SYNOPSIS

Pile foundations are traditionally used to support heavy loads when soil conditions at a site indicate that shallow foundations will not be either stable or will result in unacceptable settlements. With the wealth of knowledge available for static analysis, a designer is well capable of designing such foundations efficiently and economically for static loads. Apart from static forces these foundations are often subjected to dynamic forces from heavy machines, wind, earthquake and sea waves. Rapid industrial and technological advancements have necessitated construction of big industrial complexes with installations of heavy machines and plants, tall structures, offshore oil platforms etc., supported on pile foundations. Prompted by this urgent need, during the last decade several theoretical approaches have been put forward for dynamic analysis of pile foundations subjected to various modes of vibration.

The interaction between an elastic pile and the surrounding soil represents a very complex phenomenon, which is yet to be fully understood. As such, some of the available approaches are quite simple and do not account for dissipation of energy or other important factors; other approaches are too mathematical and complicated to be approachable by researchers rather than by practising engineers.

Even though some work has been done on the study of dynamic behaviour of pile foundations, no work (to the best of

author's knowledge) has been initiated so far on the dynamic behaviour of foundations supported on under-reamed and tapered piles. As a result, the study on the dynamic behaviour of pile foundations is very much incomplete to arrive at some definite guidelines for rational design of such foundations.

Therefore, the present study has been taken up with a view to developing a rational and reasonably accurate method of analysis of foundations supported on single or group of vertical piles (including under-reamed and tapered piles) subjected to various modes of vibration. The proposed method of analysis has taken into account the soil-pile interaction in a simple way and has been able to predict the dynamic response of such foundations satisfactorily. The theoretical study has been carried out to understand the dynamic characteristics of soil-pile system under different modes of vibration.

The thesis has been broadly divided into eight chapters. An introduction to the problem has been put forward in Chapter-I, indicating the necessity and importance of the problem from the point of view of research and design. The detailed review of existing literature on the subject together with critical discussion on the works of earlier investigators has been furnished in Chapter-II. This has helped the author to define the scope of the present study, which has been outlined in Chapter-III.

Pile foundations supported by single or group of piles and subjected to frequency dependent harmonic excitations causing different modes of vibration have been analysed. The theoretical formulations so developed are presented in Chapter-IV under five broad sections, i.e., (i) vertical vibration of piles, (ii) vertical vibration of under-reamed piles, (iii) vertical vibration of tapered piles, (iv) horizontal and rotational vibration of piles, and (v) torsional vibration of piles.

Based on certain assumptions, the expressions have been developed to replace the soil-pile interactions by elastic stiffness and equivalent viscous damping functions for different modes of vibration. The differential equations of motion of piles undergoing various modes of vibration have been developed. Using finite difference method with appropriate boundary conditions, the differential equations have been solved for pile nodal displacements with depth, from which the stiffness and damping coefficients of pile at the pile head have been calculated for respective modes of vibration. The stiffness and damping coefficients of individual piles have been used to determine the equivalent stiffness and damping coefficients of pile-supported footings for different modes of vibration. Then the dynamic response of such foundations have been obtained by standard procedure as in the case of shallow footings.

In order to check the validity and accuracy of the author's proposed method of analysis, the results of experimental investigation and other theoretical solutions on the response of foundations supported on single and group of piles (reported by earlier investigators) have been compared with theoretical results calculated from the author's approach. The comparisons and discussions thereon have been presented in Chapter-V.

Extensive theoretical study has been carried out to ascertain the influence of various factors on the stiffness and damping parameters of piles, and dynamic response of pile supported foundations under various modes of vibration. Some of the numerical results in nondimensional form have been furnished in graphs and tables in Chapter-VI. Computer programs have been developed in Fortran-IV to work on Burroughs B6700 computer. Chapter-VI furnishes the analysis and discussion of the theoretical results indicating the influence of different parameters on the dynamic characteristics of pile foundations.

A summary of conclusions on different aspects of study carried out has been presented in Chapter-VIII. Some of the major conclusions drawn are reproduced below :

(1) The relaxation of pile tip in vertical direction reduces both the resonant frequency and the resonant amplitude of pile supported foundations.

(2) Due to the lack of fixity of pile tip, the stiffness decreases and damping increases. With the increase in length, the stiffness of a floating pile increases, but the stiffness of an end-bearing pile decreases.

(3) The stiffness and damping parameters of piles vary with dimensionless frequency, slenderness ratio, wave velocity ratio, mass density ratio and Poisson's ratio of soil medium.

(4) For foundations supported on floating under-reamed piles, the resonant frequency increases, but the resonant amplitude decreases with the increase in base enlargement ratio. This effect of base enlargement on dynamic response of foundation is more pronounced with short piles.

(5) In case of foundations supported on floating tapered piles, the resonant frequency increases and resonant amplitude decreases with the increase of angle of taper of piles.

(6) Dynamic group effect reduces the stiffness and increases the damping of individual piles in a group.

(7) In case of footings supported by single pile and subjected to coupled motion, the resonant frequency and resonant amplitude (both sliding and rocking) increase with the increase of relative stiffness of soil.

(8) For pile group subjected to coupled mode of vibration, the first resonant peak is dominated by sliding and the second peak by rocking.

(9) The relaxation of pile tip (in vertical direction) decreases the first and second resonant frequencies of pile group subjected to coupled horizontal and rotational modes of vibration.

(10) With the increase in distance of pile from the centre line of footing, both the first and second resonant frequencies increase, while the amplitudes of vibration (both sliding and rocking) decrease.

(11) Both the resonant frequency and resonant amplitude of footings, supported by single or group of piles and subjected to torsional mode of vibration, increase with the increase of relative stiffness of soil.

(12) For pile groups undergoing torsional vibration, the resonant frequency increases and resonant amplitude decreases with the increase of pile spacings.

At the end of Chapter-VIII, the scope for further studies has been outlined. A list of references has been furnished at the end of the thesis. It is expected that the present study will contribute some additional useful information on the dynamic behaviour of pile foundations and help to understand the soil-pile interaction mechanism in evolving a safe design procedure for such type of foundations.

During the progress of study, some aspects of the present investigation have been published/accepted for publication in national and international conferences and journals. The list of these papers is included in References (Saha and Ghosh[102-108a] 1984, 1985).