RADIAL GATE HYDRAULIC MODELLING OF SULTAN ABU BAKAR DAM, CAMERON HIGHLAND.

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By

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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 :

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ABSTRAK

Objektif utama kajian ini adalah untuk menentukan pekali kadar aliran dan untuk membangunkan lengkung pengkadaran untuk satu pintu, gabungan dua pintu dan semua pintu jejari daripada Empangan Sultan Abu Bakar, Cameron Highland, Pahang. Model fizikal empangan Sultan Abu Bakar telah dihasilkan seperti model yang sedia ada dengan skala mendatar 1 nisbah 25 (model:prototaip) dan skala menegak 1 nisbah 25(model:prototaip). Perkakas yang digunakan semasa proses ujian ialah “Nixon Streamflo Velocity Meter” dan “Ultrasonic Flow Meter”. “Nixon Streamflo Velocity Meter” boleh mengukur halaju air daripada bukaan pintu jejari manakala “Ultrasonic Flow Meter” boleh mengukur kadar alir daripada paip semasa model fizikal sedang berfungsi. Untuk mengetahui ketepatan perkakas ujian, ujian penentukuran telah dilakukan sebelum digunakan semasa proses ujian ke atas model fizikal. Hasil daripada proses ujian menunjukkan pekali kadar aliran dan hubungan antara kadar alir (m^3/s) dengan takungan kepala hulu (mm) di pembukaan pintu jejari yang berbeza. Dari ujian model fizikal tersebut pekali kadar alir bagi pintu jejari adalah diantara 0.75-0.84. Selain itu, untuk skala penuh model fizikal untuk bukaan 0.5m, 0.65m, 0.5m untuk semua pintu jejari adalah 239 m^3/s. Proses ini dapat membantu TNB dalam proses pelepasan air dari SAB Dam bagi mengelakkan banjir berlaku.

ABSTRACT

The main objective for this study is to determine discharge coefficient and to developed a discharged rating curve for individual gate, combination of two gates and all radial gates from physical model of Sultan Abu Bakar Dam, Cameron Highland, Pahang. The physical model of Sultan Abu Bakar Dam was produced as a normal model with a horizontal scale of 1/25 and a vertical scale of 1/25. The equipment that are used during testing process are Nixon Streamflo Velocity Meter and Ultrasonic Flow Meter. Nixon Streamflo Velocity Meter can measure the velocity of water from the opening of the radial gate while Ultrasonic Flow Meter can measure the discharged from the pipe during the physical model was running. To know the accuracy of this testing equipment, the calibration testing was done before use it during the testing process on physical model. The result from the testing process show the discharge coefficient and the relationship of discharge (m^3/s) with the upstream head (mm) of reservoir at difference opening of the radial gate. From this physical model testing, discharge coefficient (Cd) from all radial gates are between 0.75-0.84. Besides that, for the full-scale physical model, opening of 0.5m, 0.65m, 0.5m for all radial gate show the highest discharge which is 417 m^3/s. This will help TNB in process to release water from SAB Dam to avoid occurrence of flooding.

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LIST OF ABBREVIATIONS

HPG	Hydraulic Performance Graph
PPKA	Pusat Pengajian Kejuruteraan Awam
TNB	Tenaga Nasional Berhad
USM	Universiti Sains Malaysia

NOMENCLATURES

A	Area
C_d	Discharge coefficient
F	Froude number
g	Gravitational constant
h_1	Upstream head
h_2	Gate opening
k	Kinematic viscosity
L_r	Length scale
L_m	Length model
L_p	Length prototype
L	Characteristic length
r	Gate's radius of curvature
R	Hydraulic radius
S	Bottom slope
V_r	Velocity ratio
V_p	Velocity of prototype
V_m	Velocity of model
θ	Gate leaf angle
α	Pinion height

CHAPTER 1

INTRODUCTION

1.1 Background of the study

Hydraulic model is the technical process consisting in reproducing free surface flow dynamic using physical or mathematical model. The hydraulic model testing is usually required in many major water-related projects such as dam, water supply, irrigation, barrage, inlet channel and others. A testing on hydraulic model is to ensure suitability and the safety of the design and to possibly at the end will minimize the cost of operation and maintenance of the system in the long run. Hydraulic models are essential be implemented in designing hydraulic structures where these models can provide effective solution to complex hydraulic problems with unmatched reliability.

Sultan Abu Bakar Dam is located at Sungai Bertam, Ringlet, Pahang, Malaysia. Location coordinates of Sultan Abu Bakar Dam are; latitude of 4.4229 and longitude of 101.3894. Sultan Abu Bakar Dam was designed for a hydro power plant with a designed capacity of 100 MW and has 6 units of Pelton turbines. It was commissioned in 1963, and since it is operated by Tenaga Nasional Berhad (TNB). The Sultan Abu Bakar Dam and Ringlet Reservoir is situated on the Sungai Bertam in Mukim of Ringlet, Cameron Highland. Sultan Abu Bakar Dam impounds 4.7 million m^3 of water storage with a total surface area of 60 ha at full supply level (FSL) at EL 1071.71. Ringlet Reservoir as shown in Figure 1.1 is formed by impounding waters of the Sungai Bertam and its tributaries, those of Sungai Telom, Sungai Plau' ur, Sungai Kudol and Sungai Kial which have been diverted from the Telom catchment through the Telom tunnel into the Bertam catchment (Jaafar et al 2010).

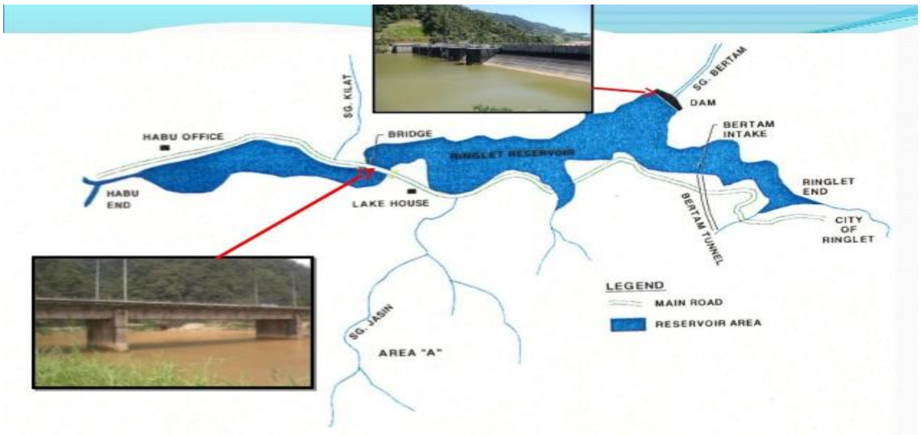

Figure 1.1: Ringlet reservoir (Source: Jamil, 2015)

Spillway is a section of a dam designed to pass water from the upstream side of a dam to the downstream side. There are two types of spillway gate that are used on Sultan Abu Bakar Dam which is radial gate and tilting gate. Overflow from the Ringlet reservoir is controlled by one tilting gate and three radial gates as shown in Figure 1.2 which together will release a total flow about 965 m^3/s. Table 1.1 show the control discharge from the Sultan Abu Bakar Dam with difference scenario (Eisakhani et al.,2009). The tilting gate is bottom hinged at 1068 m (3503.9ft) above the Malaysia surface level (MSL) and is arranged to commence opening when the reservoir has risen to 1071m (3513.8ft). The radial gate commences opening at a water level of 1071.09 (3514.1ft) and are fully open when the reservoir has risen to 1071.37m (3515ft)

Table 1.1: Control discharge scenario of Sultan Abu Bakar Dam

(Source: Eisakhani et al., 2009)

Flow (m^3/s)	Scenario	Surface level (ft)
4 – 5 m^3/s	During periodic flushing exercise	When necessary
31.2 m^3/s	For full opening of hollow jet	When necessary
65 m^3/s	For full opening of tilting gate	When necessary
300 m^3/s	For single radial gate opening	3515

Figure 1.2: Location of spillway gate at SAB Dam (Source: The Star Online, 2015)

1.2 Problem Statement

The 2013, the event of Cameron Highland mud flood took place on 23 October. As a result, for the first time in history of the 50 years old reservoir, water level surged at a rate of 0.000127 m/s (1.5ft/hr) (TNB, 2013), which is three times more than the normal monsoon rain condition. The unusually intense downpours had brought huge volume of water to Ringlet reservoir with solid wastes, debris and siltation from the massive land clearing and farming activities upstream. The water from Sultan Abu Bakar Dam was released three time that are larger than normal. The water from Sultan Abu Bakar Dam was released starting at the midnight, then another at 1.00am, and finally again at 2.45am that are more than 100 m^3/s.

The uncontrolled water release from Sultan Abu Bakar Dam caused the Sungai Bertam suddenly rise and breach its banks. From this tragic event, three people died while another was missing and 100 houses were severely damaged due to the immediate releasing of water at Sultan Abu Bakar Dam that lead to mud flood in Bertam valley. This was probably because the uncontrolled discharged of three radial gates caused nuisance to residence and destroy properties and agriculture farm as shown in Figure 1.3.

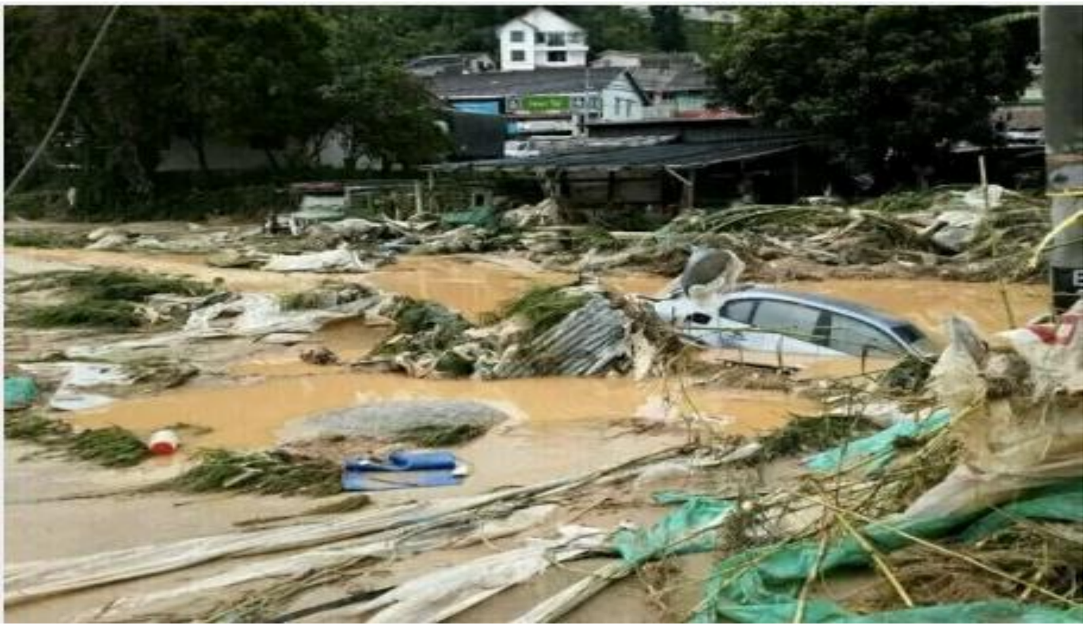

Figure 1.3: The mud flood that caused destruction in Bertam valley (News, 2013)

1.3 Objectives

The main purpose of this study is to determine the amount of the water released from Sultan Abu Bakar Dam. Thus, the objectives are listed as follow:

1. To determine discharge coefficient for individual gate, combination of two gates and all radial gates from a physical model.
2. To develop a discharged rating curve for individual gate, combination of two gates and all radial gates from a physical model.

1.4 Scope of works

The scope of works for the hydraulic model testing includes:

1. Constructed drawing using AutoCAD 2015 (Version: 20.0) of Sultan Abu Bakar Dam from the plan given.
2. Calibrate testing equipment in Hydraulic Lab, School of Civil Engineering, Universiti Sains Malaysia.
    - Nixon Streamflo Velocity Meter
    - Ultrasonic Flow Meter
3. Design and construct a scaled physical model of Sultan Abu Bakar Dam and spillway gate structure according to the actual dimensions for the scaled of 1:25. (Model: Prototype)
4. Carry out physical hydraulic model testing to confirm the suitability and effectiveness of the designed hydraulic structure control procedure.
5. Developed rating curved of water released from the Sultan Abu Bakar Dam.

1.5 Justification of research

A model study is an important part of the design or rehabilitation process of hydraulic structures. Model study allows us to simulate a prototype condition by constructing a smaller scale replica of a hydraulic structure. The model can be operated over the full range of expected flow rates, in which enables us to observe flow conditions, flow patterns, velocities, pressures and others. Besides that, by using physical a modelling, future and highlight potential impact can be simulated and address them before they occur.

1.6 Limitation of the study

The limitations of this study are:

i. Scale effects, because is impossible to correctly scale a free-surface hydrodynamic model using water that satisfies all the law of similitude. To minimize scale effect, one should construct as large a model as possible that fits within time, costs and available facility space constraints.

ii. Laboratory effects consisting of model boundaries, instrumentation support, mechanical wave, flow generation losses and others, are a concern in physical models. In the model, walls are necessary to contain the water, but they induce laboratory effects due to reflection and flow restriction. In the real world, there are no artificial boundaries to produce these effects. In the model, instruments are typically mounted some type of rigid support that may have a larger impact on the flow field than a similar instrumentation support in the prototype. However, measures can be incorporated in the model to minimize and mitigate these effects. The generation of waves and currents by mechanical means in a laboratory is not exact between model and prototype. In the real world, waves may have multidirectional characteristics with frequency and directional spreading that are not always possible to simulate as accurately in the laboratory.

iii. Material of model and prototype might not be made from the same material and the level of skill is required to construct a model.

1.7 Dissertation Outline

This thesis consists of five chapters.

Chapter 1: Introduction to the background of physical modelling and overall scope of study. The problem statement, objectives, scope of work and justification of the study are all stated in this chapter.

Chapter 2: This chapter include the review of the pervious study that have been done on the physical model. The development of radial gate rating curve and the concept, how to construct and how to measure the physical modelling also being discussed in this chapter.

Chapter 3: The overall methodology has been applied in this study is discussed and stated clearly in this chapter. The brief description of testing that has been carried in order to determine the rating curve has been stated. Finally, the procedure of testing is also being discussed in this chapter.

Chapter 4: Calibration results of Nixon Streamflo Meter and Ultrasonic Flow Meter with Yokogawa Flow Meter are presented in order to ensure the accuracy of testing equipment. The results of discharge of radial gates from the various openings are also presented. Finally, the radial gate discharged rating curve for the single radial gate and combination of three radial gate are developed

Chapter 5: Conclusion is drawn based on the results obtained from experiment work.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter describe about the literature review of the physical hydraulic modelling, spillway and development of discharge rating curve for the physical model. For the physical hydraulic modelling, concept, scale effect, similarities such as geometric similarity, kinematic similarity and dynamic similarity, design and construction of physical model was present in this chapter. Besides that, for the literature review of spillway, type of spillway such as controlled and uncontrolled gate, radial gate such as free and submerged flow condition and tilting gate also present in this chapter. For the literature review of development of discharge rating curve, from the previous study (Kim et al., 2016), it describes about the development of discharge rating curve by using hydraulic performance graph (HPG).

2.2 Physical Hydraulic Modelling

Physical hydraulic modelling is a hands-on and practical approach to developing effective engineering designs and conducting applied hydraulic research. Based on chapter 1, physical hydraulic modelling allows us to simulate a prototype condition by constructing a smaller scale replica of a hydraulic structure. This model can be operated over the full range of expected flow rates, in which enables us to observe flow conditions, flow pattern, velocities, pressure and others. Figure 2.1 show the example of hydraulic physical model.

Physical hydraulic models are often used to predict prototype performance in designing and rehabilitating hydraulic structures. The physical modelling studies ultimately increase the safety of hydraulic structure such as dam, barrage, channel and others by identifying and eliminating potential problems, thus reducing construction and maintenance costs. They are particularly useful where hydraulic structures and systems are of unusual design or configuration and hydraulic parameters cannot be adequately evaluated by state-of-the-art analytically or computational methods.

Furthermore, physical models will incorporate the appropriate governing equations without the simplifying assumptions that are often necessary in analytical or numerical models. Physical hydraulic models may also be used to establish conservative and reasonable design or operating bases of sites, structures or system involving thermal and erosional problems (Burke, 2008).

Figure 2.1: Example of physical model of Folsom Dam, California, United State, (Source: Einhelig et al., 2011)

2.3 Concept of hydraulic physical modelling

In a physical model, the flow conditions are said to be similar to those in the prototype if the model displays similarity of form (geometric similarity), similarity of motion (kinematic similarity) and similarity of force (dynamic similarity) (Heller, 2011). In general, the ratio of quantities in the model needs to be the same in the prototype. A model is a representation of a physical system that may be used to predict the behaviour of the system in some desired respect. It is also known as scale model or simply model. A prototype is a physical system for which the prediction was to be made. The ratio of quantities. A hydraulic model scale is determined through a composite review of reproducibility, ability of flow supply to test laboratory, test model manufacturing space and measuring convenience (Kang et al., 2014). There are two types of model scale which is Undistorted model (normal model) and Distorted model (Fischer, 1971). Table 2.1 show the difference between Undistorted and Distorted model. In this table, it shows that the undistorted model has same geometric scale, but distorted model has different scale for horizontal and vertical dimension.

Table 2.1: Difference between undistorted and distorted model

(Resources: Wang and Jiang, 2013)

Undistorted Scale/Normal model	Distorted model
Has same geometric scale in both horizontal and vertical reactions.	Has different scale for horizontal and vertical dimensions.

There are some advantages of undistorted scale (normal scale) and distorted scale. Table 2.2 and Table 2.3 show the advantages and disadvantages of those two scales. The main advantage of undistorted model is the behaviour and working details of hydraulic structure can be easily predicted from it model.