Interaction of Waves and Pile Group-Supported Offshore Structures: A Large Scale Model Study

Lisham Bonakdar and Hocince Oumeraci
Leichtweiss-Institute for Hydraulic Engineering, Technical University of Braunschweig
Braunschweig, Lower Saxony, Germany

ABSTRACT

The interaction of non-breaking waves and pile group-supported offshore structures is studied by means of extensive and systematic large-scale laboratory tests performed in the Large Wave Flume (GWK) of the Coastal Research Centre (FZK) in Hannover, Germany. Three different arrangements of pile groups, including tandem, side by side and staggered are tested for subcritical, critical and supercritical flow regime. The effect of non-dimensional parameters on the resulting wave load on a pile within a group of piles is comprehensively investigated. Empirical wave load formulae are developed for different configurations using a non-linear regression and their performance is evaluated by different statistical parameters.

KEY WORDS: Non-breaking wave loads, slender pile groups; side by side arrangement; tandem arrangement; staggered arrangement; Keulegan-Carpenter number; relative spacing.

INTRODUCTION

Pile-supported structures commonly found in a coastal or offshore environment are generally built by means of a group of piles in different arrangements. In the offshore environment, these structures are used for offshore platforms (oil and gas) (Fig.1). In the coastal environment, pile group-supported coastal structures are widely used in marine transportation systems, for instance for the construction of sea bridges, piers and jetties. In such structures vertical piles are closely spaced so that the wave load on a single slender pile is significantly affected by the neighbouring piles and can thus not be calculated by the commonly applied formulae for a single isolated pile which are generally based on the concept of Morison et al. (1950). Severe forces may cause considerable damage to load carrying members and endanger the overall stability of the structure. A failure of a marine structure would not only cause an enormous financial cost, but might also result in widespread damages in the sea environment, thus underlying the importance of the safe design of pile-supported offshore structures.

In the case of slender piles, in which both drag and inertia forces induced by highly complex turbulent flow are important, an analytical solution is hardly feasible. Given the complexity of the interaction between waves and pile groups in different arrangements, laboratory experiments still represent the most reliable alternative. Some small-scale experimental investigations have been carried out to study the interference effects of neighbouring piles. In general, two methods have been mostly applied to analyze non-breaking wave loads on a cylindrical pile within pile groups:

(i) "Wave force coefficient approach": The inertia ($C_M$) and drag ($C_D$) coefficients are determined by applying methods like the least square fit when the velocity and acceleration are known. This method has been applied by Chakrabarti (1981), Chakrabarti (1982) and Smith and Haritos (1997). Using the calculated drag and inertia coefficients, Chakrabarti (1981) and (1982) computed maximum wave forces and compared them to measured forces. Smith and Haritos (1997) reported that drag and inertia coefficients are dependent on relative spacing ($S_0$/$D$) between the piles with diameter $D$ and KC-number. The major drawback of this approach is that, using force coefficients $C_D$ and $C_M$ is not appropriate to estimate wave force on pile groups as both flow velocity and acceleration are also affected by the pile group interference.

(ii) "Total wave force approach": In this approach, wave load on pile group is generally determined as a function of the most relevant