Comparison of Physical and Numerical Model on Dam Break Flood Wave Propagation in Horizontal Channel

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Abstract. This paper presents experimental results and the development of a numerical model for simulating dam break flood wave propagation. Floods caused by dam breaks have special flow characteristics due to potential energy caused by upstream and downstream elevation differences, and very high flow rates, from the collapse of the dam wall. The physical model is built on a horizontal channel, with 10 meters length and 1-meter width. The reservoirs used are upstream and downstream. Channels used are made of steel materials with negligible friction. The building used is made from wood with a volume of 10x10x40 cm. Flood wave propagation is modelled as a flash flood due to the mass movement of water in large quantities with the sudden opening of water gates. As the initial conditions, the door will be closed. On the upstream of the door, given the initial conditions of water level. Physical models result is used as calibration of numerical models. The developed numeric model is open foam that produces 3D modeling. The result of the physical model and numerical model show the highest flow velocity and good agreement of the pattern of flow velocity profiles during the first 3 seconds. The comparison of the Numerical model and Physical Model indicates whether the numerical model is feasible for use in dam-break modeling. For better results, it is necessary to develop a further model. Solutions to this physical and numerical model can be part of the mitigation effort in case the disaster phenomenon occurs.

1. Introduction
Indonesia is an archipelagic country with a very large population, so the clean water requirement becomes a major problem in the next generation. Therefore, Indonesia needs proper infrastructure to ensure the supply of water needs throughout the year. An alternative water supply infrastructure is a lake. In the rainy season, the lakes will become temporary storage of rainwater to prevent flooding. In the dry season, the lakes will provide water that has been stored during the rainy season. Lake is preferable to the reservoir as it is more constructive in terms of social, economic, and environmental. The advantages of the lake as a water supply infrastructure caused many lakes are built mainly in Jakarta as the capital with a densely populated population. Problems arise when Dam Break occurs in lake that causes a disaster. One of them is the Gintung Lake disaster that occurred in March 2009. Dams can collapse due to various reasons such as insufficient spillway capacity, piping, runoff, and earthquakes [1-2]. The damages caused by the dam failure incidents create disaster in the vicinity area of downstream reach causing loss of human life and loss of properties to the tune of millions to billions [3]. Cases of
major floods in residential areas have several issues that need further study. The flow direction that occurs no longer depends entirely on the topographic conditions of the land because of the buildings that block the direction of flow. The flow is direction changed because it hit the building. The modeling of buildings in the case of flooding this settlement is a challenge in flood modeling.

Accordingly, forecasting of severe floods is necessary for prevention and emergency plans, which may avoid live losses and severe damages [4]. The dam break experiment represents idealized conditions, where a gate separating the reservoir and the downstream channel is rapidly removed [5]. The physical model of dam-break flow has mainly involved measurement of temporal and spatial variation of water depth and velocity as the flow propagates as a rarefaction wave [6-12]. Nevertheless, the development of Dam Break's physical model is far from perfect because of the many parameters that affect it. Conceptual approaches are used to minimize the number of parameters that affect. These approaches require sufficient validation in the form of distributed speed water information in the propagation domain. The physical model study is one step to obtain information by doing the running model in the laboratory.

The numerical model dam break was developed to provide an overview of flow conditions as performed on the physical model. So, if the numerical model is feasible and gives results according to the observation, then the numerical model can be used to give the flow forecast due to dam break without the need to do a physical model in the laboratory. Hydraulic models for dam breaking include depth-averaged 2D models and 3D models, both have a mathematical model and numerical model; the other for the dam break model is the clustered model. Some scenarios such as Single Structure Failure Scenarios and Domino Effects (such as the collapse of various hydraulic structures and collapse of buildings) can be assumed [13]. This research is expected to give a result comparison between the physical model and numeric model on channel influenced by flow due to dam break. So, it can be seen whether the numerical model is feasible for use in forecasting flow due to dam break.

2. Method
2.1. Experimental Set-Up and Instrumentation
Dam break experiment facility developed by Kusuma et al. [14] in Civil Engineering Hydraulics Laboratory of Institut Teknologi Bandung. It consists of a rectangular horizontal channel of 10 m length, 0.85 m width, and 0.5 m depth. A reservoir that is used is at upstream and downstream. The channel's base is made of steel which its friction can be ignored. The channel wall is made of flexible glass with a thickness of 8 mm, which visually observes the flow of water. The channel bed is made of frictionless stainless steel. A small rectangular water pool is used as a reservoir in the upper part and as a water recirculation tank in the lower part. The upstream reservoir is made of concrete, 4 m long, 2 m wide, and 0.6 m high. The water recirculation tank is made of steel and is supported by a centrifugal pump and pipe (Figure 1).

Flood flow is modeled as a flash flood caused by the mass movement of large amounts of water with the sudden opening of the sluice gate. As an initial condition, the gate will be closed. In the upstream will give the initial conditions of water height 40 cm. The flow due to dam break will be modelled by a sudden opening of the swing gate (Figure 2). The swing gate made from steel is used to generate a dam-break flow. A dam break flow is generated every time there is a sudden upward swing of the gate. It is recommended to choose a swing gate rather than a vertical liftgate, as the horizontal movement of the swing gate appeared to decrease the failure related to the dam break wave, as rather low failures, were detected with reasonable opening speeds of the gate [15].

Flow velocity was measured using a current meter in Figure 3 supported by a digital data logger connected to the data acquisition system. The velocity measuring instrument used is a current meter with a diameter of 1.5 cm with a high-speed type that can measure the flow at high speed. The velocity measurement begins when the gate is opened until the velocity tool cannot read the value of the velocity of the flow passing at that point. The flow meter is positioned 2 cm from the bottom of the channel to obtain velocity data during low and high flow depth conditions.
Figure 1. Set up Model

Figure 2. Photograph of Channel and Dam Break Mechanism

Flow velocity meter used is a current meter that uses a fan, a counting machine that calculates the intensity of the rotation in units and the data logger as a recorder of data that records data over time and transfers it in the form of readable data by computer in volts. The current type of fan meter used is high speed (Tool Series No.: B2896), the digital counter used is streamflow-430, Data logger used Data Q (no tool series: DI-710).
2.2. Scenario Measurement Scenario

Measurements in the physical model of flood propagation within buildings due to Dam break are done in scenarios without buildings. Seed measurement points are measured from grid 2 to grid 8 and also measurements around the point of the building plan. Point Speed measurement is done at points in Figure 4.

2.3. Numerical Model

The model used in this study is based on the open-source computational fluid dynamics (CFD) platform called OpenFOAM (OpenCFD, 2008), available for free on the Internet OpenFOAM, primarily designed for problems in continuum mechanics using tensorial approaches and object-oriented techniques [13]. It is an open-source library (source file in C++) to solve partial differential equations and enables numerical breakdown adjustments for continuum mechanics with special emphasis on fluid dynamics. To simplify the numeric model and speed up the calculation process, the model is made in half part. This is due to fact in the laboratory, the physical model has a symmetrical shape, so it is considered that the other half has the same condition because it has the same parallel parameters and conditions (See Figure 5).
3. Results and Discussion

The comparison between the physical model and numerical model result is presented in Figure 6. The computational mesh is taken as a rectangular grid. The initial condition at the reservoir is set as 40 cm. Measurement point are taken at 2E5 (+1.45 m), 3E5 (+2.45 m), 4E5 (+3.45 m), 5E5 (+4.45 m), 6E5 (+5.45 m), 7E5 (+6.45 m) and 8E5 (+7.45 m).

![Figure 5. Model Domain](image)
Figure 6. Time Evolution of Speed for Configuration without Building. (a) Station +1,5 m (Channel 2E5) (b) Station +2,5 m (Channel 3E5) (c) Station +3,5 m (Channel 4E5) (d) Station +4,5 m (Channel 5E5) (e) Station +5,5 m (Channel 6E5) (f) Station +6,5 m (Channel 7E5) (g) Station +7,5 m (Channel 8E5)

Figure 6-a and Figure 6-b show that the numerical model gives a bigger value than the physical model for all time. The comparison results show that there is a velocity difference, an average of 0.5 m/s during the observation time but obtained a similar pattern. Figures 6-c, 6-d, 6-e, and 6-f show the numerical model gives a slightly different result with the physical model, especially for 1-5 s. After 8 s, the numerical still show velocity difference but still have a similar pattern. Figure 6-g shows that at in seconds to 6 and to 7 physical model results indicate that the velocity is greater than the velocity obtained in numerical model results, but after 8 s the numerical result gives the bigger value than the physical model. The results of this study provide the same results as the research conducted by Kusuma et al. [14], wherein a configuration without building the highest speed at the 5th second occurs at 3.5 meters from the gate.

Overall, the value of the numerical model velocity is greater than the value of the physical model. This is because in the numerical model, the conditions are considered ideal, the channel is considered frictionless. Whereas in the physical model, although the bottom of the channel is frictionless, there may be friction due to the bottom condition of the channel even though it is small.

4. Conclusion
The simulation result described earlier shows that a numerical model based on the open-source computational fluid dynamics (CFD) platform called Open FOAM give a good result in solving the dam break problem. Although not giving exact results exactly as resulted in the physical model, the result of this numerical model is able to give an idea of the result of speed changes due to breaking dam flow. In general, there is reasonable agreement between the experimental data and numerical results. Due to the
difficulty of obtaining field data for such a flow, laboratory data may be necessary for researchers to verify their mathematical models.

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