

Wave Transformations over Porous Beds

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ABSTRACT

This study investigates wave transformation when wave pass over a submerged porous obstacle. The numerical model is based on the Boussinesq equation demonstrated by Cruz et al. (1997), and is expressed by depth-averaged velocity and depth-averaged seepage velocity. This model which introduces a parameter related to shoaling and seabed contours proposed by Madsen and Sørensen (1991), is applied to a larger relative water depth, h/L . The numerical model utilizes the Fourth-Order Adams-Bashforth-Moulton Predictor-Corrector Scheme and is coupled with a source function and absorbing boundary condition to enhance the stability of calculations and to reduce the required processing time. Numerical experiments are made to simulate the wave transformations over a submerged porous obstacle. Based on the numerical results, the effects of the transformation influenced by the porosities and the intrinsic permeability, k_p are examined. The deformation of the primary wave and second harmonic wave indicates that the wave height decreases as the relative depth increases when the condition of the porosity is less than 0.44 and $k_p=2.5 \times 10^{-8} \text{ m}^2$.

KEY WORDS: Boussinesq-type equation; wave transformation; absorbing boundary; porosity; intrinsic permeability; the harmonics; the submerged porous obstacle.

INTRODUCTION

When waves propagate from deep water into shallow water, the properties of the bottom affect the wave transformations. The bottom is nearly porous in the nearshore region. Hence, the effect of porous beds on wave transformations must be considered. Additionally waves are usually nonlinear near the shore. The nonlinear governing equations are appropriate for simulating interactions between porosity and wave nonlinearity. Research on waves and porous beds includes the following works. Sollitt and Cross (1972) considered porous inertial resistance and viscosity in porous media, based on the work of Ward (1964). They derived a linearized unsteady Bernoulli equation. In their study, the resistant force associated with the viscosity in the porous medium is linearized. Several researchers have developed methods for studying wave transformations over porous beds. Madsen (1974) also

utilized this method proposed by Ward (1964) to elucidate the transmission and reflection of waves in a porous medium.

Putman (1949) examined the interactions between waves and porous beds. He assumed the flow to be irrotational to simplify complex problems. The porous medium is an isotropic rigid body. The fluid in the medium satisfies Darcy's law. Liu (1973) considered the continuity of the pressure at the boundary of the porous medium. This paper applied the boundary layer method and order analysis to ensure the continuity of the horizontal velocity. However, assumption that the porous medium is a rigid body is not physically accurate. Biot (1956a, 1956b) introduced two ideas for studying the porous medium. The stress and strain must satisfy Hook's law. The fluid must obey Darcy's law in the porous medium. This last fact has been extensively applied in studies of the permeability of soil. Numerous researchers have also employed the method suggested by Biot (1956a, 1956b) to explore wave transformations over porous beds. Huang and Song (1993) utilized potential flow and Darcy's law to examine the dynamic response of linear wave transformations with uniform depth and flat porous beds.

Recently, Boussinesq equation has become the most popular equation in the prediction of wave transformations. Boussinesq (1872) derived the original Boussinesq equations. Thereafter, numerous researchers improved and extended their applicability. Peregrine (1967) considered various water depth conditions to derive a shallow-water wave equation from small amplitude wave theory. He used a depth-averaged velocity as the dependent variable to derive the Boussinesq equation at a constant water depth. Witting (1984) included the free surface velocity as the dependent variable in a nonlinear depth-integrated momentum equation. Expanding velocity terms as Taylor series yields a one-dimensional Boussinesq equation; however, the weakness of the equation is its limited applicability to constant-depth situations and the difficulty of applying it to two-dimensional cases.

Conventional Boussinesq equations are limited to relatively shallow water. Hence, many studies have focused on extending them to deeper water. McCowan (1985, 1987) calculated nonlinear wave propagations in shallow water using the Boussinesq equation. The error between the derived phase velocity and the linear phase velocity was under 5%, and the relative depth of the water was extended to 0.2. Madsen et al. (1991) improved the Boussinesq equation to enable it to be applied to relatively deeper water. The improved Boussinesq equation has a better