II-569 FREE-SURFACE FLOW OF WASH-DOWN TYPE WAVE MAKER

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1. Introduction Wash-down type wave makers are suited to generate non-periodic waves with no or little power. They generate an isolated travelling waves one at a time. Its recent application is to simulate natural beach waves at a surfing pool, in which high travelling waves need to be generated efficiently. The idea of the wash-down type wave maker is to flush a tankful of water by gravity without using power. A simplified model is shown in Fig.1. First, with the gate at the bottom of the tank closed, water is pumped into the tank, then the gate is opened to let the water flow through it. Just downstream of the tank there is an artificial "reef" which deflects the water flow upward to create a surface wave. In order to understand the fluid dynamics of this type of wave-making mechanism and to be able to optimize the design and the operation methods, we have studied the associated two-dimensional free-surface flow problem both experimentally and numerically.

2. Experiments A series of experiments were conducted using the model facility shown in Fig.1. The initial tank depth H and gate opening timing(t_o, t_h, and t_c the time it took to open, held open, and to close, respectively) were varied and the flow, particularly the movement of the free surface, was observed by videotaping the flow from the side and the top of the wave maker by four VCR's as shown in Fig.1. The initial undisturbed downstream water level was kept constant and was the reference for the vertical positions. The gate was operated by pulling and pushing on the handle attached to the gate, and was not precisely controllable. However, the gate timing, t_o, t_h, and t_c could be accurately determined by replaying the tape at a slow speed and observing a marker on the gate and the clock with resolution of 1/100 sec.

3. Numerical calculation and comparison with experiments Numerical calculation corresponding to the experiments described above were carried out using a method called "SOLA VOF"[1)] as described in Ref 2). This method solves the two-dimensional Navier-Stokes equations for unsteady laminar flows, with an additional variable F, which takes values between 0 and 1 depending on the ratio of the volume of the mesh occupied by the water. Due to the rather coarse grid used in the present calculation, the boundary layers on the bottom are not modeled. The full and nonlinear free-surface boundary conditions are used.

Some calculation results compared with experiments are shown in Fig.2. Fig.2(a) and (b) are the cases of two different gate operation timing with a low initial tank depth of 50cm, while Fig.2(c) is the case with higher tank depth of 70cm. The solid lines indicate the calculated free-surface profile while the dashed lines indicate the experimental results. The arrows indicate the calculated velocity vectors. It can be seen that in all cases, the calculation and the experimental observation of the water surface profiles agree very well at the early times of the wave making cycle. In the case of fast gate operation with low tank dept of Fig.2(a), they agree fairy well until the end of the gate closure. In the case of slow gate operation, the disagreement is seen between the calculated and experimental results. In order to investigate the reasons for the discrepancy, a close examination of the videotaped images was made. It has been found that the flow becomes turbulent on the curved surface of the reef and when the turbulence intensity becomes large, the air is entrained and the water lumps of high-momentum shoot into the air. The regions of high air entrainment are indicated with hatches in Fig.2. Finally, Fig.3 shows the generated wave height as a function of H.

4. Conclusions Experimental observation and numerical calculations were made of the free-surface flow generated by a wash-down type wave maker. It has been found that with a rather steep obstacle with concave curvature, the flow becomes highly turbulent at the Reynolds number of the experiment. The initial stages of the flow with low turbulence can be computed fairly well by a laminar SOLA-VOF method, but as the turbulence intensity increases, a significant amount of air bubbles are entrained and the numerical computations significantly underestimate the generated wave height.

References
1) Hirt, C.W. and Nichols, B.D., J. Computational Physics, Vol.39, pp.201-225, 1981.
2) So, M. : Numerical Simulation of Flows with Air bubbles, M.S. Thesis, Kobe University, 1992.

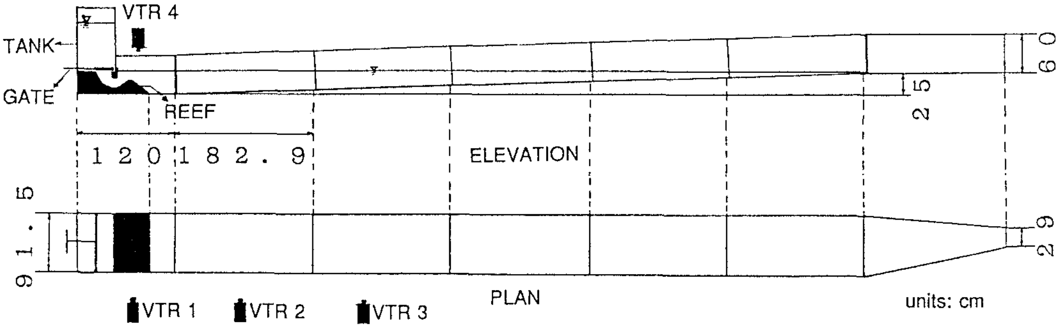
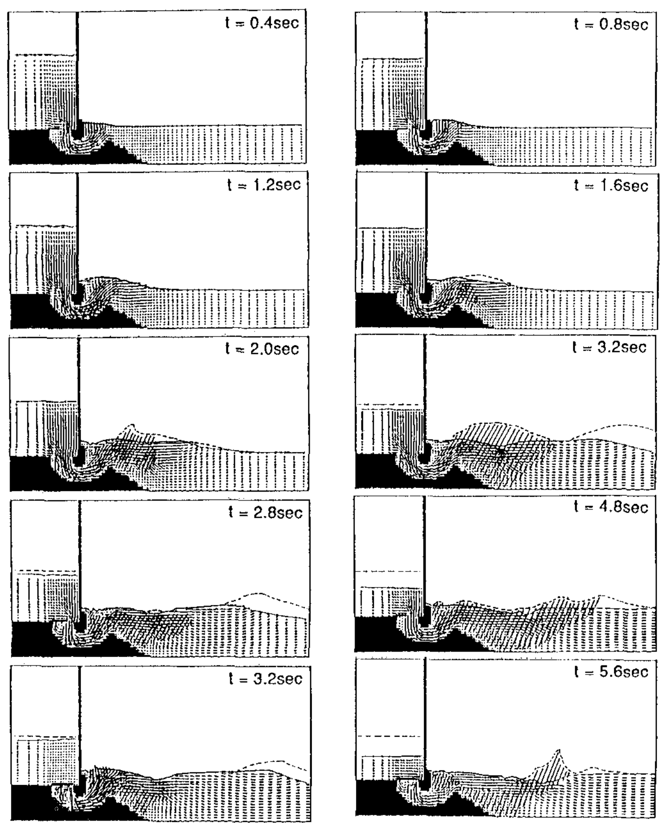


Fig.1. Schematic of the Wash-down type wave maker.

(a) d=50cm, t_o=.28, t_h=.3, t_c=.32sec. (b) d=50cm, t_o=.59, t_h=.61, t_c=.64sec. (c) d=70cm, t_o=.16, t_h=.25, t_c=.54sec.



---- Experiment —— Calculation //// Region with air bubble entrainment

Fig.2. Comparison of calculations and experiments.

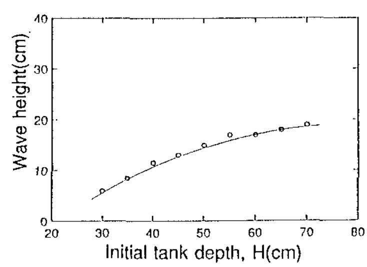


Fig.3. Height of propagating wave for various initial tank depths.