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SOLUTION OF REFLECTION AND ENERGY SPECTRUM COEFFICIENTS OF IRREGULAR REFLECTED WAVES FROM PERFORATED CAISSON BREAKWATERS

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Introduction

Wind waves which are generally progressive in nature, can move far distances out of their area of formation towards seashore. For decades conventional sloping or vertical rigid breakwaters were used to protect harbors against these waves. However for this kind of breakwater wave load on the structure and wave reflection are considerable. High reflected waves can disturb the movement of ships and boats and induce scoring in front of the breakwater. This can lead to instability of breakwater. Therefore various vertical perforated breakwaters have been gradually used in coastal engineering. These new forms not only are more economical based on construction material but also induce lower reflection in front of the breakwater. The perforated breakwaters can be single, double or multiple layers. In practice the front wall has some continuous vertical slots from bottom to top. Issacson et al. (1998) presented a numerical calculation for wave interaction with a thin vertical slotted barrier extending from the water surface to some distance above the seabed based on an eigenfunction expansion method. Comparisons with experimental measurements of the transmission, reflection, and energy dissipation coefficients for this partially submerged slotted barrier showed good agreement between results, and indicated that the numerical method is able to account adequately for the energy dissipation by the barrier. Zhu and Chwang (2001) based on linear wave theory and eigenfunction expansion studied the interaction between waves and slotted breakwater. Their research showed that the reflection characteristics of a slotted sea wall depend mainly on the porosity of the slotted plate and the incident wave height. Analytical models based on potential flow for predicting wave reflection from a perforated-wall caisson breakwater have been developed by Suh et al. (2001). Laboratory experiments have also been conducted for irregular waves with various significant wave heights and chamber width. It was concluded that the reflected wave spectrum shows a frequency dependent oscillatory behavior. The present study is a modified solution to double perforated caisson breakwater for prediction of reflection coefficient and wave energy spectrum.

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Analytical Model

Fig. 1 shows the geometry of a typical slotted single chamber breakwater and incident normal waves. In this figure *h* and *B* are constant water depth and wave chamber width respectively. The distance between the centers of the two adjacent members of the perforated wall is denoted as *2A* and the width of a slit as *2a*. Therefore the porosity can be expressed by *r* = *a/A*. The thickness of the perforated wall is denoted as *d*.

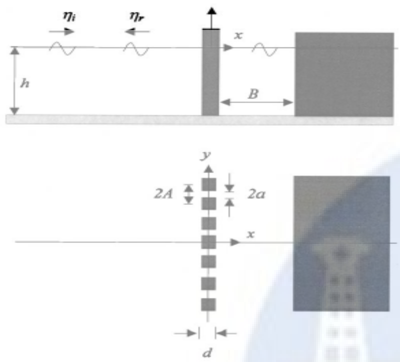

Fig. 1) Cross section and plan view of a typical slotted breakwater

According to linear wave theory an irregular wave can be expressed as infinite number of regular waves with height H_n and period T_n leading to a water level profile as:

$$\eta_i(x,t) = \sum_{n=1}^{\infty} \frac{H_n}{2} \exp(i(k_n x - \omega_n t + \varepsilon_n)) \qquad (1)$$

in which $i = \sqrt{-1}$, H_n، k_n ، ε_n and ω_n are the height, wave number , phase angle and angular frequency of the nth component of the wave respectively. The subscript i denotes the incident waves. The wave number k_n satisfies dispersion relation as:

$$\omega_n^2 = gk_n \tanh(k_n h) \qquad (2)$$

The velocity potential consists of free propagating and non-propagating evanescent wave modes. The total velocity potential for the propagating wave modes $\Phi'(x,z,t)$ can be expressed as (Suh et al., 2001):

$$\Phi'(x,z,t) = \sum_{n=1}^{\infty} \Phi_n(x,z,t) = \sum_{n=1}^{\infty} \frac{gH_n}{2\omega_n} \phi_n(x) \frac{\cosh k_n(z+h)}{\cosh k_n h} \exp(i(-\omega_n t + \varepsilon_n)) \qquad (3)$$

in which $\phi_n(x)$ is the horizontal spatial variation of the nth component wave potential Φ_n. In practice, very close to the front wall incident waves behave three dimensionally. However neglecting this feature and considering some simplifications, horizontal regular components of irregular wave in each region of breakwater can be expressed as below (Suh et al., 2001):

$$\phi_{n1}(x) = e^{ik_n x} + C_{rn} e^{-ik_n x}, x \le 0 \qquad (4)$$

$$\phi_{n2}(x) = C_{fn} e^{ik_n x} + C_{bn} e^{-ik_n x}, 0 \le x \le B \qquad (5)$$

in which C_{rn} is the complex-valued reflection coefficient and C_{fn} and C_{bn} are the complex-valued coefficients denoting the amplitude of the forward propagating wave and back-scattered wave inside the wave chamber, respectively. Three auxiliary boundary conditions are required to determine three unknowns of potential equations.

Results and Discussion

A comparison with experimental and analytical works shows that this model can accurately predict frequency-averaged reflection from this type of breakwaters. This model can provide a good trend to predict frequency-averaged reflection from breakwater and has an effective ability to predict the reflected energy spectrum from slotted breakwaters. The effect of effective parameters such as wave chamber width, significant wave height, significant wave period and porosity of the slotted wall was also considered on frequency-averaged reflection and reflected energy spectrum in this model. One of the most important results is calculation of frequencies in reflected spectrum which have a minimum energy close to zero (denoted as zeroth frequency points). This means that a large part of wave energy in such frequencies is absorbed by the structure of breakwater.

References

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