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Study of Frame Foundation for Rotary Type Machine with Base Isolator

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Abstract—*Machines are the most important equipment in the industry. These machines produce different types of loads on foundations when they are operated. Generally the load produced with-in the machine is dynamic in nature caused due to vibratory motion, impact of hammer, earthquake or wind, pile driving, etc. Due to the action of all these vibratory loads, over a long period of time the performance, safety, stability of machine gets affected and it largely depend upon its foundation. The machine foundations should be designed in such a way that the dynamic forces of machines are transmitted to the soil through the foundation such that all kinds of harmful effects such as resonance of foundation and machine will be eliminated and also the amplitude of vibration during operation of machine will be minimized. Thus the machine foundation is very important aspect for performance of any machine. In present study the frame foundation for rotary type machines are designed according to IS codes for different soil parameters. Time history ma analysis is done for same foundation for earthquake loading with and without base isolators. The effect of change of stiffness of frame columns on the natural frequency of machine and foundation has been studied.*

1. INTRODUCTION

The main constituents of a typical machine foundation system are machine, foundation and support medium.The machines are classified based on their type of motion asrotary,reciprocating, impact machines. A suitable foundation is selected, depending upon the type of machine. The types of machine foundation are block foundation, frame foundation, wall foundation etc. soil continuum, or a soil-pile system can be taken as supporting medium. In this paper the rotary type machine with frame foundation

And soil as a supporting medium is considered. The foundation is analysed by manual method and using software SAP2000. The different loads acting on foundation and the load combination that are useful in analysis of machine foundation are considered from IS2974 part3:1992. The base isolator has been introduced in the model of machine foundation. The parametric study of natural frequencies has been done with and without isolator and also time history analysis has been done by considering the data from "IMPERIAL VALLEY EARTHQUAKE - EL CENTRO".

2. PROBLEM STATEMENT

For this study a problem of frame foundation for rotating type is taken from foundations for industrial machines" hand book for practicing engineers by Bhatia as detailed below. Fig. 1.1 shows the typical top view of TG foundation showing bearing locations, major notch and columns.

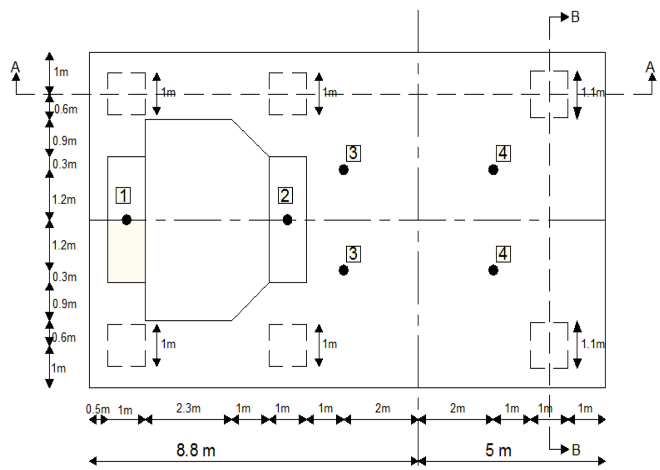


Fig. 1.1 Plan of the Turbo Generator Foundation showing the bearing locations of the Machine

Fig. 1.2 shows the front elevation and side view of TG foundation.

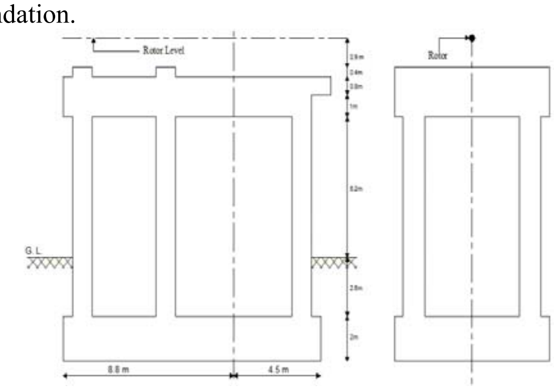


Fig. 1.2 Section A-A: - Elevation of the TG Foundation and Section B-B: - Side View

Table 1.1 shows the loads acting at the bearing locations of machine.

Table 1.1 Machine Load Data

Bearing Points	1	2	3	4	Total (kN)
Total machine weight	400	360	200	200	1160
Rotor weight	25	35	70	70	200
Unbalance Force					
Lateral/Vertical	5	7	15	15	42
Longitudinal	2	3	6	6	17
Blade Loss force	3	11	-	-	14

Table 1.2 shows the material properties of the TG foundation.

Table 1.2: Foundation Data

Foundation material Properties	
Grade of Concrete	M:25
Mass density of concrete	ρ = 2500 kg/m3
Modulus of elasticity	E = 3 x 107 kN/m2
Poisson's ratio	υ = 0.15
Shear modulus	G = 1.3 x 107 kN/m2

Table 1.3 shows the soil properties considered below the TG foundation.

Table 1.3: Soil Data

Soil Properties	
Coefficient of uniform compression	Cu = 40000 kN/m3
Coefficient of non-uniform compression	CØ = 80000 kN/m3
Coefficient of uniform shear	Cζ= 20000 kN/m3
Coefficient non-uniform shear	CΨ = 30000 kN/m3

3. ANALYSIS OF FRAME FOUNDATION

The analysis shall be done using a simulated mathematical model of linear-elastic properties. The modeling should take into account the basic characteristics of the system, that is, mass, stiffness and damping. Here rotary machine foundation modeled using SAP2000 software. And by the manual analysis also natural frequencies calculated. In manual analysis both static analysis and dynamic analysis are considered.

3.1 Manual Analysis

Manual analysis considers mainly static analysis and dynamic analysis.in static analysis the eccentricity check is considered and in dynamic analysis natural frequencies and total amplitude of vibration. for the analysis purpose it is considered as three frames.

Centre of stiffness with respect to Frame I

Źkx =5.83 m

Źky =4 m

Centre of Gravity of the masses with respect to Frame I

Źmx =5.93 m

Źmy =4 m

Top deck Eccentricity along X direction

ex = Źmx–Źkx= 0.1 m

Top deck Eccentricity along Y direction

ey = Źmy - Źky = 0 m

e = (0.1 / 13.8)X100

e = 0.72% (It is less than 1%)

Hence, Eccentricity is within permissible limit. (clause 8.6 from IS2974 part3:1992)

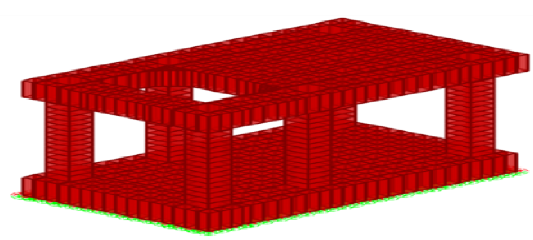
Dynamic analysis Natural Frequencies by manual method			
Mode		**rad/sec**	**Hz**
Translational Mode along X	Px	16.74	2.65
1st Vertical Mode along Y	Py1	140	22.041
2nd Vertical Mode along Y	Py2	270	43
Overall Total Vertical Amplitude of Top Deck slab	16.88	microns	

3.2 Modeling For Frme Foundation- Software Analysis

The elements of the foundation system such as beam, column, deck slab and raft are modeled as solid elements.. In this model the boundary condition and make all the nodes at the bottom of the raft fixed in all six directions assuming the soil below the ground as very rigid. During modeling the small opening, notches, pockets, cut-outs, projections, etc. which unnecessarily increases the complexity of the problem without much influencing the results of the structure in the analysis are avoided. Only major openings and depressions are taken into consideration which is enough to represent the actual structure Turbine and generator masses are lumped at four bearing locations at the top deck.

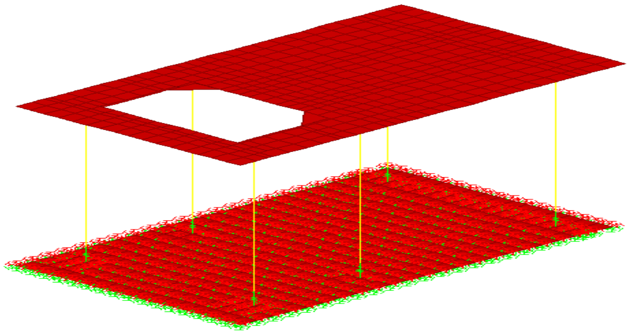
MODEL FOR CASE1: SOLID MODEL WITH FIXED END

The elements like beam, column, deck slab and raft are modelled as solid elements and soil is modelled as six spring elements stiffness in all six directions

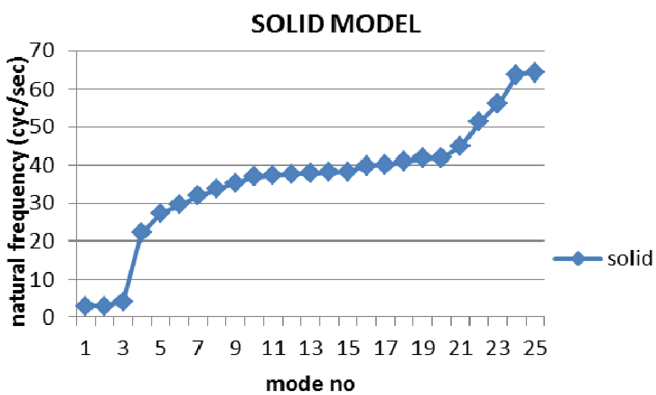


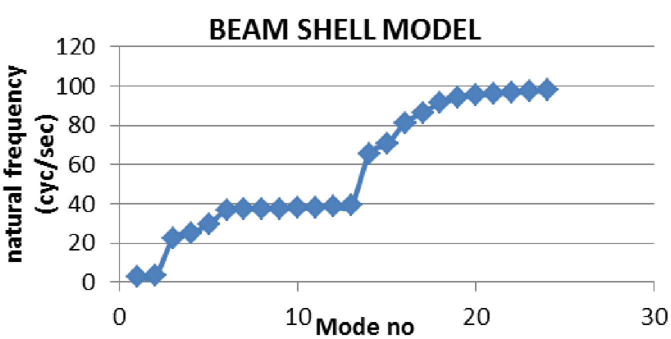
MODEL FOR CASE2: BEAM SHELL MODEL WITH CHANGED COLUMN SIZES

Deck slab and Raft modelled using shell element and columns are modelled using frame elements and soil is modelled using springs in all six directions



modal analysis has been done for two models and the difference in nature of natral frequencies presented below.





Observation:

The operating frequency of the machine is 50Hz. So it is necessary to avoid frequency ranging from 40 Hz to 60 Hz .according to IS2974 part3:1992 the modal frequencies should not fall near to the operating frequency of the machine. For this the model is re defined its column sizes and this frequency range of resonance is avoided. In case2 the column sizes have been changed such that the required frequency range is obtained.

Base Isolation

The seismic isolation has an important role in decreasing the response of structural systems and has been used with the development of science and technology. In studies related to seismic rehabilitation the roles of bearings have been under consideration as well. Today it has been proven that the base isolation is an effective way of reducing the lateral load of earthquake but there is no major attention paid to the role of the diaphragm on the isolators.

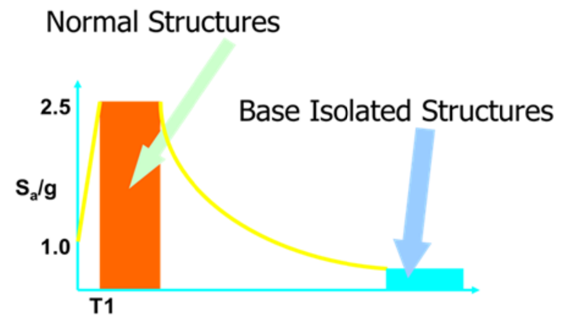
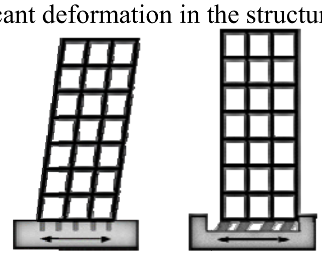


Fig. 3: Response Spectrum curve of a structure subjected to base isolation

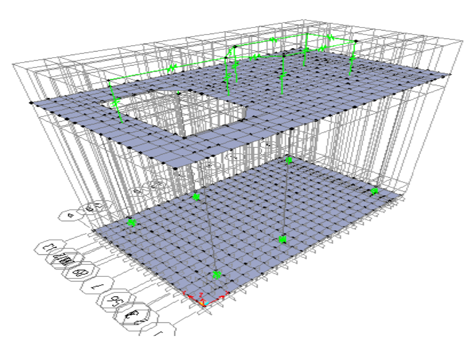
i. The key points of the Base isolation system can be taken as:
ii. Deflects the earthquake energy
iii. Period shift and energy dissipation are the key elements of an isolation system
iv. Accelerations and Forces in structural members reduced substantially
v. Large displacements occur at isolator level without significant deformation in the structure

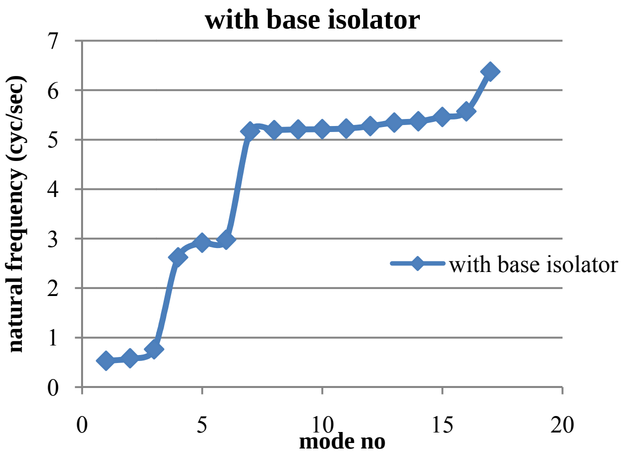


Fixed BaseBase isolated

As the fabrication of Lead core Rubber bearing system is easier, it will be taken as the Base isolation system required for the study of this thesis. the base isolators have been provide for each column.

Model with base isolator

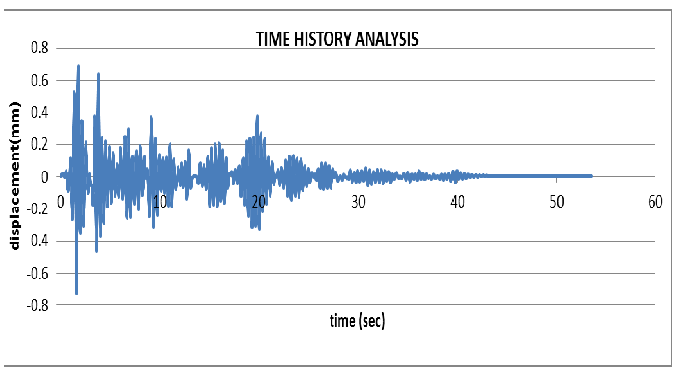




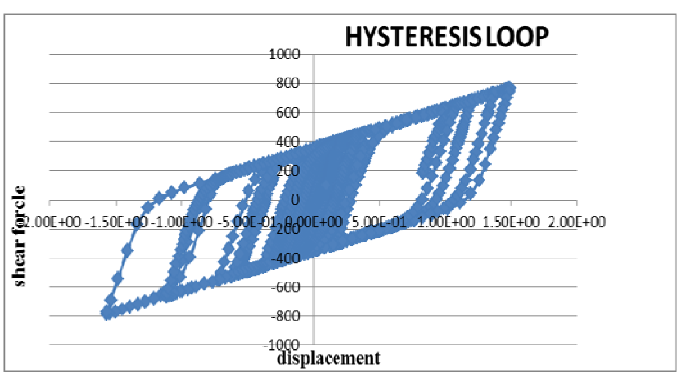
Observation

The difference in oscillation of machine foundation reduced significantly by the usage of the base isolator as we can observe in above charts with and without isolator.

The study of displacement vs. time and has been done with isolator and also time history analysis has been done by considering the data from "IMPERIAL VALLEY EARTHQUAKE - EL CENTRO"



The study of energy dissipation has been done by getting hysteresis loop with isolator and also time history analysis has been done by considering the data from "IMPERIAL VALLEY EARTHQUAKE - EL CENTRO".



4. CONCLUSIONS

1. With the change in sizes means stiffness of columns we can get desired modal frequencies which are useful in machine foundation design.
2. The different models have been analysed in SAP 2000 to understand the behavior of foundation .
3. The use of base isolator clearly represents the reduce in oscillation under earthquake loading which is very helpful for safety of structures.
4. The hysteresis loop represents the energy dissipation under the earth quake loading which is helpful for understanding of the damping phenomena.

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