using the following methods:

1. Amplitude method
2. Resonance method
3. 3-D FEM.

The frame foundation is analysed for fixed base as well as elastic base conditions using the above mentioned 3 approaches. The details of methods and the assumptions involved are not discussed here as these are available in standard text books.

To include the effect of soil in 2-D analysis, split raft method has has been used. The associated soil parameters are then computed and used in the analysis. One mass and two mass analytical models used for resonance and amplitude methods are extended to two mass and three mass models respectively to include the soil structure interaction effects. In 3-D FEM analysis 6 degrees of freedom has been considered at each nodel point, the No.

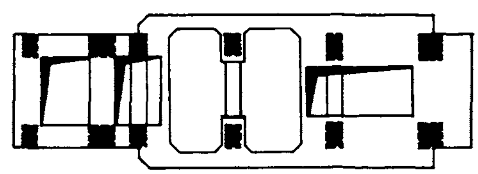

FIG. 2 TOP DECK PLAN.

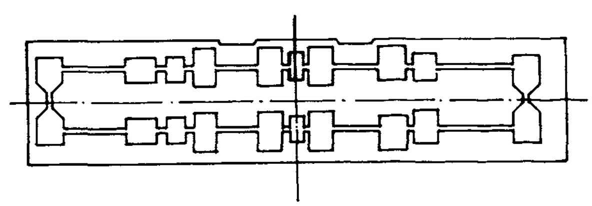

FIG. 3 PLAN AT TOP OF RAFT.

of nodes being 75 in fixed base idealisation and 175 in elastic base idealisation. As the problem size becomes too large in 3-D analysis it was considered essential to obtain response in vertical and horizontal direction separately by suppressing the required degrees of freedom in each case.

DISCUSSION OF RESULTS:

The vertical natural frequencies of a typical frame for the fixed base conditions as well as for the elastic base conditions are listed in table (I) both for the resonance and amplitude methods.

TABLE I. Comparision of vertical natural frequencies of a typical frame for fixed base and elastic base.

	Natural frequency (CPM)		
Resonance method:			
Fixed base		1438	
Elastic base	820	1808	
Amplitude method:			
Fixed base		1659	3423
Elastic base	720	1913	3609

From the 3-D analysis the vertical natural frequencies both for fixed base and elastic base conditions are listed in table (II). Also for the strength design of the foundation the forces and moments at bottom of columns are listed in table (III) for fixed and elastic base conditions.

TABLE II. Vertical and horizontal natural frequencies for fixed base and elastic base - 3-D FEM analysis.

Mode No.	Natural frequency (CPM) Vertical fixed base.	Natural frequency (CPM) Vertical elastic base.
1.	1092	651
2.	1343	1067
3.	1482	1264
4.	1566	1382
5.	1591	1510
6.	1791	1541
7.	1799	1625
8.	2005	1859
9.	2047	1930
10.	2235	2008

TABLE III. Forces and moments at column bottom.

Frame.		Axial Thrust (T)	Moment M_1 (TM)	Moment M_2 (TM)
I.	Fixed base	129	13	12
	Elastic base	152	6	16
II.	Fixed base	206	2	3
	Elastic base	213	5	5
III.	Fixed base	240	6	10
	Elastic base	248	15	30
IV.	Fixed base	132	14	11
	Elastic base	145	1	13
V.	Fixed base	209	2	3
	Elastic base	215	2	3
VI.	Fixed base	240	6	10
	Elastic base	272	36	18

It is observed that the variation in the frequency for fixed base condition and elastic base conditions, using resonance method, is of the order of 15 - 30% whereas using amplitude method, this variation is of the order of 11 - 20%. However, in the higher structural modes the variation is within 2 - 5%. The results of 3-D FEM analysis also indicate a significant variation in the vertical as well as horizontal natural frequencies. As the amplitude of vibrations are a function of these frequencies the effect on the amplitude of vibration is also significant.

Since the vertical natural frequencies in a frame foundation happens to be closer to the operating speed of the machine, the variation in the frequencies for fixed and elastic base conditions for different transverse frames is indicated in fig. (4). The variation of amplitude of vibration for fixed base and elastic base conditions is given in fig. (5).

CONCLUSION:

From the analysis of the results - it becomes obvious that vertical natural frequency of a plane frame, if established safe using fixed base condition may approach towards resonance for elastic base conditions thereby giving rise to serious vibration problems, both with respect to frequency and amplitudes.

It is also evident that resonance method approach does not give any feel of the upper structural deformation mode frequency. Thus keeping the customer/user into dark with respect to its approaching into resonance zone. Generally 2-D analysis is preferred over 3-D analysis as a Design office practice. However 3-D analysis can be used as a check analysis.

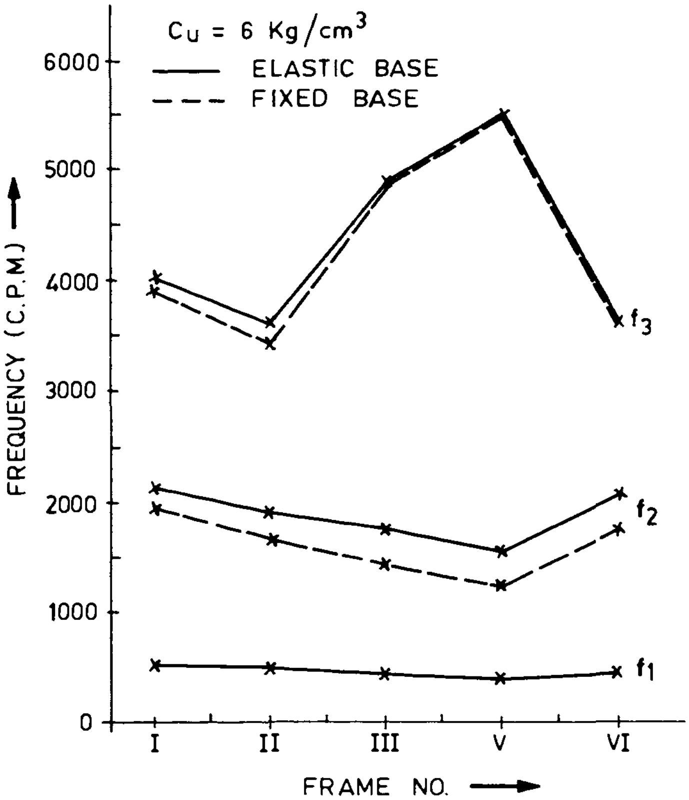

FIG. 4 NATURAL FREQUENCY OF FRAME FOUNDATION.

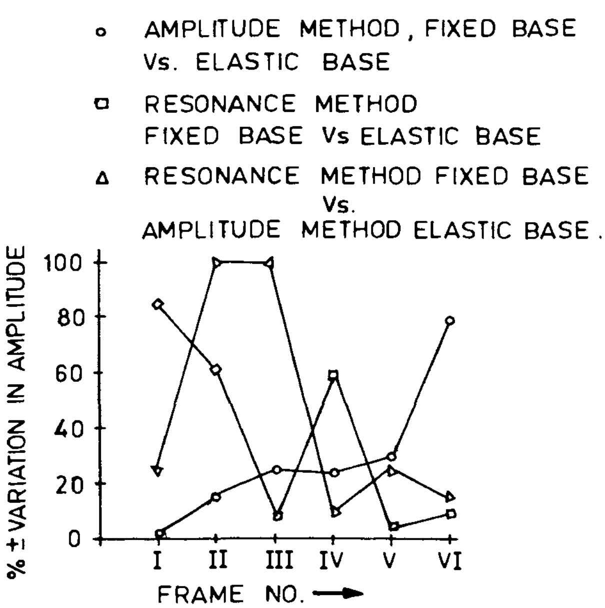

FIG. 5 % VARIATION IN AMPLITUDES.

It is, therefore, recommended that resonance method should not be used for under-tuned foundations wherein the upper structural deformation mode of the frame is likely to be in the range of operating speed of the machine. However, for those machines operating at very high speed ie. compressors etc. (speed is of the order of 10,000 rpm), the resonance method may be used as the upper structural deformation mode frequency of the frame may be well below the operating speed of the machine.

It is evident from the results that the effect of soil structure interaction on the response of the frame foundation is significant. For the purpose of design and analysis the following recommendations are made:

1) For analysing individual frames the effect of the base elasticity must be considered for all under-tuned foundation.
2) For under-tuned foundation analysis, amplitude method is preferred over Resonance method.
3) For over-tuned foundation analysis Resonance method can safely be used even with rigid base conditions as the effect of soil is to increase the frequency.
4) Effect of elasticity of the base for over-tuned foundation should be considered only to check the frequency for soil deformation mode and to ensure that the same is away from the operating frequency.
5) As the effect of base is to increase the structural frequency, the effect of ± 20% variation in frequency for computation and dynamic loads as recommended by code of practice should be modified to only + 20% if soil structure into reaction is not considered and should be only ± 10% if interaction is considered.

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