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OPEN CHANNEL FLOW THROUGH SUBMERGED RIGID VEGETATION

Suphill Paul A/L Suthan

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Title : Open Channel Flow Through Submerged Rigid Vegetation

Student Name : Suphill Paul A/L Suthan

Matric No : 15345

Has been read and approved by:

Charles Bong Hin Joo

(Project Supervisor)

21/5/2010

Date

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SUPHILL PAUL A/L SUTHAN

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Dedicated to my beloved family and friends who have always been there for me.

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ABSTRACT

The interest to perform the study of flow in compound channels has been a major subject of hydraulic research in recent years. Studies on compound channel have proven that the flood plain vegetation has significant effects on the channel's roughness, velocity and discharge values. As for this project, the aim is to determine the flow characteristics in a compound channel with submerged rigid vegetation on its floodplain and comparing the results with different methods. The model used to conduct this study was a custom-built non-symmetrical compound channel section. To simulate the floodplain vegetation, wooden rods of identical shapes were attached on plywood and fixed on the flood plain. The arrangement of the wooden rods is then altered so that the results of different density flood plain vegetations can be compared. The observed results from the experiment are also compared with the traditional hydraulic methods (i.e. DCM-Horizontal, DCM-Vertical and SCM). To validate the traditional divided channel methods, the Weighted Divided Channel Method (WDCM) was used and the method which best suit the observed result was determined. It was found that for this study, both divided channel methods (i.e. DCM-Horizontal and DCM-Vertical) are appropriate to determine the velocity and discharge of the non-symmetrical compound channel.

ABSTRAK

Minat untuk membuat kajian mengenai aliran saluran gabungan aliran menjadi topik utama kajian hidraulik dalam beberapa tahun kebelakangan ini. Kajian terhadap saluran gabungan telah membuktikan bahawa tumbuh-tumbuhan dataran banjir mempunyai pengaruh yang signifikan terhadap kekasaran saluran, halaju dan isipadu aliran. Tujuan projek ini adalah untuk menentukan ciri-ciri aliran dalam saluran gabungan dengan tumbuh-tumbuhan kaku berendam pada dataran banjir dan membandingkan hasilnya dengan kaedah yang berbeza. Model yang digunakan untuk mengendalikan kajian ini adalah saluran gabungan tidak-simetri yang dibina khas untuk projek ini. Untuk mensimulasikan tumbuh-tumbuhan dataran banjir, batang kayu yang bentuk homogen disambung pada papan lapis dan ditetapkan pada dataran banjir. Susunan batang kayu kemudian diubah supaya keputusan untuk kepadatan tumbuh-tumbuhan dataran banjir yang berbeza dapat dibandingkan. Hasil pengamatan dari eksperimen juga dibandingkan dengan kaedah hidraulik tradisional (iaitu DCM-Melintang, DCM-Menegak dan SCM). Untuk mengesahkan kaedah saluran terbahagi tradisional, kaedah saluran terbahagi berpemberat (WDCM) telah digunakan dan kaedah yang paling sesuai dengan keputusan yang diperhati telah ditentukan. Didapati bahawa untuk penyelidikan ini, kedua-dua kaedah saluran terbahagi (iaitu DCM-Melintang dan DCM-Menegak) berpadanan untuk menentukan halaju dan isipadu aliran saluran gabungan tidak-simetri.

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A	-	cross-section area
ξ	-	weighting factor for weighted divided channel method (WDCM)
fp	-	flood plain
h	-	depth of main channel below flood plain
H	-	total flow depth
mc	-	main channel
n	-	Manning's roughness coefficient
Qobs	-	total observed discharge
Q_{WDCM}	-	discharge calculated using WDCM method
R^2	-	coefficient of determination
V	-	mean velocity
Vave	-	total observed velocity for the whole cross-section
Vmc-DCM-H	-	main channel velocity calculated by using the horizontal division method
Vmc-DCM-V	-	main channel velocity calculated by using the vertical division method
Vmean-WDCM	-	velocity calculated using the WDCM formula

CHAPTER 1

INTRODUCTION

1.1 General Overview

A compound channel consists of a channel with two stages. The main river channel carries low flows whereas the floodplains which are normally dry only comes into action during high flows (Strum & Sadiq, 1996). There are many theoretical problems that occur when studying about steady or unsteady flows in compound channel. Therefore by limiting our consideration to uniform flow, the theoretical problems consists of predicting the flow field in a compound channel while the practical problem consists of studying how the knowledge of the flow field influences the analysis (Pezzinga, 1994).

When analyzing the flow in a compound channel, the calculation of the flow transmitted by the main channel and by the floodplains are done separately and by assuming that the channels are independent (Pezzinga, 1994). This is because it is difficult to analyze the flow in the main channel and floodplains together since the interaction between the main channel and flood plain flow is complex due to the momentum transfer at the interface (Strum & Sadiq, 1996).

Some current research have been done for compound channels such as velocity predictions using genetic programming for vegetated flood plains (Harris *et al*, 2003), hydrodynamic behavior of partly vegetated open channels (Naot *et al*, 1996), Reynolds stress modeling of vegetated open-channel flows (Choi & Kang, 2004) and effect of submerged flexible vegetation on flow structure and resistance (Jarvela, 2005). These researches concentrates on numerous aspects such as the effect of vegetation on velocity distributions, the hydrodynamic response of turbulent flow in compound channel with a vegetated area to the vegetation density and diameter, computation of pressure–strain term, diffusion and dissipation rate of Reynolds stress and determining resistance coefficients for natural flood plain and wetland flows. Even though there have been many experiments conducted by researchers, the estimation of discharge in a compound channel have yet to be determined or agreed (Bong & Mah, 2008).

1.2 Problem Statement

In this research the properties of an open channel flow through submerged rigid vegetation are studied. The problem that will be investigated in this research is how the existence of rigid vegetation in a compound channel will affect the flow characteristics when the vegetation is submerged. It should be realized that there are many problems associated with this research compared to the real life situations that occurs in a compound channel. The problems that might be faced in this experiment are the type of the vegetation that will be used, geometry of the model channel and the flow characteristics through the submerged vegetation.

1.3 Objectives

The purpose of this study is to determine:

i. The stage-discharge characteristics of flow through submerged rigid vegetation in non-symmetrical compound channel

ii. The effect of the roughness on the characteristics of the flow through submerged rigid vegetation.

iii. To compare the validity of different methods available in predicting the discharge capacity.

1.4 Scope of work

This study has been conducted at the Civil Engineering Hydraulics laboratory of UNIMAS. A model compound channel was designed and built in the lab with the guidance of the project supervisor. The model was constructed using ply wood as the channel material. For the rigid vegetation representation, wooden rods were cut into identical shapes and attached on the flood plain at equal spacing.

After that water will be passed through the channel at different stages. The vegetation will be submerged at all stages whereas the depth of water above it will be adjusted for the comparison of results. A current meter will be fixed in the channel to measure the velocity and discharge of the flow at all stages. Then the value of the velocity and discharge will be used to plot the stage-velocity and stage-discharge graphs. From these results, conclusion will be made based on the observed data.

1.5 Outline of following chapters

Brief outlines for each of the following chapters are explained in this part. The following chapters consist of Literature Review, Methodology, Results, Analysis & Discussion and Conclusion & Recommendation.

1.5.1 Literature Review

In this chapter all the main aspects of the project are described in detail such as the definition of compound channel, its characteristics and problems to be solved. The types of traditional methods used to analyze the discharge capacities of a compound channel are mentioned in detail. Finally previous researches on compound channel related to this project topic are also discussed in this chapter.

1.5.2 Methodology

The experimental arrangements such as the details of the model are first discussed. Then the photographs of all equipments used and important parts of the model are shown. Lastly the procedures of the experiment to determine the velocities, discharge and roughness are discussed in detail.

1.5.3 Results, Analysis & Discussion

The results obtained from the experiments are analyzed here by plotting all the necessary graphs. From these graphs the results obtained are then explained with evidence from previous researches. For results that are not in the possible range or had deviated away from the expected values, realistic reasons are given to support the incorrect data.

1.5.4 Conclusions & Recommendations

This chapter concludes the whole project by stating the conclusion for each of the analysis. The conclusion is then compared with the objectives of the project to decide if the objectives are achieved. Then the limitations and problems faced while carrying out this project is explained in detail. Recommendations are given to improve the studies of compound channel in future.

CHAPTER 2

LITERATURE REVIEW

2.1 Hydraulics of compound channels

Compound channel geometries such as rivers assure reasonable depths at low flows. This provides an appropriate environment for fish and other flora and fauna which depend on it to survive, whereas the flood plains operate as a passageway for floods during and after heavy downpours. On the other hand, researchers have difficulties in estimating the discharge capacity in rivers which have a cross-sectional shape of a compound channel. Methods which have been developed for determining the discharge capacity for simple cross-sectional shapes do not provide accurate results when applied to overbank flows. These methods when used, results to an over-estimation or under-estimation of discharge capacity.

The flow in a compound channel is complicated due to the existence of a turbulent shear region at the interface between the main channel and flood plain flows. This takes in the form of a momentum transfer mechanism, therefore delays the main channel velocity and discharge but the equivalent factors on the flood plain are increased (Myers *et al*, 2001). A few traditional methods have been used to determine the discharge in compound channels such as the Single Channel Method (SCM) and the Divided Channel Method (DCM) which consists of Vertical Division Method (DCM-V), Horizontal Division Method (DCM-H) and Diagonal Division Method (DCM-D).

2.1.1 Single Channel Method (SCM)

The Single Channel Method is the simplest form of determining the uniform flow in a compound channel. The compound geometry is treated as a single unit and some suitable standard for the friction coefficient is applied. The multiple characters of the channel for this method are redundant and for the whole cross-section the velocity is assumed to be uniform. Hence with the application of this method the discharge capacity is drastically underestimated at low overbank flow depths since the velocity is assumed to be uniform (Ozbek, 2004).

2.1.2 Division Channel Method (DCM)

The Divided Channel Method (DCM) is the most commonly used method for computing the discharge in compound channels. As shown in Figure 1, the compound cross-section is divided into hydraulically identical sub-areas in such a way that the velocity in each sub-section may be assumed to be uniform. These division lines which are between the sub-sections could either be vertical, horizontal or diagonal. The most common and practical option that is used are the vertical lines (Ozbek, 2004).

Normally for the discharge calculation of the main channel flow, the vertical division lines between the main channel and its flood plains are included in the wetted perimeter but for the flood plain discharge calculation the vertical division lines are excluded in the wetted perimeter. This method is anticipated to have the consequence of retarding the main channel flow but boosting the flood plain flow and by changing the wetted perimeter by the vertical line does not totally reveal the interaction effect since this interaction effect is not a straightforward function as the water depth of the flood plain increases (Tang *et al*, 1999).