EXPERIMENTAL INVESTIGATION OF THE VELOCITY DISTRIBUTION FOR A BENDWAY WEIR

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APPROVAL SHEET

This project report entitled **"EXPERIMENTAL INVESTIGATION OF THE VELOCITY DISTRIBUTION FOR A BENDWAY WEIR"** prepared and submitted by Ng Suh Hong in partial fulfilment of the requirement for Bachelor of Engineering (Hons) Degree is hereby partially accepted.

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EXPERIMENTAL INVESTIGATION OF THE VELOCITY DISTRIBUTION FOR A BENDWAY WEIR.

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A Project report submitted in partial fulfilment for the Bachelor Degree of Engineering (Civil) with Honours in the Faculty of Engineering

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Dedicated to my beloved family and loved ones.

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ABSTRACT

Bendway weirs is a set of structure used to reduce erosion problems at sharp bends of natural stream. Its ability to realign velocity distribution to a better alignment has been proved through previously installed bendway weirs. The effects of different bendway weir's length and degrees of angled downstream were found valuable as a mean to decrease the velocities at the outer bend while not unduly increase the inflow depth. In this study, the effect of different length and different angles downstream of the weirs is presented. The study is conducted in a channel that has been modelled up according to one real bend located in Batang Sadong. Whereby serious erosion at the outer riverbank has caused damages to villages nearby, and even worse especially at flood season. Experiment data shows that, a 3.5cm of bendway weirs angled downstream has successfully realigned the cross section velocities distribution along the bend. High velocities at outer bend have been reduced, cross section velocities were more evenly distributed and acceptable small increment in inflow depth. Thus, a 3.5cm bendway weir with a 20° angle downstream is more effective in velocity redistribution and outer bend erosion elimination.

ABSTRAK

Bendway weir merupakan satu set alat yang amat berkuasa dalam menangani masalah hakisan yang selalunya berlaku pada selekoh tajam. Kebolehannya dalam penyusunan semula taburan kelajuan telah dibuktikan. Kesan daripada bendway weir yang berlainan panjang dan juga darjah bendway weir bersudut kepada aliran hilir merupakan aset yang amat penting dalam menentukan keberkesanannya untuk menurunkan kelajuan air pada selekoh luar dan pada masa yang sama tidak meninggikan kedalaman air. Dalam kajian ini, kesan daripada bendway weir yang berlainan panjangnya dan sudut kepada aliran hilir disampaikan. Kajian ini dilakukan ke atas sebuah model selekoh yang terletak dalam Batang Sadong. Dimana terdapat hakisan tanah yang serius berlaku pada selekoh luar dan menyebabkan kerosakan pada kampung-kampung yang berhampiran, terutamanya pada musim banjir. Keputusan daripada kajian ini telah menunjukkan bahawa 3.5cm panjang bendway weir bersudut 20 darjah kepada aliran hilir telah berjaya menyusun semula taburan kelajuan keratan rentas sepanjang selekoh tersebut. Kelajuan yang tinggi pada selekoh luar telah dikurangkan dan lebih tersusun kelajuan keratan rentasnya serta tidak meninggikan kedalaman aliran air. Maka dapatlah disimpulkan bahawa bendway weir yang bersaiz 3.5cm panjang serta menghala 20° kepada aliran hilir berkebolehan dalam penyusunan semula taburan kelajuan air sepanjang selekoh serta menangani masalah hakisan tanah.

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CHAPTER 1

INTRODUCTION

Bendway weir is a structure used to solve natural stream problem, especially in reducing erosion at the outer bank of a bend and also excessive deepening of bendway and finally narrowing of navigation channel by the formation of point bar at the inner bank. The design of bendway weirs to be installed at the stream has to be done through model study. A small scale of the proposed bendway has to be constructed and followed by the analysis of the effect of the weirs to the flow at the bend has to be carried out thoroughly. Understanding of the effect of the weir's height, angle to upstream and length to the flow lines must be thoroughly investigated at this stage and finally come out with the best dimension of the weirs to be constructed at site. It is also essential for the designer to make sure that the weirs will react with the stream accordingly at the proposed site by considering the site condition. Adjustment still can be done at the construction stage.

The purpose of this final year project is mainly focusing at the effect of the bendway weirs to the flow lines at one of bends in Batang Sadong, part of the Sarawak River System. Shape of the bend will be scaled to a small model study for laboratory testing. The effects of the bendway weirs on the velocities distribution along the bend were studied and observed based on laboratory experiment. Weirs were tested under different lengths and also different angles.

By conducting experiments in the Hydraulic Lab, the effects of the weirs on the velocities distribution and flow lines alignment will be determined and finally the most effective dimension of the weirs for that specific bend will be determined.

CHAPTER 2

LITERATURE REVIEW

2.1 BACKGROUND AND HISTORY

Natural river system may needs improvement for navigation. This involves channel realignment, which includes corrective dredging, stabilization, training structures, and modification or replacement of existing bridges.

Corrective dredging is used to realign the bank lines and to develop cutoffs. Dredging in the channel bed involves the removal of erosion-resistant material such as gravel bars, rock outcrops, or clay plugs. This method without some training structures will produce a temporary result and might have to be repeated after each high water period in river stages.

Channel stabilization involves the protection of the streams or channel from erosion caused by currents and waves. Natural channel which are always under erosion will tend to meander, migrate and then constant changing in its lifetime. Erosion of the stream will continuously steeper its slope to the point that sloughing of the bank occurs. It can adversely affect the channel alignment and cause serious damages to the valuable lands and local installations such as buildings, bridges and so on.

Cutoffs is another recommended solution to eliminate sharp bends, eliminate troublesome reaches, reduce the length of the navigation channel, or increasing the flood-carrying capacity of the stream. It is usually constructed by dredging a pilot channel across the neck of one or more bends. It is rarely practiced at the natural river system caused by the extremely high construction cost and also environmental effects.

River training structures especially bendway weirs play a very important rule in solving these problems. It can be constructed in very low cost compared to dredging and cutoffs and it does not need much maintenance after the construction.

Bendway weirs are the most recently developed river training structures that involve the concept of modifying the channel by using a set of weirs. The bendway weir concept was first conceived in January 1988 by Mr. Thomas J. Pokrefke at the U.S. Army Engineer Waterways Experiment Station for use in a physical movable-bed model of a 32km reach of the middle Mississippi river. The result shows that it have performed exceptionally well in channel realignment. The flow lines have been redirected to a better alignment, erosion of the outer bank has been eliminated, and the channel becomes wider for safe navigation. [http:// chl.wes.army.mil/research]

2.1.1 TYPES OF BENDWAY WEIRS

Bendway weirs are basically grouped into two, depending on the location of its application, which are navigable river weirs and stream weirs. In a navigable river, bendway weirs can be classified as a rock sill located in the navigation channel of a bend, usually angled 20° to 30° upstream, spaced between 400 to 1400 ft apart, varying in length from 400 to 1600 ft, and level-crested at an elevation low enough to allow normal river traffic to pass over unimpeded. In a stream or river with unrevetted bank a bendway weirs is a low level, upstream-angled stone sill, attached the outer bank of a bend. It is usually angled 5 to 25 degrees upstream, spaced 50 to 100 ft apart, 2ft high at the stream end rising to 4ft at the bank end, and finally the length varying from ¼ to ½ the base flow width of the system.
[http:// chl.wes.army.mil/research]

2.2 THEORY OF BENDWAY WEIRS

Bendway weirs become a very important river training structures because of its efficiency in solving the natural river system. Erosion at the outer bank of a bend can be easily solved by reducing the flow velocities and the concentration of currents at the outer bank of the bendway. All these improvements will lead to a better current alignment through the bend and downstream crossing.

For a natural unimproved bend, surface water current tends to move from the inside of the bend toward the outside. It will cause the concentration of the flow and thus increasing the velocities along the outer bank of the bend. The high velocities current will lead to increased bank erosion. But with the use of bendway weirs, water flowing over the weirs will be redirected at an angle perpendicular to the axis of the weir and finally the strong *secondary currents* in the bend are broken up. [http:// chl.wes.army.mil/research] The resulting currents are thus more evenly distributed across the channel. Therefore the bendway weirs will effectively control excessive channel deepening and reduces adjacent riverbank erosion on the outside bendway. Because excessive river depths are controlled, the opposite side of the riverbank is widened naturally. This results in a wider and safer navigation channel through the bend without the need for periodic maintenance dredging.

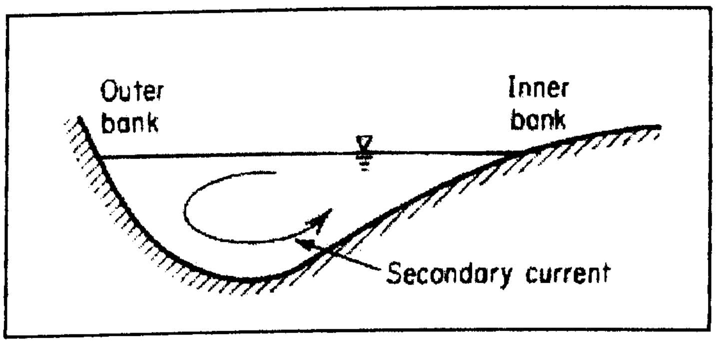

Figure 2.1 : Typical Section at a Natural River Bend
[Henderson, 1966]

Secondary currents, always occur at bend of a natural stream. Its explanation is very simple. Secondary currents occur because of the uneven velocities distribution at the *cross section of stream at the bend will generate pressure gradient between the outer and inner bank. Finally a circulatory flow pattern will be generated at the bend cross section. This flow pattern has the most important influence in natural river, tending to scour sediment from the outside of the curve and deposit it on the inside, shoaling the inner bank by forming a point bar and in the mean while eroding the outer bank to deepen.* [Henderson, 1966]

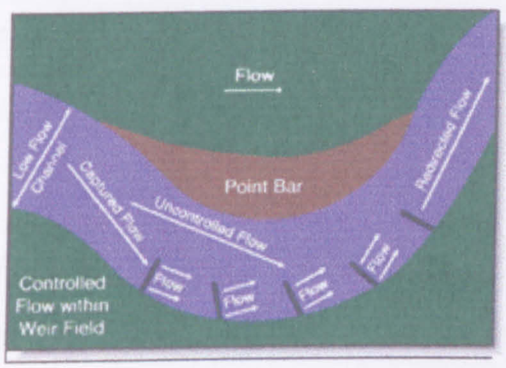

Figure 2.2 : Application of Weirs at Bend
[http:// chl.wes.army.mil/research]

By referring to the figure above, it shows that with the bendway weirs angled upstream, the flow is directed away from the outer bank of the bend and toward the point bar. This redirection occurs at all stages of the stream.

As mentioned before, a lot of experiments have to be carried out before designing bendway weirs. Prototype and model testing in part of the Demonstration Erosion Control (EDC) Program at Harland Creek Bendway have indicated the improvements in the navigation channel of the bendway weirs as follows:

- The channel through the bend and immediately downstream is widened and better aligned.
- Deposition occurs at the toe of the revetment on the outside of the bend, which increasing bank stability.
- Scouring occurs on the point bar creating a flow path on the inside of the bend.
- Surface water velocities are more even across any cross-section.
- Flow patterns in the bends are generally parallel with the banks and no more concentrated at the outer bank.

  [http:// chl.wes.army.mil/research]

The functions of bendway weirs are not restricted to erosion protection. It also can lead to an environmental improvement in the habitat. The weirs may act like reefs, drawing lower member of the food chain and ultimately fish.

2.2.1 BENDWAY WEIR APPLICATIONS

Application of bendway weirs includes:

- Bank Protection / Habitat improvement
- Highway bridge protection
- Low-cost bendway weir solutions.

2.2.2 ADVANTAGES / DISADVANTAGES OF BENDWAY WEIRS

Benefit of bendway weirs to natural stream systems:

- Flow can be redirected and predicted
- Perform well under high-flow, high energy condition
- Flow is considered controlled within the weir field
- It blend well with other bank protection methods
- Aquatic habitat is improved.

[http:// chl.wes.army.mil/research]

Disadvantages of bendway weirs:

- Discontinuous protection is usually less effective than continuous protection in eliminating bank erosion.
- Bendway weirs are more vulnerable to floating debris than blankets or continuous toe protection.

2.3 DESIGN OF BENDWAY WEIRS

Previously installed bendway weirs in many projects at United States like Missisippi River have shown that it is a very powerful tool. Its application that can change the direction of the stream flow at a bend implies the important of a proper design is needed for such a structure. Because it is recently developed, there are still no general design guides. The design therefore requires a thorough understanding of bendway weirs theory and practice, and extensive knowledge of the stream flow in which the structure will be installed.

Survey should be carried out in order to the assesses the existing bend conditions, geometry, planform, stages and discharges, sediment transport capacity and stream features. Because of the application of the bendway weirs in redirecting the currents direction at the outer bank of a bend, therefore the direction of stream flow and velocities entering the area of the proposed weir field must be carefully measured and analyzed. [http:// chl.wes.army.mil/research]

The design of the bendway weirs involves complicated procedures. Understanding of the hydraulic effects by the weirs and the natural stream condition will be helpful in designing efficient weirs. Because it can work under all river stages, it is essential for the designer to design the weirs for low, medium and high flow condition, with more weight allocated to the higher energy that is medium to high conditions.
[http:// chl.wes.army.mil/research]