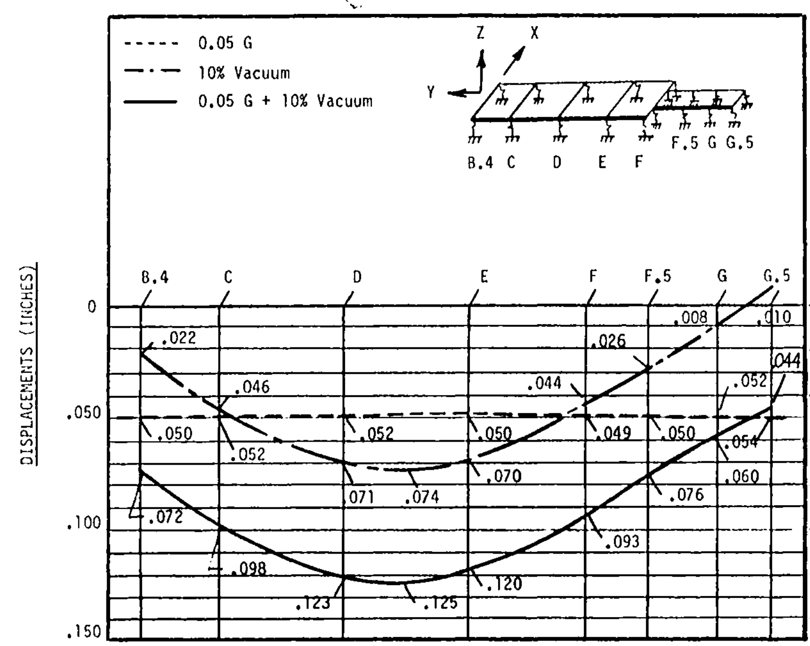

Fig. 4--Displacement of turbine support due to live loads

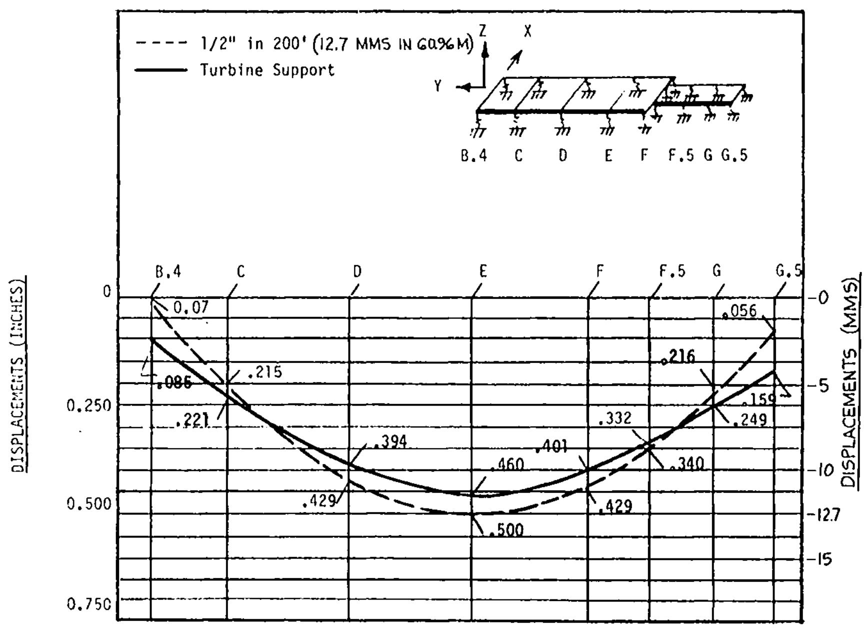

Fig. 5--Turbine support displacement due to 1/2-inch platform displacement

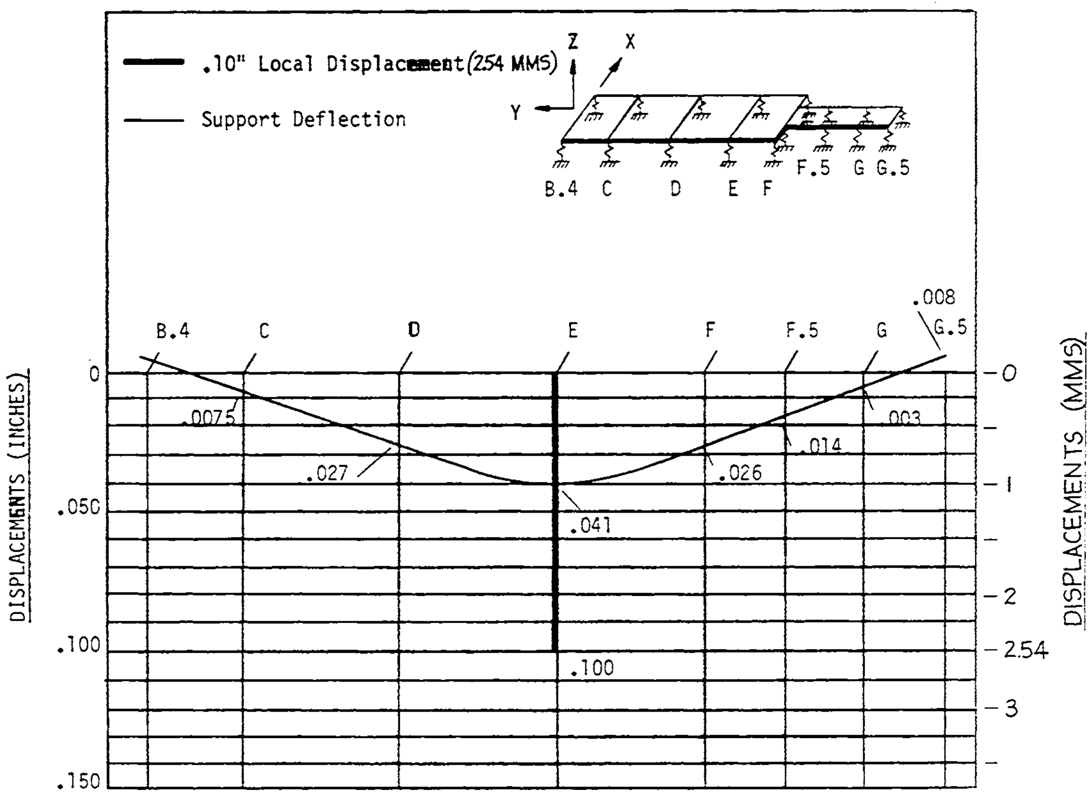

Fig. 6--Displacement of turbine support due to local column displacement

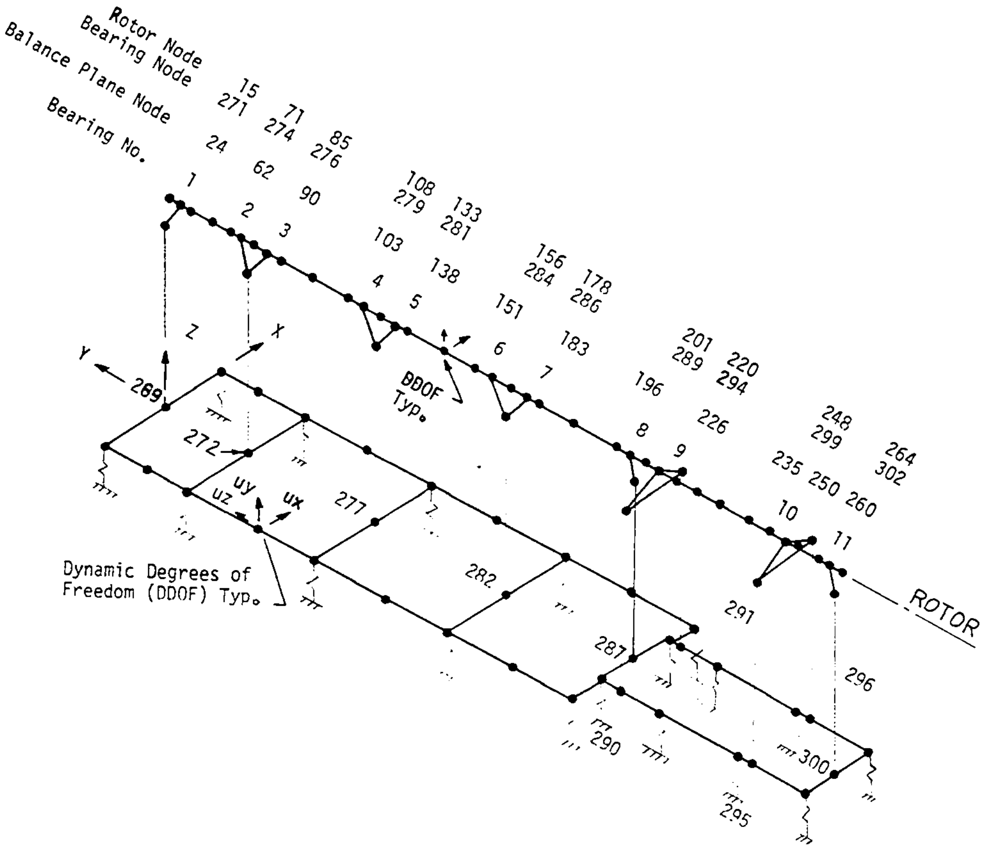

Fig. 7--Dynamic model of support and turbine generator

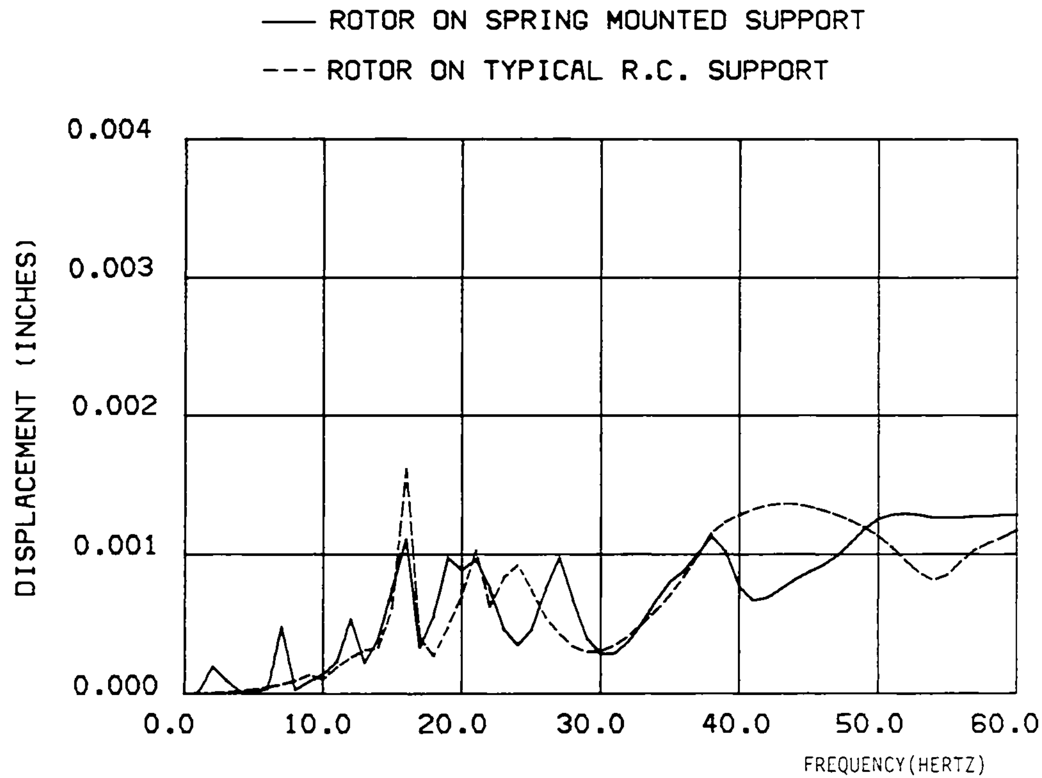

Fig. 8--Vertical response at Node 133 (rotor) at Bearing 5 due to a harmonic load at Node 138

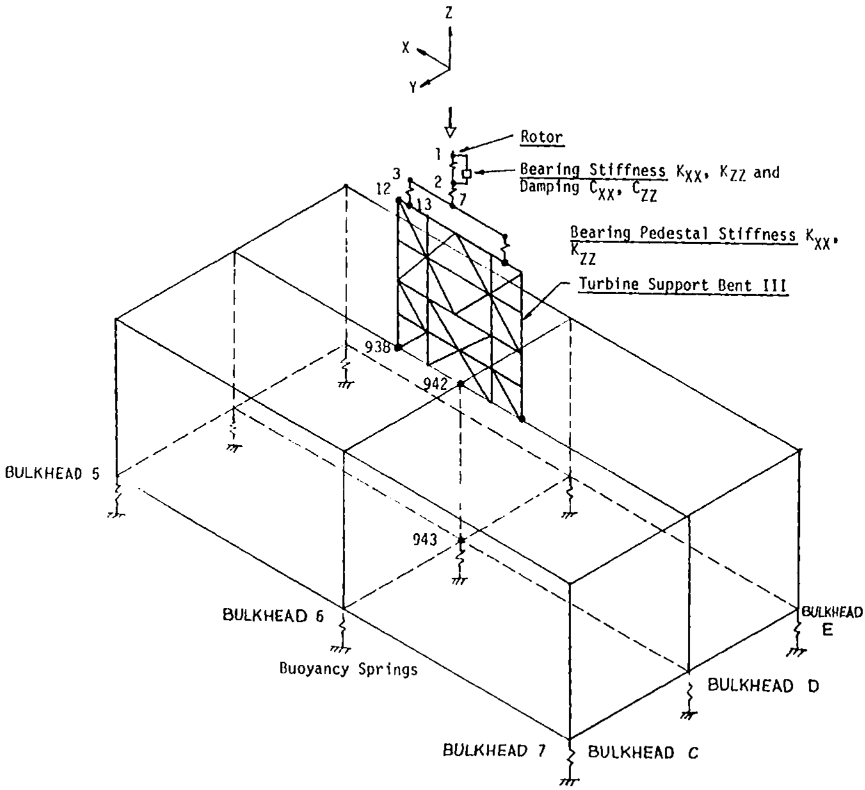

Fig. 9--Structural model for interaction analysis

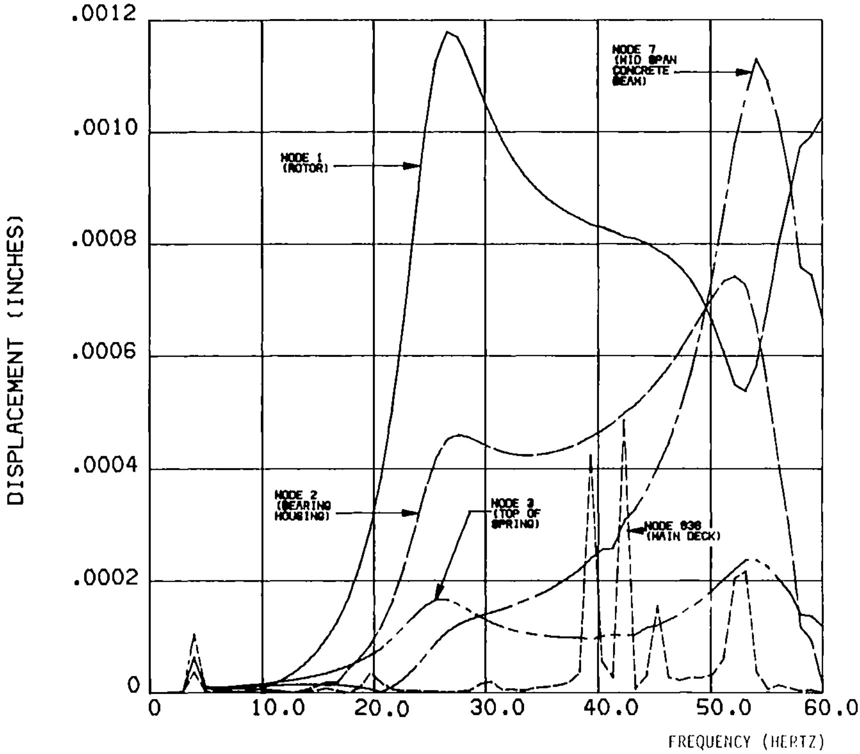

Fig. 10--Interaction analysis--Vertical response of steel substructure (Nodes 3 and 938) and vertical response of turbine support (Nodes 1, 2, and 7)

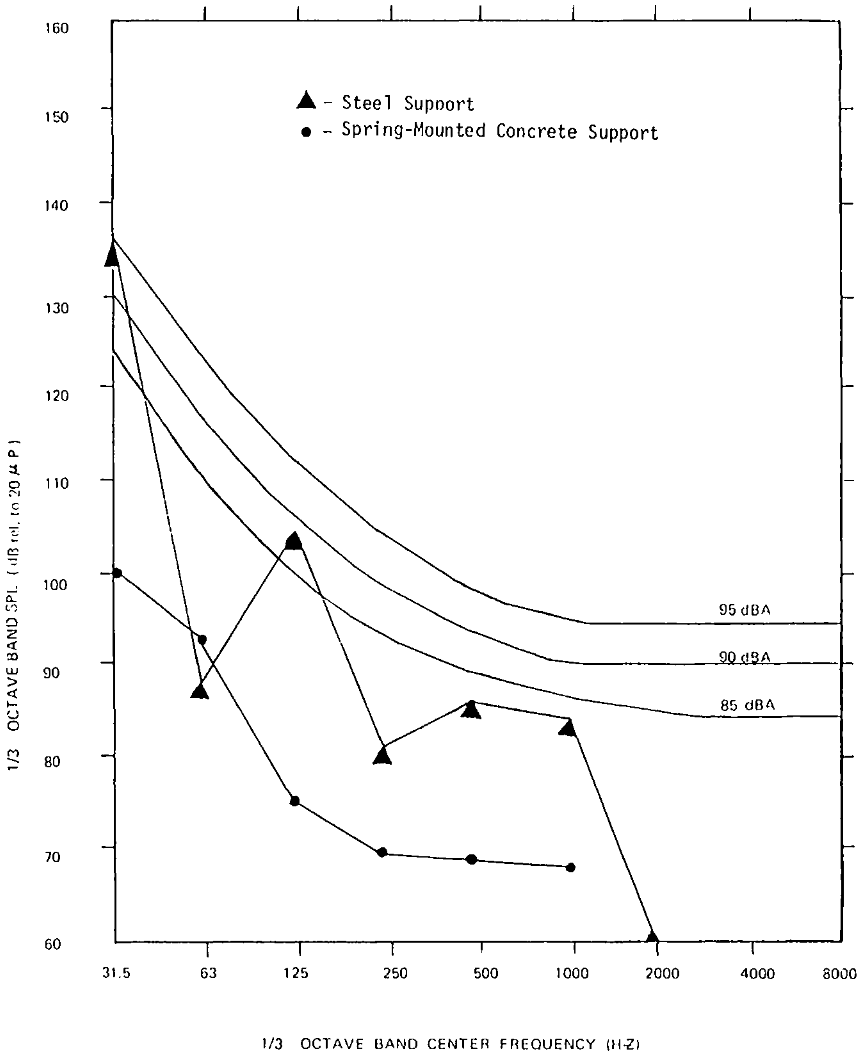

Fig. 11--Predicted sound levels in turbine area

SP 78-8

Design and Performance of Machine Foundations Under Dynamic Loads — Typical Case Studies

By P. Srinivasulu and N. Lakshmanan

Synopsis: In the first part, the paper critically reviews the current state of art on the analysis and design of typical types of machine foundations. The uncertainties in the design data and paucity of essential information required for a rational design are highlighted. The need to study the geotechnical features and other environmental factors at the proposed site of a machine foundation is emphasized. The various aspects of the problem of a machine foundation are illustrated with the explanation of five typical case studies selected from authors' experience in this line of work. The paper also underlines the need for a close co-ordination between the civil and mechanical engineers responsible for the installation of machine foundation right from the early stages of planning.

Keywords: concrete piles; crack propagation; dynamic loads; friction; grout; joints (junctions); machine bases; performance; shock mechanics; stresses; structural design; tolerances (mechanics); vibration.

P. Srinivasulu has been closely associated with dynamic problems in civil engineering especially machine foundations. He is the group leader of the Structural Dynamics Section at the Structural Engineering Research Centre, Madras (India) and has several publications to his credit, including the popular 'Handbook of Machine Foundations'.

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INTRODUCTION

Machine foundations form the nucleus in any industrial plant. Vibration problems in machine foundations are a common occurrence today in any industrial environment. If the vibration exceeds a certain acceptable limit, necessary steps should be taken promptly to control its damaging influences, lest it may progressively cause increasing damage leading to a total loss to the plant. It is imperative, therefore, that the design and construction of a machine foundation are handled by those who are conversant with its actual performance.

The design of a machine foundation is an inter-disciplinary art. It calls for a thorough understanding of the machine, the supporting structure and the soil underneath. Experience has shown that machine foundations designed on an empirical basis ignoring the geotechnical and environmental features of the site are bound to end up with serious failures.

The pace of industrialisation in recent years has necessitated the installation of heavy and complex machinery at many locations. The capacities of the machinery have increased a great deal as also the sizes of the constituent units involved, calling for a fresh look at the design philosophy for their supporting structures. The designer cannot afford to simply project his past experiences gained with smaller machines. It is gratifying to note, however, that there is an increasing awareness of the problem of vibration today among civil engineers,and researchers are engaged on finding solutions based on rational analysis and improved criteria. Some analytical developments have also taken place in the area of dynamic soil-structure interaction. The theories evolved are further being improved to incorporate features which are hitherto ignored. For example the effects of soil layering, embedment, nonlinear behaviour of soil etc. are now being considered in the analysis. There is yet no conclusive evidence, however, by way of field tests, to establish the validity of the improved mathematical models proposed for practical applications.

PROBLEMS IN DESIGN PRACTICE - A CRITICAL SURVEY

A review of the current practices in vogue in various countries for the evaluation of design parameters and the design philosophy itself suggests diverse trends. On the evaluation of dynamic soil properties required for the design of a machine foundation, there are different practices in vogue in different countries. In the United States, the resonant column test among the laboratory methods and the cross-hole test (to mention one of the most popular ones) among the field tests are generally preferred for the evaluation of the dynamic shear modulus of soil which is an important design parameter. The Indian Standard IS 5249-1969 (1) suggests the resonant block test for evaluating the dynamic soil properties. Uncertainties, however, still exist in interpreting the model test results to yield satisfactory design parameters required for the design of the prototype foundation.

Apart from the uncertainties in the choice of appropriate model systems for the analysis and a realistic method for evaluating the dynamic soil properties, it is the common complaint of structural designers that they are often not provided with adequate information concerning the machinery itself. For example, the dynamic loads induced by the machinery are not usually provided by the machine suppliers. Some designers are satisfied if the natural frequencies of the foundation are kept about 30% away (usually on the higher side) from the machine speed to avoid proximity of resonance. Satisfying the resonant condition is only one criterion for the foundation design. The amplitude criterion, which limits the amplitudes computed for a given set of dynamic loads, should also be satisfied. A sound design ensures that the net stresses resulting under the combined influence of static and realistically evaluated dynamic loads are well within the allowable limits. The computation of amplitudes is generally omitted mainly on account of paucity of data concerning dynamic loads. It is the common experience to find that foundations so designed are usually on the conservative side. Checking for resonance alone has been the practice in design