Dynamics of Machine Foundation Supported by Piles - A Review

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Abstract - **High-speed machinery has been developed with the advancement of technology in industry. As the speed of the machinery increased, so did the vibrations. Machines impart vibrations to the supporting structure. It is therefore important to design and develop such a structure that supports the machinery's vibrations. The vibration amplitudes and the forces transferred to a medium can become the governing variable of these machines' foundation. The complex effects of the machines play a major role in the size of the foundation where conditions such as vibration, are eliminated by changing the stiffness and mass of the structure resulting in adjustment sizes. The machine foundation includes a detailed analysis of the foundation response to the complex load arising from the machine's expected operation. Dynamic machine foundation analysis depends on that different supporting system like piles, micro piles, isolators, etc. In machine foundation on poor soil condition piles were used in many more cases as a supporting system. In this review paper attempts, investigated review on study related to dynamic analysis of machine foundation with different supporting system and using different machinery on different machine foundation type on different soil conditions. It can generally be divided into different categories in this review field. First one, related to machine foundation with pile as support system with reciprocating machinery, second one related to dynamic analysis of rotary machine foundation and third one related to impact type machine foundation. It's shown here in, that there has been a significant amount of research in each of these categories. The main purpose of this analysis is to provide a reference through a systematic and critical overview of each of these types of reviews.**

keywords - **Machine foundation, piles, vibration, soil condition.**

I. INTRODUCTION

Machine foundation pass on dynamic loads to soil in adding with static loads owing to weight of foundation, machine and its attachment which require special consideration. A machine's vibration amplitude and rotating frequency are the most critical variables to be considered in the machine structure research. With effect to a depth of decoding, the natural frequency may increase, but the amplitude of foundation vibration may decrease considerably. The six degrees of freedom vibrates with the machine foundation system of the six modes, translation can happen independently of any other movement along the vertical axis and rotation around the vertical axis and are called decoupled modes. Machines running at low to medium operating frequencies are usually supported based on a rigid foundation. The main reason for maintaining these low to medium frequency machinery on the foundation block is to ensure that the foundation's natural frequencies are significantly above the machine's operating frequency because it is very difficult to design these machines by having all the foundation's preliminary natural frequencies below the operating frequency. The basic goal in a machine foundation's development is to reduce the motion to amplitudes that do not affect the machine's satisfactory operation or disturb people operating in the immediate vicinity. Many engineers with different conditions are engaged in machine foundations analysis, design, construction, maintenance, and repair. Therefore, during the design process, the owner / operator, geotechnical engineer, structural engineer and equipment supplier must work together.

Machine foundation have three types of machine foundation system which are block, box and frame type which is used on different types of machinery like reciprocating, impact and rotary type machines. In reciprocating machinery, it has less than 600 rpm operating frequency and it produced periodic unbalanced force (e.g.; compressor, reciprocating engine, etc.). In impact type machinery, it has 150 blows/min operating frequency and it produced impact load (e.g.; forge hammer, etc.). In rotary type machinery, it has 3000 to 10000 rpm operating frequency (e.g.; turbo generator, rotary compressor, etc.).

II. REVIEW OF LITERATURE

The tensioning mechanism blends cement or other composite components with steel strings or cables of high strength, also referred to as tendons. Plan includes buildings with office and apartments, car parks, slabs, bridge, sports stadium, tanks of water, stone and soil anchors. Post-voltage plan. Some authors already discussed about the post-tensioning, Load balancing concept for the post- tensioning buildings, shear and deflection criteria for the post tensioning buildings.

GENRAL REVIEW

Ibtihal et. al. (2014) [3] modelled a machine foundation resting on end bearing piles using finite element software, ANSYS v.11. Author concluded that, oscillation of displacement decreases while pile cap thickness increases and the frequency, the maximum displacement increases while pile diameter of the group increases. K. G. Bhatia (2008) [1] worked on industrial machine foundations and earthquake consequences and concluded that Earthquake impact on machines and their bases in view of recorded

harm to many industrial systems. It is strongly recommended to use commercially available finite element packages to evaluate and model foundations. Suhol Bu (1997) [12] defined the technique of infinite boundary elements for three-dimensional machine foundations dynamic study and got result that, the boundary element in quetenite has great potential advantages in evaluating boundary element process unbounded problems. Van Koten et. al. (2012) [2] researched on vibrations in the structure and surrounding soil were caused by machines and concluded that, Soil at the base sides significantly increases the damping and significantly reduces the amplitudes of displacement. Gohnert et. al. (2008) [7] designed foundation with piles for vibrating machinery using CP 12. Authors concluded that, the intensity of a group of piles is smaller than that of the same set of isolated piles.

RELATED TO MACHINE FOUNDATION WITH PILE AS SUPPORT SYSTEM WITH RECIPROCATING MACHINERY.

Bharathi et. al. (2012) [6] described the behavior of reciprocating machines resting on piles subjected to dynamic loads. Authors used MATLAB programs for different modes of vibration like vertical, sliding, rocking and coupled. Authors analyzed the machine foundation system for different parameters of the ground, pile, and equipment and the variation in the normal frequency and amplitude of the system was studied.

The speed of operation and the weight of the reciprocating machine is chosen in such a way that the parameters match the characteristics of the devices used in the industries. The running speed of the commercial reciprocating machines typically varies from 300 to 1000 rpm. The reciprocating machine's weight ranges between 300 kN and 1700 kN.

Authors illustrated five types of case to analysis the results from MATLAB.

Table- I: Five Cases using MATLAB Program

Case No.	Case 1	Case 2	Case 3	Case 4	Case 5
Weight of machine	Constant	Constant	Varied	Constant	Constant
Operating frequency	Constant	Varied	Constant	Constant	Constant
Spacing between piles	Varied	Constant	Constant	Constant	Varied
Pile Diameter	Constant	Constant	Constant	Varied	Constant

Authors concluded with the results of these five cases using MATLAB program is illustrated that, When the spacing between the piles is raised, the increase in the density is lower compared to the change in the system weight and thus the natural amplitude is lower. The amplitude decreases as the difference between the average frequency and the frequency of operation increases. The increase in the weight of the system leads to a nominal change in the normal frequency, therefore the decrease in amplitude is also very small. The average frequency reaches a maximum value when the pile's L / d ratio is raised when it moves away from the operating frequency.

Tank Yati et. al. (2017) [15] presented on the pile-based block design reciprocating machine structure was studied with many pile design parameters such as the length to pile diameter ratio and the distance between two adjacent piles for medium soil quality with a static value of the shear wave velocity ratio, the pile cap thickness to verify the dynamic behavior. Authors used SAP:2000 Vs. 16 software and got best results with different parameters of piles.

Authors took block foundation supporting machine which was gas compressor reciprocating machine which was taken by ICS (Infinite Civil Solution Pvt. Ltd.) and its operating frequency was 328 rpm.

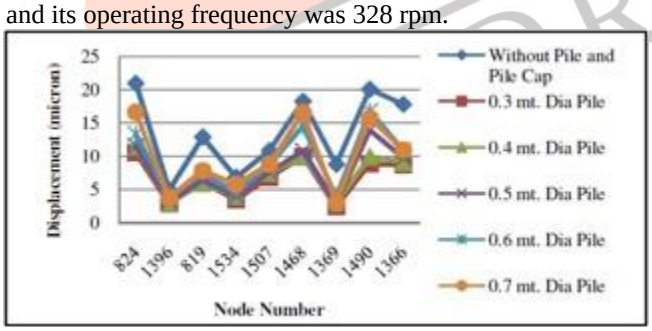

Fig. 2. Vertical Displacement Vs. Node Number for Different Model

Authors concluded that, ⅰ) From the results of resonance, frequency of vibration decreased and frequency ratio increased while diameter of pile increased. ⅱ) From the results of amplitude, amplitude of vibration increased while diameter of pile increased.

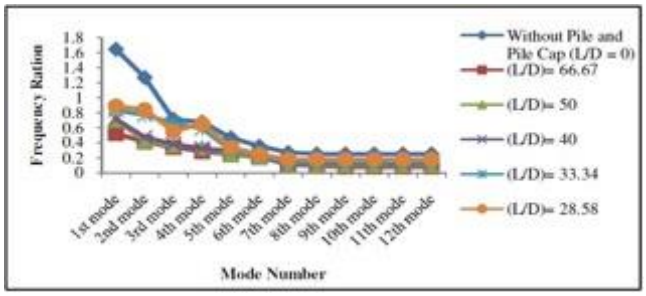

Fig. 3. Frequency Ratio Vs. Mode Number for Different Models

Patel Hardik et. al. (2017) [10] carried out separate foundation functional analysis of low frequency soil contact unit. Authors used box and black type machine foundation and also compare these two foundations and used lesser machine which is used in cloth industry. Patel Hardik et. al. collected different data related to machine and draw a plan of machine foundation is SAP:2000. Dynamic shear modulus was used as parameter in software. Author constitute the slope of shear stress versus shear strain curve and also experimented on different soil. Authors concluded that, the bigger the contact area of the foundation the lower the stress on the soil and the bigger the foundation's average frequencies and in block and box foundation three more stress develop at bottom of machine and two side portions of box respectively.

RELATED TO DYNAMIC ANALYSIS OF ROTARY MACHINE FOUNDATION.

Dr. Jigar Sevelia et. al. (2015) [13] carried out a dynamic analysis of foundation supporting rotary machine. In the field of industry, as the speed of machinery had raised, vibrations also raised. Author implemented the study on foundation supporting rotary type of machine using two parameters like frequency and amplitude. And design methods to foundation development have repented and studied the foundation dynamic activity of blower type system that was subjected to force by blower machine effect. Two different types of foundations of rotary model engine, which is blower, are checked for parameters including displacement, frequency and von mises force. Author used two types of blower which has horizontal and vertical. Author terminated that hollow block foundation with pile show better performance similar to the foundation block placed on the table. There are more stresses from Mises in the Hollow Block System of Piles as all the forces moved from machine to block are essentially drawn from piles and therefore the whole block system is in the lower stress region. There are no piles in table mounted block foundation so all loads are to be transferred to the ground below by R.C.C walls and block foundation and therefore qualities of von Mises tension contours are more.

Jayrajan et. al. (2014) [5] investigated on Dynamic analysis of turbo-generator machine foundation. The most dynamic and valuable machine of a power plant 'Turbo-generator machine' are used in machine foundation. Author determined natural frequency for various modes of vibration and foundation response to loads due to machine foundation with helped of free & forced vibration analysis. Jayrajan et. al. measured FEM of foundation structure. Additionally, a pro example was performed by authors use SAP 2000 technology from the TG machine. The authors concluded that the approach of finite elements provides an effective tool for simulation and complex analysis of turbo-generator foundations. SAP2000 provides a real computational framework for the modeling of a single model of structure, system and soil and for the free and forced analysis of vibration.

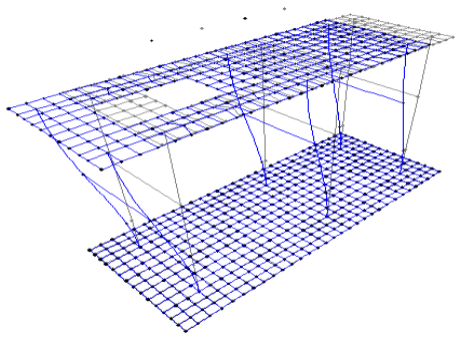

Fig. 4. Foundation Mode Shape - First Mode

RELATED TO IMPACT TYPE MACHINE FOUNDATION.

Novak (1983) [8] investigated on foundations for shock-producing impact machinery. The key requirements were defined for the design of hammer foundations and the methods for determining constants of stiffness and damping for shallow foundations and pile foundations are checked. The implementation of damping was based on consideration of energy and has been checked by comparison with results obtained using the dynamic method of self-value. Author concluded that the use of damping allowed the solution prediction more realistic and could prevent major overestimation of the response and overdesign of the base. The initial model of velocity and modal damping based on an energy factor can be used to estimate damped hammer foundations resistance. The foundations supported by Pile had smaller amplitudes than the shallow foundations, but they reflected greater strength.

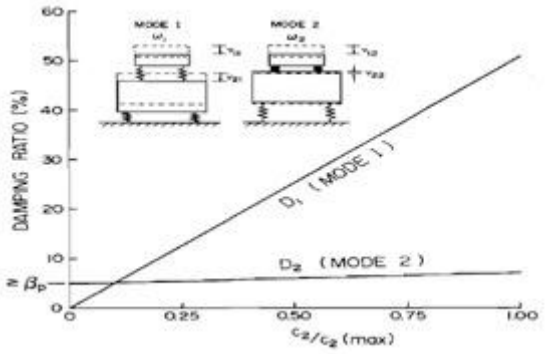

Fig. 5. Damping Ratios of Two-Mass Hammer Foundation Vs. Foundation Damping Intensity C2/C2(Max).

III. CONCLUDING REMARK

It can be concluded from the study of the above research papers that,

- In the field of structure dynamics, suitable understanding and care must be required in the evaluation and specification of the machine foundation.
- The amplitude and frequency are the main parameters of the system foundation's analysis and design Certain variables such as displacement, soil carrying capacity, pile size, pile diameter, pile length, machine weight, machine rate, machine operating frequency may also influence the machine foundation's operation.
- As the diameter of pile increases; frequency of vibration decreases, amplitude of vibration increases.
- Compared to the table-mounted block foundation hollow block foundation with a pile demonstrate better performance.
- While contact area of foundation increases, stress on soil decreases and foundation average frequency increases.
- While spacing between piles increases, natural frequency decreases and density increases.
- While amplitude decreases, difference between average frequency and frequency of operation increases. And, while average frequency increases, pile's L/D ratio increases.

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