Water Wave Theory and Experiments

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Abstract
We summarize some interesting interactions between theory and experiments in the context of water waves. Some of the theory suggests new experiments and experiments naturally influence the development of theory. The discussion will include work on long-crested waves where two-dimensional models suffice and also three-dimensional wave situations.

Vortex Structures Underlying Free Surfaces of Shoaling Solitary Wave and Dam-break Generated Bore Propagating over Sloping Bottoms

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ABSTRACT

The characteristics of flow fields for the evolutions of shoaling solitary waves and dam-break generated bores propagating over different sloping bottoms are presented. The experiments were conducted in a glass-walled and glass-bottomed wave flume with dimensions of 14.0 m long, 0.25 m wide and 0.5 m deep. The flume was equipped with a piston-type wave maker, which was triggered by a precise servo motor and could produce highly repeated solitary waves. On the other hand, bore experiments were also carried out in the same flume by generating dam-break created flows, induced right downstream of a suddenly lifted gate (located at a position 3.0 m downstream of the wave maker), propagating over horizontal bottom and then over sloping bottoms. Two capacitance type wave gauges were employed to measure the water surface elevation. The sloping models made of acrylic, having slopes ranged from 1:20 to 1:3, were used for the experiments. A flow visualization technique (FVT) with neutrally suspending particles was utilized to qualitatively observe the flow characteristics. A laser light sheet was employed to illuminate the 2-D motion of the tracers on a vertical plane. A high-speed camera was used to capture images with maximum framing rate of 1200 Hz and maximum image resolution of 1,024 × 1,024 pixel. A high-speed particle image velocimetry (HSPIV) system was also used to measure the velocity fields of large-scale vortex structures and high-speed meandering streams in the run-down phase of shoaling solitary waves and bores. This study mainly focuses on: (1) the occurrence of flow separation on the boundary layer under an adverse pressure gradient and subsequent hydraulic jump with the abrupt rising of free surface during run-down motion of the shoaling wave, together with emphasis on the evolution of vortex structures underlying the separated shear layer and hydraulic jump; and (2) the flow reversal zone with time-lead effect and formation of shear layer near the boundary, accompanied by the development of vortex train (or street) in the shear layer between two opposite currents of onshore external flow and offshore reverse flow over a sloping boundary.

Keywords: Run-up; Run-down; Flow separation; Separated shear layer; Flow reversal; Vortex structure, Vortex Train (or Street); Hydraulic jump

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Wave energy focusing induced by submerged crescent plate

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Abstract

A structure of submerged crescent plate, which is able to focus wave energy and enhance wave energy density, will be discussed in this research for increasing the efficiency of utilizing wave power. Capability of the structure is similar to convex-concave lens and leads wave shoaling to enhance energy density and concentrate wave energy on a region behind submerged plate.

A numerical analysis, based on linear wave theory, by usage of boundary element method is developed for investigating the capability of submerged crescent plate, and its advantage will be verified by means of model tests carried out in wave basin. Discussions will be focused on wave transformation in wave field, the relationship between wave focusing and submerged crescent plate, region of wave focusing. The effects of plate on contracting wave energy and enhancing energy density will also be discussed.

Wave scattering by submerged composite wavy plate breakwaters

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Abstract: The concept of the Bragg reflection is adapted to the design of submerged composite wavy plate breakwaters. In this paper, the composite wavy plate is formed by the superposition of three sinusoidal ripples which have the same relative ripple amplitude and different relative ripple lengths. Numerical analyses and laboratory experiments are performed to investigate the characteristics of the reflection due to submerged composite wavy plate breakwaters. The dual boundary element method (DBEM) is formulated and applied to study the impermeable composite wavy type plate breakwaters, which is modeled as a thin or non-thickness structure. The numerical method is validated by comparison with other previous published analytical solutions and reliable laboratory data of the same model.

The reflection coefficients increase as the number of composite wavy plate breakwaters increases in both numerical results and laboratory measurements. In addition, the numerical results of wave reflection for a submerged, impermeable horizontal plate, a wavy plate and a composite wavy plate breakwater are presented and discussed. As expected, the performance is more effective for the composite wavy plate breakwater than for the other types of horizontal plate breakwaters. The new observed results show that the peaks of the reflection coefficients of the composite wavy plate are larger than those of the horizontal plate or wavy plate, especially for wavenumbers approximately in the range of $1.0 \le kh \le 2.5$. The numerical results show that when choosing a reasonable value of kh, the reflection coefficients of the composite wavy plate can be controlled to approximate the total reflection. For deep water waves, the results also reveal that the composite wavy plate is a better reflector than the others, with more plate numbers being more effective.

Keywords: Horizontal plate; wavy plate; composite wavy plate; Bragg reflection.

3D Numerical Schemes for Solving Nonlinear Moving Solid and Bingham Flow Problems

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Moving boulders in the are frequently observed in the nature disasters, such as tsunamis, storm surges, river floods, and landslides. Resulted in violent impinging forces on the structures and sever local scours. The keys of the successful simulation are the technique that is able to solve the solid and fluid motions simultaneously, with the ambient fluids behave as high viscous non-Newtonian Bingham flows.
In this presentation, we shall focus the discussions on solving the 3D Navier-Stokes (NS) equations with newly developed Discontinuous Bingham Fluid (DBM) model and two-way coupled moving-solid algorithm. The volume-of-fluid (VOF) method with Piecewise Linear Interface Calculation (PLIC) technique is adopted to describe the multiple phases in the fluids. Validations and Examples will be presented and discussed.

Initial-boundary value problems

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ABSTRACT

The full equations for waves on the surface of an ideal fluid were derived by Euler and Bernoulli in the 18^{th} century. This system is not always convenient in practice, however, model equations that formally approximate solutions of the full problem have been developed from the 19^{th} century up to today. It is natural to run controlled laboratory experiments to see how well these model equations work.

In a laboratory wave tank, a flap-type wavemaker is turned on at time $t = 0$ and waves are generated which propagate down the channel. If the frequency and throw of the wavemaker are adjusted appropriately, the waves generated are in the formal range of validity of various model equations. The wave amplitudes are monitored at several stations along the channel as a function of elapsed time. These measurements are then used in the context of initial-boundary-value problems to check the model's predictive power.

This comes up several interesting mathematical issues. First, one needs to understand whether or not the relevant boundary-value problems are well posed in the classical sense of having existence and uniqueness of solutions. Second, the solutions should also vary only slightly if the imposed boundary conditions change slightly - i.e. the model should be robust. The relevant model equations are nonlinear and exact solutions are not available even for very simple boundary data. Thus, when such models are used in practice, a numerical scheme for approximating its solutions must be implemented. This requires the spatial domain to be cut off, and that in turn raises the thorny issue of whether or not this will have an unwanted, artificial effect on the solutions. Theory relating to this issue will also be discussed.