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## A Review on the Dynamic Behaviour of Foundation Supporting Vibrating Machines

Yati R. Tank<sup>1</sup>, Hitesh K. Dhameliya<sup>2</sup>

P.G. Student, Department of Civil Engineering, CGPIT, Uka Tarsadia University, Bardoli, Gujarat, India<sup>1</sup>

Assistant Professor, , Department of Civil Engineering, CGPIT, Uka Tarsadia University, Bardoli, Gujarat, India<sup>2</sup>

**ABSTRACT:** In developing countries like India, vibration problems from industrial assets have been drawing attention of industrial owner and engineers since decades, world over to find ways and mean to have desired satisfactory performance of machines and to minimize failures. In the past, due importance was not given to the design of machine foundation. Simple methods of calculation were used for strength design of foundation by multiplying static loads with an estimated dynamic factor. Even with these so called excessive loads harmful effects were observed during operations. And the vibration may create problem of resonance in structure and there by damage the structure. This necessitated a research in the area of dynamics of machine foundation. At the same time, a more detailed study became urgent because of the development of machines of higher capacities. In this paper, an attempt has been made to review the new empirical methods developed for dynamic analysis and design of machine foundation. For that the past papers related to the dynamic behaviour of machine foundation has been studied and the fruitful conclusion has been made.

**KEYWORDS:** dynamic analysis, vibration, machine foundation, review, piles

### I. INTRODUCTION

The design of a machine foundation is more complex than that of a foundation which supports only static loads. In machine foundations, designer must consider, in addition to the static loads, the dynamic forces caused by working of the machine. These dynamic forces are, in turn, transmitted to the foundation supporting the machine. The designer should, therefore, be well conversant with the method of load transmission from the machine as well as with the problems concerning the dynamic behaviour of the foundation and the soil underneath the foundation. It is well established that the cost of machine foundation is but a small fraction of that of the equipment and inadequately constructed foundations may result in failures and shutdowns exceeding many times the cost of the capital investment required for properly designed and built foundations. The performance, safety and stability of machines depend largely on their design, manufacturing and interaction with environment. In principle machine foundation should be designed such that the dynamic loads of machines are transmitted to the soil through the foundation in such a way that all kinds of harmful effects are eliminated. Many scientists have contributed to the field of machine foundation system and contributed greatly to the practical and theoretical development of the same. The observations from the failure analysis investigation and review of machine foundation behavior conducted on various types of machines for various industrial projects viz. petrochemicals, refineries, power plants etc. over the last few decades, suggest need for improvement in the design of foundations for the better performance of machines. The outcome suggests the need for more comprehensive evaluation of site soil data, better understanding of machine data and improvement in the design philosophy. Hence, it has been aimed to execute the study on foundation supporting vibrating machineries.

### II. LITERATURE REVIEW

To define the loads to establish performance criteria, to check resonance condition, to limit amplitude vibration, to proportion various structural members of foundation etc. are the key issues in the design of machine foundation.<sup>[3]</sup> Many engineers with varying circumstances are engaged in the analysis, design, construction, maintenance, and repair

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of machine foundations. Therefore, it is important that the owner/operator, geotechnical engineer, structural engineer, and equipment supplier collaborate during the design process.

Srinivasulu P. and Vaidyanathan, C.V. published a handbook on machine foundation. The author has given design parameters, geometric properties, experimental determination of soil constants, Analysis and design of block foundation and numerical example of the same; also the analysis and design of framed foundation for high speed machines has been explained. Authors have also presented some studies on vibration isolation and construction detail of machine foundation. Some illustrative case histories of sick machine foundations are also included in handbook. Latter Ehlers (1925) and Prager (1927-30) studied the theory of vibrations and its practical applications. In 1925 Rausch published a paper on the turbine foundation. After that Timmoshenko (1928), Den Hertog (1934), Jacobson (1958), Norris (1959) and Grade (1961) contributed to very large extent in this field.

William E. Saul & Thomas W. Wolf (1979) mentioned that the use of piling for machine foundation can add flexibility for designer. It helped to solve special problem and possibly reduce the cost. Z. Huang & S. Hindiya explained how the cost of an existing foundation for machine can be minimized by optimizing the parameters like thickness of concrete in the machine pit and platform. Payal Mehta stated that dynamic load is not short lived but act over a large period of time. Dynamic force depends upon the machine type & its operation mechanism & frequency. Rohit R Sharma, Prashant V. Muley, Prashant R. Barbude narrated about the machine that creates vibration on foundation due to which higher dynamic forces are generated. So the designed aids / method for foundation design were suggested. An idea about the characteristics of harmonic force introduced by Cyril Harris in his book "Harris' Shock and Vibrations" was proved to be beneficial while making the mathematical model of the looms machine. M. J. Pender executed a review about the main issues in the design of shallow foundation and deep foundation which may be subjected to earthquake loading. Many researchers and authors have presented their views for analysis and design of machine foundations and some of views are as follows:

[A] Ramesh S., Kumar V. Vinoth, "Parametric Study on an Industrial Structure for Various Dynamic Loads", *International Journal of Research in Engineering And Technology (IJRET)*, Feb-2015

Ramesh S. and Kumar V. studied a numerical analysis of an industrial structure, subjected to wind, earthquake and blast load. The results are compared for severity, and the remedial measures shall be discussed. By adopting the remedial measures, the analysis is performed and the effect is compared with the earlier results of a normal structure. Drafting software AutoCAD is used for modeling the structure and SAP 2000 analysis software is used for dynamic analysis.

The purpose of this paper is to study and understand the behavior of structure for dynamic loadings. At the end, it is concluded that, the structural components must be of huge sections to absorb the blast load that would be helpful to increase the cost of the structure. An explosion in the open space will have less loss. Hence, by giving way to dissipate the blast energy, the structure may be safe. This can only be achieved by providing openings in wall and in roof. In these figures (Figure:1-2), the mode shape analysis and the effect of blast load to the structure is shown.

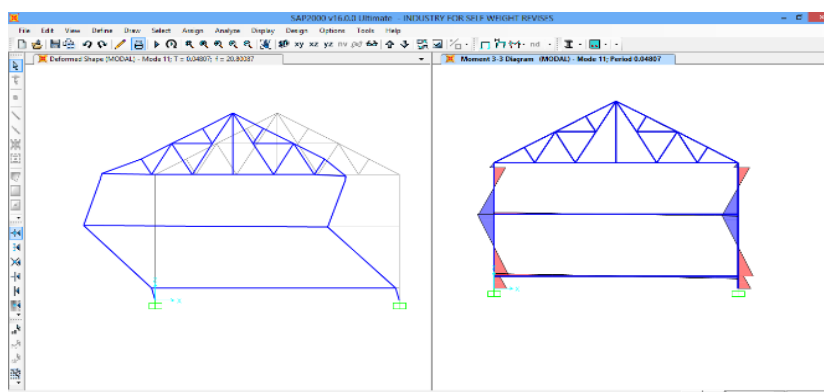


Figure 1: Modal Analysis

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The behaviour of an industrial building subjected to dynamic loads is cleared during earthquake, time history- modal analysis and blast load analysis.

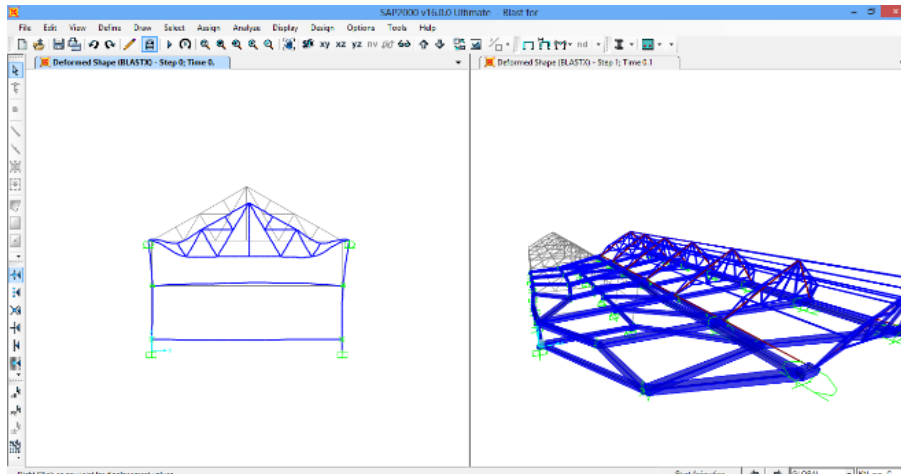


Figure 2: Blast Load Analysis

Purlin failure is a local failure. So it is allowed to fail, but the main truss and the RC frame element if fails, it may lead to global failure. There is no chance that blast load will reduce. Thus by providing large surface area to face the blast pressure, the stresses are reduced. This can be achieved by providing shear walls. Along with existing columns, the structure shall be modified with shear walls.

**[B] Bharathi M., Dr. Saran Swami And Dr. Mukerjee Shyamal, “Analysis of Reciprocating Machine Foundations Resting on Piles”, ISET Golden Jubilee Symposium, Department of Earthquake Engineering Building, IIT Roorkee, October- 2012**

**Bharathi M., Dr. Saran Swami and Dr. Mukerjee Shyamal** described the behaviour of reciprocating machines resting on piles. The author attempted to study the behaviour of the reciprocating machine foundation system subjected to dynamic loads. A reciprocating machine resting on a pile group was selected such that the soil, pile and machine parameters resemble actual field conditions and it was analysed for the dynamic conditions.

MATLAB programs were developed for different modes of vibration i.e. (vertical, sliding, rocking and coupled) and the machine foundation system was analysed for different soil, pile and machine parameters and the variation in the natural frequency and amplitude of the system was studied. Results of the analysis have been presented in the form of charts for vertical and coupled modes of vibration.

In the present study, the operating frequency and the weight of the reciprocating machine are selected as the parameters. The operating frequency of the reciprocating machines used in the industries varies between 300 to 1000 rpm usually. The weight of the reciprocating machine varies from 300 KN to 1700 KN.

When the spacing between the piles is increased, the increase in the stiffness is less when compared to the increase in the mass of the system and hence the natural frequency decreases. As the difference between the natural frequency and operating frequency increases the amplitude decreases. The increase in machine weight contributes a nominal change in the natural frequency, hence, the reduction in amplitude is also very less.

When L/d ratio of the pile is increased the natural frequency attains a maximum value when it moves far away from the operating frequency.

Varying both the spacing between the piles and the machine weight the natural frequency of the system moves far apart from the operating frequency for coupled mode of vibration. Hence, coupled mode of vibration has the least amplitude when compared to vertical mode of vibration.

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Based, on the results obtained from MATLAB programs concluding remark was made. The following cases were prepared with the help of MATLAB programs by varying the parameters. In which, the parameters selected were: the weight of machine, operating frequency, Spacing between the piles and pile parameters.

Table 1: Different Cases Prepared with the help of MATLAB Programs

No.	Machine Weight	Operating Frequency	Spacing between the Piles	Pile Parameters
1	Constant	Constant	Varied	Constant
2	Constant	Varied	Constant	Constant
3	Varied	Constant	Constant	Constant
4	Constant	Constant	Constant	Varied
5	Varied	Constant	Varied	Constant

[C] **Dr. Sevelia Jigar K., Patel Utkarsh S., Mangukiya Siddharth H., Miyani Ankit L., Patel Hardik A., Vora Smit V., “ Dynamic Analysis Of Foundation Supporting Rotary Machine”, International Journal Of Engineering Research And Applications, August 2015**

**Dr. Sevelia Jigar K., Patel Utkarsh S., Mangukiya Siddharth H., Miyani Ankit L., Patel Hardik A. and Vora Smit V.** executed a better interface between foundation designer and machine manufacturer for better performance of machine. The design aids/approaches for foundation design is also described and an attempt has been made to study the dynamic behaviour of a foundation structure for blower type machine subjected to forces due to operation of blower machine. Two different types of foundations for Rotary type Machine that is Blower have been studied for the parameters as, displacement, frequency and Von Mises Stress.

As far as displacement is concern, in X-direction it is clear that table mounted block foundation has maximum displacement in X-direction at top node and bottom node than hollow block foundation with piles because table mounted block foundation shows more flexible behaviour structurally. At the same time, frequency values are very less in case of table mounted block foundation as compared to hollow block foundation with piles. Hence, displacement is more in case of table mounted block foundation. Also, in Y-direction displacement is concern, hollow block foundation with piles is better in performance as compare to table mounted block foundation. The reason behind that is hollow block foundation with piles has piles below block foundation which helps in preventing Y-direction (vertical) displacement. Hollow block foundation with piles shows a great variation in frequency as compared to table mounted block foundation. The variation in frequency from mode 1 to mode 6 in case of hollow block foundation with pile is about 496% and in case of table mounted block foundation is 207%. The hollow block foundation with pile is more stiff foundation due to provision of pile below and hence frequency is more.

Von Mises stresses are more in Hollow block foundation with piles as all the forces transferred by machine to block is ultimately taken by piles and hence, entire blocks foundation is in lower stress zone. In table mounted block foundation, there exist no piles hence all the loads are to be transmitted by R.C.C walls and block foundation to the soil below and hence values of Von Mises stress contours is more.

### III. CONCLUDING REMARKS

From the study of above research papers it can be concluded that,

- In analysis and design of machine foundation proper knowledge and care must be required in the area of structure dynamics.
- The amplitude and frequency are the important key parameters in analysis and design of machine foundation. The other parameters as, displacement, bearing capacity of soil, properties of pile, spacing between piles, weight of machine, speed of machine, depth of water table may also affect to behaviour of machine foundation.

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- Another methodology such as, use of piles, base isolations or dampers may also be developed at the same time for the better behaviour of foundation system. Furthermore, research and development should be needed in this area.
- Application of piles and dampers along with foundations for the industrial buildings may increase the performance of structure.

## IV. SCOPE OF WORK

In this review paper, the various methods such as application of piles, base isolations or dampers along with foundations for the industrial buildings have been discussed. But the implementation of the same with respect to practical application and numerical analysis can be developed for the different conditions of soil. And the performance can be compared for the worst condition.

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**Mr. Yati R. Tank** is a Post Graduation Student at CGPIT, Uka Tarsadia University, Bardoli, and his field of interest is in structural analysis, machine foundation, dynamic analysis and concrete technology.



**Mr. Hitesh K. Dhameliya** is an Asst. Professor, in CGPIT, Uka Tarsadia University, Bardoli, and his field of interest is in structural analysis, concrete technology.