UNIVERSITI PUTRA MALAYSIA

EFFECTS OF NAPIER AND CATTAIL GRASSES ON OPEN CHANNEL FLOW CHARACTERISTICS

MANAL M. ABOOD

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By

MANAL M. ABOOD

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Partial Requirements for the Degree of Master of Science

October 2005

DEDICATION

I dedicate this work

To My Country Iraq,

Abstract of the thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the partial requirement for the degree of Master of Science

EFFECTS OF NAPIER AND CATTAIL GRASSES ON OPEN CHANNEL FLOW CHARACTERISTICS

By

MANAL M. ABOOD

October 2005

Chairman : Badronnisa Yusuf

Faculty : Engineering

Laboratory study has been conducted to analyze the effects of two types of vegetations namely Napier grass and Cattail grass on the characteristics of flow in an open channel. The main objectives of this study are to determine the effects of vegetations on Manning's roughness coefficient and velocity distribution, and to develop relationships between the characteristics of vegetation (density, degree of submergence and distribution) with the properties of flow (Manning roughness coefficient, velocity and Reynolds number).

The resistance properties for each of vegetation were examined in the flume which is rectangular in cross section and has dimensions of 12m length, 0.32m width and 0.32m height.

The results show that the presence of vegetations increases the values of Manning's roughness coefficient, n, and affected significantly the vertical velocity profiles. The effects depend on factors such as flow depth, degree of submergence, density and arrangement of plant.

The Manning's roughness coefficient, n, for flows with Napier grass increased with the increased in flow depth for both submerged and unsubmerged situations, and this increments varied from 0.017 to 0.065 with flow depth for high vegetation density (100 veg/m^2) and from 0.0058 to 0.0427 for low vegetation density (20 veg/m^2). In the presence of Cattail grass, the effects were reversed. The increased in flow depth leads to reduction in the roughness coefficient, and this decrements varied from 0.031 to 0.022 for the high density and from 0.024 to 0.0157 for the low density. This may be due to the physical characteristics of the cattail, which has no branching stems and leaves.

Manning's n in the case of low density (20 veg/m^2) of Napier grass decreased with the increase of Reynolds number, Re for both submerged and unsubmerged vegetations. However, for higher density (100 veg/m^2), this phenomenon only occurred for submerged vegetation. In the case of unsubmerged vegetation the n values increased with the increased of Re. For cattail, the n values decreased with Re for all densities of vegetation.

The dependence of n on density of vegetation was found to be represented by a linear relationship (R^2=0.93-0.96) for both submerged and unsubmerged vegetations. The results indicate a tendency for n to increase with increasing values of density for the same value of flow depth. Napier grass increased the Manning's, n with the increased of density by 35%, while the Cattail grass increased the value of n with the increased of density by 25%. Increment in Manning's, n with the density of vegetation is not only with the flow depth but also with the different types of vegetation. The Manning roughness coefficient, n was also found to be affected by the vegetation arrangement. The results show that the arrangement where the vegetations were at both sides of the channel gave the highest values of n followed by the vegetations at the channel center and then the vegetations were randomly distributed. The n value increased almost linearly with the depth of flow in three types of arrangements.

The effects of vegetations in the vertical velocity distribution of flow were examined, the results showed that the present of vegetation change the shape of velocity distribution and reduced the velocity by 61.5% inside the canopy and 36% above the canopy.

Abstrak tesis dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi sebahagian keperluan Ijazah Master Sains

KESAN TUMBUHAN (RUMPUT *NAPIER* DAN *CATTAIL*) KE ATAS CIRI ALIRAN DALAM SALURAN TERBUKA

Oleh

MANAL M. ABOOD

October 2005

Pengerusi : Badronnisa Yusuf

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Kajian makmal telah dilakukan untuk menganalisis kesan dua jenis tumbuhan yang berbeza, iaitu rumput Napier dan Cattail, ke atas ciri-ciri aliran dalam saluran terbuka. Objektif utama kajian ialah untuk mendapatkan kesan tumbuhan ke atas pekali kekasaran Manning dan profil halaju, dan untuk membangunkan hubungan antara ciri-ciri tumbuhan (ketumpatan, tahap ketenggelaman dan agihan/susunan) dengan sifat-sifat aliran (pekali kekasaran Manning, dan nombor Reynolds).

Sifat rintangan untuk setiap tumbuhan kepada aliran telah kaji di dalam flum terbuka segiempat yang berdimensi 12 m panjang, 0.32 m lebar dan 0.32 m tinggi.

Keputusan menunjukkan tumbuhan meningkatkan nilai pekali kekasaran Manning dan memberi kesan yang ketara terhadap profil tegak aliran. Kesan ini bergantung kepada faktor seperti kedalaman aliran, tahap ketenggelaman, kepadatan serta agihan dan susunan tumbuhan.

Pekali kekasaran Manning, untuk aliran dengan rumput Napier didapati meningkat dengan peningkatan kedalaman aliran dalam keadaan tenggelam dan juga separa tenggelam. Peningkatan ini berubah dari 0.017 ke 0.065 untuk kepadatan tumbuhan tinggi (100veg/m^2) dan dari 0.0058 ke 0.0427 untuk kepadatan tumbuhan rendah (20 veg/m^2). Manakala rumput Cattail memberi kesan yang berbeza. Peningkatan kedalaman aliran menyebabkan penurunan pekali kekasaran. Penurunan ini berubah dari 0.031 ke 0.022 untuk kepadatan tumbuhan tinggi dan dari 0.024 ke 0.0157 untuk kepadatan rendah. Ini berlaku mungkin kerana ciri-ciri fizikal rumput Cattail yang tiada batang dan daun bercabang.

Manning n, untuk aliran dengan rumput Napier berkepadatan rendah didapati menurun dengan peningkatan nombor Reynolds, Re, di dalam kedua-dua keadaan, iaitu tenggelam dan separa tenggelam. Walaubagaimanapun, pada kepadatan tinggi pemerhatian ini hanya benar dalam kes tumbuhan tenggelam. Dalam kes tumbuhan separa tenggelam, nilai n meningkat dengan peningkatan Re. Untuk aliran dengan rumput Cattail, nilai n menurun dengan Re pada semua kepadatan tumbuhan.

Kebergantungan nilai n kepada kepadatan tumbuhan, didapati mempunyai hubungan linear (R^2=0.93-0.96) untuk kedua-dua keadaan, tenggelam dan separa tenggelam. Rumput Napier meningkatkan nilai n dengan peningkatan kepadatan tumbuhan. Keputusan menunjukkan pada kedalaman aliran yang sama nilai kekasaran meningkat sebanyak 35% dengan peningkatan kepadatan tumbuhan sebanyak 33.3%.. Manakala rumput Cattail dengan peningkatan kepadatan tumbuhan yang sama telah meningkatkan nilai n sebanyak 25%. Peningkatan nilai Manning n, dengan kepadatan tumbuhan tidak hanya dengan bergantung kepada kedalaman aliran tetapi juga dengan jenis tumbuhan. Pekali kekasaran Manning's juga didapati dipengaruhi oleh agihan tumbuhan. Keputusan menunjukkan agihan tumbuhan pada kedua-dua sisi saluran memberi rintangan tertinggi, diikuti dengan agihan tumbuhan ditengah saluran dan kemudian agihan tumbuhan rawak. Nilai n meningkat hampir linear dengan kedalaman aliran untuk semua jenis agihan tumbuhan.

Kesan tumbuhan kepada profil menegak juga di kaji. Keputusan menunjukkan kehadiran tumbuhan telah merubah bentuk profil halaju dan menurunkan halaju sebanyak 61.5% di dalam tumbuhan dan 36% di aliran di atas tumbuhan.

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I certify that an Examination Committee met on 7th October 2005 to conduct the final examination of Manal M. Abood on her Master thesis entitled "effects of Napier and Cattail grasses on open channel flow characteristics" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulation 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institution.

MANAL M. ABOOD

Date:

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LIST OF SYMBOLS

A	Flow cross- sectional area normal to direction of flow.
A_i	Projected area of ith plant in upstream direction
C	Chezy coefficient
C_d	Drag coefficient vegetation
C_d ΣAi/AL	Density of vegetation
D	Mean water depth (assumed as R for wide channel)
D_i	Drag force on ith plants
Dv	Density of plant (veg/m^2)
E	Modulus of elasticity
F_x	Force in x direction
G	Gravitational constant
h	Roughness height
I	Second moment of area
k	Roughness height (deflected)
L	Length of channel
m	Number of roughness elements

n	Manning roughness coefficient including boundary and vegetation effect
$n_{(ave)}$	Equivalent Manning’s roughness coefficient
n_b	Manning boundary roughness coefficient which excludes influence of vegetation
n_{veg}	Vegetative roughness coefficient
P	Wetted perimeter
R	Hydraulic radius defined as a ratio of cross- sectional area of flow to the wetted perimeter
Re	Reynolds number
S	Bed slope of channel
S_w	Water surface slope (cm/cm)
S_o	Bed slope
U_*	Shear velocity
V	Mean velocity
Vi	Average approach velocity to ith plant
γ	Specific weight of liquid
τ_w	Shear force per unit area on channel boundary

CHAPTER 1

INTRODUCTION

1.1 General

Vegetations present in many rivers, streams, and man made channels throughout the country. Vegetations can be found growing naturally on the bed of the channel or on the riverbanks or have been purposely planted. They are often classified by their shape and the locations where they grow. Vegetations that grow on the river floodplains typically comprises of various combination of trees, herbs, shrubs, hedges, bushes and grasses. The in-channel vegetations usually consist of aquatic plants and these may be divided into four categories: emergent, submerged, floating-leaf, and free-floating.

Emergent plants are rooted in the soil close to or below the water level but stems, flowers and most of the mature leaves are protruding above the water surface. They are generally found by the banks of the river. Submerged aquatic plants have flexible stems and leaves, are rooted in the soil, and are completely covered by water. The floating-leaf plants are rooted in the submerged soil with many of their leaves floating on the water surface. These are usually seen along the margin of river that is not fast flowing. The last group is free-floating plants, most of their leaf and stem tissue are at or above the water surface. They obtain their nutrients directly from the water, since they are not rooted to the soil.

The presence of vegetations in river channel provides both benefits and problems. From environmental point of view, aquatic plants are essential parts of natural aquatic systems and form the basis of a waterbody's health and productivity. From engineering point of view, vegetation can improve the strength of bank materials through buttressing and root reinforcement. However, invariably aquatic plants become over abundant or unsightly and require control. The obvious problem related to excessive growth are flow retardment , flow capacity reduction and causing flood. Although the flow capacity can be increased by complete or partial removal of vegetation, this is a costly procedure. A complete removal of the vegetation in channels can lead to erosion of the banks and turbidity of the water. Unrestricted growth of such vegetation can lead to a nearly complete loss of capacity to convey water. Therefore, it is essential that the balance between risk and benefit of having vegetation in the channel is weighed and proper engineering judgement be made.

1.2 Effects of Vegetation

The vegetations in a channel influence the flow across the channel and the degree of influence depends on vegetations characteristics such as vegetations species, distribution, flexibility, degree of submergence and density as well as flow characteristics, including flow area, depth and boundary characteristics (Jarvela, 2002).

The effect of vegetation in the channel is mainly on the velocity of flow. The average water velocity at a cross section tends to decrease, because of roughness presented by the stems and leaves of the plants. Vegetation generally increases roughness or flow resistance (Frschenich, 2000). Increases in roughness due to vegetation can be as much as higher than that due to channels particle size alone (Chow, 1959). According to Thompson and Roberson (1976), the growth of thick vegetation in channel can reduce capacity by up to 50% in less than a year. Righetti and Armanini (2002) reported that the vegetations effect varies seasonally. Vegetations in wet season give less resistance to flow compared with vegetations that are partially submerged during dry season. Shih and Rahi (1982) discovered that during the growing season the value of Manning roughness coefficient, n increased by 300%.

1.3 Statement of the Problem

An understanding of flow resistance is the most fundamental and essential to hydraulics engineers and the effects of vegetations on overall flow resistance are significant and cause difficulties in many hydraulic designs (Jarvela, 2004). The planning, design and operation of water resources projects often require knowledge of discharge in a given channel as a function of flow depth. In area where flow occurs through vegetation, the flow depth may be largely determined by the roughness and resistance provided by the vegetation.

Well-established flow resistance formulas, such as the Manning, Darcy– Weisbach, and Chezy equations, have long been used to analyze river flows but yet the accounts on the effect of vegetation on the resistance are still widely studied. Research on vegetative resistance in open-channel flows has been motivated by an increase in awareness of the importance of the ecological and environmental effects of vegetation in a river system.

Advances in understanding the behavior of flow over vegetation will improve both the knowledge of flow-velocity profiles and flow resistance. This will lead to the development of better way in estimating resistance or roughness due to vegetations.

In Malaysia, there are many kinds of tropical vegetation and aquatic plants and their effects on the channel flow yet to be studied. Research in this area played important role in determining the flow capacity and water surface elevation in vegetated channel or wetland.

1.4 Objectives

The general objective of this study is to determine the effect of vegetations on the characteristic of flow in an open channel. The specific objectives are to analyze the effects of Napier and Cattail grasses on hydraulic roughness and velocity distributions as well as to develop empirical relationship between characteristics of vegetation and flow.

1.5 Scope of the Study

The study involved collecting data through experimental works. Two types of vegetation (Napier and Cattail grass) were tested. The effects of the vegetation on the velocity profile and hydraulic roughness were analysed and empirical equations that relate these parameters with the various characteristics of vegetation were developed.

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