GATED SPILLWAY HYDRAULIC MODELLING OF SULTAN ABU BAKAR (SAB) DAM AND THE GATED SPILLWAY

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UNIVERSITI SAINS MALAYSIA
2017

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By

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This dissertation is submitted to

UNIVERSITI SAINS MALAYSIA

As partial fulfilment of requirement for the degree of

BACHELOR OF ENGINEERING (HONS.)
(CIVIL ENGINEERING)

School of Civil Engineering,
Universiti Sains Malaysia

May 2017

SCHOOL OF CIVIL ENGINEERING
ACADEMIC SESSION 2014/2015

FINAL YEAR PROJECT EAA492/6
DISSERTATION ENDORSEMENT FORM

Title: Gated Spillway Hydraulic Modelling of Sultan Abu Bakar (SAB) Dam and the Gated Spillway

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I hereby declare that all corrections and comments made by the supervisor(s)and examiner have been taken into consideration and rectified accordingly.

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Date :

ACKNOWLEDGEMENT

In the In the name of Allah, The Compassionate, The Merciful.

The first person I would like to thank is my principal supervisor Dr. Nuridah Sabtu. Her overly enthusiasm and integral view on research and her mission for providing knowledgeable and high quality student has left a deep expression on me. I owe her lots of gratitude for having shown me this way to complete my final year project. She could not realize how much I learned from her. Besides of being of excellent supervisor, she was also close like a mother to me and other final year student.

Special thanks also go to Prof Dr. Ismail Abustan, as my co-supervisor for his extremely knowledgeable advices, tips and encouragement that help me a lot in staying on the right track for this research.

I owe also my sincere gratitude to all hydraulic technician, who gave me opportunity to work with them and gave me untiring help during my laboratory test in their lab. I warmly thank to Muhd Khairi Abdullah for their valuable expert advise and friendly help within my experimental study and data collection.

My appreciation and thanks is also to all the academic and technical staff of the School of Civil Engineering, Universiti Sains Malaysia for their assistance directly and indirectly throughout the duration of this work.

I feel a deep sense of gratitude to my parents Mat Isa Bin Othman and Rahimah Binti Talib who formed part of my vision and taught me the good things that really matter in my life.

ABSTRAK

Kajian ini dijalankan bagi memodelkan ciri-ciri aliran dalam model fizikal empangan menggunakan alat meter aliran. Prosedur eksperimen termasuk pengumpulan data menggunakan meter aliran di dalam makmal. Eksperimen ini mempunyai tujuh kes bagi tiga jenis bukaan pintu. Jenis satu adalah hanya untuk satu pintu radial terbuka dan mempunyai tiga kes untuk jenis ini. Kes pertama adalah pintu radial yang pertama sahaja dibuka dan untuk kes kedua adalah pintu radial kedua terbuka dan yang terakhir pintu pagar terbuka ketiga terbuka. Untuk jenis kedua adalah gabungan dua pintu radial dibuka untuk kes ini juga mempunyai tiga kes. Bagi kes-kes pertama adalah hanya pintu radial satu dan dua terbuka. Kes-kes yang kedua adalah pintu radial satu dan tiga terbuka dan akhir sekali hanya radial pintu dua dan tiga terbuka. Kes yang terakhir adalah gabungan bukaan tiga pagar. Meter aliran memberi keputusan dalam unit (L/s). Kesilapan bagi kes-kes ini tidak melebihi 10% untuk semua kes-kes dalam eksperimen ini. Ini adalah output yang baik untuk menentukan masalah di empangan SAB untuk masa depan. Selain itu, nilai R2 aliran adalah dalam nilai 0.96-0.99 diperolehi daripada hubungan plot taburan antara tujuh kes dan tiga jenis bukaan pintu radial. Oleh itu dari kajian ini, dapat disimpulkan bahawa pemodelan fizikal untuk alur limpah boleh digunakan untuk mengenal pasti punca utama masalah yang dihadapi dari pemodelan fizikal tersebut.

ABSTRACT

This study attempts to model the flow characteristic in a spillway physical model by using flow meter equipment. The experimental procedures include the data collection using a flow meter in laboratory. This experiment have seven cases for three types of opening gate. Type one is when only one radial gate is opened with three different cases for this type. First, second and third case refers to experiments with only radial Gate1, 2 and 3 opened respectively. The second type refers to a combination of two opened radial gate also with three different cases. For the first case in second type, only radial gate, Gate 1 and Gate 2 is opened. The second case in second type is when radial gate, Gate 1 and Gate 3 is opened and lastly, radial gate, Gate 2 and Gate 3 is opened. The third type for this experiment is combination of all 3 gates open. The flow meter output is discharge in (L/s). The error for this cases is not exceed 10% for all cases in this experiment. This is a good output to determine the problem in the SAB dam for the future. Moreover, the coefficient of determination,correlation coefficient (R^2)values obtained from the experiment ranges from 0.96 to 0.99. Thus from the study, it can be concluded that the data obtained from the physical model of the Sultan Abu Bakar dam can be used to solve the problem and to know the cause from the physical model.

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NOMENCLATURES

ρ	Fluid Density
m_{in}	Flow Rate in
M_{out}	Flow Rate out
A_v	Area
R_e	Reynolds Number
υ_t	Kinematic Viscosity
μ	Dynamic Viscosity
g	Gravitational Constant
F_D	Froude Number
C_d	Discharge Coefficient
H_w¢	Horizontal Hydrostatic Forces
V_w¢,	Vertical Hydrostatic Forces
HPG	Hydraulic Performance Graph
n	Manning Coefficient
h	Water Depths at Upstream Faces
h¢	Water Depths at Downstream Faces
T	Thickness @ Width of the Dam Base

CHAPTER 1

INTRODUCTION

1.1 Background

Sultan Abu Bakar Dam is located at Ringlet-Bertam Valley Road, Cameron Highlands. It has the ability to store up to 4.7 million m^3 of water in the ringlet reservoir and has a total surface area of $0.6km^2$, with full supply level at EL 1071.71. The dam started commissioning 80 years ago.

Sultan Abu Bakar Dam has three radial gates and only one tilting gate. Radial gates are the most common type of spillway gates and the least expensive type for most applications. The function of a radial gate is to lower flow disturbances and provide a better coefficient of discharge than the vertical lift gates. (Chander,1996) . Our spillway type is the ogee-crested spillway because of its superb hydraulic characteristic. This type of spillway allows flows to pass efficiently and safely.

Spillway function is to store the water to avoid the flooding happen at surrounding. So in project, a scaled physical model was used to simulate existing conditions at the the dam in order to determine the main problem and hence allowing the respective authorities to prevent flooding from occurring. The effect of doing physical modelling is a compromise between computational efficiency and accuracy (Kate et al., 2014). The physical model is scaled at ratio 1 to 25 and the complexity of spillway flow can be understood if a physical model is used. The data and the result from physical modelling can be apply to the model and the physical model also can be the best tool available because site conditions vary so much from the idealized conditions (Bhajantri et al., 2007).

1.2 Problem Statement

A dam can bring many benefit to human, but it also poses serious dangers to society in case of failure. A dam functions to supply water for domestic, industrial or irrigation. The main function of dam constructed to prevent flood and also have other reason such as irrigation, water supply, reaction and other. Flooding could happen to the surrounding area from the unknown discharge from the radial gate. When a dam release, there is a huge volume of impounding water. (Sidek et al., 2011). Flooding could be the dangerous natural disaster if don't take any action to stop the flooding happen (Banasik et al., 2008). This experiment used to avoid flooding happen to happen.

Flash floods is the main factor that why Cameron Highland become flooding. Flash floods occur when there is a high accumulation of water because of raining within a period of six hours. These flooding events are potentially dangerous because high velocity and intensity of water can knock down trees and wipe out bridges and buildings. While flooding happen with the collapse of a dam it's become more dangerous.

The discharge of the water out from the dam is the most important thing to do in this experiment. If the discharge water not in suitable condition its can may occur the flooding in the surrounding area. It can be dangerous to the people who live surrounding that area. Water discharge is the volume of water flowing through a river cross section per unit time. Water discharge is one of indicators for detect flooding (Hasanah et al., 2013).

These problems encountered in the dam will affect the dam performance and significantly increase the operational and maintenance costs. Through physical modelling, the experimentally can determined the main problem happen at the dam and can cut the cost to avoid that because the cause problem was determined early. It's the best method and we can reuse the physical modelling if another problem could happen at the dam. Its can save our energy, cost and time.

Therefore, the main factor contributing the failure of the dam can be possibly be determined through an understanding of the correlation between headwater, discharge and gate opening. The headwater, discharge and gate opening can cause the change of discharge out from the dam. Causes and will found the best method to prevent the flooding happen again at Cameron Highland. In this experiment the method with detail to limit the damage from dam release.

1.3 Objectives

Based on the problem statement mentioned, the objectives of the study are as listed below:

The objectives are as listed below:

1. To establish the correlation between headwater, discharge and gate opening of Sultan Abu Bakar (SAB) Dam for at least THREE (3) gate opening angles condition in the physical model
2. To obtain the optimum gate opening based on the range of flow

1.4 Scope of Research

The scope of the research is:

i) Hydraulic data collection on the model testing – In this study, three types of measurement were conducted which involve flow, headwater and gate opening for radial gate and tilting gate. The main focusing factor is discharge of the water in front of gate, behind gate and at the weir.

Type	Gate 1	Gate 2	Gate 3
Caes 1	√		
Case 2		√	
Case 3			√
Case 4	√	√	√
Case 5	√	√	
Case 6	√		√
Case 7		√	√

Table 1: Show the opening gate for every type

ii) The data collection was done with flow meter equipment. The flow meter reading was taken to make the rating curve and to know the flow for every headwater in this experiment.

1.5 Advantages of the Research

The outcome of the research will provide an understanding of the flow feature by experimental methods. Other advantages are as listed below:

1. To optimize a structure and to ensure a safe operation of the structure.
2. A hydraulic model may help the decision-makers to visualize and to picture the flow field, before selecting a suitable design.
3. Model investigated in a laboratory under controlled conditions if we use physical mode

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter describes the dam structure, headwater, Reynolds number, Froude number, gated opening and problem encountered in the dam. Finally, a review is presented on its application in the physical model of the dam.

2.2 Types of Gate

Physical models are scaled representations of a physical system. The use of physical model is clearly established to what can be simulated accurately using numerical models. Physical model also can provide an understanding of process interaction. The process how to be generated in a visual and also provide technique how to handle or overcome the problem of physical model. The importance of physical model as a method of visualising, interpreting, observing and measuring physical processes, and any problem arising can be easily seen through the physical model. (Green, 2014)

The physical model should have the same or accurate condition with prototype if the model displays similarity of form (geometric similarity), similarity of motion (kinematic similarity) and similarity of forces (dynamic similarity). (Chanson, 1999). Figure 2.1 shows the basic flow parameters that happen at the radial gate when the radial gate was react with water flow out from the spillway to the weir.

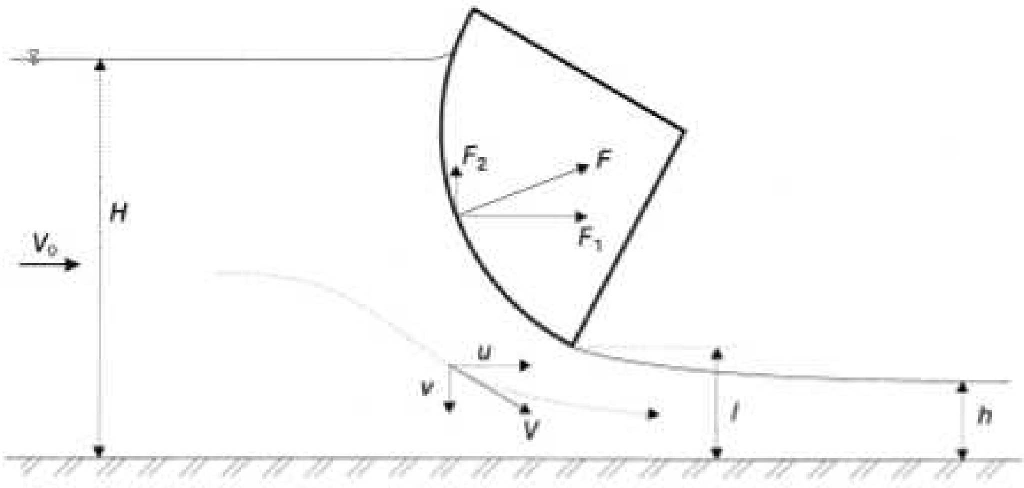

Figure 2.1: Basic flow parameters (Chanson, 1999)

Sultan Abu Bakar Dam has three radial gates and only one tilting gate. Radial gates are the most common type of spillway gates and the least expensive type for most applications. The function of a radial gate is to lower flow disturbances and provide a better coefficient of discharge than the vertical lift gates. (Chander, 1996). Figure 2.2 shows the radial gate at Sultan Abu Bakar dam.

Figure 2.2 : Radial gate at SAB dam

i. Radial Gate

Radial gate is the most common type of spillway gates. They are the most expensive for most applications because they do not require a slot at the pier for their support, the door also causes disruption radial flow coefficient is lower and better relief from the vertical lift gates. Unlike vertical lift gates, radial gates do not require high overhead structure, usually called the tower door, the doors need to support vertical lift gate hoist in the fully raised position of the gate. (Chander, 1996)

ii. Tilting Gate

Flap gates (also called Tilting Gates) are mainly employed to control the flow of water through flood barriers, reservoirs and rivers. Tilting gates are of a heavy duty structural design consisting of a steel reinforced skin plate the outer side of which is loaded against the water pressure when the gate is in a closed position. The tilting gates are designed to operate in a vertical position whereby they restrict the main flow of water but at the same time create a hydraulic jump over the top of the gate, from upstream side to downstream side of the gate. When the tilting gates are fully open they lowered to the bottom level of the river so enabling full water flow to pass over them. (Flap Gate, 2016)

Figure 2.3 shows general arrangement of crest type radial gate. The figure show the detail in the radial gate. The figure show in two view. There is left view and front view. The figure show the component usually used in the radial gate.

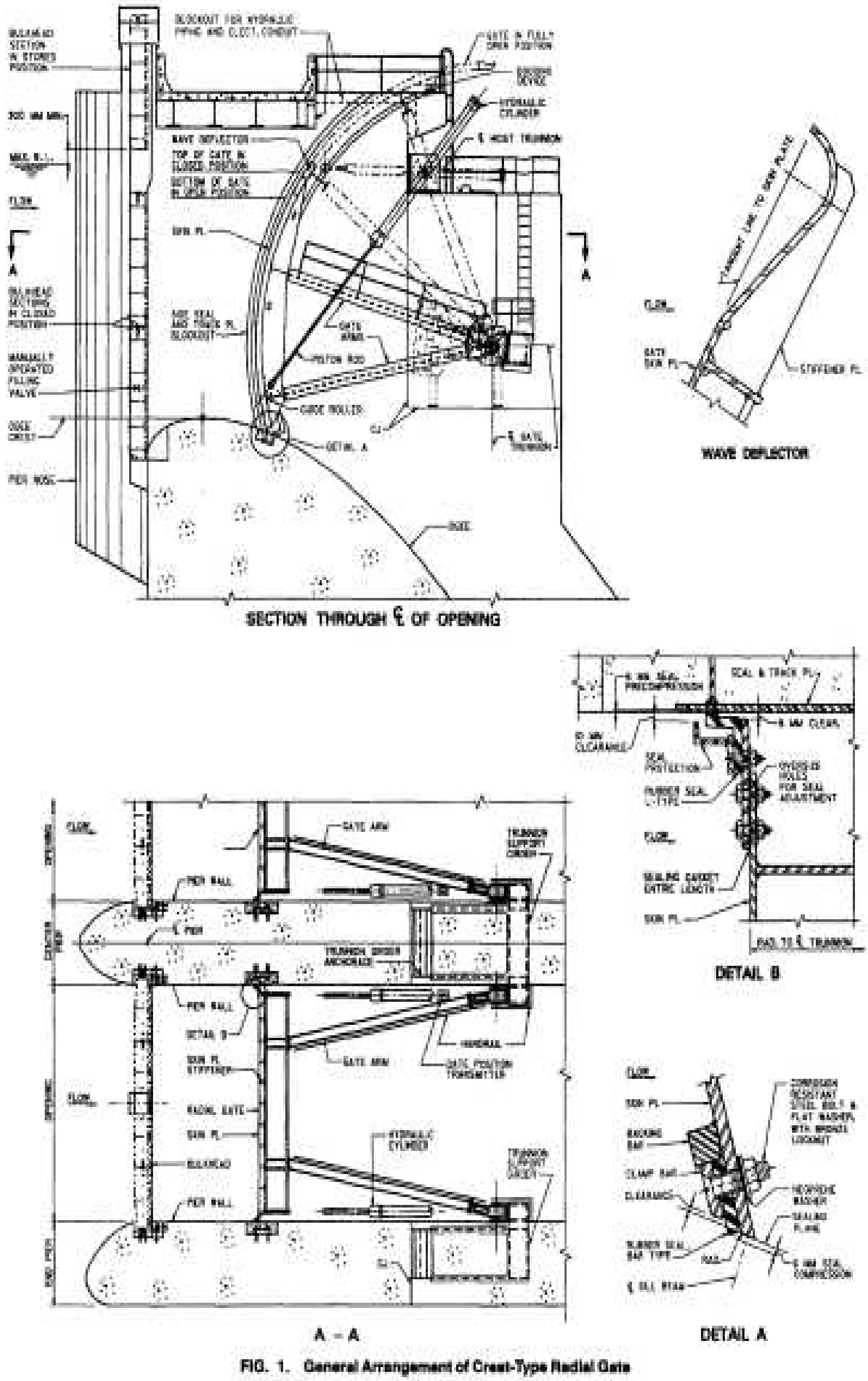

Figure 2.3: General Arrangement of Crest-Type Radial Gate (Chander, 1999)

2.3 Physical Modelling

Physical models are scaled representations of a physical system. The use of physical model is clearly established to what can be simulated accurately using numerical models. Physical model also can provide an understanding of process interaction. The process how to be generated in a visual and also provide technique how to handle or overcome the problem of physical model. The importance of physical model as a method of visualising, interpreting, observing and measuring physical processes, and any problem arising can be easily seen through the physical model. (Green, 2014)

2.3.1 Physical Modelling

i. Similitude

Similitude also known as similarity, involves the model resembling and being correspondent to the system which the model is based upon. Geometric, kinematic and dynamic similitude are the type of similitude. Firstly, geometric similitude involves the physical model created with the actual length. Therefore, the enlargement or reduced the dimension of the physical model is needed to achieve geometric similitude. Secondly, the similarity in motion need to achieve between the mode and real world system in kinematic similitude, with the ratio of movement in both systems being directly proportional. As a result, true kinematic similitude produces model particle similar to the actual physical system. Finally, the proportion of relevant forces acting upon fluid flows and boundary surfaces being comparable between the model and full scale systems are in dynamic similitude type. The length, mass and time measurement need to be in constant ratio of force between both system.. The main factor to achieve dynamic similitude is geometric and kinematic similitude. (Green, 2014)

2.3.2 The Ratio of Physical Modelling

The objectives of the study, the size of the model and considering the similarity rules and possible scale effects, the physical model has been built to a scale of 1:25. (Zainol, 2007)

All the structures are interdependent and the proper operation of each single unit and their interactions have to be studied, in particular:

• Verification of spillway capacity and rating curve for different scenario of gate opening and sequence of operation

• Verification of approach flow conditions, flow through the spillway.

2.3.3 Conservation of Mass

Conservation of mass means mass is always conserved, it does not appear or disappear. If we look at a pipe from a qualitative point of view, mass conservation says that:

Rate mass goes in = Rate mass goes out + Rate mass accumulates in pump

Quantitatively, this is expressed as:

$$m_{in} = m_{out} + \frac{\partial m\, fluid\, pump}{\partial t}$$

m_{in} = Rate at which mass flow in

m_{out} = Rate at which mass flow out

If we can assume:

1. Rigid Pump: The pump body can’t change shape, meaning volume pipe is constant.

2. Incompressible: The fluid in the pipe cannot be compressed into a smaller volume so the amount of fluid per unit volume is constant.

3. Full Pump: The pump remains full of fluid (not draining or filling) during operation.

Then we can say that the mass inside of the pump remains constant, or:

$$\frac{\partial m\, fluid\, pump}{\partial t} = 0$$

To help you see this, think of a pump as a full cup of water. If the cup does not change shape,the water is not compressible and the cup was initially full, then the water you pour into the cup must equal the water that comes out the cup. So we can say that the rate at which mass in the pipe changes is negligible. (MITCOURSEWARE , 2002)

This leaves us with;

$$m_{in=}\, m_{out} \qquad \text{Equation (2)}$$

Intuitively, this makes sense because if you cannot add to, or subtract from something, then what goes in must equal what comes out.

Now we need to put this in terms which are important to pumps and motors.

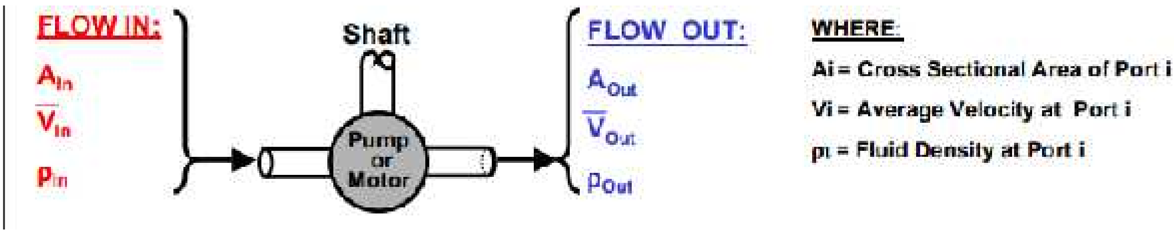

Figure 2.4: Important Flow Variable In Hydraulic Pumps and Motors

The mass flow in a pipe or pump/motor entry or exit (the inlet or outlet ports) is:

$$m_k = \rho_k \cdot A_k \cdot V_k \qquad \text{Equation (3)}$$