THE EFFECTIVENESS OF RECTANGULAR BLOCK AS ENERGY DISSIPATION STRUCTURE

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ABSTRACT

Velocity of flow water in a channel will increase when there are different between water level at upstream and downstream of a channel. High velocity of flow water can be possessed by water flow in a spillway which the flow is caused by the gravitational force. High water flow velocity can caused bad impacts such as erosion, scour, sedimentation and cavitations around spillway toe, weir bed and downstream of river. In order to overcome these problems, the flow velocity has to be reduced. This can be done through constructing an energy dissipating structure at the affected areas. Therefore, a rectangular open channel model structure consists of spillway part is constructed and used to conduct an experiment to study the performances and effectiveness of rectangular concrete block as a energy dissipation structure. The blocks used in this study have different size and different slope of spillway. The blocks are arranged in various pattern of arrangements in stilling basin of a channel. For blocks size 30 x 25 x 23 mm with slope 27^0, the best pattern with a highest percentages reduction in velocity is pattern 5. For blocks size 30 x 30 x 30 mm with slope 27^0, the best pattern with a highest percentages reduction in velocity is pattern 5. Based from the result, its shows that the decrease of slope will be increase the percentage reduction in velocity.

ABSTRAK

Halaju aliran air dalam saluran yang akan meningkat apabila terdapat perbezaan di antara paras air di hulu dan hilir saluran. Halaju aliran yang tinggi disebabkan oleh aliran air di alur limpah yang mana aliran disebabkan oleh daya graviti. Halaju aliran air yang tinggi boleh menyebabkan kesan buruk seperti hakisan, kerosakan dan pemendapan sekitar alur limpah dan hilir sungai. Untuk mengatasi masalah ini, halaju aliran yang telah dikurangkan. Ini boleh dilakukan melalui pembinaan struktur pelesap tenaga di kawasan yang terlibat. Oleh itu, satu struktur model saluran segi empat tepat terdiri daripada bahagian alur limpah dibina dan digunakan untuk menjalankan satu eksperimen untuk mengkaji prestasi dan keberkesanan blok konkrit segi empat tepat sebagai struktur pelesapan tenaga. Blok-blok yang digunakan dalam kajian ini mempunyai saiz yang berbeza dan cerun alur limpah yang berbeza. Blok-blok disusun dalam pelbagai corak pengaturan dalam lembangan penenang saluran. Untuk blok bersaiz 30 x 25 x 23 mm dengan cerun 27^0, corak yang terbaik dengan pengurangan peratusan yang tertinggi dalam halaju adalah corak 5. Untuk blok bersaiz 30 x 30 x 30 mm dengan cerun 27^0, corak yang terbaik dengan pengurangan peratusan yang tertinggi dalam halaju adalah corak 5. Berdasarkan keputusan itu, menunjukkan bahawa penurunan cerun akan meningkatkan peratus pengurangan halaju.

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LIST OF SYMBOLS

Symbol		Item
v	-	velocity
v_o	-	initial velocity
y	-	Measured flow depth
y_o	-	Initial velocity
Q	-	Flow rate
D	-	Hydraulic depth
g	-	Gravity
ρ	-	Density of the fluid
μ	-	Viscosity of fluid
γ	-	Unit weight of water
φ	-	Angle of channel with the horizontal
S	-	Bottom of slope channel
R	-	Hydraulic radius
P	-	Wetted parameter
A	-	Area of hydraulic section
m	-	Meter
mm	-	Millimeter
m^3/s	-	Meter cubes per second
m/s	-	Meter per second
m^2	-	Meter square

E	-	Specific Energy
B	-	Width of channel
Fr	-	Froude number
Δv	-	Reduction in flow velocity

LIST OF ABBREVATIONS

USBR	-	United States Bureau of Reclamation
MSMA	-	Manual Saliran Mesra Alam

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CHAPTER I

INTRODUCTION

1.1 BACKGROUND OF STUDY

Energy dissipation are devices designed to protect downstream areas from erosion by reducing the velocity of flow to acceptable limits. According to MASMA, energy dissipaters are usually required where the flow regimes change from supercritical to subcritical, or where the flow is supercritical and the tractive forces or flow velocities are higher than the maximum allowable values.

Energy dissipater is a device located in the base of a channel of flow water which used to dissipate the energy of the flow. The energy dissipation structure reduces velocity of flow water by spreading the water flow over a large area and to protect the structure and adjacent area from excessive damage due to erosion.

Energy dissipaters can be constructed in several forms and from different materials including rocks, gabion, logs, steel baffles and concrete blocks. Although there are various type of devices that can be used as energy dissipater structure, the concept are that the dissipation of energy is through internal friction and turbulence or impact and diffusion of the high velocity flow in the mass of water.

Energy dissipation should be considered part of the larger design system which includes the culvert and channel protection requirements (upstream and downstream) and may include a debris control structure. The interrelationship of these various components must be considered in designing any one part of the system.

The best conveys from the upstream into the downstream involves number of hydraulic phenomena. The transition from supercritical to subcritical flow occurred when water flow from spillway (upstream) into the stilling basin (downstream). In this condition, the velocity of flow water need to be concerned and controlled.

1.2 PROBLEM STATEMENT

Energy of water flowing down from a high altitude slope area will experience increase of kinetic energy. This kinetic energy can be correlated to the velocity of flow. As water approaches downstream, the velocity will increase and induces erosion to river and scouring downstream of river.

Spillway, weir and dams are man-made structure built to deal with scour, cavitations and erosion problems caused by the high water velocity flow. Due to this, studies need to be conducted to protect and preserve the environment and hydraulic structure itself.

1.3 OBJECTIVES

The objectives of this study are:

i. To determine and analyze the performance of selected Energy Dissipation Structure at stilling basin.
ii. To identify the most effective of selected Energy Dissipation Structure at stilling basin.

iii. To analyze the performance of Energy Dissipation Structure at spillway and stilling basin using different slope of spillway.

1.4 SCOPE OF STUDY

A prototype model of an open channel consist of spillway and stilling basin is constructed in laboratory for testing purpose. The water flow through the rectangular cross-section model indicates the actual flow of water from the reservoir or high altitude slope area where the energy dissipation can be observed and studied. Study scopes that have been fixed are:

i. Experiment is conducted in Hydraulic & Hydrology Laboratory of Faculty of Civil Engineering & Earth Resources, Universiti Malaysia Pahang.
ii. The model structure associated with a spillway and stilling basin area.
iii. Limited to (30cm x 50cm) rectangular cross section open channel of a certain fix gradient (27°).
iv. Take into account of various size of concrete block (30 x 25 x 23 mm and 30 x 30 x 30 mm) and arrangement of Energy Dissipater Structure to obtain the most effective design.

1.5 SIGNIFICANT OF STUDY

Based from this study, the best arrangement of concrete block design with the best types of roughness can be identified based on their performance. It will helps for prevent erosion, sedimentation, cavitations and scour problem in open channel.

1.6 EXPECTED RESULT

The best performance and effective design of Energy Dissipation structure will be determined.

CHAPTER II

LITERATURE REVIEW

2.1 SPILLWAYS

Spillways (dams) is a structure which passes floodwater through, over or around a dam. Provision is usually made to prevent scour and the removal of rock at the downstream face of the dam by spillway discharges. This may consist of a concrete apron at the toe or other construction in the design of spillway (Nelson and Ken, 2005).

Figure 2.1 shows a typical spillway of Oldman Dam at Canada which assigned to pass flood flows, thereby preventing overtopping and failure of the dam. Aside its principal function of passing down the surplus water from the reservoir into the downstream river, other particular functions that related to spillway are discharging water for utilization, maintaining initial water level in the flood-control operation, and lowering water levels in an emergency.

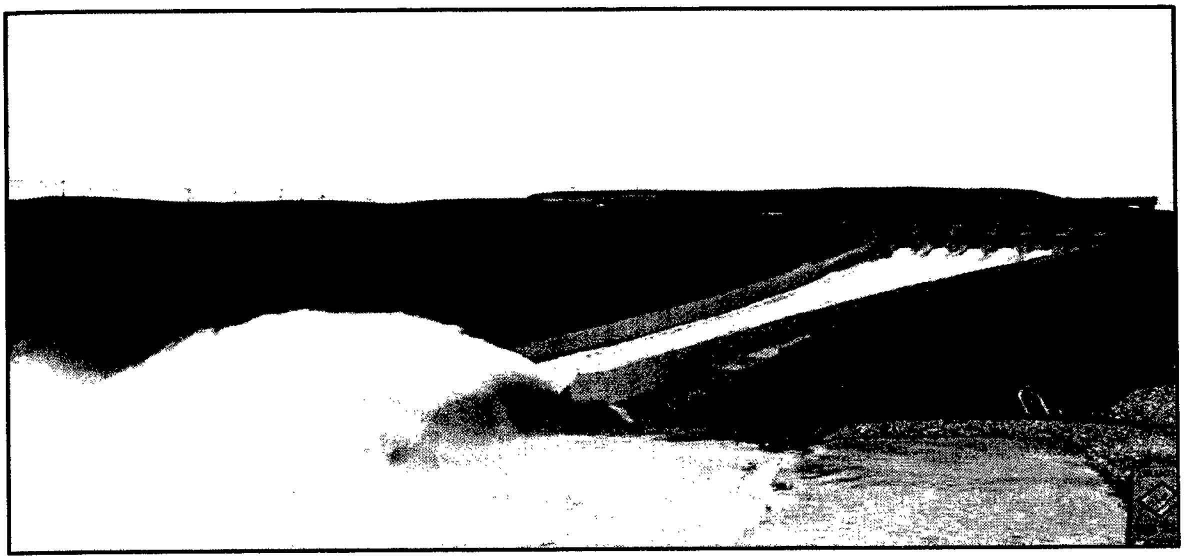

Figure 2.1: Main Spillway of Oldman Dam, Alberta (wwww.uleth.ca, 1999)

In spillways design, there were numbers of considerations that need to be considered which includes hydraulic considerations, topography, geology, type of the dam, layout of other associated structure, economic comparison, frequency of usage, as well as special and environment considerations. For instance, the topography that favors the selection of shaft spillways or a tunnel spillway will most likely be an ideal site for a flip bucket. Figure 2.2 shows example of Shift spillway at North Carolina which can be described as a vertical shaft having a funnel-shaped entrance and ending in an outlet tunnel that provides an outflow from a reservoir.

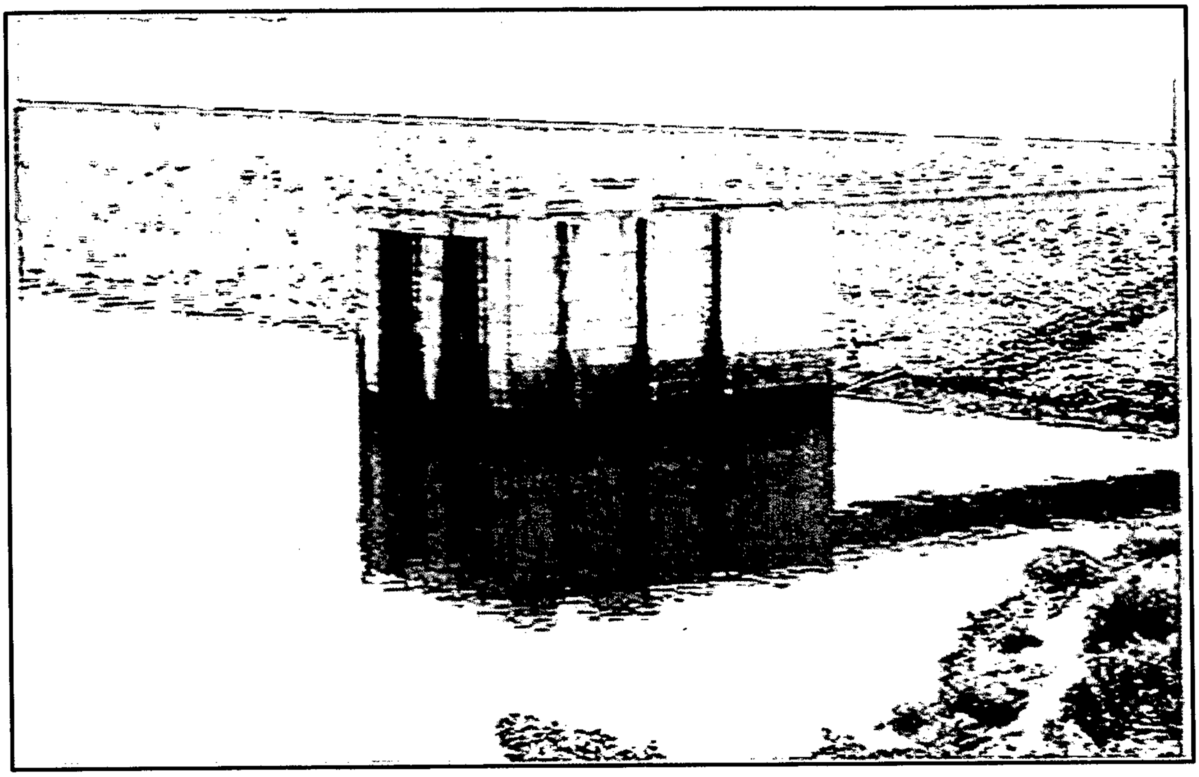

Figure 2.2: B.Everett Jordan Dam and Shaft Spillway, Haw River Chatham Contry, N.C (www.ncwater.org, 1994)

Flip buckets are commonly used to discharge flow away from a hydraulic structure into a plunge pool to dissipate energy. For the gravity or arch dams in steep and narrow canyons, ski jump buckets would be preferable. An example of spillway flip bucket is shown in Figure 2.3 which is located at Anderson Dam, California.

Figure 2.3: A spillway bucket of Anderson Dam, California (terramaterang.com,2007)

2.2 FROUDE NUMBER (Fr)

The Froude number, Fr, is a dimensionless value that describes different flow regimens of open channel flow. The Froude number is a ratio of inertia and gravitational forces. Because of the free surface, gravity is the driving force in an open channel flow. Froude number can be defined by Equation 2.1 below.

$$\mathrm{Fr} = \frac{v}{(gD)^2} \tag{2.1}$$

Where,

v	=	water velocity
D	=	Hydraulic depth (cross sectional area of flow/top width)
g	=	Gravity

The flow regime condition can be categorized according to the value of the Froude number which when,

i. Fr = 1, Critical flow
ii. Fr > 1, supercritical flow (fast rapid flow)
iii. Fr < 1, Subcritical flow(slow/tranquil flow)

2.3 SPECIFIC ENERGY (E)

The early concept of Specific Energy, E has been introduced by Bakhmeteff, a Russian émigré to the United States in his book which focused on varied flow and introduced the notion of specific energy which is an important factor for the analysis and understanding of open channel flow problems. Specific energy can be defined as in the Equation 2.2.

$$E = y + v^2/2g \tag{2.2}$$

Where,

y = vertical distance from the bed to the water surface
v = velocity of flow

And for rectangular channel,

$$E = y + \frac{q^2}{2gy^2} \tag{2.3}$$

Where,
q is the discharge per unit width of channel.

For a non-rectangular channel, Equation 2.2 may be rewritten to incorporate a mean channel velocity derived from the total discharge, Q , and the total cross sectional area, A :

$$E = y + \frac{q^2}{2gA^2} \tag{2.4}$$

Specific energy may clearly be defined as the height of the energy grade line above the channel bottom. If the specific energy is defined as the total of depth and velocity head, the possible solution of the problem for the depth depend on the variation of specific energy with depth.

Figure 2.4 shows the specific energy function plotted in graphical from called the specific energy diagram. The two possible values for y are the alternate depths. One of the solutions will lie on the upper part of the graph which represented subcritical flow (typically slow and deep); the other representing supercritical flow which is fast and shallow, will fall on the lower part of the graph.

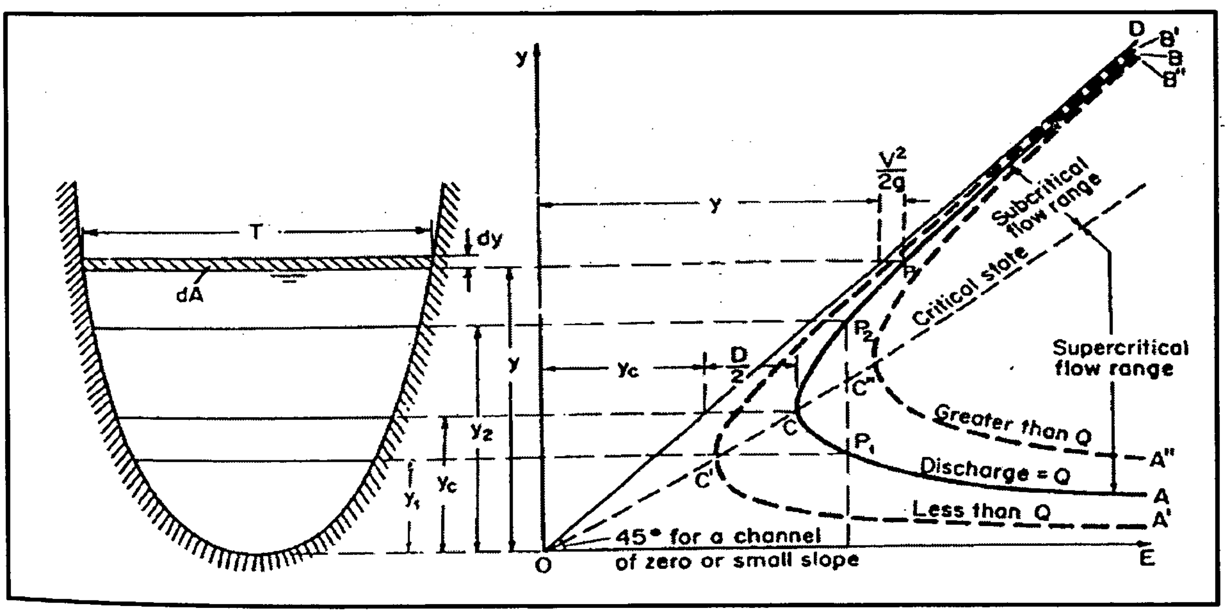

Figure 2.4: Specific Energy Diagram (DROP Manual, 1997)

2.4 REYNOLDS NUMBER

The Reynolds number can be defined for several different situations where a fluid is in relative motion to a surface. These definitions generally include the fluid properties of density and viscosity, plus a velocity and a characteristic length or characteristic dimension. This dimension is a matter of convention – for example radius and diameter are equally valid to describe spheres or circles, but one is chosen by convention. For aircraft or ships, the length or width can be used. For flow in a pipe or a sphere moving in a fluid the internal diameter is generally used today. Other shapes such as rectangular pipes or non-spherical objects have an equivalent diameter defined. For fluids of variable density such as compressible gases or fluids of variable viscosity such as non-Newtonian fluids, special rules apply. The velocity may also be a matter of convention in some circumstances, notably stirred vessels. Reynolds number formula is given by:

$$Re = \frac{\rho V L}{\mu} \tag{2.5}$$

Where,

ρ	=	density of the fluid,
V	=	velocity of the fluid,
μ	=	viscosity of fluid,
L	=	length or diameter of the fluid

The Kind of flow depends on value of R_e,

i. If Re < 2000 the flow is Laminar
ii. If Re > 4000 the flow is turbulent
iii. If 2000 < Re < 4000 it is called transition flow