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General Report — Session XII: Machine Foundations and Model Tests

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Machine Foundations and Model Tests

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GENERAL REMARKS

There are seven papers in this session dealing with different aspects of analysis and design of foundations for machines. These papers can generally be placed into the following categories:

* Analysis of machine foundations.
* Analysis for control of vibrations.
* Interaction between adjacent machine foundations.
* Effect of vibrations due to machine operation on adjacent foundations and structures.
* Reliability aspects of machine foundation design.

Some papers are broad based and cover more than one aspect.

ANALYSIS OF MACHINE FOUNDATIONS

There are three papers on this topic. A glance through the existing literature reveals that forcing functions of the type $P_o e^{i\omega t}$ have been extensively used in deriving equations for the stiffness and damping parameters for the machine foundation-soil system. (Arnold et al. (1955), Bycroft (1956,1959), Hsieh (1962), Hall (1967) and Dobry and Gazetas (1985, 1986)). These parameters are then used in an appropriate analog for predicting the resonant frequency and amplitude of vibration of the foundation (Das (1992), Prakash and Puri (1988), and Richart, Hall and Woods (1970)). Truong and Moore (1995) have used periodic forcing function of the type

$$P(t) = P_o T + P_o \sin\omega t$$

for obtaining the stiffness and damping values for vertical and sliding modes of vibration. They have used the concept of wave propagation in a perfectly elastic half space in developing **"new expressions"** for stiffness and damping (Hsieh, (1962) and Lysmer and Richart (1966)). The expressions for stiffness and damping are observed to depend on the forcing function. The resonant frequency and the amplitude of vibration are not affected by the forcing function. The authors have also observed that the apparent soil mass participating in vibrations is different for vertical and horizontal modes of vibration.

Mashhor, Abdel-Salam and El-Nggar (1995) have presented a numerical procedure for computing the frequency-dependent impedance matrix for the vertical vibrations of a rigid rectangular footing resting on a homogeneous, isotropic elastic half space, using the boundary element method. The contact interface of the foundation and the soil medium is subdivided into rectangular subdivisions. The soil footing contact surface is assumed as a relaxed boundary. Numerical integration is conducted to obtain the subgrade compliance matrix. The impedance matrix of the subgrade is then obtained by inversion of the compliance matrix. The compliance matrix and the impedance matrix depend on the excitation frequency, the plane configuration of the foundation and the properties of the underlying soil. The results have been presented as impedance function Vs dimensionless frequency plots for several values of poisson's ratio of the soil and aspect ratios of the foundation. The authors have found good agreement with the work of Israil and Banerjee (1990).

Gucunski (1995) has presented the results of a parametric study dealing with the response of a flexible circular foundation embedded into a visco-elastic half-space and a layered half-space system consisting of a single layer overlying a half-space. The "ring method" approach (Lysmer (1965); Wass (1980)) was used to discretize the foundation into a number of rings. The stiffness matrix of the of the foundation was obtained by the finite difference energy method. The matrix of influence coefficients for the layered system was obtained by following the stiffness matrix approach. The effect stiffness ratio, dimensionless frequency, shear wave velocity ratio, and layer thickness to foundation radius ratio was studied. The results of the study indicate that the response of a flexible circular foundation to vertical vibrations differs significantly from the response of a rigid foundation. The point of application of the load was also found to affect the response .

ANALYSIS FOR CONTROL OF VIBRATIONS

The paper on this subject by Abdel-Rohman and Al-Sanad (1995) discusses the use of a tuned mass damper for controlling the nonlinear vertical vibrations of a foundation resting on a sand deposit. A comparison was made of the response of the foundation with and without the damper. The authors have observed that the tuned mass damper is able to control the amplitude of vertical nonlinear vibrations of the foundation within certain frequency range depending on whether the damper is linear, softening non-linear, or hardening nonlinear.

INTERACTION BETWEEN ADJACENT MACHINE FOUNDATIONS

The interaction between adjacent machine foundations may make the vibration problem rather complex. This interaction may adversely affect the performance of the machines if it is not adequately accounted for in the design. Lee and Bohinsky (1995) conducted a case study to evaluate the interaction effects between two identical variable speed rotating machines located on a flexible concrete floor supported on steel beams. Frequency and force response analyses were conducted. The maximum responses including accelerations, velocities, and displacements at bearing level were obtained for the in-phase and out-of-phase operation of the machines. For the particular case investigated the authors have observed significant interaction effect between the two machines. The critical condition was found to occur when the machines operated out-of-phase. The pertinent details about the machines, the dynamic loads, speed of operation and the supporting system are not reported in the paper.

EFFECT OF VIBRATIONS DUE TO MACHINE OPERATION ON ADJACENT FOUNDATIONS AND STRUCTURES

The vibrating foundations may have a harmful effect on adjacent structure and foundations depending on soil conditions, characteristics of the propagated waves, and the types of structures. Svinkin (1995) has presented results of an experimental investigation conducted to study the effect operation of forge hammers on exterior walls of forging shops. The effect of a drop hammer for breaking scrap iron on settlement of column footing supporting crane tracks was also investigated.

Ten forge hammers included in this study were housed in similar structures consisting of one storey braced steel frame construction and exterior brick walls resting on spread footings or column footings with foundation beams. The soil conditions on different sites were different and varied from fine sand to saturated medium sand and clay. The exterior brick walls of the forge hammer housing had severely cracked in some cases. Vertical and horizontal vibrations were measured on column footings and on the brick walls during operation of the forge hammers. Maximum transverse wall vibrations with amplitudes of 0.7 mm were observed in some cases. The walls were observed to vibrate at operating frequencies of the hammers as well as at their own natural frequencies. Most of cracks in walls could be attributed to vibrations transmitted by the forging hammer operation. The observation on the large drop hammer indicated that nonuniform settlements of column footing occurred due to vibrations transmitted by its operation.

RELIABILITY ASPECTS OF MACHINE FOUNDATION DESIGN

Singh and Das (1995) have emphasized the uncertainties in the deterministic methods commonly used for design of foundations under dynamic loads. These uncertainties could be physical, statistical, related to the model used for analysis or due to human errors. They have suggested that reliability based design should be incorporated to ensure safety and cost effectiveness. They have also suggested a methodology for reliability based design of non-critical structures.

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