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EXPERIMENTAL MODEL OF DAM BREAK FLOW AROUND SEVERAL BLOCKAGES CONFIGURATIONS

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ABSTRACT: Dam break flood flow might lead to a very high risk of a disaster causing massive destructions either in life or property. It is more complicated if it occurs in an urban area due to the appearance of buildings that block the flow. Modeling is a tool that is common use to study dam break flood propagation to provide information of flow characteristics and mechanism of a dam break. Experimental model has been preferable due to difficulties in obtaining field data during flood flow. In this study, an experimental model with several configurations of blockages to simulate dam break flow in the urban area is developed. The purpose is to investigate flow properties in term of flow depth and flow velocity due to dam break flood flow in the urban area in term of mitigation plan and to provide a valuable tool for numerical model calibration and validation for the numerical model. The model is developed for no building case and several configurations of blockages. Flow depth and flow velocity at several points are observed to investigate flow properties. Based on the results, it is found that a significant change in water depth occurs in t = 5 seconds until t = 7 seconds. Flow velocity is also found to increase uniformly at all observed area. It is also found that energy in one building configuration is much bigger than in no building case. Furthermore, flow occurred in the no building model is subcritical and supercritical flow while in one building configuration, the flow is subcritical flow.

Keywords: Dam break, Experimental model, Flood flow, Blockages configuration, Disaster mitigation

1. INTRODUCTION

Indonesia is an archipelagic tropical country which has the largest area and the fourth rank population in the world. As a developing country, its population is not well distributed so that Indonesia faces freshwater availability problem as one of the major issues in its development programs, especially in several developed areas like West Java, Central Java, East Java etc., and several arid areas like Flores, Sumbawa etc. [1]. Therefore, water infrastructures such as a reservoir, long storage, irrigation canal, groundwater well and rain harvesting are needed to overcome this issue. Rain harvesting is a potential choice from the aspect of green water management but still requires a more in-depth and comprehensive study to find out the feasibility of its application in Indonesia [2]. That’s why reservoir still become the most favorable choice as it’s been well developed since a century ago in Indonesia. There are two types of reservoirs only: a large/medium reservoir (waduk) and small reservoir (embung/situ). The average age of the existing reservoir is above 50 years old so most of it suffered from urbanization that generates sedimentation [3] and water quality problem [4]. Sedimentation caused a decreasing capacity and increasing dam failure risk. Water quality degradation generates an increasing of dam break flood disaster risk to vulnerable people, livestock agriculture and places.

Small reservoir (situ/embung) is more favorable to develop in Indonesia as it has many advantages compared to a large reservoir. Its development is less socio complex, lower risk and more matched to climate change adaption compared to a large reservoir. However, the disaster risk of its dam break is still event very high as it's downstream usually become a favor urban area development. Sudden release of a large mass of water from the reservoir as a result of structure failure caused by an earthquake, and other factors, might cause massive destructions either in life or property particularly in an urban area [5,6]. Previous dam break case in Indonesia occurred on March 27th, 2009 in Situ Gintung which is located in Cirendeu Sub-district, Banten Province. Situ Gintung was built by the Dutch Government in 1932 [7]. The breaking dam generated massive flood that damaged many buildings, killed more than 90 lives and caused 100 people missing [8], causing great loss to the citizens and government.

During 2015-2019, the Indonesian government through the Ministry of Public Works and Housing plans to construct 65 dams to overcome water security and food security problem. In order to mitigate better the dam break flood risk of all the developed dam, it is then important to address the development of its tool prediction. This disaster mitigation activity includes identifying potential damage by studying the flood flow generated by a dam break. The study requires modeling of dam break flood propagation to provide information of flow characteristics and mechanism of dam break which is very significant to understand dam failures, dam development processes, disposal dam breaks, sudden flood disasters, and formulate emergency action plans [9]. Propagation of flood flow moving to the downstream area due to dam break occurrence is potentially dangerous to its surrounding areas and it is very important to have an accurate estimation of flow depth and flow velocity in order to have emergency planning. Regarding this matter, it is a challenge to predict dam break flow for researcher [10].

One of the most interesting in predicting dam break flow is the distribution of velocity in free-surface flow since it can provide a better understanding of the flow structure and the flow resistance [11]. However, the flow depth is also interesting and challenging because it allows for knowing water depth information which is important for hazard analysis. Flow depth is also more practical and easy to measure. Furthermore, velocity and energy loss in dam break flow can be calculated based on flow depth. Information of flow depth and flow velocities can be obtained either from field observation or from a laboratory experiment. In dam break flood case, laboratory experiment has been considered as a valuable tool because it may provide detail information of flow properties and can be used for numerical model calibration and validation [12]. Furthermore, it is more preferable due to difficulties in obtaining field data during flood flow [13].

In case of major flooding generated by a dam breaking in a residential area, it has some problems that need to be explored further. The direction of flow was no longer completely dependent only on the topography of land but also on the buildings that blocking the flow direction [14]. Buildings block flood flow and change its direction. This phenomenon is very important to be studied further because of flooding problems like this are common in many neighborhoods in the capital and caused in losses that are not small

This paper presents a dam break experimental model with several configurations of blockages to represent the building area in real cases. The purpose of this study is to investigate flow properties in term of flow depth and also flow velocity due to dam break flood flow in the urban area. It is expected that this study can provide good understanding and insight of dam break flood flow characteristic so that it may contribute to the mitigation plan as well as to facilitate calibration and validation for the numerical model.

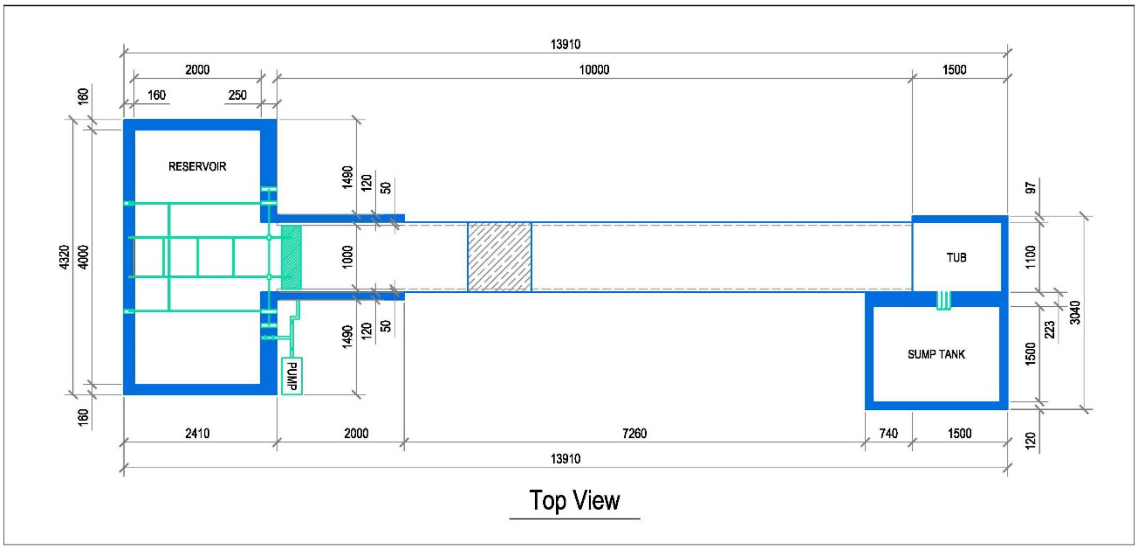


Fig.1a Layout of the constructed physical model (top view)

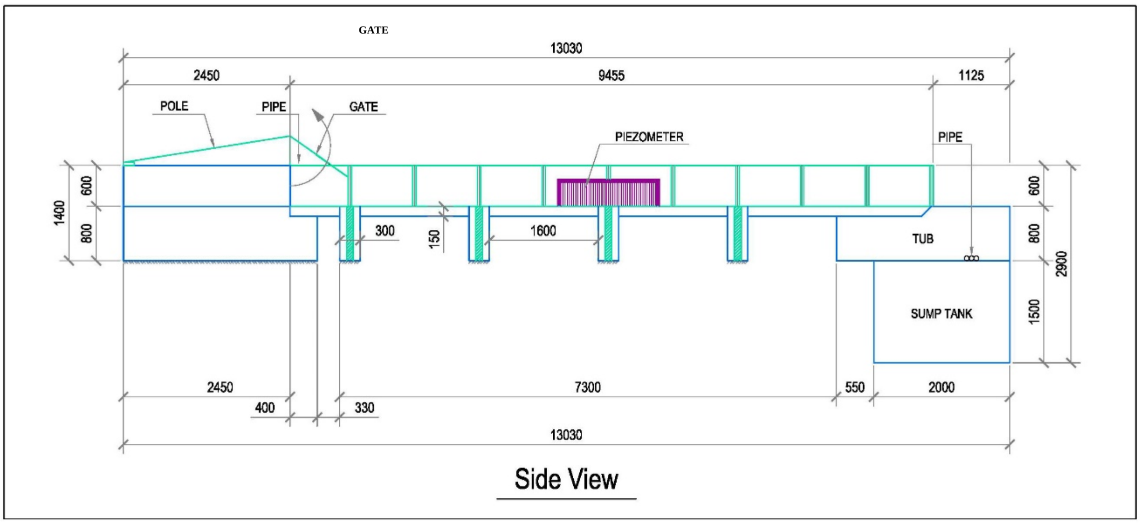


Fig.1b Layout of the constructed physical model (side view)

2. EXPERIMENTAL SETUP

The experimental setup of dam break flow is shown in Fig.1 and Fig.2. It consists of a flume, an upstream square tank, a downstream sump tank, a water circulation system, a flap gate and measurement system. The flume is developed as an open channel with 10 m long, 1 meter wide and 0.5 meter high. The channel wall is made from 8 mm thickness of flexible glass to allow visual observation of water flow. The channel bed is made from 5 mm rust protected steel to assure the placement of obstructions and piezometers. This channel bottom is marked by square mesh grid points with a resolution of 10 cm. The flume divided into 10 sections, where each section size is 1x1 m^2 and consists of ten points on the longitudinal x-axis and nine points on the transversal y-axis (as shown in Fig. 3). The upstream tank, which represents as a reservoir, is made from concrete with 4 m long, 2 m wide and 0.6 m high. The downstream sump tank is used to store water of dam break flow from the channel. The centrifugal pump is used to restore the water from the sump tank into the upstream tank through a pipe network 15-30 minute before the flap gate could be open. The flap gate is hinged on a horizontal steel bar that one could suddenly open by swinging its upper arm. This upper arm is bent steel bar so that the flap gate will be opened due to its moment on the hinged. The dam break flow is generated by swinging the upper arm of the flap gate. This generating flow mechanism is developed based on the observation result of Situ Gintung Dam Break case as discussed above.

The experimental work was conducted in three different initial conditions for each disturbed and non-disturbed dam break flow condition. The initial condition of dam break flow is set up in the upstream reservoir for a water depth of 20 cm, 30 cm, and 40 cm. The non-disturbed dam break flow is performed to identify the free flow profile from upstream part to downstream part. The disturbed dam break flow is performed to identify the influence of the installed obstacles to the flow profile from the upstream part to the downstream part. The obstacles which represent building in an urban area are made from a wood rectangular prism of 10 cm wide, 10 cm long and 15 cm high. These obstacles were placed following 4 configurations as shown in Fig. 4, which are one building, three buildings, five buildings, and eight buildings

(a) (b)

Fig.2 Dam break experimental model (a) Reservoir (b) Channel

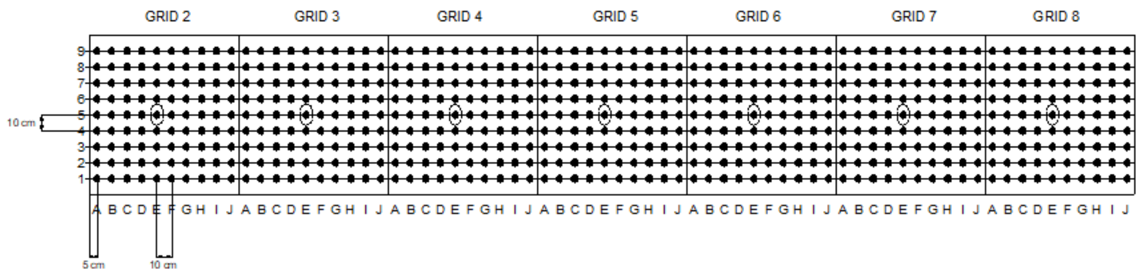
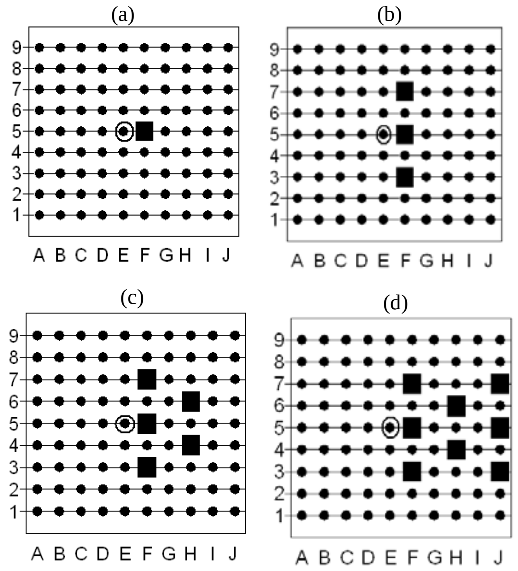


Fig.3 Grid location in dam break model



■ : Building position

Fig.4 Configurations of blockages: (a) one building, (b) three buildings, (c) five buildings, and (d) eight buildings

(a) (b)

Fig.5 (a) Current meter and wave probe (b) Piezometer

The water gate is suddenly opened and maintained until the water stops flowing in the channel. The observation results are presented in Fig. 6 to Fig. 8.

The dam break flow is investigated based on its flow depth and flow velocity. However, for this stage experimental work, flow velocity investigation is conducted only for the case of building and one building because this research is more focus in flow depth investigation due to its practical application.

The measurement devices used in this experiment, as shown in Fig.5, are wave probe, current meter, and piezometer. Wave probe and piezometer are used to measure the water level in every observed point. Wave probe is performed with a data logger to records data over time and move it in the form that is read by the computer in units of volts. The measurement of water level is performed from the opening of the water gate until the device could not read the value at the points.

The current meter is used to measure flow velocity. The measurement of velocity is performed from the opening of the water gate until it could not read the value of velocity at the point. The current meter is considered valid if the water level measured is over the size of the propeller (1.5 cm). During the measurement, this current meter is placed at the right side of the probe wave devices. It is used to make each experiment easier.

3. RESULT AND DISCUSSION

Based on the observation results of all configurations, it is obtained that a significant change of water depth occurs in t = 5 seconds until t = 7 seconds. However, most of the results show that the most significant change in water depth occurs in t = 5 seconds. Therefore, comparison of all configuration of blockages, including with no building, is analyzed based on t = 5 seconds as can be seen in Fig.6 to Fig.8

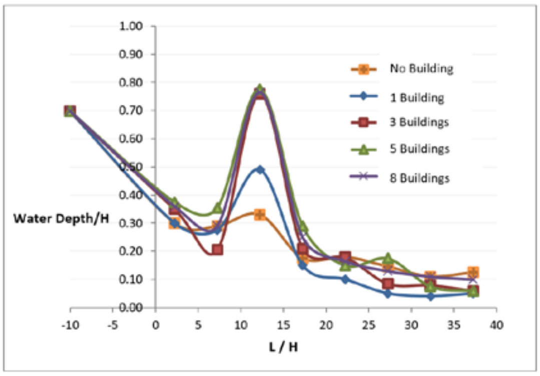


Fig.6 Comparison of water depth in long section profile for t = 5 second and initial reservoir depth = 20 cm

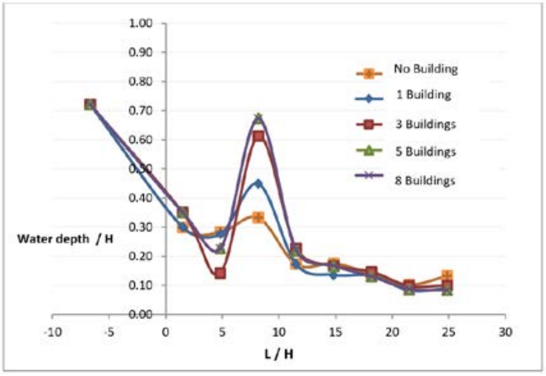


Fig.7 Comparison of water depth in long section profile for t = 5 second and initial reservoir depth = 30 cm

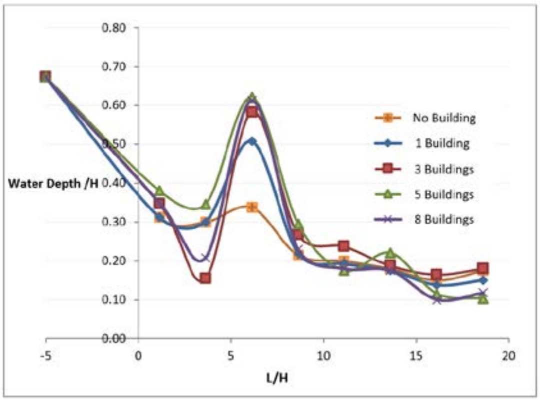


Fig.8 Comparison of water depth in long section profile for t = 5 second and initial reservoir depth = 40 cm

Based on the above figures, it can be seen that the water depth in all configurations (one building, three buildings, five buildings, and eight building) has the same pattern but differences magnitudes. The water depth increases significantly at the observed point located 2.45 m in front of the dam break which is point 3E5. It is considered to occur because the point is located near the building(s) (10 cm in front of the building(s) so that there is backwater phenomenon due to blockage of the building(s). Furthermore, at that point, water hit the first building located in point 3F5 where the flow velocity is zero so that the maximum value of water depth occurs. The maximum energy is also occurred due to the effect of the building(s). For the case of no building, the flow does not increase significantly in term of depth and velocity in any observed points. Above figures show that flow depth increases gradually and continuously from the upstream part until the downstream part. Fig. 6 to Fig. 8 show that there is no significant influence of blockages with more than 3 building to the peak of flow depth profile in t= 5 seconds.

Flow velocity measurement for this dam break flood flow experiment is conducted in order to investigate the velocity profile before and after the effect of building existence. This experiment is conducted for no building case and one building configuration with an initial condition of 20 cm water depth. The position of flow velocity measurement is shown in Fig.9 and Fig.10.

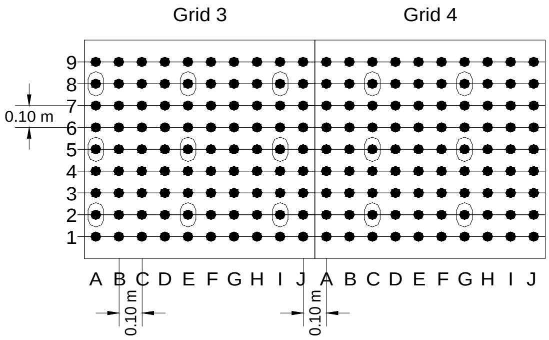


Fig .9 Position of flow velocity measurement for no building case

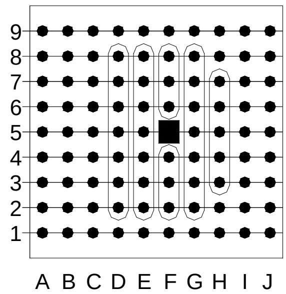


Fig.10 Position of flow velocity measurement for one building configuration

The results of flow velocity measurement in t = 5 seconds are shown in Fig.11 and Fig.12. For the case of no building, it can be seen that flow velocity starts to increase uniformly at all observed area. The maximum value of flow velocity is also obtained in this measurement time at downstream observed point 4C2, 4C5, and 4C8. For the case of one building configuration, flow velocity starts to increase due to the change of water volume to time in the upstream reservoir which also cause the change of velocity to time (flow acceleration).

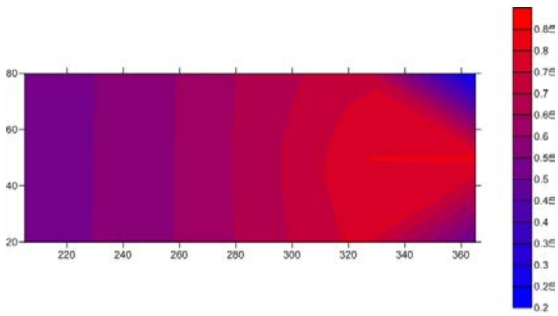
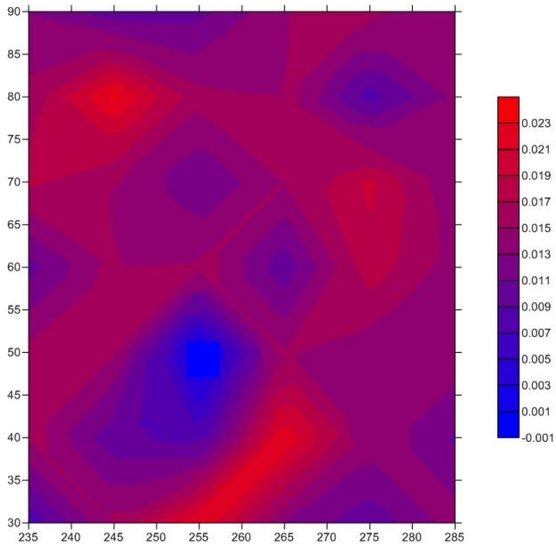


Fig.11 The position of flow velocity measurement for no building case



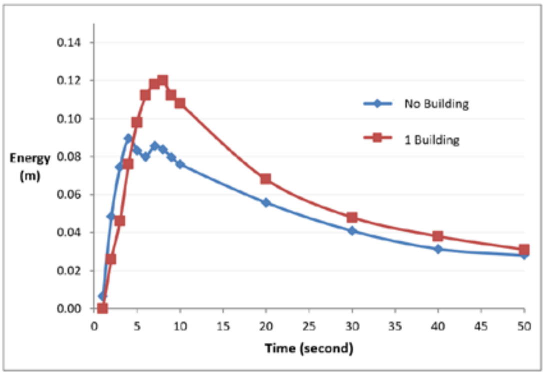


Fig.13 Comparison of energy to time for no building case and one building configuration in observed point 3E5

Based on the measurement result of flow depth and flow velocity, investigation of energy depth is conducted. As it is shown in Fig.13, a significance differences of energy are identified between no building case and one building case. Energy depth of one building configuration is much bigger than that of no building case. This is occurred due to the location of an observed point which is in front of the building. In this point, the flow velocity became zero as the water hit the building so that the water depth increases significantly.

Based on flow velocity and flow depth observation, the value of Froude number then can be obtained. The calculation results of the Froude number are presented in Fig.14 and Fig.15. As shown in Fig.14, the flow is subcritical in the first second period, then critical and supercritical during the 1-4 second period, and finally became sub critical for the rest of time. The highest Froude number occurred around 2 seconds after the opening gate. This condition obviously shows that the dam break flow of one building case much more dissipated compared to that of no building case.

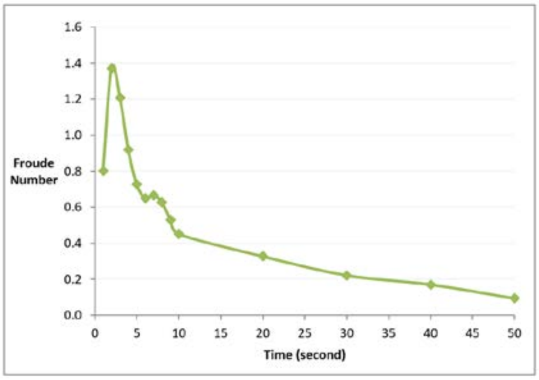


Fig.14 Froude number vs time for no building case at observed point 3E5

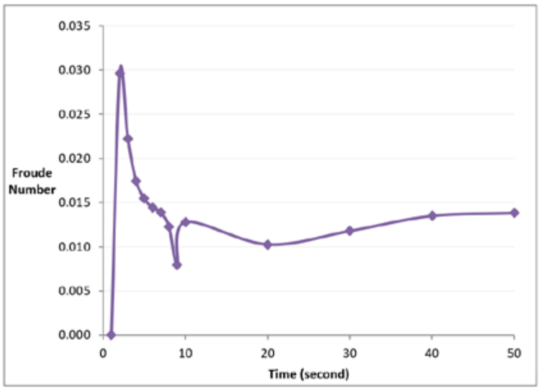


Fig.15 Froude number vs time for one building configuration at observed point 3E5

4. CONCLUSIONS

A laboratory physical model for dam break flood flow is developed to study the longitudinal profile of its water depth and its flow velocity. The experimental model is conducted to simulate dam break flow in no building case and several configurations of blockages (one building, three buildings, five buildings, and eight buildings). Flow depth and flow velocity are observed at several points to investigate longitudinal flow profile of velocity, energy, and Froude number.

Based on experimental results, it is found that a significant change in water depth occurs in t = 5 seconds until t = 7 seconds. However, most of the results show that the most significant change in water depth occurs in t = 5 seconds. The water depth in all configurations (one building, three buildings, five buildings, and eight buildings) has the same pattern while for the case of no building, the flow does not increase significantly in term of depth and velocity in any observed points. Regarding the flow velocity in t = 5 seconds, it starts to increase uniformly at all observed area and the maximum value is obtained at downstream observed point while for the case of one building configuration, flow velocity starts to increase due to change of water volume to time in the upstream reservoir which also cause the change of velocity to time. It is also found that energy in one building configuration is much bigger than in no building case due to the location of an observed point which is in front of the building. Furthermore, flow occurred in the no building model is subcritical and supercritical flow while in one building configuration, the flow is subcritical flow.

Results of this experimental study can give a better understanding and insight of dam break flood flow characteristic which can be useful as a consideration in planning disaster mitigation effort. It is also can be used as a tool for numerical model calibration and validation. The on-going research now also uses this result to improve the performance of the dam break numerical model. However, some improvement of the existing measurement device is needed to get a better flow depth and velocity data in further work. It is also suggested to conduct dam break flow with the case of the mobile bed for future research.

5. ACKNOWLEDGMENT

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