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Geotechnical Aspects In Modelling Framed Type Foundation For 210 MW Turbo Generator Using Computer Software

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Abstract— Turbo Generator consists of turbine and generator. It is used for generating Electricity. It is a very heavy machine, inducing large forces due to its self weight & operation on foundation.The Turbo Generator foundation is a vital & expensive part in a power plant complex. It is therefore essential that the foundation is designed adequately for all possible combinations of static and dynamic loads. It is a task of the structural designer to check the adequacy of the foundation under static and dynamic condition. At times it may becomes necessary to suitably alter the dimensions of the foundation as suggested by machine manufacturer so as to satisfy the design requirements.Any alterations thus found necessary must however have the prior concurrence of the Mechanical Engineer to ensure that these changes do not affect the erection operation of the machine.It is desirable therefore to have a close coordination between the foundation designer and the erection staff from the early planning stage until the foundation is completed and the machine is installed.

Keywords— Natural frequency, vibration, damping, elastic modulus, turbo generator

I. INTRODUCTION

In the early stages of development,Turbo Generator were mounted on the so called “wall type foundation” consisting the pair of walls on which were seated the turbine & generator.With the increase in the size & output of the machinery, more sophisticated type of foundation had to be devised for functional reasons. Framed foundation are now popular for supporting high speed machinery, on account of their many advantages, such as they do not limit a designer in the location of the engine & its auxiliary equipments, as do massive foundation e.g. condenser, pipeline, air vents, electric wiring which can be arranged much more conveniently, if the machine are mounted on frame foundation.The use of frame foundations facilitates considerably the inspection & access to all parts of the machine also saving in space, saving in material & less liability to cracking due to settlement & temperature changes.[1]

The common material of construction used for these foundations are reinforced concrete & steel reinforced concrete foundations which are common both in India & abroad. For the analysis of T.G.Foundations, the use of one mass or two mass idealizations has been in vogue for many years. With slender, under tuned foundations, which are commonly used today. These simple methods of analysis cannot be used to satisfy the design criteria. In the last two decades, rapid improvement in the analytical methods have taken place with the introduction of computers & the development of sophisticated techniques using matrix method & finite element techniques. As a result, number of improved mathematical models has been proposed for the analysis of T.G.foundation, comprising of beam elements & analysis is done using standard computer programs, which are commonly available.[1,2]

II. NECESSARY DATA

The machine data & the geotechnical data are necessary for the analysis & design of machine foundation.

2.1. Machine Data

The machine manufacturer shall make the following data available to the designer. Loading diagram of the machine showing the location, magnitude & direction of all the loads, speed of machine, outline dimensions of the foundation, mass moment of inertia of the machine components, details of inserts & embedments, layout of piping ducting etc & their supporting details,tempreture in various zones during operation, allowable displacements at the machine bearing points during normal operation.[3]

2.2. Geotechnical Data

Investigation of the site where the foundation is to be located shall be done to evaluate the parameters like allowable bearing pressure, in situ dynamic soil properties as per IS 5249:1992.[4,5]

III. MODEL PREPARATION

For the purpose of analysis of soil structure interaction of T.G. foundation, a model is prepared. For this purpose, the basement is modelled with a plate bending element. The soil below the base mat shall be idealized as spring element.i.e. the base mat is discretised into various nodes, each node is given with a spring support. The stiffness of spring is found out to be multiplying modulus of sub grade reaction & area contributed by particular node. The foundation is modelled as a three dimensional space frame in which the columns & beams are idealized as 3D beam elements with a six degree of freedom at each node. An uncracked section is used for calculating moments of inertia of the members.[6]

Table 1 : Range of values of modulus of subgrade reaction (K)

Sr.No.	Type Of Soil	K (KN/M^3)
1	Loose sand	4800 - 16000
2	Medium dense sand	9600-80000
3	Dense sand	64000-128000
4	Clayee Medium dense sand	32000-80000
5	Silty Medium dense sand	24000-48000
6	Clayee sand	12000-48000

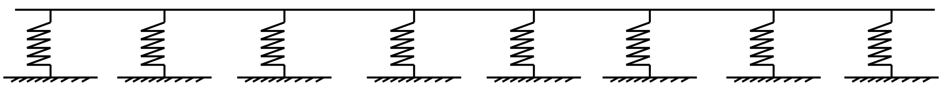

Figure 1: Planer model treating the foundation on springs

IV. ANALYSIS OF TURBO GENERATOR FOUNDATION

Analysis of Turbo Generator is done in the following three parts. Part 1 - Static analysis 2) part 2 - Dynamic analysis 3) part 3 - Time history analysis

4.1. Static Analysis

A detailed static analysis of the foundation shall be performed to ensure that the foundation carries all the loads safely. The same model which has been used for dynamic analysis may be used for static analysis.

4.1.1 Load Cases

The following loads shall be considered for the foundation design

Dead load which includes the self weight of the foundation & dead weight of the machine (DL), Operation loads supplied by the machine manufacturer which includes friction forces, power torque, thermal elongation forces,vaccum in the condenser, piping forces etc.(OL),Normal machine unbalance load (NUL),Temperature load in the foundation(TLF),Uniform temperature change,Tempreture gradients across members , Short circuit forces (SCF),Loss of blade unbalance(LBL) or Bearing failure load (BFL),Seismic load (SL).

4.1.2 Load Combinations

Operating condition

DL + OL + NUL + TLF

Short circuit condition

DL + OL + NUL + TLF + SCF

Loss of blade condition/Bearing failure condition

DL + OL + TLF + LBL/BFL

Seismic condition

DL + OL + NUL + TLF + EQL

Following are the possible load combinations as per IS-2974 (Part 3) : 1992

4.1.3 Load Case A

DL+OL+TLF+NUL +Rotating Static/± Rotating Dynamic

DL-OL-TLF- NUL +Rotating Static/± Rotating Dynamic

4.1.4 Load Case B

DL+OL+TLF+NUL+SCF +Rotating Static/± Rotating Dynamic

DL-OL-TLF- NUL-SCF +Rotating Static/± Rotating Dynamic

4.1.5 Load Case C

DL+OL+TLF+BFL+Rotating Static/± Rotating Dynamic

DL-OL-TLF-BFL +Rotating Static/± Rotating Dynamic

4.1.6 Load Case D

DL+OL+TLF+NUL+EQL+Rotating Static/± Rotating Dynamic

DL-OL-TLF-NUL-EQL +Rotating Static/± Rotating Dynamic [7,8]

For Static analysis SAP-2000 is used. In this all the elements are considered as beam elements. There are total 152 beam element & 95 nodal points. M25 Grade of concrete is assumed. Value of Modulus of elasticity for concrete = 3×10^7 KN/M^2 Density of concrete = 25×10^{-9} KN/mm^3

The self weight of foundation as well as all the forces acting on it is converted into fixed end forces except the forces acting at nodal points. Static analysis is performed in the following steps.

1) Analysis for the self weight of foundation
2) Analysis for static forces of T.G.
3) Analysis for equivalent static forces
4) Analysis for rotating element [9]

4.1.7 Critical Load Combination

From the above load combination it is observed that the critical load combination for load is load 5 most of the times. (i.e. DL+RS+OL+TLF+LBL)

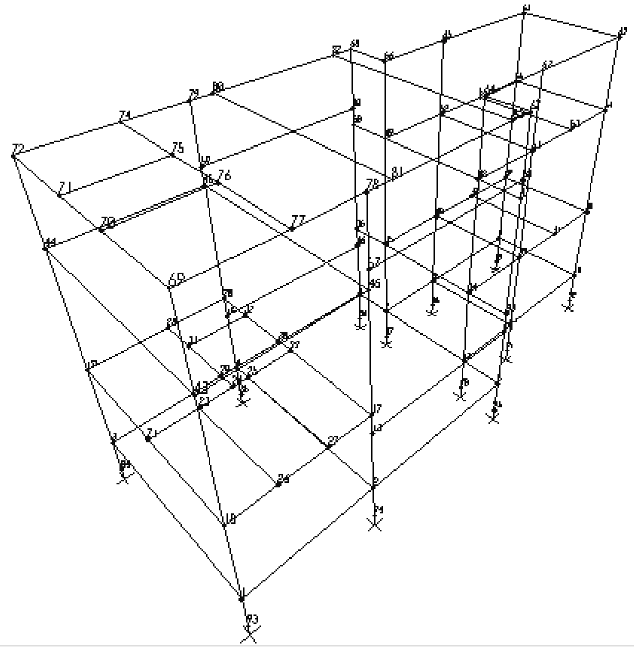

Figure 2 : Mathematical model of T.G. foundation for SAP-2000

4.2. Dynamic Analysis

Dynamic analysis is performed using SAP-2000. It includes computation of natural frequency for self weight of foundation & Eigen vectors for 14 mode shapes. Natural frequency is also computed manually by Extended resonance method. Frequencies & time period using SAP – 2000 software are shown below.[10,11]

Table 2: Modal Periods and Frequencies

Mode	Period (Time)	Frequency (Cycle/Time)	Frequency (Rad/Time)	Eigen value(Rad/Time)**2
1	0.393536	2.5410640	15.965973	254.912293
2	0.377257	2.6507160	16.654939	277.386984
3	0.364860	2.7407750	17.220795	296.555778
4	0.114797	8.7110500	54.733140	2995.71700
5	0.092605	10.798583	67.849497	4603.55400
6	0.081454	12.276862	77.137798	5950.24000
7	0.069334	14.422940	90.622003	8212.34700
8	0.066399	15.060573	94.6283730	8954.52900
9	0.060947	16.407676	103.092472	10628.0580
10	0.059211	16.888776	106.115310	11260.4590
11	0.057814	17.296824	108.679148	11811.1570
12	0.057041	17.531333	110.152611	12133.5980
13	0.056558	17.681014	111.093090	12341.6750
14	0.054368	18.393267	115.568307	13356.0340

Natural frequencies computed using various methods have been shown in the following table

Table 3: Natural frequencies computed using various methods

Method of calculations of natural frequency	Horizontal Frequency(Cys/sec)
Manually	2.579
SAP-2000	2.541

Natural frequencies computed using various methods are nearly same. For dynamic analysis the following range of dynamic elastic modulus is used.

Table 4: Range of dynamic elastic modulus

Grade of Concrete	Dynamic Elastic Modulus N/mm^2
M20	25590 - 30000
M25	28500 - 34000
M30	31200 - 37000

As the dynamic elastic modulus is changes, the natural frequency is also changes. Different values of frequencies for different values of dynamic elastic modulus (E) for first five mode shapes are shown in following table.

Table 5: Different values of frequencies for different values of dynamic elastic modulus (E)

Mode Shape	E = 2.559 x 10^7 kN/m^2		E = 2.85 x 10^7 kN/m^2		E = 3.0 x 10^7 kN/m^2	
	Time period(sec)	Frequency (Cys/sec)	Time period(sec)	Frequency (Cys/sec)	Time period(sec)	Frequency (Cys/sec)
1	0.426098	2.3469	0.403759	2.4767	0.393536	2.5411
2	0.408472	2.4481	0.387057	2.5836	0.377257	2.6507
3	0.395050	2.5313	0.374339	2.6714	0.364860	2.7408
4	0.124295	8.0454	0.117779	8.4905	0.114797	8.7110
5	0.100267	9.9734	0.095011	10.525	0.092605	10.799

Therefore from the above table it is clear that as the values of dynamic elastic modulus (E) increases, the time period decreases whereas the frequencies are increases. The standard value of dynamic elastic modulus is 30000 N/mm^2 is used.[10,11]

4.3. Time History Analysis

Since rotating element gives dynamic effect, time history analysis is performed for this rotating element. For variation of load sine curve is used. Time taken for the complete cycle is 0.02 sec.This cycle is repeated till the natural period of foundation is reached. Further this one cycle is divided into 13 parts ,each of time interval 0.00154 sec.Like this 265 time interval have been considered. Dynamic response for this time intervals have been calculated at every node using SAP 2000.[10,11]

V. CONCLUSION

The fundamental natural frequency shall be at least 20% away from the machine operating speed. The highest natural frequency of foundation is found out to be 1371.60 RPM. Hence difference between machine speed & natural frequencies is 54.28%.Maximum amplitude of vibration are 0.014 mm which is less than permissible amplitude of 0.02 mm.Out of eight load combination , the loss of blade combination is found out to be critical most of the times. From the time history analysis it is observed that maximum forces and displacements occurs at initial period less than 0.08 sec.

The natural frequencies computed by different methods are nearly same. As the values of dynamic elastic modulus (E) Increases, the time period decreses, whereas the frequencies are increases. The natural frequencies increases with the increase in value of sub grade reaction & time period decreases, as the value of sub grade reaction increases.

REFERENCES

[1] Barkan, D.D. (1962). “Dynamics of Bases and Foundations”, McGraw - Hill Book Company, New York, U.S.A.
[2] Prakash, S. and Puri, V.K. (1988). “Foundations for Machines: Analysis and Design”, John Wiley & Sons, New York, U.S.A.
[3] Arya, S. C., O’Neill, M. W., and Pincus, G., Design of Structures and Foundations for Vibrating Machines, Gulf Publishing, Houston, TX
[4] BIS (1992). “IS 2974 (Part 3): 1992—Indian Standard Design and Construction of Machine Foundations—Code of Practice, Part 3: Foundations for Rotary Type Machines (Medium and High Frequency) (Second Revision)”, Bureau of Indian Standards, New Delhi
[5] DIN: 4024 (Part - 1), 1988: Machine foundations – Flexible structures that support machines with rotating elements.
[6] International Conference of Building Officials (ICBO), (1997), Uniform Building Code – 1997 Edition, Vol. 2: Structural Engineering Design Provisions, ICBO, Whittier, CA.
[7] Kappos, A.J. et al. (2002), Dynamic Loading and Design of Structures, Spon Press.
[8] Desai, A., Rao, (1995), “Computer aided dynamic analysis of pin jointed space frames”, IASS -SYMPOSIUM, Milano –Italy, 5-9 June
[9] Maheshwari, K., V., Desai, A., Solanki, C, H, (2012), “Analytical Modeling Of Foundation Resting On Fiber ReinforcedClayey Soil”, Structural Engineering Convention (SEC-12), SVNIT, Surat, 19-21 December.
[10] MSEB,Drawing No CECC/101.027,General Arrngements of turbine generator foundation. Khapperkheda Thermal Power Station , stage II unit no 3 & 4
[11] MSEB, Drawing No 0-13100-40, load on foundation Khaperkheda. Thermal Power Station Stage II, Unit No 3 & 4

