LABORATORY STUDY ON BAFFLED APRON AS AN INTEGRAL PART OF AN ENERGY DISSPATOR SYSTEM

NURFADILA BTE RAAIBI

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FACULTY OF CIVIL AND EARTH RESOURCES
UNIVERSITI MALAYSIA PAHANG

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ABSTRACT

High water velocity can cause 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 area. Blocks were used in the experimental energy dissipating structure in this study. Various arrangements of blocks at spillway of the model were tested to obtain the most effective result in reducing the water flow velocity. The relation between the percentage of velocity decrease and various block arrangements were determined through the plotted graphs. The decrease in flow velocity varied and depended on the size of blocks, spacing between blocks and the number of rows of blocks. Generally, this study proved that blocks could be used as an energy dissipating structure.

ABSTRAK

Halaju air yang tinggi berupaya menyebabkan hakisan, kerosakan dan mendapan di kaki limpah, dasar saluran dan hilir sungai. Masalah ini perlu diatasi dengan mengurangkan halaju air. Bagi mencapai matlamat ini, pembinaan struktur pelesap tenaga di kawasan yang mengalami impak halaju air perlu dilakukan. Di dalam kajian ini,blok digunakan sebagai struktur pelesap tenaga. Pelbagai susunan blok di dasar laluan model dikaji untuk memperoleh keputusan yang paling efektif dalam pengurangan halaju air. Hubungan antara peratus pengurangan halaju dengan pelbagai susunan blok dapat diperolehi melalui graf. Pengurangan halaju aliran adalah berbeza-beza bergantung kepada saiz block, jarak antara barisan blok dan bilangan barisan blok. Secara umum, kajian ini telah membuktikan bahawa blok boleh digunakan sebagai struktur pelesap tenaga

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∀	- Volume of the container
A	- Hydraulic cross section area
B	- Width of channel
Q	- Discharge
h	- Height of block
S	- Spacing between rocks
n	- Number of rows
t	- Time duration
v_o	- Initial velocity at
v_n	- Velocity at downstream of energy dissipating structure
y_o	- Original flow depth in channel
y_n	- Flow depth at downstream of energy dissipating structure

CHAPTER I

INTRODUCTION

1.1 Introduction

High velocity flows of water caused environmental problems such as flood, damaged of roads and building and even destroys crops. High water velocity is where water moves through a distance in a short period of time. As water moves downwards, the kinetic energy in water increase causing the spillway toe and weir bed get a bad impact such as erosion, scour and cavitations. Many culverts and detention basin outlet structures undergoes damages due to erosion. Erosion forces in natural drainage network often make it worst by construction of highway and by urban development. Unstable overland flow results in increased of erosion potential.

In order to protect the culvert and other outlet devices, sometimes it needs to employ an energy dissipator. Energy dissipators are any device designed to protect downstream areas from erosion by reducing the velocity of flow to acceptable limits and by reducing the kinetic force (Albert, 1990).

However, energy dissipator structure can operate more efficiently using hydraulic jump which occurs when water flows from supercritical to subcritical. The design of the energy dissipator is largely dependent base on the characteristic of the site and the magnitude of the energy. Thus, design dimensions for energy dissipation structures are important because an inappropriate design can worsen erosion and scouring problem (Gary P.Merkley, 1995).

Due to this, a channel model is made so that experiment can runs in a laboratory. A static object must be placed at the water passage to change the flow rate and reduces its velocity. Blocks are common object used in this experiment as it is cheap and economical. However, hydraulic jump can also be created to reduce the velocity of water at the downstream of the model channel where turbulent change in flow from a low stage below critical depth to the conjugate depth above critical.

1.2 Problem Statement

Spillway, dams and weir are manmade structures built to deal with scour and erosion cause by the high velocity flow. Increasing of kinetic energy occurs when water flows from a high altitude slope area. As water approaches downstream, velocity tend to increase causing the highway structure and adjacent area to damage due to erosion. Due to this, studies need to be conducted to preserve and protect the environment and these structures.

Application of hydraulic jump as a mean of energy dissipator can effectively solve this problem. Hydraulic jump phenomena occurs when a sudden rise in the water surface with a significant loss of energy. By creating an energy dissipator in a passage for water helps prevent undue acceleration of flow and limiting the velocity so that the structure can handle the flow force.

1.3 Objectives

The objective of this study is to

1. To determine the most effective size and block spacing with regards to effective velocity reduction
2 To analyze the relationship of effective size and block spacing to be used with the number of rows to be provided.

1.4 Scope of Study

The scopes of study included the following:

i. Rectangular channel with fixed gradient of 30 degree.
ii. Blocks made of concrete with different sizes
iii. Distance of concrete blocks from spillway toe.

1.5 Importance of Study

The study seeked to observe the effectiveness of using blocks as an energy dissipating structure to create hydraulic jump. It is not only exposes the civil engineers on various types of energy dissipator that have been designed and constructed but also makes them aware of erosions, sedimentation and other further problems despite finding various solutions to these problems. The study also provides the useful information about design and construction of energy dissipator that fulfills specifications, standards or technical needs.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

In this chapter, types of hydraulic structure and energy dissipators for culverts and channels are introduced. The background studies of the past energy dissipator were discussed in this chapter. Under many circumstances, discharges from culvert and channels may cause erosion problems. To mitigate this erosion, discharge energy can be dissipated prior to release downstream.

2.2 Energy Dissipator

An energy dissipator is a concrete structure designed to reduce the velocity of the flow existing culvert to prevent erosion of the streambed and banks. It is a device for reducing the energy of storm water flows by mean of friction, impact and turbulence. "Energy dissipate" means a structure shaped channel section with mechanical armoring placed at the outlet of pipes or conduits to receive and break down the energy from high velocity flow (Albert, 1990)

2.3 Hydraulic Structure

Generally, hydraulic structures are built to control and transport water and maintain the water level of the river or waterway (Siti Aishah, 2003). Another important function of the hydraulic structure is to dissipate the high water energy. The energy dissipating structure is normally built at hill slope or dams. Energy of water flowing over weirs, dams and other hydraulic structure can be dissipated through practical application of the hydraulic jump. Another example that can be related to the energy dissipator is stepped construction paved drain and spillway (Ven Te Chow, 1959).

2.4 Hydraulic jump

A hydraulic jump is a sudden and turbulent transition in flow from a low stage below critical depth to the conjugate depth above critical whilst the velocity changes from supercritical to subcritical with a significant loss of energy (DROP Design Manual, 1997). The abrupt rise of water depth through hydraulic jump takes place as the fast flow velocity decreases to critical flow speed, which is the speed of gravity waves (Clare Steedman, 2000). The formation of surface roller from the beginning of the jump produces turbulent eddies which extract energy from the mean flow to break it down into small eddies. The mean flow energy together with kinetic energy is dissipated rapidly into heat towards the downstream (K.G.Ranga Raju, 1984)

Hydraulic jump is very common and effective way of dissipating energy at downstream of the spillway toe. Energy dissipation and erosion control of the incoming flow is depended on the available tail water depth (y_1) and the conjugate depth (y_2) (C.Nailuri, 2001). Figure 2.1 shows hydraulic jumps on a rectangular channel that can be classified according to the Froude number and Figure 2.2 shows flow profile according to Froude number as stated in Table 2.1.

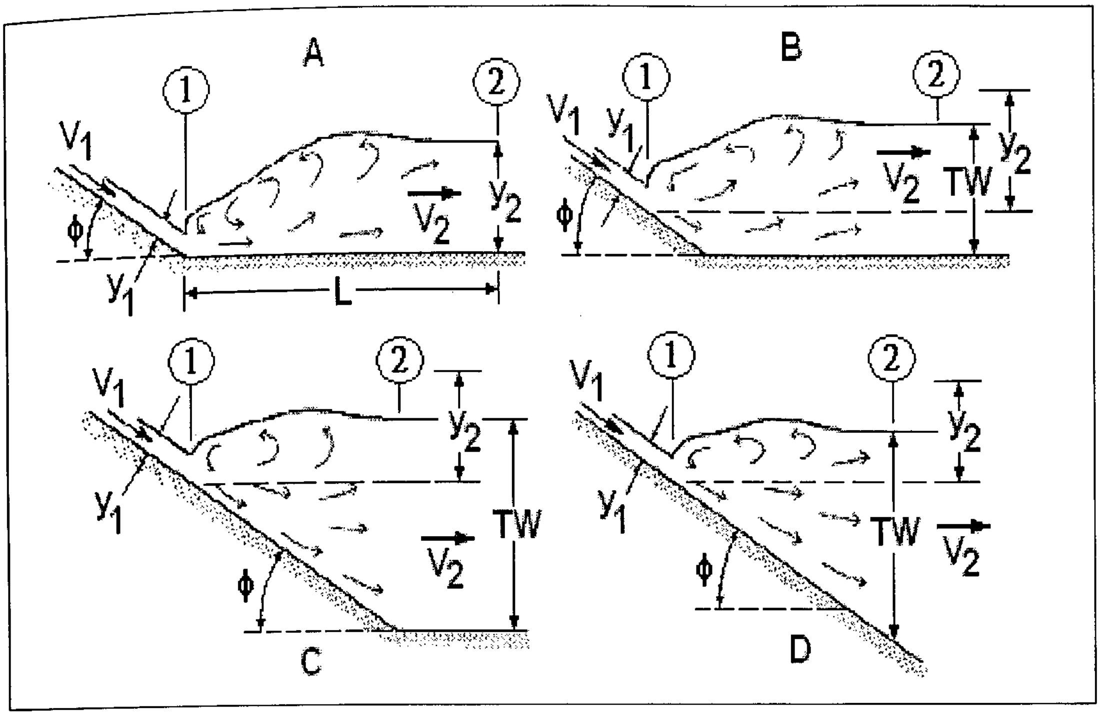

Figure 2.1 Hydraulic Jumps on a Horizontal Rectangular Channel can be Classified According to the Froude Number in the Incoming Flow. (C. Nailuri, 2001)

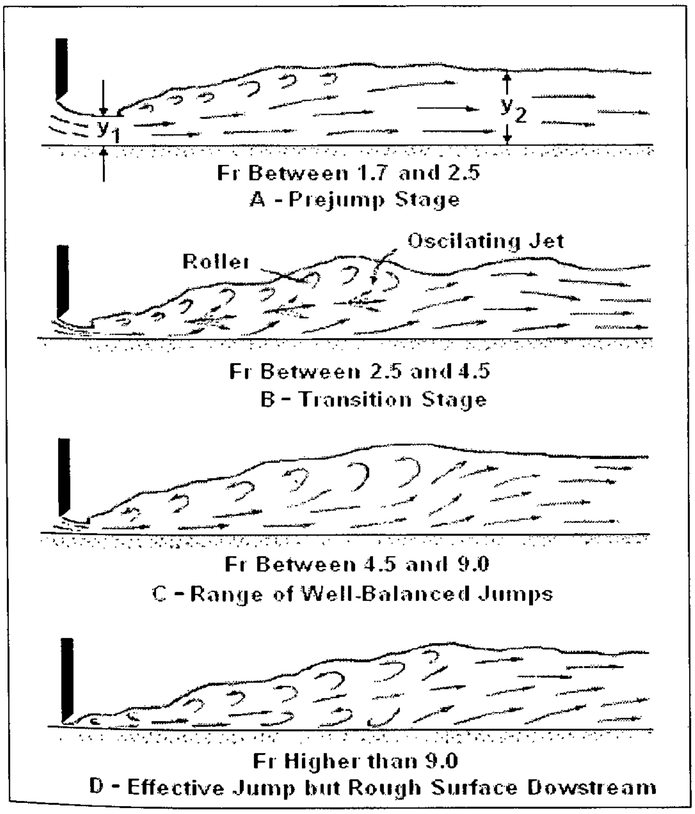

Figure 2.2 Flow Profile According to Froude Number (Philip H. Burgi, 2002)

Table 2.1 Jump Characteristics According to Froude Number (C.Nalluri, 2001)

Froude Number	Jump Characteristics
1.0-1.7	Surface waves (undular)
1.7-2.5	Weak jump. Low energy loss
2.5-4.5	Oscillating jump. Large irregular waves
4.5-9.0	Steady jump
>9.0	Strong jump

According to DROP Design Manual (1997), there are three important parameters of the jump in the design of energy dissipating structures:

i. The ratio of the incoming depth to the sequent depth
ii. The magnitude of the energy loss for any given set of incoming flow conditions.
iii. The length of the jump

Referring to Belanger momentum equation, the ratio can predict the conjugate depth base on Froude number derived from discharge per unit width (K.G. Ranga Raju, 1984). Energy loss is generally more significant for higher Froude number. Length of the jump and the end of the jump which can be defined as the point where the reverse surface roller ends or the point of maximum water depth (Subash C. Jain, 2001)

2.5 Types of Energy Dissipating Structure

Various inventions of energy dissipating structures have been developed to prevent scouring downstream from the structure. They consist of:

i. Stilling basin
ii. Steeped spillway
iii. Ski jump
iv. Baffle block
v. Riprap

2.5.1 Stilling Basin

The stilling basin as an energy dissipator is based on the concept of developing a hydraulic jump on a concrete pad immediately downstream of a spillway to dissipate the energy of the turbulent flow before it reaches the downstream channel (Philip H.Burgi, 2002). Several considerations need to be made in the design of stilling basin which is location, gradient and stabilization of the inflow channel.

The hydraulic laboratory developed seven unique stilling basin designs where a hydraulic jump is used to dissipate energy. A widely used energy dissipator in this group is the impact basin often used at the downstream end of pipe. It is very effective energy dissipator that is commonly seen today in urban flood control project.

2.5.1.1 USBR Type I Stilling Basin

Structure type I consists of a horizontal apron without blocks or end sill. The basin is suited to incoming flows characterized by Froude number in the range 1.7 to 2.5 (pre-jump condition). The structure is not commonly used as it tends to be uneconomically long and the hydraulic jump can also be sweep out at tailwaters only marginally below design level (DROP Design Manual, 1997)

2.5.1.2 USBR Type II Stilling Basin

Structure type II is suited to high velocity flows with Froude number above 4.5 conditions occurring typically below high spillways and it is therefore not considered here in detail. The jump length is reduced over the unrestrained case by around 33% through the introduction of chute blocks and a dentate end sill. Sweep out of the jump can be a problem so the USBR recommends that the apron level is fixed assuming that the tailwater depth is 5% less than expected (DROP Design Manual, 1997)

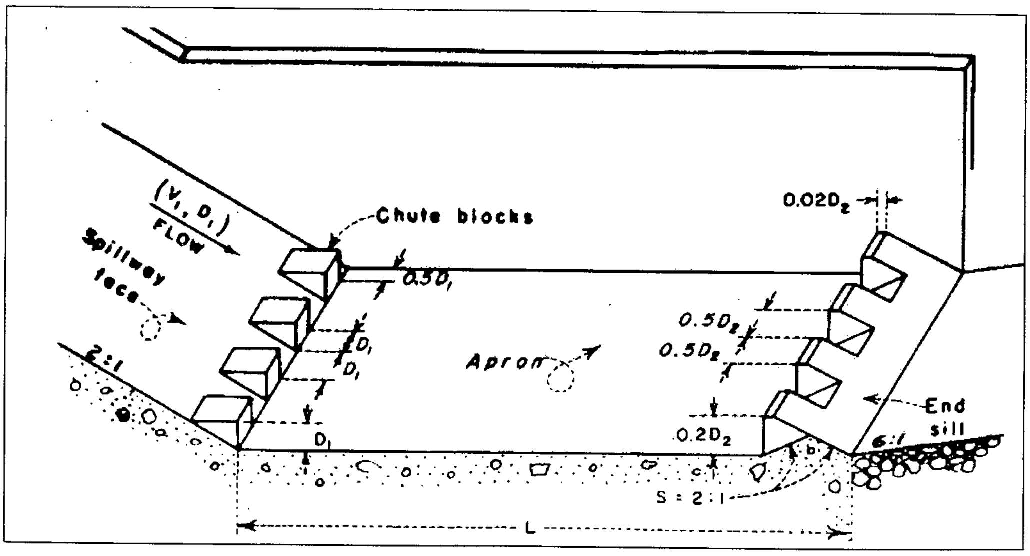

Figure 2.3 USBR Type II Stilling Basin (DROP Design Manual, 1997)

2.5.1.3 USBR Type III Stilling Basin

The structure is suited to locations where the Froude number exceeds 4.5. The incoming velocity does not exceed 15m/s and the discharge intensity is less than $18m^3/s$ per meter width. The restriction is imposed to avoid cavitations damage to baffle blocks, chute blocks and the solid end sill which are fundamental to the design of the structure. Introduction of these appurtenances shortens the jump and the basin about 60% over the comparable Type 1 structure. The structure is suited to lower head conditions small spillway, outlet works and canal structure (DROP Design Manual, 1997)

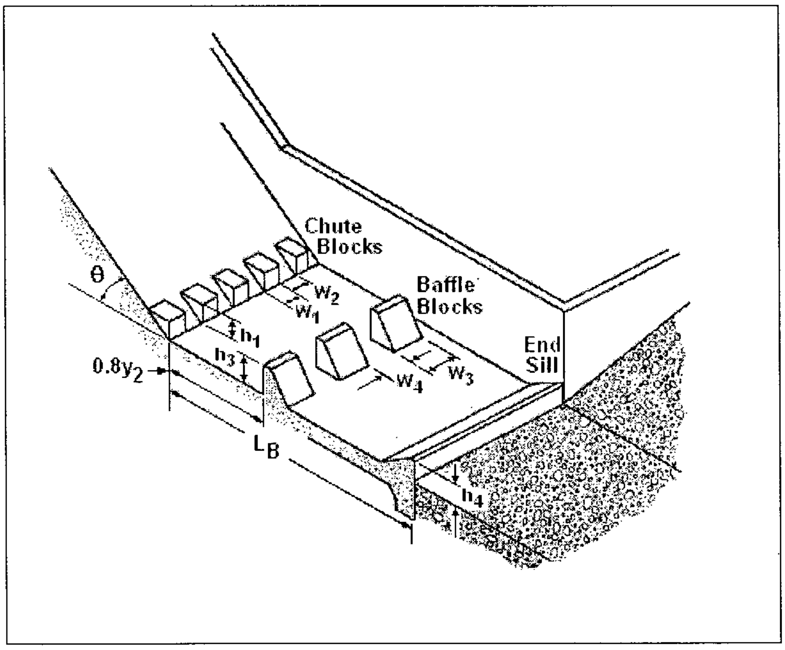

Figure 2.4 USBR Type III Stilling Basin (OHIO Department of Resources, 1999)

2.5.1.4 USBR Type VI Stilling Basin

Structure Type VI is intended for Froude number in the range 2.5-4.5 conditions which may typically occur at small drops in open channel systems. The design is intended to reduce the generation of surface waves which can travel large distances downstream and erode canal banks. For this reason the chute blocks are enlarged in order to direct the incoming jet into the base of the jump roller to help stabilize it. For situations where it is essential to minimize surface turbulence, the USBR has also developed designs for surface wave suppressors which can be placed downstream of the main structure (DROP Design Manual, 1997)

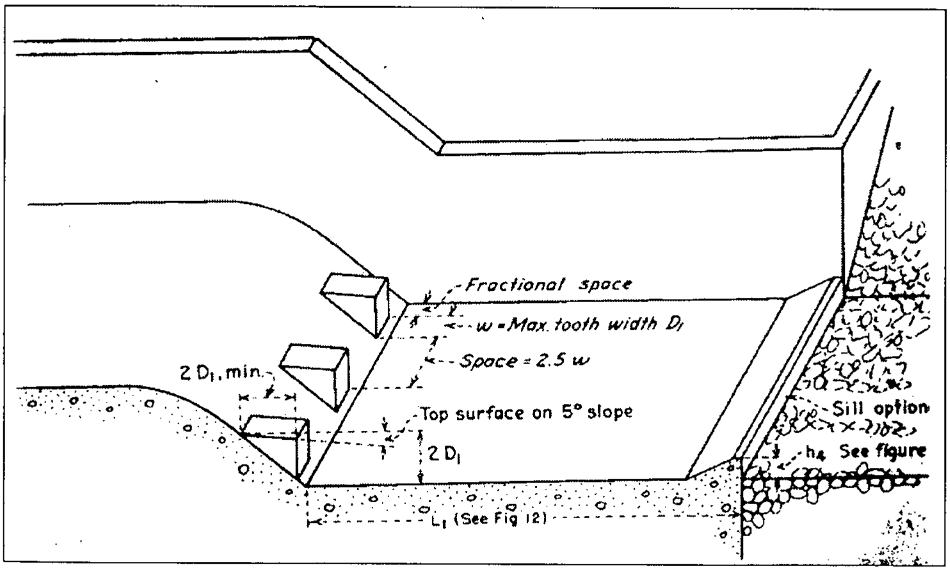

Figure 2.5 USBR Type VI Stilling Basin (DROP Design Manual, 1997)

2.5.1.5 USBR Structure Type V

The Type V structure is designed to provide effective performance when the jump sequent depth and the tail water cannot be matched across the full range of flow conditions. A sloping apron allows the jump to form at different points, depending on the discharge. This solution is not often adopted for small structures, probably because it is less simple to construct than a horizontal apron (DROP Design Manual, 1997).

2.5.1.6 SAF Stilling Basin

This small structure design was developed at the Saint Anthony Falls laboratory of the University of Minnesota, Blaisdell, 1948. The aim was to design an energy dissipating structure with the minimal practical basin length, suitable to a wide range of tail water conditions and Froude number.

The structure can produce reductions of up to 40% on the length of a simple apron structure and 40% on the calculated sequent tailwater depth. The penalty is that construction becomes more complex. An endsill, chute blocks and baffle blocks are include in the design. Transported debris is liable to become lodged in the basin. The required tailwater depth for satisfactory performance across the range of Froude number was determined from test (Varshney et al, 1977).

By the 1970s the trend for spillway terminal structure had returned to the flip bucket where the principle used was to direct the flow away from the structure and downstream a sufficient distance where the water could erode its own plunge pool. The energy dissipated within the basin at the end of the tunnel spillway up to a