On the Effects of Hydrodynamic Interaction upon the Wave Forces on Pile Arrays of Multiple Rows*

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ABSTRACT

A systematic study has been carried out on the interaction effects of 3-D wave forces on vertical pile arrays by using wave source distribution method. Not only can the properties of hydrodynamic interaction of single row piles be got, but also some new discoveries are found for the pile arrays of multiple rows. It is found that the shielding effect of multiple rows is larger than that of the single one. There is a sensitive wave frequency range in which the variation of the wave forces will probably much larger than those in the other frequency range. The mechanical characteristics for the matrix pile arrays are found different from those for the staggered pile arrays. The discoveries may give important guidance to the design of the super-large offshore structures.

KEY WORDS: Hydrodynamic interaction, wave force, pile array

INTRODUCTION

It is known that complex hydrodynamic interactions may occur for a super-large marine structure in waves due to the combinations of a large number of single blocks. From view points of engineering and application, it is of great importance to study hydrodynamic interactions upon multiple objects. This hydrodynamic problem can be tackled by using 3-D source distribution methods (Liu and Miao, 1987), which, however, may not predict efficiently the interactions of dozens (even hundreds) of objects due to the limitation of the capacity of commonly available computers.

Maniar and Newman (1996) investigated the wave forces on single-row vertical pile arrays, being bottom mounted and water surface piercing, of 100 and 101 piles with equal circular sections in regular waves with spline-Galerkin method. It is interesting in their results that the in-line wave loads upon piles in the middle part of the array may increase significantly at a certain frequency when the wave train is collinear with the pile row (referred as head sea condition hereafter). In beam sea when the propagating direction of waves is perpendicular to the pile row, the distributions of the amplitude of the in-line wave forces along the pile row exhibit absolutely different features for pile arrays of even (100) number and odd (101) number. Maniar and Newman attributed it to the effects of "trapped wave" (Callan et al, 1991).

Aimed to understand the hydrodynamic interaction mechanism more convincingly, Miao et al (1997) made a systematic study on the wave force behavior of the same single-row vertical pile array as used by Maniar and Newman (1996) by adopting the wave source distribution method (Isaacson, 1978). With the eigen-function expansion in the water depth, a corresponding 2-D problem is available. The method is benefit to increase the discrete numbers of section contours and hence the computational accuracy. And the corresponding numerical code is capable of dealing with the hydrodynamic problem of pile arrays with more than 120 piles on normal PC. Combined with the distribution of local sources, the method was extended by Miao and Liu (1991, 1993) to deal with the wave forces on multiple cylinders with arbitrary sections as well as their vibration problem in the wave frequency range and high frequency range due to earthquake. The results of the wave force behavior on the single-row vertical pile array, obtained by the above-mentioned method (Miao et al, 1997) and numerically confirmed by the 3-D source distribution method developed in CSSRC (China Ship Science Research Center), gave a different picture and mechanism from those of Maniar and Newman (1996) especially at some sensitive wave frequencies. It is found that the competition of hydrodynamic interference and shielding effect is essential to explain the variation of the wave force distributions on the pile array with the changing of the wave frequencies. Furthermore, the wave force distributions on the pile array in beam seas exhibit uniform properties in general and hold no relation to whether the number of piles in the array is even or odd as mentioned in Maniar and Newman (1996).

The present paper, with the same method used in Miao et al (1997), made a further study of hydrodynamic interaction upon pile arrays of multiple rows arranged in matrix and staggered forms. We found that the hydrodynamic characteristics of matrix-arranged piles differ from of staggered-arranged piles and, just like single pile row, there exists a sensitive range of wave frequency in which the hydrodynamic properties will change greatly with small variation of wave frequency. The study of those phenomena are very important to the design of super-large marine structures.

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