Permeability Parameter of Perforated Wall with Vertical Slits

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ABSTRACT

The matching condition at a perforated wall with vertical slits involves the permeability parameter, which can be calculated by two different methods. One is advantageous because all the related variables are known, but it gives wrong result in the limit of long waves. The other gives a correct result from short to long waves, but it requires the permeability parameter to be calibrated by comparing the mathematical and experimental results. In this paper, the permeability parameter for the latter method is given as a function of known variables without comparing the mathematical and experimental results.

KEY WORDS: Friction coefficient, perforated wall, permeability parameter, vertical slit

Introduction

Recently, porous structures composed of vertical slits such as perforated wall, curtain-wall pile breakwater, and permeable dissipative breakwater have been used widely. Many mathematical models also have been developed to calculate hydrodynamic characteristics of a perforated wall, i.e. wave reflection, transmission, and force. The wave motion through a porous wall accompanying with energy dissipation and phase shift is complicated. Thus, several assumptions are required in the theoretical study. Most of mathematical models divide the fluid domain into front and back of the porous wall, and solve the problem by using the matching condition at the wall. The matching condition involves the permeability parameter, which can be calculated by two different methods generally. One was proposed by Mei et al. (1974) and the other by Sollitt and Cross (1972). The former method has a merit because all variables of permeability parameter are a priori known, but it gives inadequate result in the limit of long waves, i.e. zero transmission and perfect reflection of very long waves. On the other hand, the latter method might give the right results for any wave length, but an experiment should be conducted first to find the related variables by comparing the mathematical and experimental results. The purpose of the present study is to express the permeability parameter as a function of known variables for the method of Sollitt and Cross (1972). Then, the permeability parameter can be directly calculated using known variables without comparing the mathematical and experimental results.

Numerical Model

Boundary Value Problem

A Cartesian coordinate system \((x, z)\) is defined with the positive \(x\) directing downwave from the crest line of the breakwater, and the vertical coordinate \(z\) being measured vertically upward from the still water line. A regular wave train with wave height \(H\) is incident in the positive \(x\)-direction. Assuming incompressible fluid and irrotational flow motion, the velocity potential exist, which satisfies the Laplace equation. Linearizing the free-surface boundary condition, the following boundary value problem for the velocity potential \(\Phi(x, z, t)\) is obtained

\[
\frac{\partial^2 \Phi}{\partial x^2} + \frac{\partial^2 \Phi}{\partial z^2} = 0 \quad (1)
\]

\[
\frac{\partial \Phi}{\partial z} - \frac{\omega^2}{g} \Phi = 0 \quad \text{at} \quad z = 0 \quad (2)
\]

\[
\frac{\partial \Phi}{\partial z} = 0 \quad \text{at} \quad z = -h \quad (3)
\]

where \(\omega\) = wave angular frequency; \(g\) = gravitational acceleration; and \(h\) = water depth. Assuming periodic motion in time \(t\), we can assume the solution to the above problem as