THE PROPAGATION OF FLOOD SHOCK MODEL ON THE STEEP MOUNTAINOUS AREA COMBINED WITH GEOMETRICAL INFORMATION SYSTEM

Ki Ho Park ¹⁾ and Muneo Hirano ²⁾

¹⁾ Department of Civil Engineering, Kyungdong College, 712 - 749 Hayaug, Korea

²⁾ Department of Civil Engineering, Kyushu University, Fukuoka, 812, Japan

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Abstract : In this study the two dimensional hydrodynamic model to simulate the propagation of flood shock on the steep mountainous area have been developed. This model is formulated by a hydrodynamic system with the assumption of unsteady flow as steady flow which can reduce computation time. The numerical computation for this model is executed by use of the eight point implicit scheme. The Incremental Dynamic Programming(IDP) technique is adopted for the optimization of grid size during the computation. The model is applied to compute the propagation of flood shock on the steep mountainous area located in southern part of the Korea. Comparison of the results between the proposed assumption model and the general type of two dimensional model indicates the proposed model is nearly as good as, and computationally much faster, than the general two dimensional.

Key Words : Two dimensional routing model, Flood shock model, GIS

INTRODUCTION

A two dimensional hydrodynamic model has been developed to simulate the propagation of flood shock on the steep mountainous area. The numerical computation for this model is executed through the 8 point implicit scheme. The geometrical information system for real basin is applied to determine the watershed of one or more target cells situated on a specified surface. The model is applied to simulate the propagation of the flood shock of the Wichon IHP representative area.

THEORY OF PROPOSED MODEL

A number of one dimension model of propagation of flood have been developed and these model can predict the propagation of flood in a channel accurately (Park, 1995a; Park and Jee, 1994). A one dimensional model are possible for simulating propagation of flood shock in a channel but is impossible to simulate the spreading of flood shock in a basin area due to two dimensional characteristics of flood propagation (Park and Hirano, 1995; Park 1995b). There is some two dimensional model for this, and is need to be improved with the simple equation as well as with the use of accuracy numerical approximation technique. The equation for two dimensional unsteady free surface flow, the governing equations are expressed in conservation form as equation (1).

$$\frac{\partial U}{\partial t} + \frac{\partial E}{\partial x} + \frac{\partial F}{\partial y} + S = 0$$

$$U = \begin{bmatrix} h \\ uh \\ vh \end{bmatrix}, E = \begin{bmatrix} uh \\ u^2 + 0.5gh^2 \\ uvh \end{bmatrix}, \quad (1)$$

$$F = \begin{bmatrix} vh \\ uvh \\ v^2 + 0.5gh^2 \end{bmatrix}, S = \begin{bmatrix} 0 \\ -gh(S_{ox} - S_{fx}) \\ -gh(S_{oy} - S_{fy}) \end{bmatrix}$$

where h is flow depth, u is velocity component in X direction, v is velocity component in Y direction, g is acceleration due to gravity, S_{ox} , S_{oy} are bed slopes in X direction and Y direction respectively, and S_{fx} , S_{fy} are friction slopes in X direction and Y direction respectively.

In general case, the bed slope (S_{ox} and S_{oy}) and the friction slope (S_{fx} and S_{fy}) in X and Y direction is expressed as

$$S_{fx} = \frac{n^2 u \sqrt{u^2 + v^2}}{h^{0.75}}, S_{fy} = \frac{n^2 v \sqrt{u^2 + v^2}}{h^{0.75}} \quad (2)$$

where n is Manning's roughness coefficient. By assuming the flow is steady, the governing equations for two dimensional steady flow is expressed in conservation form as approximation model shown in equation (3).

$$\frac{\partial E}{\partial x} + \frac{\partial F}{\partial y} + S = 0$$

$$E = \begin{bmatrix} uh \\ u^2 + 0.5gh^2 \\ uvh \end{bmatrix}, F = \begin{bmatrix} vh \\ uvh \\ v^2 + 0.5gh^2 \end{bmatrix}, \quad (3)$$

$$S = \begin{bmatrix} 0 \\ -gh(S_{ox} - S_{fx}) \\ -gh(S_{oy} - S_{fy}) \end{bmatrix}$$

In order to use the numerical approximation, the

vector term of U , E , F , S is divided by two components and equation (1) is written as

$$\frac{\partial U_1}{\partial t} + \frac{\partial E_1}{\partial x} + \frac{\partial F_1}{\partial y} + S_1 = 0 \quad (4)$$

$$U_1 = \begin{bmatrix} 0.5h \\ uh \\ 0 \end{bmatrix}, \quad E_1 = \begin{bmatrix} 0.5uh \\ u^2 + 0.5gh^2 \\ 0 \end{bmatrix},$$

$$F_1 = \begin{bmatrix} 0.5vh \\ uvh \\ 0 \end{bmatrix}, \quad S_1 = \begin{bmatrix} 0 \\ -gh(S_{ox} - S_{fx}) \\ 0 \end{bmatrix}$$

$$\frac{\partial U_2}{\partial t} + \frac{\partial E_2}{\partial x} + \frac{\partial F_2}{\partial y} + S_2 = 0 \quad (5)$$

$$U_2 = \begin{bmatrix} 0.5h \\ 0 \\ vh \end{bmatrix}, \quad E_2 = \begin{bmatrix} 0.5uh \\ 0 \\ uvh \end{bmatrix},$$

$$F_2 = \begin{bmatrix} 0.5vh \\ 0 \\ v^2 + 0.5gh^2 \end{bmatrix}, \quad S_2 = \begin{bmatrix} 0 \\ 0 \\ -gh(S_{oy} - S_{fy}) \end{bmatrix}$$

The vector components of flow U is determined by the discrete points of the variables(w, y, t) through the equations (4) and (5). To make accurate and effective a two dimensional simulation model, the computational scheme for calculating the computational grid size is carefully treated. In this study the proposed 8 point implicit scheme was applied to compute the accurate result. The time derivatives are approximated by forward different quotient centered between the i th or $i+1$ th points along the X axis and j th or $j+1$ th points along the Y axis, i.e.,

$$\frac{\partial K_x}{\partial t} = \frac{K_{x_i}^{j+1} + K_{x_{i+1}}^{j+1} - K_{x_i}^j - K_{x_{i+1}}^j}{2\Delta t_j},$$

$$\frac{\partial K_y}{\partial t} = \frac{K_{y_i}^{j+1} + K_{y_{i+1}}^{j+1} - K_{y_i}^j - K_{y_{i+1}}^j}{2\Delta t_j} \quad (6)$$

where K represents variables. The proposed eight point scheme is shown in equation (7) where P is the variables.

$$K_{x_i}^{j+1} = P_1 K_{x_{i-4}}^j + P_2 K_{x_{i-3}}^j + P_3 K_{x_{i-2}}^j + P_4 K_{x_{i-1}}^j$$

$$+ P_5 K_{x_i}^j + P_6 K_{x_{i+1}}^j + P_7 K_{x_{i+2}}^j + P_8 K_{x_{i+3}}^j \quad (7)$$

$$K_{y_i}^{j+1} = P_1 K_{y_{i-4}}^j + P_2 K_{y_{i-3}}^j + P_3 K_{y_{i-2}}^j + P_4 K_{y_{i-1}}^j$$

$$+ P_5 K_{y_i}^j + P_6 K_{y_{i+1}}^j + P_7 K_{y_{i+2}}^j + P_8 K_{y_{i+3}}^j$$

where

$$P_1 = 0.01438a^3 - 0.08173a^2 + 0.06934a$$

$$P_2 = -0.01678a^3 - 0.03899a^2 + 0.05577a$$

$$P_3 = 0.25057a^3 + 0.05914a^2 - 0.30971a$$

$$P_4 = -0.66780a^3 + 0.63087a^2 + 1.03693a$$

$$P_5 = 0.66780a^3 - 1.37254a^2 - 0.29527a + 1 \quad (8)$$

$$P_6 = -0.25057a^3 + 0.81083a^2 - 0.56028a$$

$$P_7 = 0.01678a^3 - 0.08934a^2 + 0.07256a$$

$$P_8 = 0.01438a^3 - 0.08173a^2 + 0.06934a$$

The quality of finite element solution is improved by optimizing the disposition of the nodes. The before study relied on their experience to restrict grids that make an efficient use of the available. It is also

Fig.1 The schematic configuration of applied basin with geometric information system.

possible to improve the quality of existing meshes iteratively using predefined guidelines for the distribution of nodes. The proposed IDP method (Park and Lee, 1995) considers the development of such criterion and the fundamental theory of equation is

$$-\frac{\partial \bar{F}}{\partial t} - \frac{\partial c}{\partial t} - \left[\frac{\partial F_s}{\partial t}, \Delta s \right] - 0.49 \left[\Delta s, \frac{\partial F_{ss}}{\partial t}, \Delta s \right] - h.t.$$

$$= \max \{ \text{Return}[\bar{s} + \Delta s, \bar{u} + \Delta u] + c + (F_s + F_{ss}\Delta s) + h.t., \phi[\bar{s} + \Delta s, \bar{u} + \Delta u + \Delta s] \} \quad (9)$$

$$\text{where } F_s = \frac{\partial F}{\partial s} [\bar{s} + \Delta s, t] = F_s[\bar{s}, t] + \overline{F_{ss}} \Delta s$$

$$\text{and } F_s = [\bar{s} + \Delta s, t] = \bar{F}[\bar{s}, t] + c + \langle F_3 \Delta s \rangle + 0.49 \langle \Delta s, F_{ss}, \Delta s \rangle$$

where $F^*[\bar{s}, t]$ is the optimal maximum return between the observed value and computed result of optimal grid size trajectory measured with respect to the trial grid size trajectory from the time t_0 to t_f . $\bar{F}[\bar{s}, t]$ is the return due to the trial grid size $\bar{s}$ from time t_0 to t_f , c is the difference between the maximum return due to the optimal grid size trajectory and the trial grid size trajectory, $F_s = (\frac{\partial F}{\partial s_i}, i=1,2,3,\dots,m)$, and $F_{ss} = (\frac{\partial^2 F}{\partial s_i \partial s_j}, i,j=1,2,3,\dots,m)$. Here u is decision vector and s is state vector.

THE APPLICATION TO THE REAL BASIN

The applied area in this study is IHP representative area which is located southern part of Korea as shown in Figure 1. An assumed grid is 10 x 10 m and the initial condition of upstream boundary and down

Fig.2 The steep mountainous area's two dimensional perspective flow view.

stream boundary is used by observed data. The executed simulation shows perspective view by grid based geographic analysis system in Figure 2.

The comparison among observed, approximation and conventional model represents good agreement. The computations for the examples presented here was performed on an IBM compatible personal computer with pentium processor (133 Mz and Windows95 atmosphere). For each one of the example, the execution time was approximately 26 min., 39 min., respectively, for the proposed two dimensional approximation model and general two dimensional models. The different execution times for the approximation and general models are partly due to optimized smaller computation grid adopted with IDP technique, and partly due to faster convergence of numerical results.

Fig.3 The comparison among observed value, approximation and general models.

Through the two dimensional approximation model, the propagation of flood wave front, the velocities were computed as shown in Figure 4.

Fig.4 The distribution of velocities and depth.

CONCLUSION

The two dimensional model which combined with geometric information system simulates the watershed flow in this study. For the reducing the computational time and the simplify formulation, the assumption of unsteady flow as steady flow is suggested. To make accurate and capable a numerical simulation, the parameter calibration and grid size optimizing is developed by the use of IDP optimizing technique. Also the proposed eight point scheme can solve the numerical approximation.

The suggested approximated two dimensional model and general type of two dimensional model simulate propagation of flood wave front and the depth and velocities.

The proposed approximated two dimensional model is nearly as accurate the general type of two dimensional model.

The proposed approximated two dimensional model is faster in computation and easier in numerical converge due to grid size optimization and simple form of equation.

Therefore the approximated two dimensional model which combined with geometric information system is suggested in this study for the calculation of the flood shock in the real mountainous area and results good applicability.

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