Manning Roughness Coefficient Study on Bed Materials Non-Cohesive with Parameters Using Entropy to Open Channel Flow

Hari Wibowo
Tanjungpura, University, Department of Civil EngineeringFaculty of engineering
Jalan Ahmad Yani, Pontianak, Kalimantan Barat, Indonesia
hariwibowo13@yahoo.com

Abstract - Application of entropy in open channel models presenting relevant aspects of theoretical issues and practical useful for cross-sectional velocity distribution. The ratio between the average velocity and the maximum depends on the local morphology. Recent research has suggested formulation Manning roughness, n, based on the ratio and the ratio between the position where the velocity is zero and the maximum, y_0/y_max, the flow depth of the flow regime. Based on the experience of stable flow, analysis entropy dependence on n parameters, and M for flow depth, proposes an equation y_0/y_max to know the bed channel roughness coefficient. The results showed a good linear relationship between estimate n and n entropy calculation and n with the bedform. Obtained from linear regression analysis of the data relationships flume n_calculate = 0.5803n_entropy + 0.010 with good correlation (R^2 = 0.864) using the entropy parameter Φ(M) = 0.8197, while for the data in a natural channel n_calculate = 0.754 n_entropy + 0.006 with good correlation (R^2 = 0.877) with Φ(M) = 0.914. It also has a fault tolerance (0.005 to 0.293)%), which is still below the tolerance.

Keywords: entropy models, manning's roughness; steady flow, laboratory flume

1. Introduction

In hydraulic engineering, flow resistance coefficient or the Manning roughness coefficient is an important parameter in forecasting the flow in the channel, designing hydraulic structures, the calculation of the distribution of velocities, sediment transport and accuracy in the determination of the energy loss (Bilgil & Altun, 2008). River flow forecasting is a very important step in order to improve management policies directed to the use of water resources as well as for mitigation, prevention and defense measures against environmental degradation (Greco et al., 2014). In addition, knowledge of the velocity distribution in the cross section of the river is fundamental in hydraulic modeling of the river, sediment and pollutant transport, channel design, river training work and hydraulic structures as well as in the manufacture of curves rating (Greco et al., 2014; Mirauda et al., 2011b). In relation to the resistance to flow and velocity distribution in alluvial channels is a complication of the two problems. Firstly due to changes in the bedform and second a result of certain conditions of the majority of sediment transport particles acted as a suspension. On the alluvial of bed channels that are not fixed it will change its geometry and dimensional characteristics continuously as a result of the interaction between the flow and the channel bed (Yang & Tan, 2008; Singih, 2000).

In addition, the flow in open channels is limited to the aspect ratio of the width-depth three-dimensional, and wall shear stress are not evenly distributed around the wet cross-section. This is due to the free surface and the secondary flow (Guo & Julien, 2005; Azamathulla et al., 2013). Problems in separating the bed shear stress and the sidewalls are very important in almost all studies on open channel flow in this laboratory flume studies (Guo & Julien, 2005). Boundary shear stress distribution in hydraulic equation concerning the problem of resistance to the flow and sediment transport, (Javid

A Mathematical model, which is derived from the application of the theory of information entropy maximization on the data collected, used to evaluate the flow field and calculate water discharge (Chiu, 1987, 1988 & 1989; Chiu & Said, 1995; Chiu & Hsu, 2006; Moramarco & Singh, 2010, Mirauda et al., 2011b; Greco et al., 2014).

Velocity distribution entropy, In fact, requires assessment on one parameter, M, which it can be obtained through knowledge of the ratio of the average flow velocity and maximum. In addition, the rules allow the natural flow well enough about the reliability of geometric irregularities and normal flow regime (Greco, 1998; Chiu et al., 2005; Burnelli et al., 2008). Application of the entropic profile in river flows also menawaran good results even for practical purposes.

In order to determine the velocity distribution in the cross section and provide acceleration on the method of calculation of the flow of water and reduce the calculation time of the survey and (Greco & Mirauda, 2004; Mirauda et al., 2011a, b). And also modeling the two-dimensional velocity distributions for open channel flow (Marini et al., 2011). Furthermore, the ratio between average velocity and maximum, \( \Phi (M) \), it appears to be highly dependent on the riverbed morphology with uniform flow. This shows that the investigation of the entropy parameter depends on the hydraulic and geometric characteristics of the cross section of the river (Moramarco & Singh, 2010, 2011).

Therefore, the study of bed roughness with speed theory of entropy, the proposed formulation in \( n \) Manning roughness, based \( \Phi (M) \) and the position in which the velocity of each. The purpose of this paper is the first to investigate the Manning roughness coefficient on entropy parameters in the case of low flow regimes. second to acquire bed calculation on the boundary shear stress in an open channel boundary rectangular shape. Then, assuming a variety of slope sidewalls, as a first approximation, the solution to the boundary shear stress calculations using isovel and ray procedures, ignoring the secondary currents and eddy viscosity is assumed constant value.

2. Study of Theory

2.1. Relationship Roughness (\( n \)) Manning and Entropy Parameters (\( M \))

The average velocity, \( \bar{U} \), mean and \( U_{\text{max}} \), maximum velocity, Umax, open channel flow cross section can be expressed in terms of entropy (Chiu and Said, 1995), as Equation (1)

\[
\bar{U} = \Phi (M) U_{\text{max}}
\]

which \( \Phi (M) \) can be described in the form of Equation (2)

\[
\Phi (M) = \left( e^M - \frac{1}{M} \right)
\]

where \( M \) expressed entropy parameter (Chao and Lin Chiu, 1988; Moramarco and Singh ,2010; Greco et al., 2014 ). Eq. (1) shows that \( \bar{U} \) and \( U_{\text{max}} \) together can determine \( \Phi (M) \) and then the entropy parameter M. It should be pointed out that \( U_{\text{max}} \) represents the maximum value in the data set of velocity points sampled in the flow area during velocity measurement (Chiu & Said, 1995; Greco et al., 2014). The vertical where \( U_{\text{max}} \) is sampled is defined, henceforth, as the y axis (Chiu, 1989).

The average velocity on a steady flow in open channel can be estimated by using the Manning formula as Equation (3)

\[
\bar{U} = \frac{1}{n} R_h^{2/3} S_f^{1/2}
\]

Where \( n \) is the Manning roughness coefficient, \( R_h \) is the hydraulic radius and \( S_f \) is the energy slope. Instead, to determine the maximum velocity the cross section, \( U_{\text{max}} \),
along the y-axis are assumed to be perpendicular to the bottom, modified logarithmic rule
under water (dip) for the velocity distribution in open channel flow uniformly smooth,
proposed by Yang et al. (2004), as Equation (4)

\[ u(y) = u_s \left[ \frac{1}{\kappa} \ln \left( \frac{y}{y_0} \right) + \frac{\alpha}{\kappa} \ln \left( 1 - \frac{y}{h} \right) \right] \] ...........................................(4)

Which \( u_s = \sqrt{g R_s S_f} \) is the shear velocity (g = acceleration of gravity); \( \kappa \) is the
von Kármán constant equal to (0.41); \( y_0 \) is the distance at which hypothetically velocity is
equal to zero; \( \alpha \) is the correction factor on the condition of the flow, which depends only
on the ratio between the relative distance to the location of the maximum velocity of bed
channel, \( y_{max} \) and flow depth \( h \) along the y-axis, which \( U_{max} \) location.

Location maximum velocity, based on the hypothesis that the dip phenomenon
with Yang et al. (2004 ; Moramarco & Singh, 2010) can be obtained by separating the Eqs. (4)
and differentiation \( du/\partial y = 0 \), which gives the result in Equation (5)

\[ \frac{y_{max}}{h} = \frac{1}{1+\alpha} \] .................................................................................... (5)

Experimental study by Greco and Mirauda (2002) have shown that, for channels on
various forms of cross-section, the maximum velocity is below the free surface of about
20 ÷ 25% of the maximum depth. This result was also confirmed from the values \( y_{max} \)
collected in experimental trials of this work and is shown in Fig. (1), which \( y_{max} \) is a
function of water depth \( h \)

\[ \frac{y_{max}}{h} = \frac{1}{0.4621} \] .................................................................................... (6)

By replacing Equation (3) and (1) into Equation (4), it is possible to derive a
relationship as Equation (7).

\[ \left( \frac{e^M}{e^{M-1}} - 1 \right) M = \frac{2^{1/3} R_s^{2/3} S_f^{1/2}}{\sqrt{g R_s S_f} \left[ \ln \left( \frac{y_{max}}{y_0} \right) - 0.4621 \right]} \] or \( \left( M \right) = \frac{2^{1/6} R_s^{1/6} \sqrt{g}}{\alpha \left[ \ln \left( \frac{y_{max}}{y_0} \right) - 0.4621 \right]} \) .................................(7)
which allows to connect Φ (M) with hydraulic and geometric characteristics of the flow. Finally, from Equation (30) Manning n roughness values obtained as Eq. (8)

\[
\nu = \frac{R_h^{1/6} \sqrt{g}}{\Phi (M) \frac{1}{2} \ln \left( \frac{y_{max}}{y_0} \right) - 0.4621}
\] .................................(8)

Equation (8) which concluded on the calculation of roughness (n) Manning by using the value of Φ (M) as well as calibrate the value of \( y_{max} \) as well as calibrate the value of \( y_0 \). In fact, to determine Φ (M) in each test and the application of Manning n value, which is obtained by Eq. (3) into Eq. (8), to obtain \( y_{max} \), as it has been studied by Gerco et al. (2014) and Mirauda and Gerco (2012) the importance of the ymax is equal to \( 3/4 \) of water depth (h), as in equation (9).

\[
\frac{y_{max}}{y_0} = \frac{3}{4} h
\] .................................(9)

so that Equation (31) can be written in the form of Equation (10)

\[
\nu = \frac{R_h^{1/6} \sqrt{g}}{\Phi (M) \frac{1}{2} \ln \left( \frac{y_{max}}{y_0} \right) - 0.4621}
\] .................................(10)

\( y_0 \) value is near the channel bed which is assumed as the value of equivalent roughness (k_s). There is no clear consensus on the definition k_s and not surprisingly, there are a variety of various values of k_s values’ (1,25d≤k_s≤5,1d≤84) has been proposed (Van Rijn, 1982). However Millar (1999) has found that there was no significant difference between using the D35, D50, d84 or d90. In this study, ks suggested by Casey (1935), Shields (1935), Straub (1954) will be used, ie,

\[
k_s = d_{50}
\] ........................................(14)

2.2 Shear Stress Relationship and Manning Roughness Coefficient (n)

NHC partitioned the bed shear stress into two components, total shear stress (\( \tau_T \)) and grain shear stress (\( \tau' \)), and then derived the following relation Equation (15)

\[
\frac{\tau}{\tau_T} \propto \frac{\lambda'}{\lambda_T}
\] .................................(15)

Here, \( \lambda' \) and \( \lambda_T \) are the Darcy friction factors associated with grain and total roughness, respectively. Grain roughness, \( f_g \), can be computed using the following empirical relation (Henderson, 1966):

\[
\lambda' = 0.113 \left( \frac{d_{84}}{R_h} \right)^{1/3}
\] .................................(16)

In this relation \( R_h \) is the hydraulic radius of the channel (in feet) and \( d_{84} \) is the particle diameter (in feet) that exceeds 84 percent of the particles sampled. Combining the Manning's and Darcy equations, total roughness, \( ft \), can be computed using the following Equation (17)

\[
\lambda_T = 8g \left( \frac{n_T R_h^{1/2}}{A} \right)
\] .................................(17)

According to Einstein (1942) and Meyer-Peter, Muller (1948) and Yang and Tan (2008), the shear stress can be separated into the shear stress due to the side wall and shear stress due to the bed, as written in equation (18)

\[
\tau_T = \tau_w + \tau_b = \tau_w + \tau' + \tau''
\] .................................(18)

Where \( \tau_T \) is the shear stress limit of the average; \( \tau_w \) is side wall shear stress; \( \tau_b \) is bed shear stress = \( \tau' + \tau'' \).
2.2.1 Average Bed Shear Stress Equation

By considering the steady uniform flow in rectangular open channel. In the flow direction defines the direction x, and y-z cross section is shown in Fig. (2)

![Figure 2. Coordinate Systems in Open Channel Flow (Guo & Julien, 2005)](image)

Guo and Julien (2005) analyzed the methods by considering the volume control BCHGB (Ab) in Figure (1), which has a unit of length. In the flow direction x and assumed in the determination of BG and CH are symmetric with respect to the z axis. In addition, the main flow velocity in each of the x-axis is denoted as u, and the secondary current in the yz plane is v and w. By analysis using the continuity equation and momentum, then the shear stress obtained an average basis. The average shear stress is composed of three terms, namely gravity (I), the secondary current (II), and interfaces (interfaces) shear stress (III) in equation (19)

\[
\bar{\tau}_b = \frac{\rho g S A_b}{b} - \frac{2}{b} \int_S \rho u (v \, dz - w \, dy) + \frac{2}{b} \int_L (\tau_{yx} \, dz - \tau_{zx} \, dy)
\]

.......................(19)

![Figure 3 The Cross-section Transverse Partitions Area Separation on Bed Shear Stress and Sidewall (Guo & Julien, 2005)](image)

For the case of a steady uniform flow in open channels in a rectangular shape; where g is the acceleration due to gravity; \( \rho = \) mass density of water; S = slope of the channel bottom slope; b is the width of the channel; and \( \tau_{yx} \) and \( \tau_{zx} \) = shear stress in the flow direction x is applied to each field z-x and y-x. It can be proved that although Equation (19) is taken to smooth rectangular channels, it is also applicable to all types of
cross sections along the BG and CH are symmetrical (Guo & Julien, 2005; Yang et al., 2006).

### 2.2.2 Average Side-Wall Shear Stress Equation

Similarly, the side wall shear stress on average \( \bar{t}_w \) can be formulated by applying the equation. \( \int_A \rho u \left( \frac{\partial u}{\partial y} + \frac{\partial w}{\partial x} \right) dA = \rho g S V + \int_A \left( \tau_{yx} \frac{\partial y}{\partial n} + \tau_{yx} \frac{\partial x}{\partial n} \right) dA \), with volume control BGEB or CFHC in Fig. (3). The decline in the side wall shear stress formulation average is to consider the overall balance of force in the direction of flow. As defined in Equation (20)

\[
2h \bar{t}_w + b \bar{t}_b = \rho g S A_b = \rho g S \cdot bh \quad \text{.................................}(20)
\]

Where the first form in the left hand side is the shear force on the two sides of the side walls, the second form is the shear force on the base of the channel, and the right-hand side is the component of gravity in the direction of water flow. Applying Eq. (18) in Eq. (20) give the side wall shear stress averaged as Equation (21).

\[
\bar{t}_w = \frac{\rho g S \cdot bh - b \bar{t}_b}{2h} = \frac{\rho g S A_w}{2h} + \frac{1}{h} \int_{CH} \rho u (v dz - wdy) + \frac{1}{h} \int_{CH} (\tau_{yx} dz - \tau_{yx} dy) \quad \text{..................}(21)
\]

Where \( A_w = bh - A_b \). In Equation (19) and (21), it can be seen that the shear stress boundary consists of three components: the first term is the contribution of gravity, the second term is the effect of secondary flow, and the third term is the effect of fluid shear stress, which in turn, reflects the effect of viscosity in a turbulent eddy currents. The first form that is dominant with a small contribution from the second and third forms on the right hand side of the Equation. (19) and (21).

### 2.2.3 First Approximation Without Secondary Currents

To estimate the boundary shear stress, using Equation (19) and (21), we must know the main velocity \( u \) and secondary currents, \( v \) and \( w \), shear stress \( \tau_{yx} \) and \( \tau_{zx} \) and and integration path BG and CH. On the other hand, to solve for the velocity field, we must know the boundary shear stress. Interaction between velocity and shear stress makes the solution to the boundary shear stress or velocity profiles are very complex profile, as shown by Chiu and Chiou (1986). As an approach, we can ignore the effects of secondary flow and fluid shear stress. Thus, equation (19) into Equation (22a) and (22b)

\[
\bar{t}_b = \frac{\rho g S A_b}{b} \quad \text{.................................}(22a)
\]

or

\[
\frac{\bar{t}_b}{\rho g S h} = \frac{A_b}{bh} \quad \text{.................................}(22b)
\]

And Equation (19) into Equation (23a) and (23b).

\[
\bar{t}_w = \frac{\rho g S A_w}{2h} \quad \text{.................................}(23a)
\]

or

\[
\frac{\bar{t}_w}{\rho g S h} = \frac{A_w}{2h^2} \quad \text{.................................}(23b)
\]

The remaining problem is to find an area of \( A_b \) and \( A_w \), which is equivalent to finding the determination of BG and CH in Figure (3).
2.2.4 Delimitations BG and CH

By showing that the momentum equation corresponding to the flow direction x is as Equation (24)

$$\rho \left( v \frac{\partial u}{\partial y} + w \frac{\partial u}{\partial z} \right) = \rho g S + \frac{\partial \tau_{yx}}{\partial y} + \frac{\partial \tau_{yx}}{\partial z}$$

Convective acceleration on the left side of Equation (24) accounted for the secondary flow. The first form on the right side is the component of gravity in the direction of flow, and the other two are a potential flow (net) shear stress is applied to the fluid differential element. The first approach assumes that: (1) secondary current is not negligible; and (2) eddy viscosity $\nu_t$ is constant. Applying these two assumptions to Equation (24) gives Equation (25)

$$\frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2} = - \frac{gs}{v + u_t} = \text{constant}$$

Where $\tau_{yx} = \rho(v + u_t) \frac{\partial u}{\partial y}$; $\frac{\partial u}{\partial y}$; $\frac{\partial \tau_{yx}}{\partial z}$ and $v = \text{kinematic viscosity of water}$. Equation (25) is called the Poisson equation and can be solved by means of Laurent series (White, 1991; Guo & Julien, 2005). That is, orthogonal velocity contours are used to describe the BG and CH in Figure (3). Although the solution to Equation (24) provides a laminar velocity profile, and orthogonal provide a first approximation to the boundary shear stress. To determine the limits of the potential lines and flow lines. Its solution using the Schwarz-Christoffel transformation (Driscoll et al., 2002, Spiegel, 1993) by using an assumption of rectangular cross section channel width b and depth h flow of figure (3) and the aspect ratio of the channel side walls.

By using formulation Transformation Schwarz-related Chistoffel the physical domain flow (plane $-\omega$) and middle upper field (plane $-\zeta$) as Equation (26a) and (26b).

$$\omega = A + B \int (z - x_1) \frac{\alpha_1}{\pi} (z - x_2) \frac{\alpha_2}{\pi} dz$$

or

$$\frac{\partial \omega}{\partial \zeta} = B \left( z - x_1 \right) \frac{\alpha_1}{\pi} (z - x_2) \frac{\alpha_2}{\pi}$$

In the form of orthogonal and isotropy as Equation (26c)

$$\frac{\partial \omega}{\partial \zeta} = B \left( \zeta - x_1 \right) \frac{\alpha_1}{\pi} (\zeta - x_2) \frac{\alpha_2}{\pi}$$

by taking $x_1 = -b/2$; $x_2 = b/2$; $w_1 = -\pi/2$; $w_2 = \pi/2$; dan $\alpha_1 = \pi/2$; $\alpha_2 = \pi/2$, then Equation (26c) will be Equation (27)

$$\frac{\partial \omega}{\partial \zeta} = B \left( \zeta + \frac{n\pi}{b} \right) \frac{1}{2} \left( \zeta - \frac{n\pi}{b} \right)$$

Where $z = y + iz$ and $\omega = \zeta + in$; B is a constant change of form; -b / 2 and b / 2 is any value in each of the left and right ends of the cross section in the channel changes. In other words, the value of which crossed at an angle equal to -b/2 and + b/2. Applying the theorem of integration in Equation (27) can be solved by several methods, namely Hipergeometri (Javid & Mohammadi, 2012), using the Laurent series (Guo & Julien, 2005) and entropy (Chao-Lin Chiu, 1986 & 1988; Houjou et al., 1990; Samani el al., 2013).
• Dengan prinsip Isovel

By taking \( \zeta = \frac{b}{\pi} \) dan \( \frac{d}{2} \exp \left( -1,261 \frac{y}{b} \right) \)..............(28)

And the cross-sectional area average shear as Equation (29)

\[
A_b = 2 \int_0^h \frac{\tau_b}{\rho gh s} = \frac{0.793 b^2 (-1+\exp (1.261 h/b))}{bh} = 0.793 \frac{b}{h} (\exp (-1,261 h/b) - 1) .............(30)
\]

Similarly to the side wall shear stress on average, by substituting Equation (30) into Equation (23b) the importance of the equation (31b)

\[
\frac{\tau_w}{\rho gh s} = \frac{bh - A_b}{2h^2} = \frac{(bh - 0.793 b^2(-1+\exp (-1,261 h/b)))}{2h^2} .............(31b)
\]

### 2.2.5 Second Approximation with Correction Factors

The first approach implies that the maximum velocity occurs at the surface of the water. However, research by Javid (2011) and Javid and Mohammadi (2011) illustrates that specific performance on the secondary flow cell in a rectangle channel changing pattern of flow lines and potential lines, especially in the corners and the surface of the water. Thus, the second approach aims to improve on the first approach by introducing two empirical correction factors are lumped in the first approach.

By substituting Equation (29) into equation (22b) gives Equation (32)

\[
\frac{\tau_b}{\rho gh s} = 2 \int_0^h \frac{\tau_b}{\rho gh s} = \frac{0.793 b^2 (-1+\exp (-1,261 h/b))}{2h^2} .............(32)
\]

Application integration theorem in further section and the mean value theorem for integration in the above equation gives Equation (33)

\[
\frac{\tau_b}{\rho gh s} = 0.793 b^2 (1 - \exp (-1,261 h/b)) .............(33)
\]
By including the effect of secondary flow, variable flow viscosity and perhaps other effects, two empirical correction factor that is $\lambda_1$ and $\lambda_2$. Equation (33) can be assumed to be the Equation (34).

\[
\frac{r_b}{\rho ghS} = \exp \left( -1.261 \frac{h}{b} \right) - \lambda h \frac{1.261}{b} \exp \left( -1.261 \frac{\lambda h}{b} \right)
\]

............................................(34)

Where $\lambda h$ is located at a point such that $0 < \lambda < 1$ and to satisfy the value theorem average conditions, numerical evaluation shows that the first form on the right side of the meruokan main form and provide only a small effect on the first form. This is analogous to Guo and Julien (2002), so that Equation (34) can be fixed into Equation (35).

\[
\frac{r_b}{\rho ghS} = \exp \left( -1.261 \frac{h}{b} \right) - \lambda_1 \left( \frac{h}{b} \right) \exp \left( -1.261 \frac{\lambda_2 h}{b} \right)
\]

............................................(35)

By substituting Equation (35) into Equation (22b) and provides a second approach on the side wall shear stress on average. In rectangular channel sidewall aspect ratio, Equation (23b) reduces to Equation (36).

\[
\frac{r_w}{\rho ghS} = \frac{1}{2} \frac{b}{h} \left( 1 - \frac{r_b}{\rho ghS} \right)
\]

............................................(36)

To get the value of $\lambda_1$ and $\lambda_2$, the calibration of the Equation (34) so that it will comply with the empirical formula.

3. Experimental Data

The experimental tests were carried out in the Hydraulics Laboratory of Bandung Institute of Technology, on a free surfaceflume of 3,0 m length and with a cross section of 0,1 x 0,4 m² (Fig. 1a), whose slope can vary from 2/300 % up to 4/300 %. at a distance of 1 from the upstream timber bulkhead installed upstream so that the sand does not exit. An example of a sample of sand with a maximum grain diameter of 0,45mm to 0,85mm. Picture design can be found at Fig.5

![Figura 5. Flume Conditions along with AdditionalEquipment used](image)

4. Experimental Data Analysis

The data used for the analysis of experimental results of Choo et al. (2011) and Greco et al. (2014) as in Table (1).
Table 1. Results of Linear Regression Analysis between $U_{\text{rerata}}$ and $U_{\text{max}}$

<table>
<thead>
<tr>
<th>Data Source</th>
<th>Data</th>
<th>Relationship Equation</th>
<th>$\Phi$ (M)</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory</td>
<td>Abdel=Ael,F.M(1969)</td>
<td>$U_{\text{mean}} = 0.8657 U_{\text{max}}$</td>
<td>0.8657</td>
<td>0.9998</td>
</tr>
<tr>
<td></td>
<td>Govt. of W. Bengal(1965)</td>
<td>$U_{\text{mean}} = 0.8197 U_{\text{max}}$</td>
<td>0.8197</td>
<td>0.9987</td>
</tr>
<tr>
<td></td>
<td>Chyn, S.D(1935)</td>
<td>$U_{\text{mean}} = 0.8521 U_{\text{max}}$</td>
<td>0.8521</td>
<td>0.9998</td>
</tr>
<tr>
<td></td>
<td>Costello, W.R.(1974)</td>
<td>$U_{\text{mean}} = 0.8667 U_{\text{max}}$</td>
<td>0.8667</td>
<td>0.9998</td>
</tr>
<tr>
<td></td>
<td>Greco el al. (2014)</td>
<td>$U_{\text{mean}} = 0.7314 U_{\text{max}}$</td>
<td>0.7300</td>
<td>0.8840</td>
</tr>
<tr>
<td>River</td>
<td>Acop Canal data of</td>
<td>$U_{\text{mean}} = 0.911 U_{\text{max}}$</td>
<td>0.9110</td>
<td>0.999</td>
</tr>
<tr>
<td></td>
<td>Mahmood, et al. (1979)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hii River data of</td>
<td>$U_{\text{mean}} = 0.882 U_{\text{max}}$</td>
<td>0.8820</td>
<td>0.992</td>
</tr>
<tr>
<td></td>
<td>Shinohara, K. and Tsubaki, T.(1959)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Leopold, L.B.(1969)</td>
<td>$U_{\text{mean}} = 0.914 U_{\text{max}}$</td>
<td>0.9140</td>
<td>0.999</td>
</tr>
<tr>
<td></td>
<td>Greco el al. (2014)</td>
<td>$U_{\text{mean}} = 0.702 U_{\text{max}}$</td>
<td>0.7060</td>
<td>0.8957</td>
</tr>
</tbody>
</table>

Table 2. Results of Laboratory Experiments.

<table>
<thead>
<tr>
<th>No.</th>
<th>Slope</th>
<th>$Q_{\text{flow}}$ (l/dt)</th>
<th>$h$ (cm)</th>
<th>$U_{\text{flow}}$ (cm/dt)</th>
<th>$Q_{\text{delivery}}$ (l/dt)</th>
<th>$h_{\text{delivery}}$ (cm)</th>
<th>$u_1$ (m/dt)</th>
<th>$S$ (cm/dt)</th>
<th>$u^*$ (m/dt)</th>
<th>$u/u^*$</th>
<th>$d_{50}$ (cm)</th>
<th>$n$</th>
<th>$n_p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.1.1</td>
<td>0.00657</td>
<td>2.51440</td>
<td>0.08</td>
<td>3.14</td>
<td>0.007</td>
<td>0.355</td>
<td>0.072</td>
<td>5.055</td>
<td>0.001</td>
<td>0.0196</td>
<td>0.0166</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A.1.2</td>
<td>0.00657</td>
<td>2.86780</td>
<td>0.11</td>
<td>2.61</td>
<td>0.007</td>
<td>0.251</td>
<td>0.085</td>
<td>2.646</td>
<td>0.001</td>
<td>0.0367</td>
<td>0.0166</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A.1.3</td>
<td>0.00657</td>
<td>2.67970</td>
<td>0.12</td>
<td>2.50</td>
<td>0.007</td>
<td>0.194</td>
<td>0.090</td>
<td>2.726</td>
<td>0.001</td>
<td>0.0354</td>
<td>0.0166</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A.1.4</td>
<td>0.00657</td>
<td>4.52140</td>
<td>0.14</td>
<td>2.23</td>
<td>0.007</td>
<td>0.276</td>
<td>0.096</td>
<td>3.241</td>
<td>0.001</td>
<td>0.0298</td>
<td>0.0166</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A.1.5</td>
<td>0.00657</td>
<td>3.06100</td>
<td>0.12</td>
<td>2.51</td>
<td>0.007</td>
<td>0.232</td>
<td>0.126</td>
<td>2.207</td>
<td>0.001</td>
<td>0.0438</td>
<td>0.0166</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A.1.6</td>
<td>0.00657</td>
<td>3.70830</td>
<td>0.13</td>
<td>2.85</td>
<td>0.007</td>
<td>0.253</td>
<td>0.130</td>
<td>2.178</td>
<td>0.001</td>
<td>0.0443</td>
<td>0.0166</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Results of Calculation Manning with the basic form

<table>
<thead>
<tr>
<th>$Q$ (l/dt)</th>
<th>$h$(m)</th>
<th>$R$(m)</th>
<th>$u1$(m/dt)</th>
<th>Slope</th>
<th>Fr</th>
<th>$u^*$</th>
<th>$u/u^*$</th>
<th>$d50$</th>
<th>$n$</th>
<th>$n_p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.51440</td>
<td>0.08</td>
<td>0.26</td>
<td>0.314</td>
<td>0.007</td>
<td>0.355</td>
<td>0.072</td>
<td>5.055</td>
<td>0.001</td>
<td>0.0196</td>
<td>0.0166</td>
</tr>
<tr>
<td>2.86780</td>
<td>0.11</td>
<td>0.32</td>
<td>0.261</td>
<td>0.007</td>
<td>0.251</td>
<td>0.085</td>
<td>2.646</td>
<td>0.001</td>
<td>0.0367</td>
<td>0.0166</td>
</tr>
<tr>
<td>2.67970</td>
<td>0.13</td>
<td>0.35</td>
<td>0.214</td>
<td>0.007</td>
<td>0.194</td>
<td>0.090</td>
<td>2.726</td>
<td>0.001</td>
<td>0.0354</td>
<td>0.0166</td>
</tr>
<tr>
<td>4.52140</td>
<td>0.14</td>
<td>0.38</td>
<td>0.323</td>
<td>0.007</td>
<td>0.276</td>
<td>0.096</td>
<td>3.241</td>
<td>0.001</td>
<td>0.0298</td>
<td>0.0166</td>
</tr>
<tr>
<td>3.06100</td>
<td>0.12</td>
<td>0.34</td>
<td>0.253</td>
<td>0.013</td>
<td>0.232</td>
<td>0.126</td>
<td>2.207</td>
<td>0.001</td>
<td>0.0438</td>
<td>0.0166</td>
</tr>
<tr>
<td>3.70830</td>
<td>0.13</td>
<td>0.36</td>
<td>0.285</td>
<td>0.013</td>
<td>0.253</td>
<td>0.130</td>
<td>2.178</td>
<td>0.001</td>
<td>0.0443</td>
<td>0.0166</td>
</tr>
</tbody>
</table>
\begin{array}{|c|c|c|c|c|c|c|c|c|c|c|c|c|}
\hline
Q (l/dt) & h(m) & R(m) & u1(m/dt) & Slope & Fr & u^* & u/u^* & d50 & n & np \\
\hline
3.81730 & 0.14 & 0.38 & 0.273 & 0.013 & 0.233 & 0.135 & 2.240 & 0.001 & 0.0431 & 0.0166 \\
4.34490 & 0.15 & 0.40 & 0.290 & 0.013 & 0.239 & 0.140 & 2.289 & 0.001 & 0.0421 & 0.0166 \\
2.81110 & 0.11 & 0.32 & 0.256 & 0.007 & 0.246 & 0.085 & 3.343 & 0.000 & 0.0290 & 0.0152 \\
4.25980 & 0.12 & 0.34 & 0.352 & 0.007 & 0.323 & 0.089 & 4.389 & 0.000 & 0.0175 & 0.0152 \\
2.86610 & 0.13 & 0.35 & 0.229 & 0.007 & 0.207 & 0.090 & 3.112 & 0.000 & 0.0311 & 0.0152 \\
4.10420 & 0.14 & 0.38 & 0.293 & 0.007 & 0.250 & 0.096 & 2.931 & 0.000 & 0.0329 & 0.0152 \\
2.90150 & 0.10 & 0.30 & 0.290 & 0.013 & 0.293 & 0.114 & 2.831 & 0.000 & 0.0344 & 0.0152 \\
4.99270 & 0.13 & 0.36 & 0.381 & 0.013 & 0.336 & 0.131 & 3.094 & 0.000 & 0.0312 & 0.0152 \\
5.44780 & 0.14 & 0.38 & 0.389 & 0.013 & 0.332 & 0.135 & 2.924 & 0.000 & 0.0330 & 0.0152 \\
6.42860 & 0.15 & 0.40 & 0.429 & 0.013 & 0.353 & 0.140 & 2.791 & 0.000 & 0.0345 & 0.0152 \\
\hline
\end{array}

n = Manning roughness values calculate; np = Manning roughness values with bedform

Comparison with Experimental Data

Calculate the prediction accuracy by using the average normal faults (MNE) is

\[
MNE = \frac{100}{N} \sum_{i=1}^{N} \frac{|X_{mi} - X_{ni}|}{X_{mi}}
\]

\[
\text{with } N \text{ = many of data, } X_{ni} = \text{ measurement data in the laboratory and } X_{mi} = \text{ Data results of numerical calculations.}
\]

<table>
<thead>
<tr>
<th>n ent</th>
<th>M(\Phi)=0.866</th>
<th>n</th>
<th>n bed</th>
<th>error Function</th>
<th>n ent</th>
<th>M(\Phi)=0.820</th>
<th>error Function</th>
<th>n ent</th>
<th>M(\Phi)=0.852</th>
<th>error Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.021</td>
<td>0.0196</td>
<td>0.0166</td>
<td>0.094</td>
<td>0.154</td>
<td>0.023</td>
<td>0.155</td>
<td>0.154</td>
<td>0.022</td>
<td>0.111</td>
<td>0.154</td>
</tr>
<tr>
<td>0.040</td>
<td>0.0367</td>
<td>0.0166</td>
<td>0.085</td>
<td>0.548</td>
<td>0.042</td>
<td>0.146</td>
<td>0.548</td>
<td>0.040</td>
<td>0.102</td>
<td>0.548</td>
</tr>
<tr>
<td>0.038</td>
<td>0.0354</td>
<td>0.0166</td>
<td>0.074</td>
<td>0.533</td>
<td>0.040</td>
<td>0.134</td>
<td>0.533</td>
<td>0.039</td>
<td>0.091</td>
<td>0.533</td>
</tr>
<tr>
<td>0.031</td>
<td>0.0298</td>
<td>0.0166</td>
<td>0.036</td>
<td>0.444</td>
<td>0.033</td>
<td>0.094</td>
<td>0.444</td>
<td>0.031</td>
<td>0.052</td>
<td>0.444</td>
</tr>
<tr>
<td>0.056</td>
<td>0.0438</td>
<td>0.0166</td>
<td>0.272</td>
<td>0.622</td>
<td>0.059</td>
<td>0.344</td>
<td>0.622</td>
<td>0.057</td>
<td>0.293</td>
<td>0.622</td>
</tr>
<tr>
<td>0.050</td>
<td>0.0443</td>
<td>0.0166</td>
<td>0.124</td>
<td>0.626</td>
<td>0.053</td>
<td>0.188</td>
<td>0.626</td>
<td>0.051</td>
<td>0.142</td>
<td>0.626</td>
</tr>
<tr>
<td>0.055</td>
<td>0.0431</td>
<td>0.0166</td>
<td>0.281</td>
<td>0.616</td>
<td>0.058</td>
<td>0.353</td>
<td>0.616</td>
<td>0.056</td>
<td>0.301</td>
<td>0.616</td>
</tr>
<tr>
<td>0.053</td>
<td>0.0421</td>
<td>0.0166</td>
<td>0.262</td>
<td>0.607</td>
<td>0.056</td>
<td>0.333</td>
<td>0.607</td>
<td>0.054</td>
<td>0.282</td>
<td>0.607</td>
</tr>
<tr>
<td>0.034</td>
<td>0.0290</td>
<td>0.0152</td>
<td>0.173</td>
<td>0.477</td>
<td>0.036</td>
<td>0.239</td>
<td>0.477</td>
<td>0.035</td>
<td>0.192</td>
<td>0.477</td>
</tr>
<tr>
<td>0.025</td>
<td>0.0175</td>
<td>0.0152</td>
<td>0.408</td>
<td>0.135</td>
<td>0.026</td>
<td>0.487</td>
<td>0.135</td>
<td>0.025</td>
<td>0.431</td>
<td>0.135</td>
</tr>
<tr>
<td>0.042</td>
<td>0.0311</td>
<td>0.0152</td>
<td>0.338</td>
<td>0.511</td>
<td>0.044</td>
<td>0.413</td>
<td>0.511</td>
<td>0.042</td>
<td>0.360</td>
<td>0.511</td>
</tr>
<tr>
<td>0.033</td>
<td>0.0329</td>
<td>0.0152</td>
<td>0.000</td>
<td>0.539</td>
<td>0.035</td>
<td>0.057</td>
<td>0.539</td>
<td>0.033</td>
<td>0.016</td>
<td>0.539</td>
</tr>
<tr>
<td>0.042</td>
<td>0.0344</td>
<td>0.0152</td>
<td>0.224</td>
<td>0.559</td>
<td>0.045</td>
<td>0.293</td>
<td>0.559</td>
<td>0.043</td>
<td>0.244</td>
<td>0.559</td>
</tr>
<tr>
<td>0.035</td>
<td>0.0312</td>
<td>0.0152</td>
<td>0.125</td>
<td>0.514</td>
<td>0.037</td>
<td>0.188</td>
<td>0.514</td>
<td>0.036</td>
<td>0.143</td>
<td>0.514</td>
</tr>
<tr>
<td>0.035</td>
<td>0.0330</td>
<td>0.0152</td>
<td>0.076</td>
<td>0.540</td>
<td>0.037</td>
<td>0.136</td>
<td>0.540</td>
<td>0.036</td>
<td>0.093</td>
<td>0.540</td>
</tr>
<tr>
<td>0.033</td>
<td>0.0345</td>
<td>0.0152</td>
<td>0.049</td>
<td>0.561</td>
<td>0.035</td>
<td>0.005</td>
<td>0.561</td>
<td>0.033</td>
<td>-0.034</td>
<td>0.561</td>
</tr>
</tbody>
</table>

Table 4. Function Error on the Value of n Manning
The relationship between Manning Roughness Coefficient with Various $\Phi(M)$

**Figure 6. Relationship Between Manning Coefficient between n calculation and n entropy**

The next calculations carried Tabelaris

**Table 4 The Results of Calculations with Different Values $\Phi(M)$**

<table>
<thead>
<tr>
<th>Data Source</th>
<th>Data Source Details</th>
<th>Relationship Equation $n$</th>
<th>$\Phi(M)$</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory</td>
<td>Abdel-Ael,F.M(1969)</td>
<td>$n_{hitung} = 0.693n_{ent} + 0.007$</td>
<td>0.8657</td>
<td>0.846</td>
</tr>
<tr>
<td></td>
<td>Govt. of W. Bengal</td>
<td>$n_{hitung} = 0.5803n_{ent} + 0.010$</td>
<td>0.8197</td>
<td>0.864</td>
</tr>
<tr>
<td></td>
<td>Chyn, S.D(1935)</td>
<td>$n_{hitung} = 0.682n_{ent} + 0.007$</td>
<td>0.8521</td>
<td>0.846</td>
</tr>
<tr>
<td></td>
<td>Costello, W.R.(1974)</td>
<td>$n_{hitung} = 0.694n_{ent} + 0.007$</td>
<td>0.8667</td>
<td>0.846</td>
</tr>
<tr>
<td></td>
<td>Greco el al. (2014)</td>
<td>$n_{hitung} = 0.584n_{ent} + 0.006$</td>
<td>0.7300</td>
<td>0.846</td>
</tr>
<tr>
<td>River</td>
<td>Mahmood, et al. (1979)</td>
<td>$n_{hitung} = 0.729n_{ent} + 0.0067$</td>
<td>0.9110</td>
<td>0.846</td>
</tr>
<tr>
<td></td>
<td>Shinohara&amp;Tsubaki(1959)</td>
<td>$n_{hitung} = 0.7058n_{ent} + 0.0067$</td>
<td>0.8820</td>
<td>0.846</td>
</tr>
<tr>
<td>Source Data: Results Calculate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------------------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The results are plotted in Table (3) and Figure (6) and (7) and showed a good acceptance pda good roughness coefficient of using entropy as well as with the bedform. Relationships between variables in both methods showed a good correlation with the variation of entropy parameters $\Phi (M) = 0.706$ to $0.911$ for the natural river that gives the correlation value of $R^2 = 0.846$ to $0.877$. While in the laboratory flume entropy parameter value $\Phi (M) = 0.730$ to $0.867$; with a correlation value of $R^2 = 0.846$ to $0.864$.

Therefore, at low depth or low regime, the use of Eq. (10) together with the assumption verified $y_{max}$ in $\frac{1}{4}h$ from the bottom of the channel, will provide a better assessment and faster than the Manning roughness against perhitung on Moramarco and Singh (2010) with a constant value at $y_0$, and the observed values of $y_{max}$, it will be difficult to be evaluated in field measurements. Furthermore, important to be underlined that is how, with a regime of low or shallow depth, giving effect to the parameter $M$ on geometric and hydraulic characteristics of the flow, and provide valid results through analysis performed on the experimental data presented here.
This analysis defines the sidewall shear stress and the average base on steady uniform flow in smooth rectangular channels. Analysis of the continuity and momentum equations produce formulations for the average shear stress in Eq. (19) and the sidewall shear stress in Eq. (21). Both formulations showed the importance of the three main terms in the shear stress analysis: (1) the form of gravity; (2) forms of secondary flow; and (3) stress shear at the interface. Analytical solutions are possible for the case in which the eddy viscosity is constant and the secondary flow can be ignored. This analytical solution is obtained after considering the Schwarz-Christoffel transformation. This leads to a first approximation for the series expansion of the shear stress in Eq. (31a) and sidewall shear stress in Eq. (31b).

In figure (8) above results show the relationship of non-dimensional shear stress there is the aspect ratio B/h on the wall showed good results, while the side walls showed poor correlation. Traditionally the bed shear velocity is determined by fitting the near bed velocity profile to the logarithmic law when studying turbulent velocity profiles in flume experiments (Nezu and Nakagawa 1993). In relation with the aspect ratio resulting a good correlation between these variables, it is shown by the Figure (10) the relationship $\frac{\nu_b}{\nu_{ghs}} = 0.2007 \ln \left( \frac{B}{h} \right) + 0.999$ with correlation $R^2 = 0.9999$.

5. Conclusion

- Application entropic on the velocity profile to the river, can be used in evaluating the flow rate, reducing the time and trouble in the fluvial control and monitoring activities.
- In addition, the formulation of $n$ Manning roughness, which is based on entropy parameter (M), and the ratio between the position where the velocity is zero and the maximum velocity, $y_0/y_{max}$, which could be useful to overcome the uncertainty in the evaluation of the resistance parameters, especially the existence of roughness relatively large.
- The analysis shows how $y_0/y_{max}$ dependence on bed roughness value $h/y_0$ in promoting the Manning roughness $n$, through the formulation proposed by Moramarco Singh (2010) and modified by considering $y_{max}$ for $\frac{3}{4}$ of water depth (h). The results of that impose on the relationship between entropy and the parameters of hydraulic and geometric characteristics of the flow.

References


Johnson, W., 1942.” The Importance Of Side Wall Friction in Bed Load Inverstigation “.CivilEngrg., Vol. 12, 239-331.
Mohammadi, M., “ Shape Effects on Boundary Shear Stress in Open Channels”, proceeding Journal of Eng., Faculty of Eng., Tabriz University, Tabriz, Iran. (In Farsi).