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SIMULATION OF DAM-BREAK FLOW

Mohammad Ebrahim Banihabib　Ph. D. Student, student member of JSCE
Muneo Hirano　Professor, member of JSCE
Dept. of Civil Engineering, Kyushu University, Fukuoka 812, Japan

Introduction

Human life and property in the potentially inundated region downstream of the dam are threatened by flood waves of the sudden collapse of dams. Since after collapsing a dam flood wave propagates in two directions, one dimensional simulation can not express flow condition and a two-dimensional simulation is required for proper analysis of the flood flow near dam site. The purpose of this research is the simulation of the two-dimensional propagation of the flood flow in dam-break case and verification of the results with the experimental results.

2. Mathematical model

Since dam-break flow is a kind of flow with steep front, the basic equations have been found by the de St. Venant hypotheses are not valid in the neighborhood of the steep front. Therefore Conservation form of the equations should be used to conserve mass and momentum in the neighborhood of the steep front.

The governing equations can be derived by integrating the Navier-Stokes equation for an incompressible fluid over the flow depth (chaudhry 1993). Shallow water assumptions have been used in deriving the Equations. Two dimensional momentum conservation equations can be written in the Cartesian orthogonal coordinate system with the x-y plane parallel to the channel bottom as follows:

$$\frac{\partial h}{\partial t}+\frac{\partial (uh)}{\partial x}+\frac{\partial (vh)}{\partial y}=0 \quad \text{[1]}$$

$$\frac{\partial uh}{\partial t}+\frac{\partial}{\partial x}(u^2h+(1/2)gh^2\cos\theta_{bxo})+\frac{\partial}{\partial y}(uvh)=gh(S_{o_x}\cos\theta_{bxo}-S_{f_x}-\sin\theta_{bxo}) \quad \text{[2]}$$

$$\frac{\partial vh}{\partial t}+\frac{\partial}{\partial x}(uvh)+\frac{\partial}{\partial y}(v^2h+(1/2)gh^2\cos\theta_{by0})=gh(S_{o_y}\cos\theta_{by0}-S_{f_y}-\sin\theta_{by0}) \quad \text{[3]}$$

where h = flow depth; u = flow velocity in the x-direction; v = flow velocity in the y-direction; g = acceleration due to gravity; S_{0x}= channel bottom slope in the x-direction; S_{0y}= channel bottom slope in the y-direction; θ_{bx0}= inclination of x axes; θ_{by0}= inclination of y axis; and S_{fx} and S_{fy} are the slopes of the energy grade lines in the x and y-directions, respectively.

The equations [1]--[3] are first order hyperbolic partial differential equation and analytical solution is not available for its complete form. Therefore, a finite difference scheme has been employed to integrate the equations [1]--[3]. The Alternating Direction Implicit algorithm has been used to decrease the number of equations that should be solved simultaneously. Backward space differences have been used in x and y-directions and forward space difference has been used for time as equations [4]--[6]. Since the scheme is implicit, it uses $k+1$ time level for space derivatives except for cross terms, in which we use mix time level.

$$\frac{\partial \Psi}{\partial t}=\frac{\Psi_{i,j}^{n+1/2}-\Psi_{i,j}^{n}}{1/2\Delta t} \quad ....[4] \qquad \frac{\partial \Psi}{\partial x}=\frac{\Psi_{i,j}^{n+1/2}-\Psi_{i-1,j}^{n+1/2}}{\Delta x} \quad ....[5] \qquad \frac{\partial \Psi}{\partial y}=\frac{\Psi_{i,j}^{n+1/2}-\Psi_{i,j-1}^{n+1/2}}{\Delta y} \quad ....[6]$$

The dissipative interface is used to suppress the nonlinear instability. The procedure of Jameson et al (1981) for generating artificial viscosity is found as a suitable dissipative interface (Authors 1995). It adds more dissipative interface in front area than other areas.

Computational Results and Discussion

A dam break has been simulated. The set up of the experiment is as follows: A rectangular tank 2.8m long, 1.7m wide and 0.8m high is used as reservoir. The downsteam of the dam is a wooden flat plate of 4m long and 1.9m wide. The collapse of the dam is modeled by suddenly opening gate. The gate is 5cm wide. The water head of the upstream of the dam is 20cm. The downstream plat has 1/200 slop.

Computation has been done for 0.1mX0.05m grid size. Since there is no Courant instability problem, the time step can be as large as 0.1 second, but for very accurate results, smaller time step is needed. All the boundary conditions have been considered as close boundaries except the dam sit and an opening in the downstream wall of the experimental set up with 0.5m wide.

Comparison has been done for depth hydrographs along the centerline stations of the experimental set up. Figure 1 and Fig. 2 show the computed depth hydrograph at middle of the reservoir and at 240cm downstream of the dam site, respectively. There are good agreements between experimental results and computational results. Therefore comparison between experimental results and simulated results illustrate the ability of proposed scheme in simulation of the depth hydrographs of the dam-break.

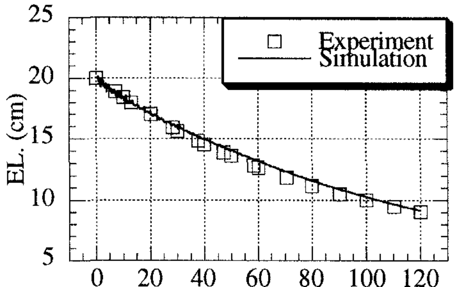

Fig. 1 Comparison between depth hydrograph of the simulated flood and experimetal one at middle of the reservoir

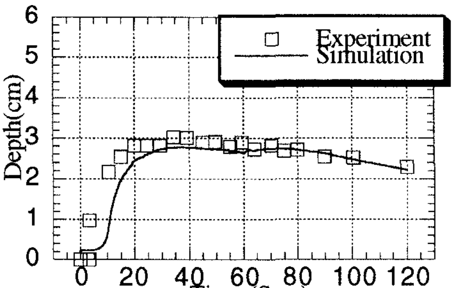

Fig. 2 Comparison between depth hydrograph of the simulated flood and experimetal one at 240 cm downstream of the dam site

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