NUMERICAL SIMULATION OF DAM BREAK FLOW

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1. INTRODUCTION

A dam failure creates a flood wave with destructive consequences for the downstream area. The dam break and the flood wave created by a dam failure is widely studied by many researchers. In addition, some researchers also study the tsunami wave using a dam break model. Tsunami run-up on horizontal coastline is similar to the dam break flow with generation of the strong shock in front of the water level. Chanson (2006) applied dam break wave equation to tsunami surges on dry coastal plain. Although lots of discussion regarding dam break simulation, assesment of bed stress is still lack.

This study aims to determine hydraulic flow properties that includes water level, velocity, bed shear stress and vertical velocity distribution. Herein a dam break mechanism is simulated numerically assuming 2D unsteady flow using Shallow Water Equations (SWE). Two methods is implemented to assess hydraulic flow properties i.e. Manning approach and k-ω turbulent model.

2. GOVERNING EQUATION

In this study, a shallow water equation model is used to the fixed bed in a two-dimensional channel. Here, the following basic equation was discretely solved by the finite difference method using the Mac Cormack scheme (Kusuma et al., 2008).

$$\frac{\partial h}{\partial t}+\frac{\partial (uh)}{\partial x}+\frac{\partial (vh)}{\partial y}=0 \tag{1}$$

$$\frac{\partial U}{\partial t}+U\frac{\partial U}{\partial x}+V\frac{\partial U}{\partial y}+g\frac{\partial (h+z)}{\partial x}+\frac{\tau_{0x}}{\rho h}=0 \tag{2}$$

$$\frac{\partial V}{\partial t}+U\frac{\partial V}{\partial x}+V\frac{\partial V}{\partial y}+g\frac{\partial (h+z)}{\partial y}+\frac{\tau_{0y}}{\rho h}=0 \tag{3}$$

$$\frac{\tau_{0x}}{\rho}=g\times n^2\frac{U|U|}{h^{4/3}} \tag{4}$$

$$\frac{\tau_{0y}}{\rho}=g\times n^2\frac{V|V|}{h^{4/3}} \tag{5}$$

where (x, y) = plane coordinates; h = depth of water; u = velocity in an x direction; v = velocity in a y direction; t = time; g = acceleration due to gravity; τ_0 = bed stress; ρ fluid density and n = Manning's roughness coefficient.

The governing equation for the k-ω model is based on the Reynolds-averaged equations of continuity and momentum, which can be written as follows:

$$\frac{\partial u_i}{\partial t}+u_j\frac{\partial u_i}{\partial x_j}=-\frac{1}{\rho}\frac{\partial P_i}{\partial x_i}+\frac{1}{\rho}\frac{\partial \tau_{ij}}{\partial z} \tag{6}$$

Where u_i and x_i denotes the mean velocity and location in the grid, and P is the static pressure.

$$\frac{\tau_{ij}}{\rho}=(\nu+\nu_t)\frac{\partial u_i}{\partial z} \tag{7}$$

The k-ω model equation is given as follows:

$$\frac{\partial k}{\partial t}=\tau_{ij}\frac{\partial u_j}{\partial z}-\beta^* k\omega+\frac{\partial}{\partial z}\left[(\nu+\sigma^*\nu_t)\frac{\partial k}{\partial z}\right] \tag{8}$$

$$\frac{\partial \omega}{\partial t}=\alpha\frac{\omega}{k}\tau_{ij}\frac{\partial u_j}{\partial z}-\beta^* k\omega+\frac{\partial}{\partial z}\left[(\nu+\sigma\nu_t)\frac{\partial \omega}{\partial z}\right] \tag{9}$$

Where k is the turbulent kinetic energy and ω is the specific dissipation rate. The eddy viscosity is given by:

$$\nu_t=\frac{k}{\omega} \tag{10}$$

The values of the closure coefficients are given by Wilcox as β = 3/40, β *=0.09, α = 5/9, and σ = σ * = 0.5. A numerical model is applied based on the 2D SWE using McCormack numerical scheme (Adityawan, 2010). Previous simulation has been carried out by Bellos and Hrissanthou (2011) using 1D SWE and McCormack scheme. In this study, Manning approach and k-ω turbulent model are applied to the model. Simulations performed on a numerical flume which has a model domain (0.3 mx 9.96 m) divided by a grid of 0.01 meters which is Δx = 0.01 m and Δy = 0.01 m. Manning roughness coefficient = 0.010, Courant- Friedrichs-Lewy (CFL) number = 0.6 and the simulation time = 10.2 s. Water depth in a tank placed upstream of flume is set to 0.40 m and water depth in the downstream flume is 0.10 m. Sudden opening of sluice gate creates a dam break flow (**Fig.1**).

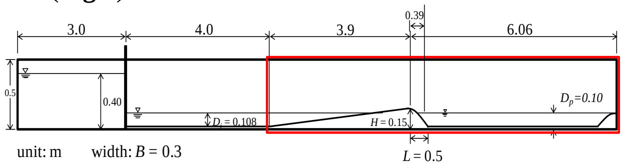

Fig. 1 Numerical flume condition

3. RESULT AND DISCUSSION

Peak water level of dam-break flow run from upstream to downstream. At a one point in the flume can be observed changes in water level suddenly rose and then receded again. At a distance of 2 meters from the upstream boundary conditions simulating changes in water level and velocity illustrated by **Fig. 2**. In this case Manning method and k-ω model give results of water level and velocity that really coincide.

Different behavior of bed stress are observed (**Fig. 3**). The k-ω turbulence model shows the effect of rapid deceleration to the bed stress profil. It is observed that the bed stresses obtained from Manning approach are smaller than to the k-ω model. In addition k-ω model is able to show a different direction to the direction in which the flow velocity direction is positive but shear stress direction is negative. It can not be simulated with the approach of Manning.

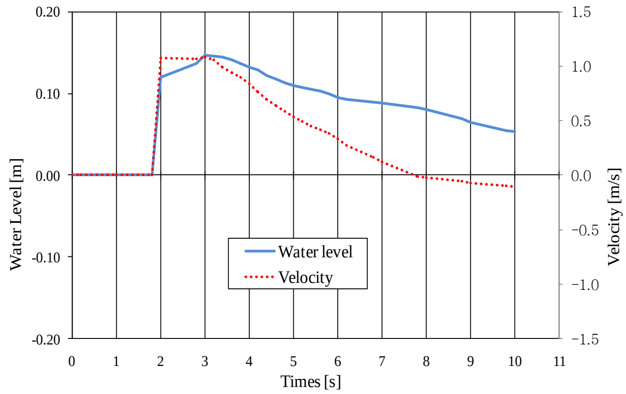

Fig. 2 Water level and velocity

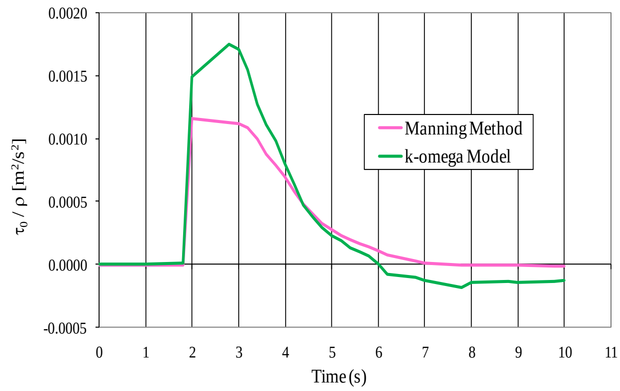

Fig. 3 Bed shear stress

Another hydraulic charateristic is vertical velocity distribution. **Fig. 4** shows vertical velocity distribution generated by k-ω model at distance of 2.0 m from upstream boundary condition. When the simulation time reaches 7 seconds, the flow velocity profile is starting to show negative values indicate the flow direction turned away from its original direction. Negative flow direction is a reflection caused by water hitting the downstream boundary conditions.

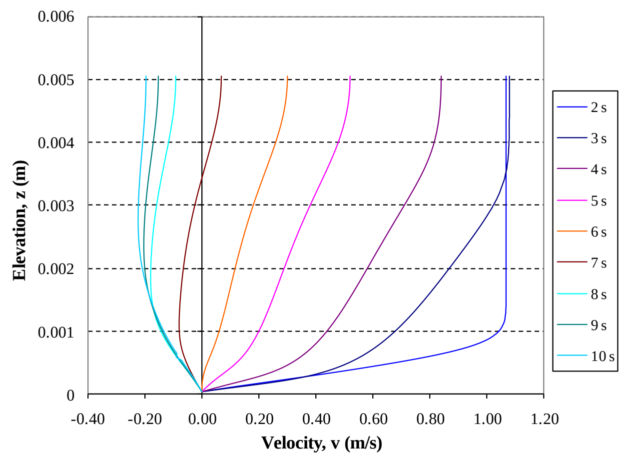

Fig. 4 Vertical velocity distribution

The vertical velocity distribution over time shows a gradual development of the boundary layer thickness as well as behavior. It shows that k-ω model is able to assess the boundary layer development. Velocity over boundary layer is free stream velocity.

4. CONCLUSIONS

Model of 2D Shallow Water Equations (SWE) is able to simulate the dam break flow. Water level, velocity, bed shear stress and vertical velocity distribution are obtained from the simulation. Manning method and k-ω turbulent model have similar results for water surface elevation and velocity. As for the bed shear stress both methods produce significant differences. The k-ω model is capable of causing bed shear stress in the opposite direction with velocity. In this paper, the simulation results have not been verified by laboratory data. This is the future work.

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