INVESTIGATION OF THE PROPERTIES OF FLOW BENEATH A SLUICE GATE

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ABSTRACT: Generally, empirical equation is widely being used in few decades by the engineer in designing an open channel system. The prediction of water surface elevation in open channel is quite important in order to evaluate and to determine the required sidewalls height of the channel. However, determining the depth of flow is complicated by side inflows and boundary features with existing of transition structure such contractions, expansions, curves, weir and obstructions. This study is objected to predict the properties of flow beneath a sluice gate using physical model to analyze the profile of water surface around the sluice gate. As the results of analysis, some graphs have been provided to present the relationship among flow rate, flow depth, gate opening and specific energy with indication that the flow rate and the opening of gate are the most important parameters to form the profile of water surface of flow beneath a sluice gate.

KEYWORDS: Sluice gate, Open Channel Flow, Free Surface Flow

1. INTRODUCTION

A sluice is a water channel that is controlled at its head by a gate. A sluice gate is traditionally a wooden or metal plate which slides in grooves in the sides of the channel. Sluice gates are commonly used to control water levels and flow rates in rivers and canals.

1.1 Problem statement

Water is one of the most important things for humans. Experts devise many methods to obtain this source in the easiest and most impressive. So that, human were contributed wire at a main river to get the water. At the same time, it is one way to overcome flood disaster at upstream river and it also can provide hydrostatic energy.

Due to the fact that design wire is too big, overflows will occur near wire during rain session at catchments area at upstream. Thus, studies about sluice gate were recognized to control the water levels and flow rates in rivers and canals from overflowing. When a sluice gate is fully lowered, water sometimes spills over the top, in which case the gate operates as a weir.

Figure 1: Sluice Gate Location at Sungai Sembrong in Parit Raja

While we detected the effect that will occur due to flow changing, many types of method were recognized to prevent this problem. One of the ways to prevent this issue is by building up the wire together with the sluice gate as a control flow stream. The structure is important due to its primary function which controls flood when it occurs, prevents tidal level, acts as a hydroelectric power generator and as water source (supply to water).

Thus, this study includes the laboratory aspect that present the open channel model with sluice gate where the functions will be applied to study the flow stream to preventing flood and supply water at the real site.

1.2 Objectives

The objective of this study is to determine and investigate the properties of flow beneath a sluice gate and to determine the relationship between the specific energy and flow depth which can cause by water flowing under a sluice gate.

1.3 Scope of study

This study will focus on investigating the characteristics of flow and to determine the profile of stream for water flowing under a sluice gate. Laboratory test will be carried out to find the interconnected data, such as water level, opening of the channel, the flow velocity and the related data in open channel. This laboratory study will be done at the Water Resources Laboratory, Department of Water Resources and Environmental Engineering, UTHM. Sluice Gate in open channel model will be used to recognize the concept of stream.

2. LITERATURE REVIEW

Figure 2 shows a schematic drawing of the side view of the sluice gate. Flow upstream of the gate has a depth *ho* while downstream the depth is y_1.

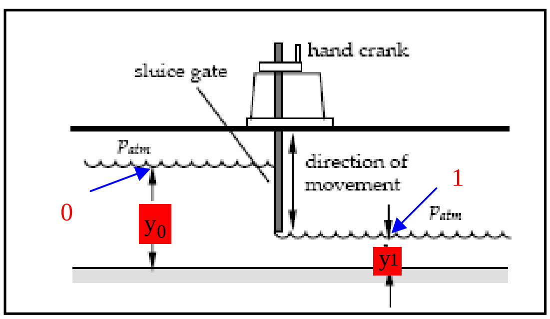

Figure 2: Flow beneath sluice gate

The flow rate through the gate is maintained at nearly a constant value. For various raise positions of the sluice gate, different liquid heights y_0 and y_1 will result. Applying the Bernoulli equation to flow about the gate gives

$$\left(\frac{v_0^2}{2g}\right)+\left(\frac{P_0}{\rho g}\right)+y_0=\left(\frac{v_1^2}{2g}\right)+\left(\frac{P_1}{\rho g}\right)+y_1$$

The velocity at point 0 is too small if compare with velocity at point 1. Then, $v_0 \simeq 0$ and $y_0 = E_0$. The pressure at point 0 and point 1 are both equal to atmospheric pressure, so that Po = P1, so they cancel each other then rearranging the formula gives

$$y_0 - y_1 = \left(\frac{v_1^{\,2}}{2g}\right)$$

3. RESULTS AND DISSCUSSIONS

Using certain similar energy, the amount flow and other related data which use Excel to processes the experiment parameters. The result will be in 3 types of graph where the experiment is illustrated as follows:

i) *Flow Depth against Flow Rate*, *Q*. This graph shows the relations between flow rate and flow depth to each opening of sluice gate.

ii) *Flow Depth* y0, y1 *and* y2 *against Flow Rate*, Q. This graph shows gradient graph for flowing through each opening of sluice gate.

iii) *Flow Depth against Specific Energy*. This graph shows the relations between specific energy and flow depth (ideal) with opening and flow rate per unit width, q is determined.

3.1 Data Analysis and Discussion

This experiment has been conducted in 15 times for each 5 opening and 5 different flow rates to get the flow pattern and ideal flow rate for each opening.

3.1.1 The Properties of Flow beneath Sluice Gate

Figure 3.1 shows at opening of 20 cm and flow rate of 0.014m³/s, no flow depth at y0 because of over flow at this level. While, flow depth, y0 at opening of 25 cm and flow rate of 0.014m³/s reach 0.447m compared with opening of 40 cm at same flow rate, the flow depth at y0 reduces till 0.212m. The result shows that the highest flow depth level increase with additional flow rate when opening gate is becoming smaller.

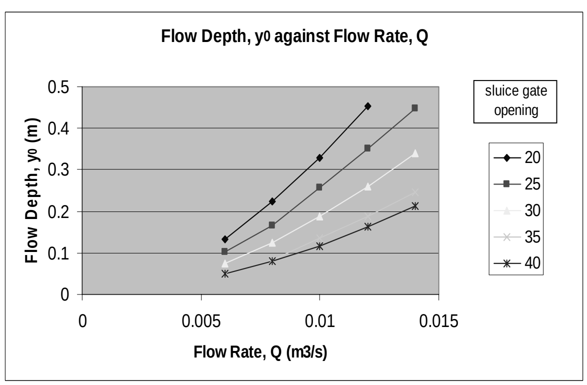

Figure **3.1:** Relationship between flow rate and flow depth, y0 for every opening

While in Figure 3.2 found that the depth at y1 changing at each 5 opening where the flow rate are 0.006, 0.008, 0.010, 0.012 and 0.014 m³/s. It shows the ratio of flow depth level become higher while the flow passes through the bigger opening gate.

Figure 3.2 also shows that the gradient graph is level at each opening gate except at the opening of 35 cm and 40 cm (flow rate 0.006m³/s). This is because the back flow happens at that opening and cause the depth at y1 and y2 are almost same. Generally the increase of depth y1 is relative with the increasing size of opening but additional flow rate does not influence the increasing of flow depth.

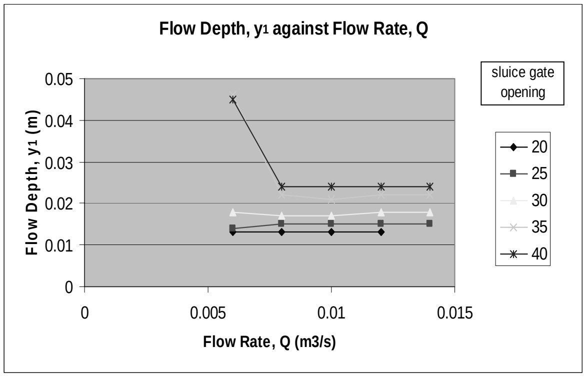

Figure 3.2: Relationship between flow rate and flow depth, y1 for every opening

While for the flow depth at y_2 for every gate opening is same as the flow depth at y0. The result shows that the highest flow depth level increases with additional flow rate and the gate is opened smaller.

3.1.2 Gradient graph

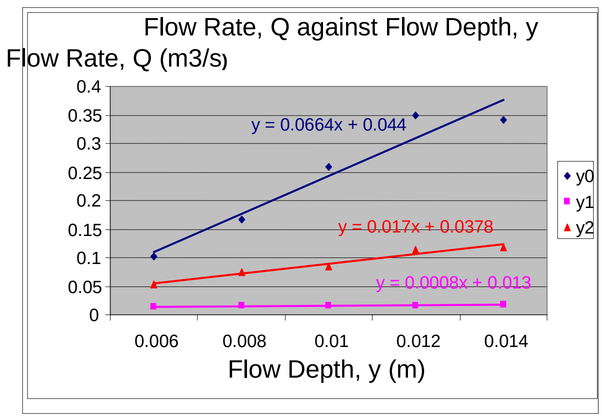

Figure 3.3: Gradient Graph for Flow at Opening 0.25 cm

From: **y = mx + c**

Equation shown is used to determine the flow depth (y0, y1, y2) for each opening with flow level have been determined first and the value of c is constant as in the derivative equation (see table 3.1). The gradient changes between lines y0 and y2 at all opening are sloping because with a bit increase flow rate will cause the big changing at the flow depth. Whereas at gradient y1 for each opening is level. This is due to the flow rate at y1 is increased without influencing the gradient at that flow depth. Diagram 4.3 is an example of gradient graph for flow at the opening 0.25 cm.

Table 3.1: Summary of Gradient Result for every Sluice Gate Opening

Opening (cm)	y_0	y_1	y_2
20	y = 0.1064x + 0.018	y = 0.013	y = 0.0229x + 0.0295
25	y = 0.0664x + 0.044	y = 0.0008x + 0.013	y = 0.017x + 0.0378
30	y = 0.067x + 0.0036	y = 0.0178	y = 0.0187x + 0.0237
35	y = 0.0501x - 0.0107	y = -0.0048x + 0.041	y = 0.0192x + 0.0168
40	y = 0.0409x + 0.0017	y = -0.0042x + 0.0408	y = 0.0162x + 0.0194

3.1.3 Types of Hydraulic Jumps

Base from table 4.2 at reference are the few types of hydraulic jump at each opening and flow rate. From the experiment, found that at flow rate 0.006m³/s and at opening 0.20m, oscillating jump occurs because the value of Froude number is 2.89 is between 2.5<Fr<4.5. (Figure 3.4). While, increasing of flow rate at same surface, the hydraulic jump changing to the steady jump (4.5<Fr<9.0). (Figure 3.5)

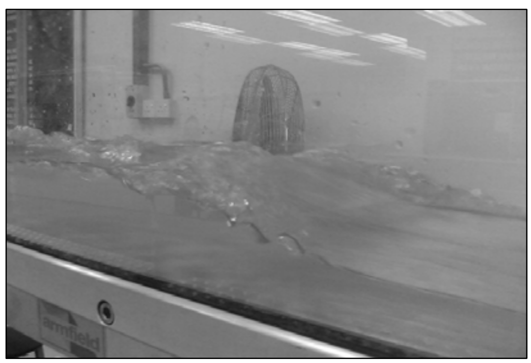

Figure 3.4: Oscillating Jump

Figure 3.5: Steady Jump

As for others opening shows when flow rate increased, the hydraulic jump becomes strong. From table 4.2 also shown at opening 0.35m and 0.40m (0.006m³/s) the value of Froude number is less than one. Hence, no hydraulic jump happened due to back flow occurs at that opening. (Figure 3.6)

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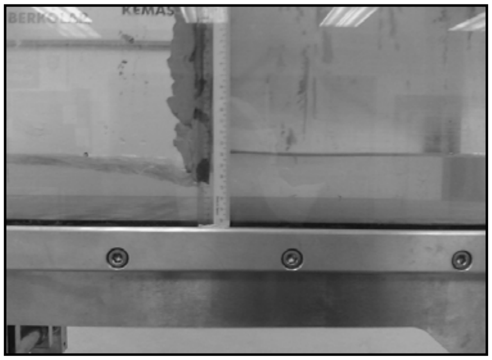

Figure 3.6: Back Flow

3.1.4 Relationship between Specific Energy and Flow Depth

From the research found the relationship between the flow depth (y) and the specific energy (E) to each opening and flow rate. Energy value to flow through y1 is the highest compare with y0 and y2. This is because at y1 the hydraulic jump was occurring. So, more energy required to flow through at that area.

For the opening of 0.20 m required high energy to ensure through flow beneath the sluice gate compared to other openings**.** This is happened because of the small opening sluice gate were needed higher energy to force at the gate. Figure 3.7 is an example of Specific Energy Curve with opening sluice gate at 0.20m.

Table 3.2: Sluice Gate Opening 0.20m, Flow Rate 0.008 m³/s

Flow Depth, y (m)	Flow rate per unit width, q ($m^3/s/m$)	Specific Energy, E (m)	Energy Dissipated (dE)	Power Dissipated, ΔP (W)
y0=0.224	0.027	0.225	0.055	3.532
y1=0.013	0.027	0.233		
y2=0.081	0.027	0.087		

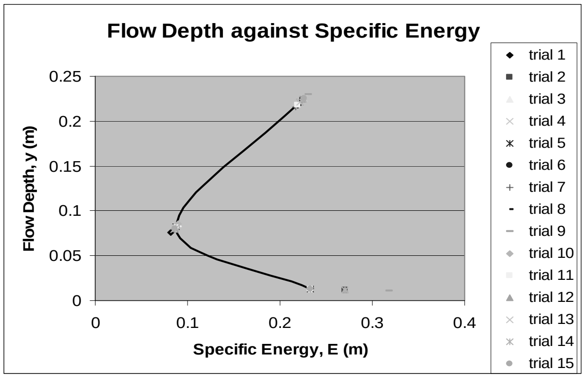

Figure 3.7: Specific Energy Curve with Opening Sluice Gate 0.20m, Flow Rate 0.008 m³/s

While at the opening 0.35m and 0.40m with flow rate of 0.006m³/s, the energy dissipated becomes negative. (See Table 3.3). This is because the situation of back flow happens without needed energy to beneath the gate; subsequently the energy is from the opposite direction to the force of water. Figure 3.8 shows that the specific energy curve when back flow occurs.

Table 3.3: Sluice Gate Opening 0.40 m, Flow Rate 0.006 m³/s

Flow Depth, y (m)	**Flow rate per unit width, q ($m^3/s/m$)**	**Specific Energy, E (m)**	**Energy Dissipated (dE)**	**Power Dissipated ΔP (W)**
y0=0.049	0.020	0.064		
y1=0.045	0.020	0.055	-0.009	-0.530
y2=0.044	0.020	0.055		

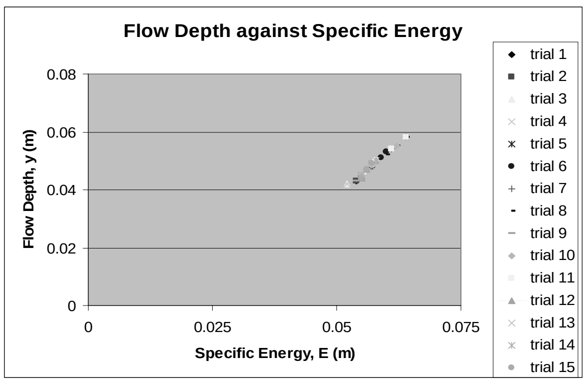

Figure 3.8: Specific Energy Curve with Opening Sluice Gate 0.40m, Flow Rate 0.006 m³/s

4. DISCUSSIONS

In this study, the survey is more focus to laboratory experiment, used open channel flow model with sluice gate where the functional to application as to see the properties of flow beneath a sluice gate and to determine the relationship between the specific energy and flow depth which can cause by water flowing under a sluice gate.

From the experiment and the relationship graph between flow rate and flow depth, we found out the criteria of hydraulic through fives opening, where the flow depth y0 and y2 show the decrease of opening, the increase of flow rate hence the higher flow depth found. Whereas for flow depth at y1, when the smaller gate opening, the higher flow rate is impose, so the water level become lower.

From gradient graph shown the derivative equation and gradient value at each opening gate between y0, y1, and y2 are different. The function of this equation is to get the flow depth, y for each values of sluice gate opening with flow rate, x been determine first. With enter any flow rate value to the equation; the flow depth at any opening from this study can be determined.

In overall, it is found that the amount of flow rate and the opening of sluice gate is very important in identifying the flow properties at sluice gate. At flow depth of y0 and y2 shows the higher flow rate, the highest depth measurement can be obtained. Whereas at flow depth of y1, the increase amount of flow rate does not influence the flow depth.

Hence, from the specific energy curve shows that the value of ideal flow depth and specific energy for each opening and flow rate is given as follows:

i) At the opening of 0.20m requires the highest energy to go through the sluice gate. This is possible for small opening gate that cause higher force at the gate.

ii) Energy dissipated during hydraulic jump can cause power dissipated. Power dissipated depending on the amount of flow forced, energy dissipated, the opening of sluice gate and other more characters.

iii) The curve also shows the higher measurement in flow causes the energy increased for subcritical, but increase measurement flow causes losing energy for super critical flow.

In conclusion, the smaller size of opening the sluice gate, hence more energy required for through to the sluice gate.

5. RECOMMENDATIONS

From experiment conducted in lab, still found lacking of perfect result. The recommendations below are some of the improvements that can be carried out for further study.

i) Variety study scope such as variable position sluice gate to see the effect against changing of flow found.

ii) The data which conducted should be more and sufficient to find the best flow profile especially to get curve shape as required

iii) As for continuous study, suggest that, to get the flow profile through bigger amount of flow rate and opening of sluice gate than the amount of this study. Other than blocking structure i.e. boxes, pillar and bends put it in front of sluice gate can be suggested to see the changing of flow depth.

iv) Design sluice gate and open channel model can be modified from square to triangle or trapezium.

v) In order to increase the accuracy of each laboratory test, every single error should be avoided. For example, the general error, which is caused by lack of experience while conducting the laboratory test like wrong way of reading data or recording data and errors in calculation. These can be avoided by practices and reading data more than one time.

vi) Apart of the above, the laboratory tests maybe influenced by conformance error; which is caused by the wrong way of equipment setting-up. Thus, a thorough understanding every of equipment is needed before running the relevant tests.

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