

Reflection and Transmission of Irregular Waves by Multiple-Row Curtainwall-Pile Breakwaters

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ABSTRACT

In this study, we have expanded the regular wave model proposed by Suh and Ji (2006) to an irregular wave model in order to calculate the reflection and transmission coefficients of multiple-row curtainwall-pile breakwaters. Laboratory experiments have been conducted to verify the proposed mathematical model. The results of the mathematical model have also been compared with the results of the experiments for permeable breakwaters used at the Busan International Cruise Terminal. The results show a concurrence between the mathematical model and the experiments.

KEY WORDS: Breakwaters; Curtain wall; Pile structure; Irregular waves; Laboratory experiments; Mathematical models; Wave reflection and transmission.

INTRODUCTION

A curtainwall-pile breakwater (abbreviated as CPB hereafter) has an upper part that is a curtain wall and a lower part that consists of an array of vertical piles. The CPB may be a useful alternative to gravity-type breakwaters for protecting small craft harbors. In general, a CPB allows smaller construction costs and less environmental impacts compared with conventional gravity-type breakwaters. Suh et al. (2006) developed a mathematical model to predict wave transmission, reflection, runup and wave force acting on a CPB using the eigenfunction expansion method. They conducted large-scale laboratory experiments to examine the validity of the developed model, showing that the mathematical model adequately reproduces most of the important features of the experimental results. They also showed by numerical calculation that the CPB always provides a smaller transmission and a larger reflection than a curtain wall breakwater that has the same draft as that of the upper wall. A similar result was obtained for a pile breakwater that had the same porosity as that of the lower part of the CPB. They used both regular and irregular waves.

Nevertheless, the CPB provides a large transmission for long-period waves. In order to reduce the wave transmission, either the draft of the curtain wall must be increased, or the porosity between the piles must be decreased. However, this procedure results in an increase in the

wave reflection and the wave forces and moments acting on the breakwater. Therefore, it is difficult to increase the draft or decrease the porosity beyond certain limits. Consequently, Suh and Ji (2006) suggested a multiple-row CPB, where the draft of the curtain wall and the porosity between piles are increased and decreased, respectively, from an upwave to a downwave direction. This is performed in order to reduce wave transmission below an acceptable level while not increasing the wave reflection and wave force and moment acting on the breakwater. They developed a mathematical model and carried out hydraulic model experiments for regular waves.

In this study, we expand the regular wave model to an irregular wave model and conduct hydraulic model experiments. The results of mathematical model are compared with those of laboratory experiments and with the results of the experiments for the permeable breakwater used at the Busan International Cruise Terminal.

MATHEMATICAL MODEL

Boundary Value Problem

Let us consider the multiple-row CPB sketched in Fig. 1, in which h = a constant water depth in still water; d_j = the height of the j th curtain wall below the still water level; b_j = the thickness of the j th wall. A Cartesian coordinate system (x, z) is defined with the positive x directing downwave from a point in front of the first wall and with the vertical coordinate z measured vertically upwards from the still water line. The center of the j th wall is located at $x = x_j$. The distance between the centers of two neighboring piles is denoted as $2A_j$, and the width of the gap between the piles is $2a_j$, so that the porosity of the lower part of the j th wall is defined as $r_j = a_j / A_j$. A regular wave train with wave height H_i is incident in the positive x -direction. The fluid domain is divided into $J + 1$ regions by the J walls. The upwave and downwave regions of the j th wall are defined as Ω_{j-1} and Ω_j , respectively.