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Wave Interaction with an Emerged Porous Media

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Abstract. In this paper, we study wave interaction with an emerged porous media. The governing equation is shallow water equations with a friction term of the linearized Dupuit-Forcheimer's formula. From the continuity of surface and horizontal flux, we derived the wave reflection and transmission coefficient formulas. They are similar with the corresponding formulas of the submerged solid bar breakwater. We solve the equations numerically using finite volume method on a staggered grid. The numerical wave reduction in the porous media confirms the analytical wave transmission curve.

AMS subject classifications: 76S05, 81U30, 35L02

Key words: Emerged porous media, shallow water equation, wave transmission coefficient, wave reflection coefficient.

1 Introduction

Porous structures, such as rubble-mound breakwaters are commonly used to protect harbors against the action of incident waves. Porous breakwaters have a large impact on waves and flow because they produce flow resistance. This resistance factor associated with the porous structure. For this purpose, before implementation in the real field, it is important to assess the engineering aspect of a porous structure, such as predicting the reflection and transmission wave coefficient correspond to the porous structure.

Studies about wave interaction with porous structure have been done by many authors, for instance R. A. Dalrymple et al. [3], M. Calabrese et al. [1], N. Kobayashi and Wurjanto [8], A. T. Chwang and A. T. Chan [2], W. Sulisz [19], P. J. Lynett et al. [11], P. L. F. Liu et al. [10], C. K. Sollitt and R. H. Cross [17]. The porous structures can be classified into two categories, submerged and emerged porous structure. Submerged breakwater lies

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entirely beneath the mean water level while emerged porous breakwater's crest is visible above the mean water level. N. Kobayashi and Wurjanto [8] studied monochromatic wave reflection and transmission over a submerged impermeable breakwater, Z. Gu and H. Wang [6,7] studied maximum wave energy dissipation by porous submerged breakwaters numerically using boundary integral element method. M. Calabrese et al. [1] has presented a method for calculating 2D wave setup behind a submerged breakwater. We also have studied wave interaction with a submerged porous structure in [16,21]. In this paper, we are interested to study wave interaction with an emerged porous structure.

Two common approaches to study wave reflection and transmission due to a porous structure are by using shallow water assumption with an additional friction and potential theory. W. Sulisz [19] predicted the reflection and transmission coefficient by using potential theory. The potential theory was also adopted in many literatures to investigate reflection and transmission from porous structure, such as O. S. Madsen [12] and R. A. Dalrymple et al. [3]. C. K. Sollitt and R. H. Cross [17] formulated the wave transmission through a permeable breakwater as a linear boundary value problem. A. T. Chwang and A. T. Chan [2] studied waves moving past a porous structure by using potential theory with Darcy's Law. P. L. F. Liu et al. [10] and P. J. Lynett et al. [11] studied solitary wave interaction with porous structure by using potential theory with Dupuit-Forcheimer friction.

In this paper, we study the problem of surface gravity waves reduce due to emerged porous media. We take the Shallow Water Equation (SWE) with an additional friction force of Dupuit-Forcheimer type. Next, we will formulate wave transmission and reflection coefficients. Based on the linear wave theory, the wave has a constant frequency and we can apply separation variable. In this way, we can directly get wave reduction from dispersion relation. When we combine solution in free water area and the reduced wave inside the porous structure, and from the continuity of surface and horizontal flux, we obtain explicit formulas for wave transmission and reflection coefficient. Numerically, we solve the equation using the finite volume method on a staggered grid. Numerical result of wave transmission coefficient is in good agreement with analytical data.

2 Model formulation

In this section, the governing equation of the flow pass through a porous structure will be formulated. Let η and u denote surface elevation and horizontal fluid velocity, respectively. We consider, the continuity and momentum equations in free region reads as:

$$\eta_t + (hu)_x = 0, \tag{2.1a}$$

$$u_t + g\eta_x = 0, \tag{2.1b}$$

with g is the gravitational acceleration. Notation $h = \eta + d$ denotes water thickness, where d is bottom topography.