Determination of Flow Resistance Coefficient for Vegetation in Open Channel: Laboratory study

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Abstract. This study focused on determination of flow resistances coefficient for grass in an open channel. Laboratory works were conducted to examine the effects of varying of roughness elements on the flume to determine flow resistance coefficient and also to determine the optimum flow resistance with five different flow rate, Q. Laboratory study with two type of vegetation which are Cow Grass and Pearl Grass were implementing to the bed of a flume. The roughness coefficient, n value is determine using Manning's equation while Soil Conservation Services (SCS) method was used to determine the surface resistance. From the experiment, the flow resistance coefficient for Cow Grass in range 0.0008 - 0.0039 while Pearl Grass value for the flow resistance coefficient are in between 0.0013 - 0.0054. As a conclusion the vegetation roughness value in open channel are depends on density, distribution type of vegetation used and physical characteristic of the vegetation itself

1. Introduction

Flow resistance in open channel plays an important part in river engineering and has been studied for many years [1]. Yet, it still presents challenge to researchers and engineers, particularly in relatively study in bed channels. Better understanding and knowledge of the flow resistance in such channels can greatly improve our prediction of the flow conveyance capacity in channels, thus reducing the flooding in channels. The influence of flow resistance gives some effect to flow rate and the roughness characteristics [2]. Focusing on the experimental investigations for hydraulic roughness, [3], it used the particle image velocimetry to study the effects of roughness on the flow structure in a gravel bed channel.

Most experimental studies on flow resistance of vegetation are conducted in laboratory flumes, where it is possible to minimize hydraulic impacts due to other external influences [4-7].While the experiment with different discharges and bed material was determine the effects of bed roughness in open channel flow [8] and using various bed materials [9].

The main effect of vegetation in the channel is on the velocity of flow. The average water velocity at a channel cross-section tends to decrease, due to flow resistance from the stems and leaves of the vegetation. Vegetation generally increases roughness or flow resistance [10]. Chow [11] stated increases in roughness due to vegetation can be much higher than that due to a channel's particle size alone.

The most frequently used formulas relating open-channel flow velocity, V, to resistance coefficient are

$$V = \frac{1}{n} A R^{2/3} S^{1/2} \qquad (1)$$

$$V = \sqrt{\frac{8g}{f}} \sqrt{RS} \qquad (2)$$

$$V = C\sqrt{RS} \qquad (3)$$

in which *n, f*, and C are the Manning, Weisbach, and Chezy resistance coefficients, respectively; R=hydraulic radius, S = slope; g=gravitational acceleration [11]. Maghdam and Kouwen [12] obtained a mathematical model for estimation of roughness for unsubmerged and flexible vegetation in floodplains and vegetated zones of rivers. They concluded that in the presence of vegetation the Manning's, n value increases proportionally to the square root of flow depth and is inversely proportional to the mean velocity for submerged conditions.

2. Materials and Methods

The experiments were conducted in the Hydraulic and Hydrology Laboratory of Water Resources, UniversitiTun Hussein Onn Malaysia, UTHM. Flume with a dimension of 10 m long, 0.30 m wide and 0.46 m deep of glass-walled flume is used along the experiment process (figure 1). The vegetation is placed on the bed surface in the flume to provide a uniform roughness. The slope of the flume is fixed at 0.005 which is a typical slope of plant-covered brooks [13]. Discharged then allowed to flow through the circulation of the storage tank. The flow is controlled by the desired value by adjusting the water pump level. It can be controlled by open and closed by the steel wheel. This depth of flow will be measured along the different three sections contained four points and each point taken at least three reading values of velocities to get the mean velocities.

Figure 1. General view of glass-walled flume

2.1 Flume without vegetation

The first experiment will be acted as a controller of the flume without vegetation. There is no vegetation laid on the flume bed. As a theoretically, the only value of roughness coefficient, n is obtained on the surface by itself. The mean velocity along channel were measured at five different points in the vegetated zone. Mean velocities calculated to attain Manning's roughness coefficient. Figure 2 shows the schematic diagram for flume without vegetation.These experiments have five different types of flow rate, Q (0.007 m³/s, 0.009 m³/s, 0.011 m³/s , 0.013 m³/s and 0.015 m³/s) which is adjusted by controlling of rotor water pump, cross sectional area, A and also wetted perimeter, P. All these parameters were calculated to be utilized in Manning'sequation and are vitally needed the degree of different Manning's roughness equation.
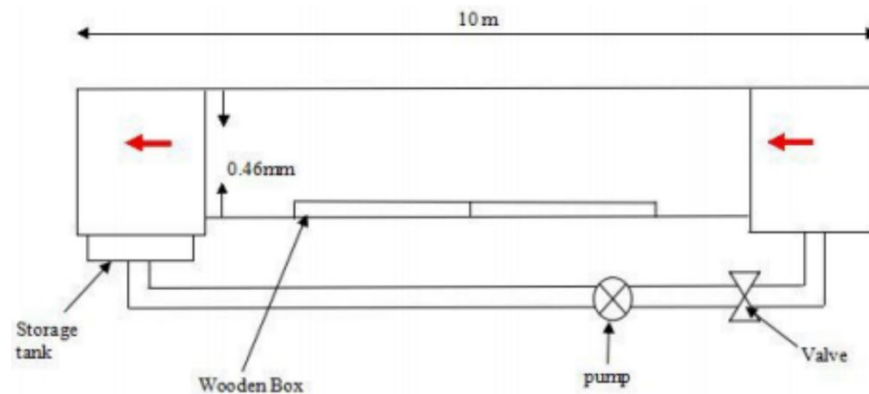
Figure 2. General view of glass-walled schematic diagram for flume without vegetation

2.2 Flume with vegetation

In this study, a vegetation that was used for experiments in the laboratory is cow grass (*Axonopuscompressus*) and Pearl Grass (*Hemianthusmicranthemoides*) as shown in the figure 3. This plant was chosen because the growing conditions which grows wild around the channel that viewedmeet the requirements of this study. Table 1 shows the characteristic about the Cow Grass andPearl Grass.

Table 1. Characteristic of cow grass and pearl grass

Common name	Cow Grass	Pearl Grass
Family	Poaceae (alt.Gramineae)	Poaceae (alt.Gramineae)
Scientific name	Axonopuscompressus	Hemianthusmicranthemoides
Grow rate	Grow on poor soil,good ground cover	Fast

a) Cow grass   b) Pearl grass

Figure 3. General view of cow grass and pearl grass

For the second and third experiments, cow grass and pearl grass was using along the flume act as corrugated bed to the flume. Figure 4 shows the cow grass laid on the flume bed. As a theoretically, the only value of roughness coefficient, n is obtained in the surface by itself.
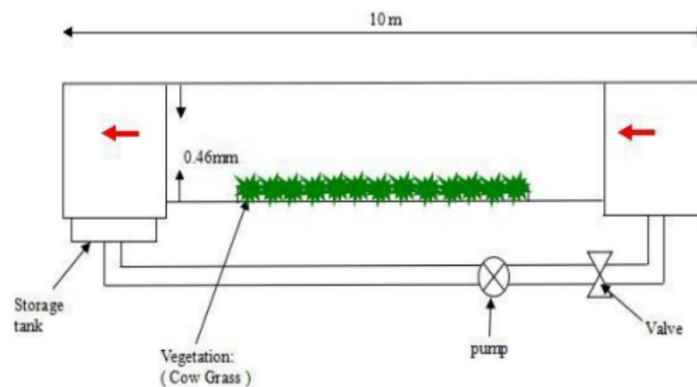
Figure 4. Schematic diagram for flume with vegetation (cow grass and pearl grass)

These experiment has five different type of flow rate, Q which is adjusted by controlling of rotor water pump, cross sectional area, A and also wetted perimeter, P. All these parameters were calculated to be utilized in Manning's equation and are vitally needed the degree of different Manning's roughness equation.

3. Result and data analysis

The result obtained from the experiment was the average of velocity, flow discharge and the flow resistance coefficient. The result has been divide into 4 cases which is Case 1 forcow grass with spacing, Case 2 for cow grass with closely type, Case 3 for pearl grass (spacing) and Case 4 for pearl grass (closely). For the five different value of Q call as Q1 for 0.007 m³ /s, Q2 for 0.009 m³ /s, Q3 for 0.011 m³ /s, Q4 for 0.013 m³ /s and Q5 for 0.015m³ /s.Based on the reference that has been made, the calculation for determining the flow resistance coefficient for various conditions of the flume with vegetation or without vegetation has been obtained.

For the values of manning caused by a plant was obtained through Soil Conservation Services (SCS) method. The impact of the plant on the flow resistance coefficient in an open channel has been made based on several factors which is type of vegetation, water depth, and the arrangement of the vegetation. Based on these factors we will be able to see the effect on the flow discharge, velocity and flow resistance coefficient in an open channel

3.1 The Velocity and Flow Discharge

Table 2 showed the result between cow grass and pearl grass on flow discharge and velocity.The relationship between this two type vegetation was shown in figure 5, figure 6, figure 7 and figure 8. From the figure 5 and figure 6, it shows that the arrangement of grass play an important role where the grass with a closely arrangement have the highest velocity compared to the grass which have spacing. As we can see at the figure 5 the highest velocity for Cow Grass is 0.4889 m/s with value 0.015 m^3/s in flow discharge, Q while in figure 6 the highest velocity for Pearl Grass is 0.5137 m/s with value 0.015 m^3/s in flow discharge

Table 2: Type of grass,flow discharge (Q), Velocity (V)

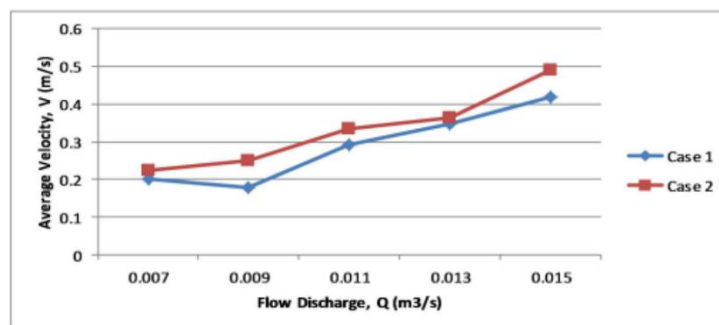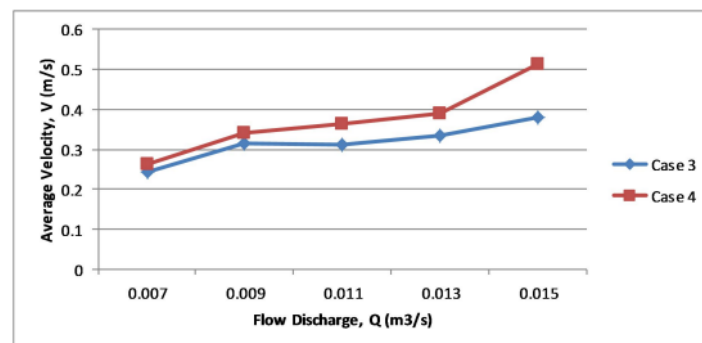| Type of Grass	Flow discharge Q (m^3/s)	Velocity $V(m/s)$
Case 1	0.007	0.2008
	0.009	0.1771
Cow Grass	0.011	0.2908
(spacing)	0.013	0.3488
	0.015	0.4204
Case 2	0.007	0.2234
	0.009	0.2485
Cow Grass	0.011	0.3348
(closely)	0.013	0.3652
	0.015	0.4889
Case 3	0.007	0.2423
	0.009	0.3173
Pearl Grass	0.011	0.3101
(spacing)	0.013	0.3357
	0.015	0.3812
Case 4	0.007	0.2636
	0.009	0.3409
Pearl Grass	0.011	0.3644
(closely)	0.013	0.3911
	0.015	0.5137

Figure 5. Relationship between average velocity and flow discharged on Cow Grass

Figure 6. Relationship between average velocity and flow discharged on Pearl Grass

Figure 6 showed the arrangement of grass which played an important rolewhere the Case 4 has the highest velocity compared to the Case 3. It also shows the highest velocity for Pearl Grass is 0.5137 m/s with value 0.015 m³/s in flow discharge, Q. It concluded that the arrangement of vegetation and type of grass will contributed the highest value in flow discharge and velocity.

3.2 The discharge and flow resistance coefficient

To investigate the relationship between the discharged and flow resistance coefficient; figure 7 was plotted under 4 type of cases. Similar lines trend was noticed. Also, it's illustrated that the Case 4 (Pearl Grass - closely) gave the peak flow resistance coefficient. However, the Case 1 (Cow grass -closely) presented the lowest values. The figure indicated that for fixed bed material with vegetation, the maximum and minimum flow resistance coefficients were located at 0.007 and 0.015 m^3/s, respectively. Consequently, it's demonstrated that fixing the bed material, the flow resistance coefficient was directly proportional to the flow discharges.
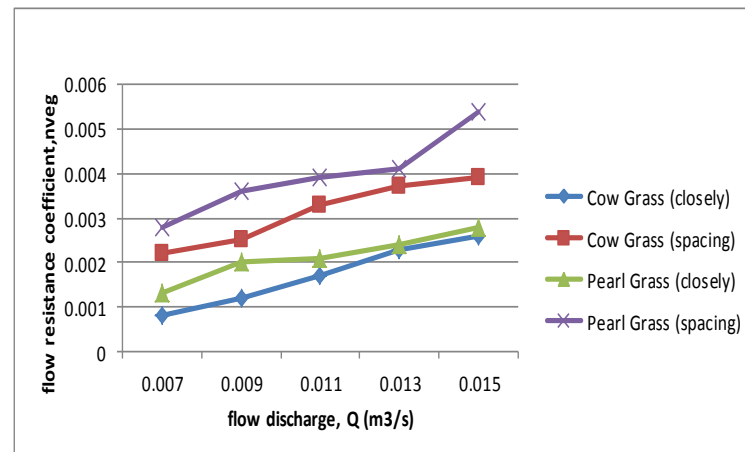

Figure 7, Relationship between discharges to flow resistance coefficient.

4.   Conclusion

As conclusion it was found that the flow resistance coefficient was stated between 0.0008 - 0.0054, depends on the arrangement of the vegetation, type of vegetation, and different flow discharges. From the experiment that has been conducted, it was found that the flow resistance coefficient increased with the increased of flow depth and discharges. It proven by Jarvela,[14] which stated that the flow resistance coefficient generally depends on the discharges and flow depth. When the flow depth increased, the flow resistance coefficient also increased.

The velocity showed inversely proportional to the value of flow resistance coefficient. It related to physical structure of the vegetation itself, which Cow Grass has the longer leaf compared to Pearl Grass where this situation are influenced the flow depth and velocity. As a conclusion, vegetation give the high impact to the open channel in terms of flow resistance coefficient, velocity and flow depth.

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