

Numerical simulations of solitary wave running and breaking on a slopping bed

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ABSTRACT

This paper describes the development of an in-house numerical model for studying solitary wave running, shoaling and breaking on the slopping bed. The significant benefit of the present study over the traditional way of analyzing wave propagation problems is to apply the RANS (Reynolds Averaged Navier-Stokes) and the embedding method by taking account of the fully nonlinear, viscous and turbulent effects to the physical problem. The $k-\epsilon$ turbulence model is employed to simulate the flow kinematics and turbulence effects in the RANS equations. The transport equations are discretized by the finite difference method, based on a staggered grid system with variable width and height. The unsteady term is treated by an explicit method. The pressure field is obtained by a predictor-corrector procedure. In order to update the transient free surface profiles with every time step, the Volume of Fluid (VOF) method is implemented. Coupling the volume of fluid method (VOF) and the embedding method, the treatment of free surface problem and complex bottom topography can be easily reached. We have compared the numerical results with existing experimental data and found a close agreement between computational and measured data. The mean velocity field and the turbulence distribution under the breaking wave are solved using the in-house model. The runup and rundown characteristics of the solitary wave on slopping bed are also discussed.

KEY WORDS: wave breaking; a slopping bed; VOF; embedding method

INTRODUCTION

The study of long wave run-up and run-down on a beach is highly relevant to tsunami hazard mitigation in a coastal region. Most tsunamis are due to undersea earthquakes in the ocean. The leading waves of tsunamis have been modeled as solitary waves (Liu *et al.*, 1991). Meanwhile, wave run-up has been studied for many years, because breaking waves in a surf zone play an essential role in nearly

all coastal processes. For example, strong turbulence which enhances the mixing rate and thus has an important impact on sediment transport in surf zone is generated after waves break.

In order to determine run-up of solitary waves, a series of theoretical and experimental studies have been performed. In the early 1950s, researchers began to investigate solitary wave run-up on a plane beach through laboratory experiments. For example, Synolakis (1986) investigated the run-up of nonbreaking long waves. In the recent years, due to the advance of computing technology, the numerical wave tank (NWT) has been widely applied in the field of coastal engineering. Currently, there are four basic types of numerical models have been used to simulate the run-up of water waves: (1) non-linear shallow water wave equation, (2) Boussinesq type models, (3) the Laplace equation, and (4) Navier-Stokes equations. One group has studied variants of the Boussinesq equations. Zelt (1991) used a Lagrangian form the Boussinesq-type equations to simulate shoreline movement.

However, the prediction of the inviscid flow fields may in some situations fail to capture important phenomena regarding the interaction of viscous fluids interacting with solid structures. In order to simulate the process of viscous flow interacting with submerged breakwaters, the Navier-Stokes equations with exact free surface boundary conditions are considered. So far, only a few of numerical models have been proposed for problems of viscous water waves interacting with a slopping bed.

The present stage of development of numerical modeling solving the Navier-Stokes equations to simulate breaking waves can be classified into three groups: The first group of numerical models are those solving the Navier-Stokes equations directly, containing no turbulence model (Miyata, 1986). The second group of numerical models are those based on the space-filtered Navier-Stokes equations. (e.g., Zhao and Tanimoto, 1998; Wijayarathna and Okayasu, 2000 and Christensen and Deigaard, 2001). The third group of numerical model