

Transformation of irregular waves propagating over a submerged breakwater

Cheng-Hsien Lee, Mao-Lin Shen and Ching-Jer Huang
Department of Hydraulic and Ocean Engineering, National Cheng Kung University
Tainan, TAIWAN, China

ABSTRACT

The unsteady, 2-d Navier-Stokes equations and the exact free surface boundary conditions were solved numerically to investigate the transformation of irregular waves propagating over a submerged breakwater. The deterministic spectral amplitude method performed by fast Fourier transform algorithm was applied to generate the incident irregular waves with the Goda-JONSWAP spectrum. Transformation of waves was discussed in terms of reflected energy and wave spectra. By providing the incident irregular waves with repeatable amplitude and phase for each wave component, effects of the height and width of the breakwater on the wave transformation were studied systematically. The numerical results show that propagation of irregular waves over a submerged breakwater produces not only the higher harmonics of the fundamentals waves, but also the subharmonic and superharmonic waves, due to the nonlinear interaction of different wave components in shallow water.

KEY WORDS: Irregular waves, submerged breakwater, subharmonic, superharmonic and reflected energy.

INTRODUCTION

Submerged breakwaters are often used for coastal protection against wave attack. The purpose of this kind of structure is to reduce the transmitted wave energy by reflecting waves and dissipating the incident wave energy by breaking up the waves. Interaction of regular or solitary waves and submerged breakwaters under non-breaking conditions has been thoroughly investigated using different approaches (Beji and Battjes, 1993 & 1994; Ohyama and Nadaoka, 1994; Huang and Dong, 1999 & 2001; Chang et al., 2001; among many others). The main characteristics of the wave transformation and the viscous flow fields around the structure are well understood.

In real breakwater applications, the incident waves are often random. Interaction of random waves and submerged breakwaters has rarely been investigated.

Yoshida et al. (1996) investigated the second-order interaction of multi-component random waves and a submerged obstacle by using Stokes'

wave expansion and Green's second identity. Experiments were also carried out to provide the transmitted wave spectra for verifying the theoretical solutions. Their results showed that as the multi-component random waves propagate over a submerged obstacle, higher harmonics of the fundamental waves and superharmonic waves due to the wave-wave interaction are generated. When wave-breaking occurs, not only more superharmonic waves are generated, but also more energy was transformed from the incident waves to the higher harmonics and the superharmonic waves.

Wave deformation and vortex shedding induced by regular and solitary waves propagating over a submerged breakwater have been investigated by Huang and Dong (1999 and 2001) by solving the unsteady 2-d Navier-Stokes equations and the fully nonlinear free surface boundary conditions. The numerical results of the water surface elevation and the velocity field have been shown to agree with experimental and analytical results very well. In this study, the numerical scheme developed by Huang and Dong (1999) was applied to investigate the transformation of irregular waves propagating over a submerged breakwater. The deterministic spectral amplitude (DSA) method performed by fast Fourier transform (FFT) was applied to produce the incident irregular waves with the Goda-JONSWAP spectrum. After verifying that the simulated incident wave spectrum is identical to the target spectrum, effects of the height and width of the breakwater on the wave reflection and transformation were studied systematically.

GOVERNING EQUATIONS AND BOUNDARY CONDITIONS

This study investigates the transformation of irregular waves propagating over a submerged breakwater. Figure 1 presents a schematic diagram of irregular waves that pass over a submerged breakwater in a two-dimensional wave flume. A piston-type wave generator with stroke S_o is located at $X = X_{\min}$ and generates the incident irregular waves. The still water depth is h_o and the shallow water depth above the breakwater is qh_o . For an incompressible, viscous fluid, the dimensionless continuity equation in the Cartesian coordinate system is