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ISPH Numerical Modeling of Nonlinear Wave Run-up on Steep Slopes

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Abstract

Non-breaking tsunami waves run-up on steep slopes can cause high damages to coastal structures. The estimation of the wave run-up rate caused by tsunami waves is important to understand the performance and safety issues of the breakwater in practice. In this paper, an Incompressible Smoothed Particle Hydrodynamics method (ISPH) method is utilized for the 2DV numerical modeling of nonlinear wave run-up on steep slopes. SPH is a meshless method based on particles, which is capable of high accurate modeling of free surface flows with large deformations. In developed model, mass and momentum conservation equations are solved in a Lagrangian form using a two-step fractional method. In the first step, Navier-Stokes equations are solved to compute velocity components by omitting pressure term and in the absence of incompressible condition. In the second step, the continuity constraint is satisfied and the resulting Poisson equation is solved to calculate pressure terms. Velocity values are then corrected and surface positions are computed. In the present model, a new technique is applied to allocate density to the particles for the calculations. By employing this technique, ISPH model is stabled. The developed ISPH model is first validated by the solitary wave propagation on the constant water depth and the corresponding results showed good agreement with analytical results. The convergence of the method and the sensitivity of relevant model parameters are discussed. Then validated model is used to study the run-up of solitary waves on steep slopes by considering a coastal breakwater for various wall steepnesses (i.e. 1:1, 2:1, 4:1, 8:1 and vertical wall).

1. Introduction

Tsunamis can propagate shoreward where they undergo changes induced by the near-shore topography and increase in height. These waves can propagate shoreward and damage coastal structures. The estimation of the wave run-up rate is important to understand the performance and safety issues of the breakwater in practice. Solitary wave or combinations of solitary-like waves are often used to simulate the run-up and shoreward inundation. The first investigation on the run-up of solitary waves was the laboratory study of Hall and Watts [1]. They used a rectangular channel with a plane beach and established a relationship between wave height a/d, the beach slope and the dimensionless run-up R/d of the form:

$$R/d = k(\beta)(a/d)^{\phi(\beta)} \tag{1}$$

Where K and Φ were reported to be functions of the beach angle β. This result was later confirmed in the experimental studies of Camfield and Street [2] and Saeki et al [3]. Synolakis