ANALYSIS OF FLOW CHARACTERISTICS IN A NARROW PATH OPEN-CHANNEL RIVER MODEL USING LABORATORY & NUMERICAL EXPERIMENTS

MARITESS S. QUIMPO[1], YOSHIKI MOTONAGA[1], TADASHI YAMADA[2]
[1]Graduate School of Science and Engineering, Chuo University, Japan;
[2]Professor, Department of Science and Engineering, Chuo University, Japan
tessquimpo@civil.chuo-u.ac.jp

INTRODUCTION

Fluid motion, like other phases of mechanics, may fully be described in units of length, time and force. Once such flow characteristics are known, any problem of fluid motion is, for all practical purposes, completely solved. Correct measurement of such flow characteristics is very essential in the study of the existing states of fluid motion.

In an open-channel flow, various experimental and numerical methods had been previously carried out. From theoretical, numerical and computer simulations, a certain hydraulic engineer can choose from a bunch of different computer software nowadays.

This paper presents the characteristics of a narrow path river model through laboratory and numerical experiments in order to determine how water flows in such kind of river condition.

METHOD OF ANALYSIS

Laboratory experiments were conducted on a narrow path small-scale river model using current meter followed by numerical experiments using DHI's Mike 21 software.

This method is conducted in order to analyze the flow characteristics and compare results of laboratory and numerical experiments of a narrow path river.

LABORATORY EXPERIMENTS

Experiments were conducted in a rectangular flume, 15 meters long and 1.80 meters wide. A small scale narrow path river model was then laid in the rectangular flume with narrow path width of 45cm and main river width of 90cm as shown in the figure 1.

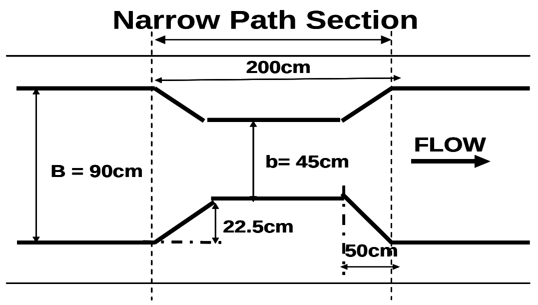

Figure 1: Small-scale Narrow Path River Model Detail

Calculation of horizontal velocity distribution and water depth at each section were computed using current meter apparatus.

NUMERICAL EXPERIMENT (DHI's MIKE 21 SOFTWARE)

After performing laboratory experiments, numerical experiments using DHI's MIKE 21 software was then performed using all the river boundary conditions from the laboratory experiments.

The two BASIC EQUATIONS used in the aforementioned software are: 1-Two Dimensional Unsteady Flow as Equation (1) and (2) and; 2-Continuity Equation (3) showed herein:

x-axis：$\frac{\partial M}{\partial t}+\frac{\partial (uM)}{\partial x}+\frac{\partial (vM)}{\partial y}=-gh\frac{\partial H}{\partial x}-\frac{\tau_{xb}}{\rho}+\frac{\partial}{\partial x}\left(\varepsilon\frac{\partial M}{\partial x}\right)+\frac{\partial}{\partial y}\left(\varepsilon\frac{\partial M}{\partial y}\right)$ ---(1)

y-axis：$\frac{\partial N}{\partial t}+\frac{\partial (uN)}{\partial x}+\frac{\partial (vN)}{\partial y}=-gh\frac{\partial H}{\partial y}-\frac{\tau_{yb}}{\rho}+\frac{\partial}{\partial x}\left(\varepsilon\frac{\partial N}{\partial x}\right)+\frac{\partial}{\partial y}\left(\varepsilon\frac{\partial N}{\partial y}\right)$ ----(2)

$\frac{\partial h}{\partial t}+\frac{\partial M}{\partial x}+\frac{\partial N}{\partial y}=0$ ---(3)

In which $\tau_{xb}=\frac{\rho g n^2 |u| \sqrt{u^2+v^2}}{h^{1/3}}$, shear stress along x-axis; $\tau_{yb}=\frac{\rho g n^2 |v| \sqrt{u^2+v^2}}{h^{1/3}}$, shear stress along y-axis; ε: Eddy's Viscosity ; M: Discharge flux at x (=uh); N: Discharge flux at y (=vh); h: water depth; u: velocity at x (=M/h); v: velocity at y (=N/h); t: time; g: gravitational acceleration; ρ: Density; n: Manning's number; H: Water Level.

LABORATORY & NUMERICAL EXPERIMENTS RESULTS

Case 1 (STEADY STATE RIVER)

This experiment was conducted using the river boundaries showed in figure 2 and 3 in order to determine how the flow behaves in a normal condition of a narrow path river model.

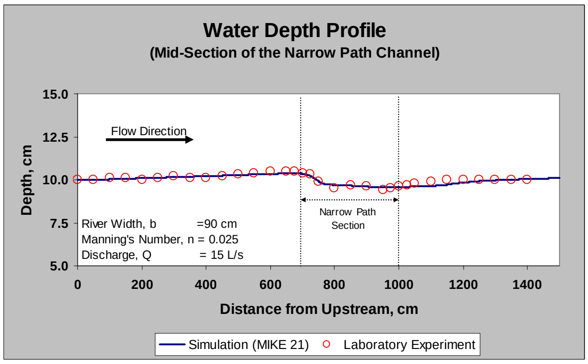

Figure 2: Water Depth Profile

Results in figure 2 shows that water depth fluctuates as it approaches the narrow path section of the channel.

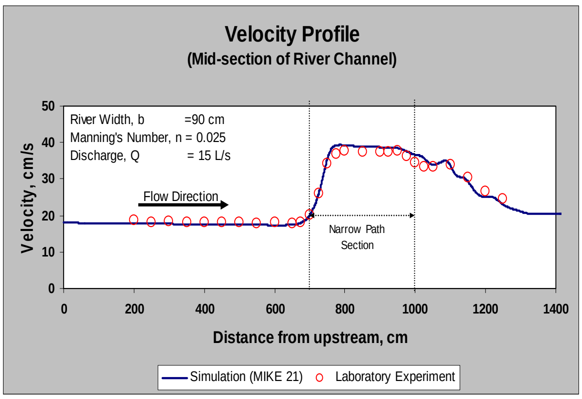

Figure 3: Velocity Profile

So with the velocity profile result in figure 3, velocity gradually increases as it enters the narrow path section of the channel. It is also observed that the velocity doubles its value at the narrow path section as compared to its velocity value at upstream section of the channel. Moreover, velocity decreases as it exits the narrow path section. Results of both experiment shows almost the same.

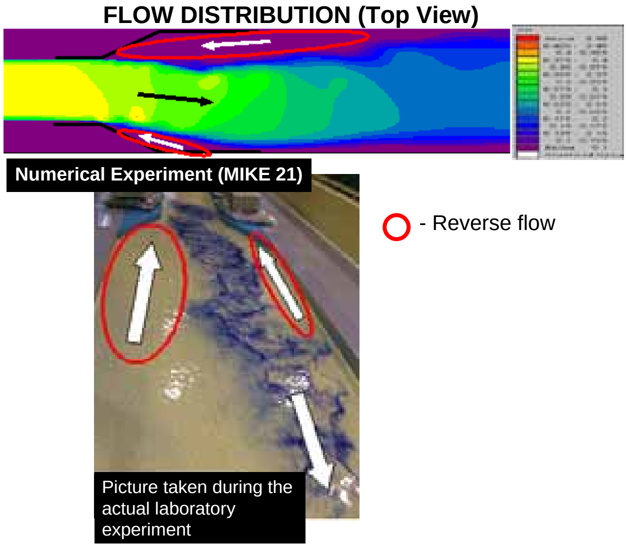

Figure 4: Quandering Flow

Figure 4 result shows that a quandering flow occurs as the flow exits the narrow path and when an adverse pressure gradient occurs along the side wall of the channel. This kind of flow was confirmed through laboratory and numerical experiments which shows almost the same results.

Case 2 (INUNDATED RIVER)

An experiment on an inundated narrow path river model was conducted to understand how the flow behaves in such kind of river condition. With the upstream boundary condition, Q equal to 30L/s and river conditions showed in figure 6, results were shown hereunder:

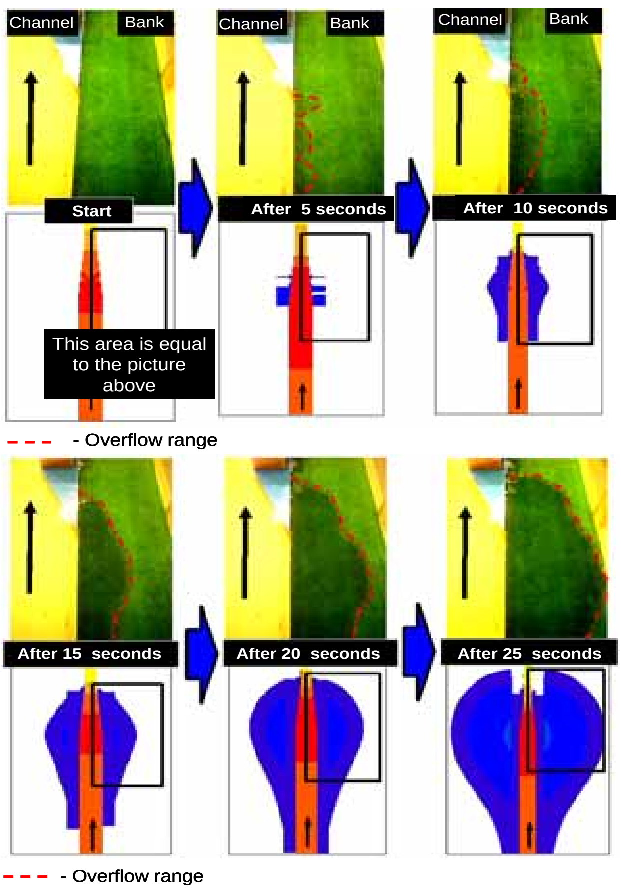

Figure 5: Inundation Results (0-25seconds)

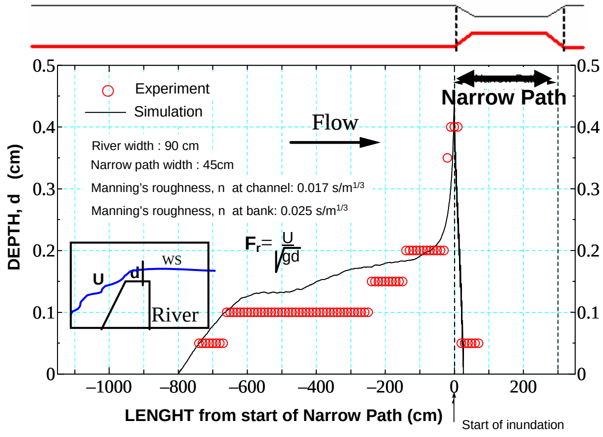

Figure 6: Water Depth Profile of Inundated River

Case 2 results in figure 5 shows that inundation starts at the upstream approach of the narrow path during the 0 to 25 seconds observation. Water starts to inundate from approach section back to upstream side direction.

Result in figure 6 on the other hand, shows that inundation flows up to 800cm (numerical) and 740cm (laboratory) from start of inundation going to upstream direction.

CONCLUSIONS

CASE 1:

Based on the results obtained from both laboratory and numerical experiments of this case, maximum water depth occurs at the approach section of the narrow path. On the other hand, maximum velocity occurs within the narrow path section. This case shows that as the flow approaches a narrow section of the channel, water depth abruptly increases and as it enters the narrow path, velocity gradually speeds up. The smaller the cross-sectional area of any channel, the higher the velocity. A flood control rigid structure should be constructed within the narrow path section to mitigate its turbulence since its where maximum velocity occurs.

CASE 2:

Both laboratory and numerical experiments on this case shows almost the same results since it shows only 8% difference. Inundation starts at the upstream approach section of the narrow path and flows horizontally and vertically, 800cm and 0.40cm, respectively. This case also concludes that this kind of river model/condition, approach section should be given extra attention especially when excessive rain occurs. A higher flood control structures should be constructed on the aforementioned section.

REFERENCES:

1. K.Suga, T. Ishikawa and T. Kasai, “The characteristics of failure embankment by overtopping”, Proceedings of the 25th Japanese Conference on Hydraulics (1981), pp. 355-360.

2. T. Ishikawa, “Water Surface Profile of a Flow Decreasing Discharge by Sidewall Overtopping”, Proceedings of the 26th Japanese Conference on Hydraulics (1982), pp. 417-422.