ISPH Modelling of Solitary Wave Interaction with Permeable Beaches

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January 2020

This thesis is submitted for the degree of Doctor of Philosophy.

Abstract

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Coastal areas are vulnerable to natural disasters such as storm surges and tsunamis. Dykes, wave-absorbing blocks, and forests, are typical solutions to mitigate coastal disasters. In coastal engineering, these protections and beaches are considered as porous media. Accurate prediction of wave motion around porous structures is necessary for the effective design of stable and durable coastal protections. Although mesh-based methods have been conventionally utilised to simulate porous flows, they often suffer from numerical diffusion due to large deformation of a grid. Mesh-free methods are more suitable for simulating violent free-surface flows. Smooth Particle Hydrodynamics (SPH) is a meshless and particle method, which can be applied to simulations of moving free surface flows with porous structures.

This thesis presents an incompressible SPH (ISPH) model that can simulate violent porous flows. In the present ISPH model, dummy particles were used to implement porous structures. These dummy particles have information on porosity, mass and density. A new water-porous interface was proposed so that the model does not need any transition zone at the water-porous boundary. Porosity was defined linearly by the amount of porous particles included in the support domain of a target particle. A new free surface condition was presented to search for free surface particles correctly even if they exist in a porous region. To obtain smooth pressure fields, the source term of the pressure equation was modified with the higher-order source term. The present ISPH model was validated

through the simulation of dambreaking with a porous block. The simulation results agreed strongly with the experiment.

To investigate wave interactions with porous media, the present ISPH model was applied to simulations of solitary wave runup on permeable slopes. In these simulations, triangle and parallelogram porous structures with various mean grain sizes were focused. Two different scale slopes were considered to generate both nonbreaking and breaking waves. For nonbreaking waves, runup height decreased nearly linearly as the mean grain size of a permeable slope became logarithmically larger. When the grain size became larger, runup height on the thickest parallelogram porous structure was smaller than that on the thinner parallelogram porous media. This phenomenon indicates that the shape and grain size of porous structures can be essential factors to determine runup height of nonbreaking waves. Meanwhile, for breaking waves, nearly the same runup height was obtained in any shape of permeable slopes even with the large grain size of porous media. This result implies that the mean grain diameter predominantly determines runup height of breaking waves.

All the above-mentioned results demonstrate that the present ISPH model is capable of simulating violent porous flows and investigating wave interactions with porous structures. The findings in this thesis can contribute to a better understanding of permeability effects on coastal disaster mitigation and to more accurate prediction of runup height on porous structures.