SECTION II

COMPUTATION OF SOLITARY WAVE RUNUP AND PRESSURE ON COASTAL BARRIER

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1. INTRODUCTION

The Volume of Fluid (VOF) method is used to simulate numerically the runup and rundown process of solitary wave on a gradual sloping beach. After that, the bore surge on the dry beach will be reproduced to investigate its interaction with a coastal barrier. The computed results are confirmed by experimental ones.

2. THE NUMERICAL MODEL

The Navier-Stokes equations are used as the governing equations and discretized in a non-uniform Eulerian mesh by using the MAC finite difference method. The x-momentum and y-momentum transports are calculated at the right and top faces of the cell, respectively. While the continuity equation is calculated at the center of the cell. A special function F is introduced for representing and updating free surfaces. The value of F in a cell represents the fractional volume of fluid. It has zero value in the void cell, and one in fluid cell. A free surface or interface cell (i, j) is defined as a cell which contains a non-zero value of F and has at least one neighboring cell $(i \pm 1, j)$ or $(i, j \pm 1)$ that contains a zero value of F. The shape of the free surface within a cell is approximated by a horizontal or vertical straight line. The orientation and the position of the line depend on the value of F in the cell and on the local gradients of F. The pressure boundary condition at free surface is applied in each free surface cell at the intersection of the straight line, representing the free surface, and a line connecting cell center. For advancing F in time, the governing equation for convecting F is introduced and calculated using the donor-acceptor method.

3. PROCEDURE OF COMPUTATION

The basic procedure of computation in one cycle can be summarized as follows:

1. Explicit approximations of the momentum equations are used to compute the temporary velocities at the new time level (n+1), using previous values (time level n). This temporal velocity field, in general, has not yet satisfied the incompressibility condition;
2. To satisfy the incompressibility condition, the pressure and velocity are modified simultaneously. The pressure is corrected in each cell, then the pressure correction is used to compute the velocity. This is done iteratively in each fluid cell until a residual divergence in each cell is satisfied (up to some limit criterion);
3. The F function is updated to give the new fluid configuration (at time level n+1);
4. All mesh cells are re-flagged by using F function as full, surface or empty cell;
5. Fluid orientation is determined in a cell.

4. RESULTS AND DISCUSSION

As a first implementation, the runup of solitary wave with $\varepsilon = 0.28$ on a gradual slope (2.88^0 or approximately 1:20) was simulated. A non-dimensional unit was chosen, and the second order solitary wave proposed by Laiton (1960) is generated as the incidence wave. The left part of Fig.1 shows that the computed wave profiles agree well with experimental data of Synolakis (1987). The incident wave collapses and transforms into the bore after breaking. The runup reached the maximum (R = 0.45 unit) at t= 45 as shown in the right part of Fig.1. This is consistent with the calculation by Zelt (1991) using FEM. Synolakis (1987) reported that for this slope, the maximum runup (based on averaged position) is represented by the relation of $R/h = 0.918\,\varepsilon^{0.606}$. The relation gives the value of $R = 0.425$ for $\varepsilon = 0.28$.

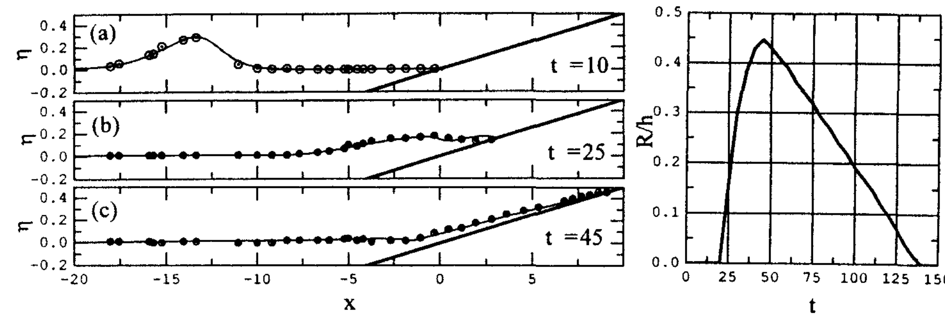

Fig. 1. *Left*: Comparison of the free surface profiles with experiments (Synolakis, 1987), where solid lines denote the numerical results and plot symbols represent the experiment results.
Right: Time history of maximum runup.

To investigate the bore-structure interaction on the dry bed, the same computational domain was used as before. The slope obstacle was modified by cutting the slope horizontally above the still water surface and putting a barrier on the horizontal dry bed. Both vertical ($\theta = 90^0$) and inclined slope ($\theta = 30^0$) barriers were used. The height of the barrier was also changed to investigate the effect of the barrier height on the pressure. The left part of Fig.2 shows the bore profile in the vicinity of the vertical and inclined barriers for height of 0.3, and the right part shows the time history of the pressure calculated in front of the barrier. In the case of vertical barrier the maximum runup occurred around t=24 and then the wave was reflected. The maximum runup on the vertical barrier is about 0.425, which is almost twice of the incident wave height. The maximum pressure occurred at t=27 after the wave reached the maximum at t=24. This result is consistent with the experiment of Ramsden (1993). In the case of inclined barrier the wave smoothly runup along the inclined slope of the barrier. A part of wave overtops the barrier and the main part of the wave is reflected offshoreward. The runup reached the maximum around t=27 and the pressure also became maximum at this time. The maximum pressure is smaller than that of vertical case and the pressure peak does not occur in the case of inclined barrier. It was found from the calculation that the vertical pressure distributions in front of the barriers (not shown here) are almost the same as hydrostatic one excluding the distribution at t=24. The pressure distribution at t=24 is larger than the hydrostatic one. Therefore, it is concluded that the wave dynamic contributes strongly to the pressure.

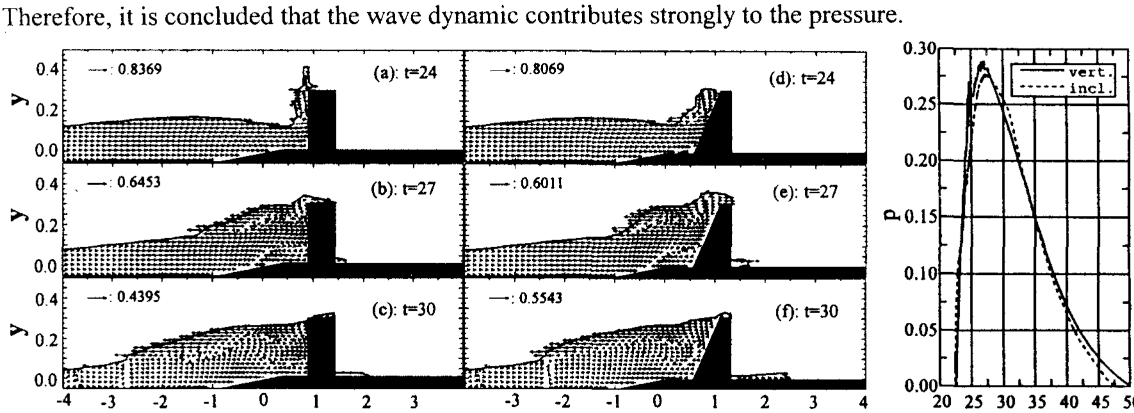

Fig. 2. *Left*: Free surface profiles and velocity fields around the vertical and inclined barriers at some time steps. *Right*: Time history of the pressure calculated in front of the barrier (offshore side).

REFERENCES

1. *Laitone, E. V.* (1960): The second Approximation to Cnoidal and Solitary Waves, JFM(9);430-444.
2. *Ramsden, J. D.* (1993): Tsunamis Forces on A Vertical Wall caused by Long Waves, Bores, and Surges on A Dry Bed, W. M. Lab. of Hydr. and Water Res., Calif. Inst. of Tech., Report No. KH-R-54
3. *Synolakis, C. E.* (1987): The Run-up of Solitary Waves, JFM (185);523-545.
4. *Zelt, J. A.* (1991):The runup of Nonbreaking and Breaking Solitary Waves, Coastal Eng., (15);237-238