Improvement of Partial Reflection Boundary on Boussinesq-type Wave Transformation Model

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ABSTRACT

PLB (Porous Layer Boundary) method was proposed by Hirayama (2001) for reproducing the partial wave reflection on the wall covered with armor blocks. In this study, the modeling of horizontal distribution of porosity in porous media is improved in order to get better accuracy in calculation and convenience in use. That is obtained by integration of the vertical distribution of porosity in each computational box. Such modeling is similar to the moving shoreline models proposed by Madsen et al. (1997) and Kennedy et al. (2000), therefore this model can also reproduce wave run-up on a slope.

KEY WORDS: Porosity; armor block; porous media; partial reflection; wave run-up; Boussinesq model; numerical simulation.

INTRODUCTION

To evaluate reflection coefficients of waves on breakwaters and seawalls is much important for estimating the harbor tranquility. They generally depend on both the properties of wave absorbing works and the incident wave conditions. In harbor wave calculation, they are usually given by harbor designers and engineers with assumptions based on some results of past model experiments.

The partial reflected waves can be calculated by using a Boussinesq-type wave transformation model with an energy dissipating boundary called “Sponge layer”. Brorsen and Petersen (1998) showed that the sponge layer whose thickness is only three computational boxes could simulate wave reflection and directional spreading at the wave absorbing works. Hirayama and Hiraishi (2003) proposed the technique that the thickness of sponge layer could be determined with both the designed reflection coefficient and the incident wave length. In harbor wave calculation, they are generally given by harbor designers and engineers with assumptions based on some results of past model experiments.

Hirayama and Hiraishi (2003) also proposed another type of partial reflection boundary for the Boussinesq-type wave transformation model, named “Porous Layer Boundary”. This model consists of the special porous region where wave energy is dissipated due to laminar and turbulent flow resistances. The parameters of them are objectively given by the physical values of the target wave absorbing works, i.e. porosity, width, and size of armor blocks. Therefore, the porous layer is modeled with considering the mechanism of wave energy reduction in a wave absorbing work.

Nishii et al. (2005) showed that the accuracy of calculated reflection coefficients could be more improved with considering the correct horizontal distribution of porosity of the actual wave absorbing work. In this paper, the useful and appropriate technique is proposed by referring the moving shoreline models proposed by Madsen et al. (1997) and Kennedy et al. (2000). In addition, it is shown that such model can also reproduce wave run-up on a sloping beach regarding the porosity under the seabed as very small.

IMPROVEMENT OF POROUS LAYER BOUNDARY

Horizontal Distribution of Porosity

For setting the Porous Layer Boundary “PLB” at wave absorbing breakwaters and seawalls in calculation, vertical walls are replaced to perfect reflection boundaries and wave absorbing works are replaced to porous layers. Considering the cross-section form of a wave absorbing work, Hirayama (2002) defines a horizontal distribution of porosity in the porous layer as;

\[ \lambda(x) = \lambda_0 + (1 - \lambda_0) \frac{x}{B} \quad (0 \leq x \leq B) \]  \hspace{1cm} (1)

For a wave absorbing work formed with vertical plane (Fig.2)

\[ \lambda(x) = \lambda_0 \quad (0 \leq x \leq B) \] \hspace{1cm} (2)

where \( \lambda_0 \) is the significant porosity in a wave absorbing work, \( B \) is the bottom width and \( x \) is the distance from the vertical wall. The wave transmission through the caisson mound is still neglected but the wave shoaling on impermeable mound is considered in the boundary.

They are modeled with the assumption that the apparent porosity is