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Wave-Current Forces on Vertical Piles in Side-by-Side Arrangement

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ABSTRACT

The in-line and lift forces on vertical piles in a side-by-side arrangement induced by both irregular waves and currents were investigated experimentally. The characteristics in both time and frequency domain of in-line, lift and resultant forces as well were analyzed. The grouping effect coefficients of in-line and resultant forces on the piles related to a KC number and relative spacing parameters are given. Also, a comparison is made of the magnitude and direction of resultant forces on vertical piles in a side-by-side arrangement with the corresponding values for a single cylinder. The range of KC number tested is 6~60; the range of Reynolds number, (0.55~3.43)*10^4.

INTRODUCTION

The wave loading on a slender cylinder and a group of slender cylinders is one of the basic problems of hydrodynamics in offshore engineering. Since the development of Morison's Equation in 1950, the prediction of in-line force on a single cylinder has become realistic. In spite of its shortcomings (unstrictness in viewpoint of theoretical analysis and sometimes a large error may occur during the calculation), so far Morison's Equation is the only practical method to be used for engineering purposes. Expect for some studies (Chakrabarti, 1982; Gao and Sun, 1987; Yu and Zhang, 1990) concerning pure wave loading on pile groups, there is almost no report about the wave-current force on cylinders caused by irregular waves combined with currents. In fact, cylindrical pile groups are used more often than isolated cylinders in engineering applications. This paper is part of the results of the authors' research on irregular wave-current forces on pile groups. Because of the complexity of the flow behaviour around cylinders, a more reliable method for this study is the physical model test.

METHOD OF ANALYSIS

The flow behaviour around multipiles is different from that around single piles, so the wave force acting on multipiles should be different from that on a single pile. This is the so-called multipile interference phenomenon. There are two kinds of methods for analyzing wave loading on multipiles. One is the method often used for single pile: To calculate the hydrodynamic coefficients by using Morison's Equation and experimental data, then to find the relationship between hydrodynamic coefficients and other parameters. Such a relationship may be used for an engineering application. Another way is to calculate the grouping effect coefficients, which is the ratio of wave force on a pile group to that on a single pile. The grouping effect coefficients of in-line, lift and resultant force are defined by K_{GI}, K_{GL} and K_{GR}, respectively. Then the relationship between grouping effect coefficients with spacing parameter, KC and Re numbers as well may be found. The second method is more convenient for data analysis and more information for a single pile can be used for an engineering application, so in this paper we used only the second method.

A. Time Domain Analysis-Statistical Distribution Analysis

In time and frequency domain analysis, the definition of grouping effect coefficients K_G is not the same. In time domain analysis, the following definition is used:

$$F_G = K_G F \tag{1}$$

where F is the wave-current force on a single pile and F_G is the wave-current force acting on one pile in a pile group. The grouping effect coefficients of in-line,lift and resultant force are defined by K_{GI}, K_{GL} and K_{GR} respectively. As for the stability of data, the significant value of wave force was taken in time domain analysis; the probabilistic distribution of wave force was also analyses. Then we may use the grouping effect coefficient of significant value of wave force and the statistical property of wave force to calculate the wave force of the small probability of exceedance.

B. Frequency Domain Analysis-Spectral Analysis

The wave force is proportional to the square root of zero order moment of wave force spectrum. Then, in frequency domain analysis, K_G is defined as:

$$\sqrt{M_{OG}} = K_G \sqrt{M_O} \tag{2}$$

where M_0 and M_{0G} are the zero order moment of wave force spectrum for a single pile and some piles in a pile array, respectively.

C. Determination of KC Number

When waves propagate with current, there are various definitions of the KC number. Li and Zhang (1986) and Iwagaki et al. (1984) found that if the following definition of the KC number was used, then the KC number in the wave-current field will be identified with that in the pure wave field. It is defined as:

$$KC = \pi S_1 / D \tag{3}$$

where S_1 the maximum displacement in one direction of water particle in one wave period, and the value S_1/D may express the repeated effect of shed vortex on a pile, i.e., S_1/D is a characteristic parameter of flow behaviour around a pile. Eq. 3 may be expressed by:

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KEY WORDS: Wave forces, wave-current interaction, vertical cylinder, pile group.