Numerical Research on Scouring and Silting of Seabed in Front of Breakwaters

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ABSTRACT
The scour and deposition in front of the vertical wall and mound breakwaters are investigated physically and numerically. A new device is developed to measure the bed-load sediment transport under standing wave. A numerical wave flume is established to simulate wave movement in front of a breakwater. Through the incipient velocity of sediment and selected bed load transport rate formula, a numerical module of bed load transport is established under wave action. The bed load transport numerical module is justified compared by the physical experimental data.

KEY WORDS: turbulence model, bed load, bed load sediment transport rate, scouring and deposition

INTRODUCTION
The scours around coastal structures, such as breakwaters and seawalls, would threaten the safety of structures, and must be considered carefully in the course of designing and constructing. Carter, Liu and Mei (1973) were the first to recognize the scour and deposition in a field of standing waves in conjunction with the development of sand bars parallel to the shore line. The 2-D scour in front of a vertical-wall breakwater has been investigated by de best, Bijker, Wichers (1971), Xie (1983), Gao (1995), Sumer and Fredsøe (2000). Gao (1991) indicated that the critical velocity for sand particles under standing waves is less than the one under progressing waves and he presented a semi-experimental formula of sand critical velocities under standing wave. Gislason (2009) studied the flow and scour under standing wave in numerical method. A new device is developed to measure the bed-load sediment transport under standing wave and a numerical wave flume is established to simulate wave movement in front of a breakwater in this paper.

FLOW NUMERICAL METHOD DESCRIPTION
The numerical scheme in this numerical model is based on a finite difference solution of a coupled set of partial differential equations governing incompressible flow. In this section, the governing equations are reviewed, finite difference conventions are discussed, and the finite difference expressions used by this model to approximate the governing equations are presented. The solution techniques employed in solving the difference expressions are also specified.

Flow model
In the 2D fluid-structure interaction, the flow motion of an incompressible fluid inside and outside the porous media is governed by the Navier-Stokes equations:

$$\frac{\partial u_i}{\partial t} + u_j \frac{\partial u_i}{\partial x_j} = g_i - \frac{1}{\rho} \frac{\partial p}{\partial x_i} + \frac{1}{\rho} \frac{\tau_{ij}}{\rho}$$

And the continuity equation:

$$\frac{\partial u_i}{\partial x_i} = 0$$

Where $u_i$, $i = 1, 2$ are the velocity components in direction along with the coordinate axes $x_i$, $p$ is the pressure, $t$ the time, $\rho$ the water density, the kinematic viscosity coefficient of the water $\nu = \mu/\rho$, and $g_i$ the i-th component of the gravitational acceleration. $\tau_{ij}$ is the viscous stress tensor.

$$u_i = \langle u_i \rangle + u_i'$$

$$p = \langle p \rangle + p'$$

$$\frac{1}{\rho} = \frac{1}{\rho}$$

In which $<>$ denotes the mean quantities and the prime “’” represents the turbulent fluctuations. Therefore, $\langle u_i \rangle = \langle p \rangle = \frac{1}{\rho} = 0$, by substituting (3),(4), and(5) into (1) and (2) and taking the ensemble average of the resulting equations, one obtains the governing equations for the mean flow field.

$$\frac{\partial \langle u_i \rangle}{\partial x_i} = 0$$