Comparing the Calculation Method of the Manning Roughness Coefficient in Open Channels

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Abstract—In hydraulic engineering, Manning roughness coefficient is an important parameter in designing hydraulic structures and simulation models. This equation is applied to both uniform open channel flow, which is used to calculate the average flow velocity. The procedure for selecting the value of Manning n is subjective and requires assessment and skills developed primarily through experience. Many empirical formulae for obtaining the roughness coefficient n have been developed, including Cowan (1956), Arcement and Schneider (1984), Limerinos (1970), Karim and Kennedy (1990), Riekenmann (1994), Riekenmann (2005), and Chiari and Riekenmann (2007). Obtaining roughness coefficient n from Manning equations is obtained empirically, with values ranging from the lowest n = 0.0015 to the highest n = 0.0075. In natural channels, Manning roughness coefficient n ranges from 0.0027 to 0.0590. However, for laboratory data, Manning roughness coefficient n ranges from 0.0256 to 0.0171, with the value of R² = 0.926 and MNE (Measurement Normalized Errors) = 82% on the method Limerinos (1970).

Keywords—Open Channel, Roughness Manning coefficient, Empirical formula

I. INTRODUCTION

Manning coefficient n is a coefficient that represents the roughness or friction applied to the flow in the channel (Bilgin & Altun, 2008). In hydraulic engineering, Manning roughness coefficient is an important parameter in designing hydraulic structures (Azamathulla et al., 2013; Samandar, 2011; Bilgin & Altun, 2008).

Manning equation is an empirical equation applied to the uniform open channel flow, which is used to calculate the average flow velocity and the speed function of the channel, the hydraulic radius and slope of the channel (Bahramifar et al., 2013).

In Europe, also known as the Manning formula Gauckler-Manning formula, or formula Gauckler-Manning-Strickler. It was first presented by the French Engineer Philippe Gauckler in 1867, and then re-developed by the Irishland engineer Robert Manning in 1890 (Bahramifar et al., 2013).

The study of the roughness coefficient has been much research done previously, including Cowan (1956) which examines the roughness coefficient and Agricultural Engineering. Arcement and Schneider (1984) make modifications to the formulation by incorporating the element of stream power. Limerinos (1970) investigating the Manning roughness coefficient of the basic measurements in a natural channel. Brownlie (1983) had developed roughness coefficient n in the flow depth relationship in the form of hydraulic conditions and characteristics of the bed materials in large amounts of data flume and field. Karim and Kennedy (1990) developed a formulation relationship to the value of n in the form of dimensionless variables in the form of relative depth and friction factor.

Riekenmann (1994) proposed the equation to calculate the total Manning roughness coefficient. Riekenmann (2005) proposed the loss calculation on the flow resistance associated with a form of drag as a function of the slope and depth of the relative flow. Bahramifar et al. (2013) who evaluated the Manning by using ANFIS method approach in alluvial channels. Greco et al. (2014) analyzed using entropy method in order to determine the value roughness coefficient Manning.

The purpose of this paper is to obtain the value of the roughness coefficient (n) Manning on the field by comparing based on existing Manning formula.

II. MATERIAL

2.1 Formulation of Manning

The value of this coefficient can be searched with the knowing flow parameters as that of the equation Equation (2.1).

\[ n = \frac{1.00}{u} R^{2/3} S^{1/2} \]
where U is average flow velocity (m / sec); n is Manning roughness coefficient; R is hydraulic radius (meters) and S is slope of the line.

2.2 Cowan (1956).

Cowan (1956) developed a method to estimate the value of the Manning roughness n, by using the geometry and hydraulic parameters. The value of the roughness coefficient (n) is calculated using Equation (2)

\[ n = (n_0 + n_1 + n_2 + n_3 + n_4)m \] ........................(2)

where \( n_0 \) is the value of the basic values of n for which a straight line, according to a uniform and smooth natural ingredients it contains, \( n_1 \) value added to \( n_0 \) to correct for the effect of surface irregularities, \( n_2 \) value for variations in the shape and size of the cross section of the channel, \( n_3 \) value for barriers, \( n_4 \) value for condition vegetation and flow and \( n_5 \) correction factor for channel bends.

Table 1. Base value of Manning’s n (modified from Aldridge and Garrettn, 1973)

<table>
<thead>
<tr>
<th>Bed Material</th>
<th>Median size of bed material (in millimeters)</th>
<th>Base n value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand Channel</td>
<td>Straight uniform Channel</td>
<td>Smooth Channel</td>
</tr>
<tr>
<td>Sand .......................</td>
<td>0.20</td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td>0.3</td>
<td>0.017</td>
</tr>
<tr>
<td></td>
<td>0.4</td>
<td>0.020</td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>0.022</td>
</tr>
<tr>
<td></td>
<td>0.6</td>
<td>0.023</td>
</tr>
<tr>
<td></td>
<td>0.8</td>
<td>0.025</td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>0.026</td>
</tr>
<tr>
<td>Stable Channel and Flood Plains</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coarse sand ..............</td>
<td>1-2</td>
<td>0.4026-0.035</td>
</tr>
<tr>
<td>Fine Gravel ..............</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Gravel .....................</td>
<td>2-64</td>
<td>0.028-0.035</td>
</tr>
</tbody>
</table>

Source: Aldridge and Garrettn, 1973

2.3 Arcement and Schneider (1984).

Arcement and Schneider (1984) has modified the Equation (2.2) to be used in the calculation of flood plains. Correction factor to form sinusoidal (m) to 1 (one) in this caseand correct the differences in size and shape of the channel \( n_2 \) which is assumed to be equal to 0 (zero). Equation (1) in the equation (3).

\[ n = (n_0 + n_1 + n_2 + n_3 + n_4)m \] ........................(3)

which \( n_0 \) is the basic value of n the openland surface. Selection on the basis of the value of the floodplains are the same as in the channel. Arcement and Schneider (1984) proposed that the effect of resistance to flow (Simons & Richardson, 1966) in the floodplains

2.4 Limerinos (1970)

Limerinos (1970) have examined the determination of Manning coefficient of bottom friction measurements in a natural channel, to establish the relationship between the value of the base on the Manning roughness coefficient, n, and the index on the basis of particle size and size distribution of the river, get the value of roughness as Equation (4).

\[ n = \frac{0.0926}{1,16 + 2,0 \log \frac{d}{d_{84}}} \] ........................(4)

where n is the total Manning roughness coefficient, R is the hydraulic radius of the channel, and \( d_{84} \) diameter riverbed material with a percentage of 84% passes.

Table 2. Value Roughness Coefficient (n) is Calculated by Equation Cowan

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description Channel</th>
<th>Recommended Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic, ( n_0 )</td>
<td>Earth</td>
<td>0.020</td>
</tr>
<tr>
<td></td>
<td>Rock</td>
<td>0.025</td>
</tr>
<tr>
<td>Fine Gravel</td>
<td></td>
<td>0.024</td>
</tr>
<tr>
<td>Coarse Gravel</td>
<td></td>
<td>0.028</td>
</tr>
<tr>
<td>Irregularity, ( n_1 )</td>
<td>Smooth</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Minor</td>
<td>0.005</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td>0.010</td>
</tr>
<tr>
<td></td>
<td>Severe</td>
<td>0.020</td>
</tr>
<tr>
<td>Cross section, ( n_2 )</td>
<td>Gradual</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Occasional</td>
<td>0.005</td>
</tr>
<tr>
<td></td>
<td>Alternating</td>
<td>0.010-0.015</td>
</tr>
<tr>
<td>Obstructions, ( n_3 )</td>
<td>Negligible</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Minor</td>
<td>0.010-0.015</td>
</tr>
<tr>
<td></td>
<td>Appreciable</td>
<td>0.020-0.030</td>
</tr>
<tr>
<td></td>
<td>Severe</td>
<td>0.040-0.060</td>
</tr>
<tr>
<td>Vegetation, ( n_4 )</td>
<td>Low</td>
<td>0.005-0.010</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>0.010-0.020</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>0.025-0.050</td>
</tr>
<tr>
<td></td>
<td>Very High</td>
<td>0.050-0.100</td>
</tr>
<tr>
<td>Meandering, ( m )</td>
<td>Minor</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>Appreciable</td>
<td>1.15</td>
</tr>
<tr>
<td></td>
<td>Severe</td>
<td>1.30</td>
</tr>
</tbody>
</table>

Source: Chwe, 1959.

2.5 Brownlie (1983)

Brownlie (1983) has developed a relationship at a depth of flow in the form of hydraulic conditions and characteristics of the bed materials in large amounts of data flume and field. The relationship shown in equation (5) and (6).

- On the condition of Lower Regime;
  \[ n = 1.6940 \left( \begin{array}{c} R \\ d_{50} \end{array} \right)^{0.1374} S^{0.1112} G^{0.1605} \left( 0.034d_{50}^{0.167} \right) \] ....(5)

- In conditions of Upper Regime
  \[ n = 1.0123 \left( \begin{array}{c} R \\ d_{50} \end{array} \right)^{0.0662} S^{0.0709} G^{0.1282} \left( 0.034d_{50}^{0.167} \right) \] ... (6)

where, R = hydraulic radius (ft); S = slope of the line (ft / ft); \( d_{50} \) = median particle size of the bed material (ft) and G = coefficient of gradation on the base material. Where
2.6 Karim and Kennedy (1990)

Karim and Kennedy (1990) apply the above procedure on the data field and flume gives the relationship in the form of relationship to the value of as Equation (7)

\[ n = 0.037 \left( \frac{\text{d}_{50}}{\text{d}_{50}} \right)^{0.126} \left( \frac{\text{I}}{S_{0}} \right)^{0.465} \] ........................ (7)

(d50 in meters) and \( \frac{\text{L}}{S_{0}} = 1.20 + 8.92 \frac{\Delta}{h} \)

2.7 Riekenmann (1994)

Riekenmann (1994) proposed the equation to calculate the total Manning roughness coefficient, as shown in Equation (8).

\[ \frac{1}{n_{\text{tot}}} = 0.56 \text{g}^{0.044} \text{S}^{0.11} \] ........................ (8)

2.8 Riekenmann (2005)

Riekenmann (2005) proposed the loss calculation on flow resistance associated with the drag shape as a function of the slope and depth of flow relative, as in Equation (9).

\[ n = 0.0835 \left( \frac{ h }{ d_{50} } \right)^{0.33} \] ........................ (9)

2.9 Chiari dan Rickenmann (2007)

Chiari and Rickenmann (2007) proposed Manning on the surface roughness values for total roughness that produces Equation (10).

\[ n = 0.0756 \text{g}^{0.11} \] ........................ (10)


Moramarco and Singh (2010), Mirauda et al (2011), Mirauda dan Greco (2014) dan Greco et al. (2014) who examined the Manning roughness coefficient in open channel parameters based on entropy, which has resulted in Equation (11)

\[ n = \frac{R_{b}^{1/6}}{\Phi (\text{M})} \ln \left( \frac{S_{0}}{\text{g}^{1/2} \text{d}_{50}} \right) - 0.4621 \] ........................ (11)

2.11 Formulation Manning Based on Linear Separation

Borojunas (1952) also states the linear separation of the Manning roughness coefficient into two (2) parts: first, the basic channel resistance granules associated friction on the surface (skin friction) known as grain roughness (n’), the basic flow resistance in relation to the existence of bedform and roughness changes known with the form (n’’). His formulation shown in Equation (12).

\[ n = n' + n'' \] ........................ (12).

in which n’ = resistance due to friction surface (skin friction) or grain roughness; \( n' = \left( \frac{R_{s}}{168d_{35}} \right) \) and \( n'' = \Phi \left( \frac{R_{s}}{168d_{35}} \right) \)

2.11 Formulation Manning Based on Linear Separation Based on Bed Configuration (Wibowo-Manning).

Wibowo (2015) also states the linear separation of the Manning roughness coefficient based on the flow resistance in the field of bed moves, equal as Equation (12). n’ As in the following Equation (13) and (14).

\[ n' = \frac{\text{R}^{1/6}}{6.0 + 5.75 \log \left( \frac{\text{b}}{\text{y}_{\text{m}}} \right)} \] ........................ (13)

and

\[ n'' = \frac{\tau_{w} (1) \text{ln} \left( \frac{\text{R}_{w}}{\text{y}} \right)}{2\rho d_{16} (51-1) \cos \theta \tan \phi \sin a} \] ........................ (14)

Where \( n' \) is the shear stress relative due to the basic form\( n'' = \tau_{w} - \tau_{w}' \), \( \tau_{w} = h S / (\rho_{t} - \rho) d_{35} k_{s} \) is shape form \( = 1 \), \( k_{s} \) is the correction factor (0.20 to 0.90), \( \lambda \) length of bedform; \( d \) is grain diameter; \( \tan \phi \) is dynamic friction coefficient and \( \alpha \) is the angle of the bed channel.

<table>
<thead>
<tr>
<th>Number</th>
<th>Shape material</th>
<th>Shape Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>□</td>
<td>0.20 – 0.39</td>
</tr>
<tr>
<td>2</td>
<td>○</td>
<td>0.40 – 0.59</td>
</tr>
<tr>
<td>3</td>
<td>●</td>
<td>0.60 – 0.79</td>
</tr>
<tr>
<td>4</td>
<td>▲</td>
<td>0.80 – 0.99</td>
</tr>
<tr>
<td>5</td>
<td>▼</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Table 3. Value Factor Correction on Alluvial Material (Corey, 1956)

<table>
<thead>
<tr>
<th>Number</th>
<th>Class name</th>
<th>φ (deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sand Very Coarse</td>
<td>32</td>
</tr>
<tr>
<td>2</td>
<td>Sand Coarse</td>
<td>31</td>
</tr>
<tr>
<td>3</td>
<td>Sand medium</td>
<td>30</td>
</tr>
<tr>
<td>4</td>
<td>Sand Fine</td>
<td>30</td>
</tr>
<tr>
<td>5</td>
<td>Sand Very Fine</td>
<td>30</td>
</tr>
</tbody>
</table>

Table 4. Angle Angle pupose (φ) on Non Cohesive Soil (Piere, 2010)
III. METHODS

3.1 The Field research

The method implemented by comparing the results of experiments in laboratorium and pitch of each empirical formula.

a. Data Field

The field data is taken based on the results of field research on the cross-section of the river in the city of Pontianak (Trenches Bansir) as listed in the Table (5).

Table 5. Results Flow Velocity Measurement in the Field

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Unit</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>meter</td>
<td>9,000</td>
<td>8,400</td>
<td>9,000</td>
<td>8,500</td>
</tr>
<tr>
<td>h0</td>
<td>meter</td>
<td>0,800</td>
<td>0,900</td>
<td>0,700</td>
<td>0,700</td>
</tr>
<tr>
<td>U</td>
<td>m/s</td>
<td>0,116</td>
<td>0,098</td>
<td>0,139</td>
<td>0,121</td>
</tr>
<tr>
<td>bo</td>
<td>meter</td>
<td>1,125</td>
<td>1,050</td>
<td>1,125</td>
<td>1,063</td>
</tr>
<tr>
<td>Qo</td>
<td>m³/s</td>
<td>0,039</td>
<td>0,057</td>
<td>0,046</td>
<td>0,027</td>
</tr>
<tr>
<td>Qtotal</td>
<td>m³/s</td>
<td>0,929</td>
<td>0,857</td>
<td>1,019</td>
<td>0,757</td>
</tr>
<tr>
<td>Total width</td>
<td>m²</td>
<td>9,763</td>
<td>8,638</td>
<td>7,465</td>
<td>6,593</td>
</tr>
<tr>
<td>velocity</td>
<td>m/s</td>
<td>0,116</td>
<td>0,098</td>
<td>0,139</td>
<td>0,121</td>
</tr>
<tr>
<td>Hydraulic radius</td>
<td></td>
<td>0,888</td>
<td>0,834</td>
<td>0,717</td>
<td>0,665</td>
</tr>
<tr>
<td>Slope</td>
<td></td>
<td>0,0000209</td>
<td>0,0000209</td>
<td>0,0000209</td>
<td>0,0000209</td>
</tr>
<tr>
<td>Roughness</td>
<td></td>
<td>0,044</td>
<td>0,041</td>
<td>0,027</td>
<td>0,030</td>
</tr>
<tr>
<td>Average value n</td>
<td></td>
<td>0,036</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

b. Data Laboratory.

Results of secondary data and primary data from direct measurements in the laboratory can be seen in Table (6).

Table 6. Results Flow Velocity Measurement in the Laboratory

<table>
<thead>
<tr>
<th>Slope</th>
<th>Qoutflow</th>
<th>width</th>
<th>h</th>
<th>Uoutflow</th>
<th>Δ</th>
<th>λ</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>liter/s</td>
<td>m</td>
<td>cm</td>
<td>cm/s</td>
<td>cm</td>
<td>cm</td>
</tr>
<tr>
<td>0,0002</td>
<td>3,000</td>
<td>0,40</td>
<td>5,20</td>
<td>14,423</td>
<td>0,14</td>
<td>7,53</td>
</tr>
<tr>
<td>0,0002</td>
<td>4,000</td>
<td>0,40</td>
<td>6,50</td>
<td>15,385</td>
<td>0,29</td>
<td>7,42</td>
</tr>
<tr>
<td>0,0002</td>
<td>5,000</td>
<td>0,40</td>
<td>7,70</td>
<td>16,234</td>
<td>0,38</td>
<td>9,68</td>
</tr>
<tr>
<td>0,0002</td>
<td>6,000</td>
<td>0,40</td>
<td>9,20</td>
<td>16,304</td>
<td>0,42</td>
<td>10,56</td>
</tr>
<tr>
<td>0,0002</td>
<td>7,000</td>
<td>0,40</td>
<td>10,20</td>
<td>17,157</td>
<td>0,46</td>
<td>8,44</td>
</tr>
<tr>
<td>0,0002</td>
<td>8,000</td>
<td>0,40</td>
<td>11,15</td>
<td>17,937</td>
<td>0,49</td>
<td>10,17</td>
</tr>
<tr>
<td>0,0002</td>
<td>3,000</td>
<td>0,40</td>
<td>4,20</td>
<td>17,857</td>
<td>0,13</td>
<td>12,22</td>
</tr>
<tr>
<td>0,0002</td>
<td>5,000</td>
<td>0,40</td>
<td>6,60</td>
<td>18,939</td>
<td>0,31</td>
<td>13,44</td>
</tr>
<tr>
<td>0,0002</td>
<td>6,000</td>
<td>0,40</td>
<td>8,15</td>
<td>18,405</td>
<td>0,67</td>
<td>7,33</td>
</tr>
<tr>
<td>0,0002</td>
<td>7,000</td>
<td>0,40</td>
<td>9,90</td>
<td>17,677</td>
<td>0,69</td>
<td>10,56</td>
</tr>
<tr>
<td>0,0002</td>
<td>8,000</td>
<td>0,40</td>
<td>10,05</td>
<td>19,900</td>
<td>0,77</td>
<td>11,00</td>
</tr>
<tr>
<td>0,008</td>
<td>3,000</td>
<td>0,40</td>
<td>5,05</td>
<td>14,851</td>
<td>0,36</td>
<td>7,56</td>
</tr>
<tr>
<td>0,008</td>
<td>4,000</td>
<td>0,40</td>
<td>7,60</td>
<td>13,158</td>
<td>0,37</td>
<td>9,74</td>
</tr>
</tbody>
</table>

Source: field Results

Source: Laboratory Results
The Composition of Experiment

The experimental tests were carried out in the Hydraulics Laboratory of Bandung Institute of Technology, on a free surface flume of 10.0 m length and with a cross section of 0.4 x 0.6 m² (Fig.2), whose slope can vary from 10/1000 % 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 0.25 mm to 0.5 mm. Picture design can be found at Fig.3

IV. DATA ANALYSIS

4.1 Calculation Results Manning Roughness on Empirical formula

- Example Method Cowan (1956)

The formula used \( n = (n_0 + n_1 + n_2 + n_3 + n_4) m = 0.020 \) (channel-forming material is ground) \( n_1 = 0.005 \) (degree of irregularity, in the channel of small (minor), slightly eroded or on cliffs eroded channel), \( n_2 = 0.000 \) (cross-sectional variation in channel, channel varies and forms cross-section is considered phased (gradual) that changes the shape channel occur slowly), \( n_3 = 0.000 \) (relative effect and the digolong barriers can be ignored). \( n_4 = 0.000 \) (because there is only a small grass. \( m = 1.00 \) degrees of bend, take the small (minor). From these analysis results obtained value of \( n = (0.020 + 0.005 + 0.000 + 0.000 + 0.000) \times 1.000 = 0.025. \)

Furthermore, the calculation is then performed in the Table (7).

Tabel 7. Summary Calculation Results From Table 5 & 6

<table>
<thead>
<tr>
<th>Roughness Coefficient</th>
<th>Data on Cross Section Width</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B =8-9 m</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Wibowo</td>
<td>-</td>
</tr>
<tr>
<td>Bojurunas (1952)</td>
<td>0.0218</td>
</tr>
<tr>
<td>Metode Entropi</td>
<td>0.0590</td>
</tr>
<tr>
<td>Cowan (1956)</td>
<td>0.0250</td>
</tr>
<tr>
<td>Arcement &amp; Schneider</td>
<td>0.0325</td>
</tr>
<tr>
<td>(1984)</td>
<td></td>
</tr>
<tr>
<td>Limerinos (1970)</td>
<td>0.0147</td>
</tr>
<tr>
<td>Brownlie (1983)</td>
<td>0.0144</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Karin &amp; Kennedy (1990)</td>
<td>0.00815</td>
</tr>
<tr>
<td>Riekenmann (1994)</td>
<td>0.0027</td>
</tr>
<tr>
<td>Riekenmann (2005)</td>
<td>0.0051</td>
</tr>
<tr>
<td>Riekenmann &amp; Chiari</td>
<td>0.0126</td>
</tr>
</tbody>
</table>

Source: calculation results

4.2 Application of Flow Coefficient of Roughness on Discharge

The general formula used as According Soewarno (1995) discharge or magnitude of flow of the river / channel is flowing through the volume flow through the a river cross section / channel unit time. Usually expressed in units of cubic meters per second (m³ / s) or liters per second (l / sec). Flow is the movement of water in the river channel / channels. In essence discharge measurement is a measurement of the wet cross-sectional area, flow velocity and water level Equation (15).

\[ Q = U \cdot A \] ..........................(15)

where:

- \( Q \) = discharge (m³/s)
- \( A \) = cross-sectional area the wet (m²)
- \( U \) = average flow velocity (m/s)

Which \( U \) as in Equation (16)

\[ U = \frac{1.00}{n} R^{2/3} S^{1/2} \] ..........................(16)

Roughness coefficient because of their sidewalls, expressed in bedform Equation (8).

\[ n_w = \frac{1}{\sqrt{3}} \left( \frac{t_w}{u} \right) \text{ and } u_{aw} = \sqrt{\frac{t_w}{\rho}} \] ..........................(8)

- Example of Average Bed and Sidewall Shear Stress

Shear stress bed (\( \tau_b \)) and sidewalls average (\( \tau_w \)) can be formulated to implement using the overall balance of force in the direction of flow (Guo & Pierre, 2005). As defined in Equation (17)

\[ 2h\tau_b + b\tau_w = \rho gA_bh = \rho gSh \] ..........................(17)

where the amount of shear stress bed (\( \tau_b \)) and sidewalls average (\( \tau_w \)) can be formulated by Javid & Mohammadi (2013) as Equation (18a) and (18b)

\[ \tau_b = \frac{h}{\rho g} \left( \frac{t_b}{u} \right) \] ..........................(18a)

\[ \tau_w = \frac{h}{\rho g} \left( 1 - \frac{\tau_b}{\rho gSH} \right) \] ..........................(18b)

Keulegan (1938) suggested that the bedformsof the internal angles of the polygonal channels can be used as a dividing line to illustrate the extent of the bed and side wall area. As Equation (19).

\[ A = A_b + A_w \] ..........................(19)

The drainage area of the bed (\( A_b \)) and drainage area of the side wall (\( A_w \)) can be expressed as Equation (20a) and (20b)

\[ A_b = 2 \int_0^h y \, dz = 1.74 \left( 1 - \exp(-0.57 \, h/b) \right) \] ..........................(20a)

\[ A_w = bh - A_b; \quad A_w = bh - \int_0^h y \, dz = 1.74 \left[ 1 - \exp(-0.57 \, h/b) \right] \] ..........................(20b)

The rate calculation results are presented in graphical form. Data used in the calculation of this flow rate
1. Data experimental Wang and White (1993): This data set consists of 108 running and experiments have been conducted on the transition regime characterized by resistance coefficient decreases rapidly with increasing strength of the current.

2. Data from experiments Guy et al. (1966) 340 is also included


Table 8. Summary Calculation Results from the All Data

<table>
<thead>
<tr>
<th>No</th>
<th>Investigator</th>
<th>Roughness Coefficient (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Limerinos (1970)</td>
<td>0.011</td>
</tr>
<tr>
<td>2</td>
<td>Brownlie (1983)</td>
<td>0.012</td>
</tr>
<tr>
<td>3</td>
<td>Borujnas (1952)</td>
<td>0.012</td>
</tr>
<tr>
<td>4</td>
<td>Karim dan Kennedy (1990)</td>
<td>0.013</td>
</tr>
<tr>
<td>5</td>
<td>Riekenmann (1994)</td>
<td>0.008</td>
</tr>
<tr>
<td>6</td>
<td>Riekenmann (2005)</td>
<td>0.012</td>
</tr>
<tr>
<td>7</td>
<td>Chiari dan Rickenmann 2007</td>
<td>0.025</td>
</tr>
<tr>
<td>8</td>
<td>Metode Entropi - Wibowo</td>
<td>0.017</td>
</tr>
<tr>
<td>9</td>
<td>Wibowo (2015)</td>
<td>0.017</td>
</tr>
</tbody>
</table>

4.3. Discussion

Based on this analysis, the coefficient calculation is done perhitung this prediction accuracy using the average normal faults (MNE), namely

$$MNE = \frac{100}{N} \sum_{i=1}^{N} \frac{|X_{ci} - X_{mi}|}{X_{mi}}$$

Where the results of with the formula estimate manning, $X_{mi}$, and $X_{ci}$= empirical calculation results.

Table 8. Resume Calculation Result Error Correction

<table>
<thead>
<tr>
<th>Investigator</th>
<th>Mean Normalized Errors</th>
<th>Correlation Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limerinos (1970)</td>
<td>82.220</td>
<td>0.926</td>
</tr>
<tr>
<td>Brownlie (1983)</td>
<td>58.613</td>
<td>0.681</td>
</tr>
<tr>
<td>Borujnas (1952)</td>
<td>52.036</td>
<td>0.849</td>
</tr>
<tr>
<td>Karim dan Kennedy (1990)</td>
<td>69.821</td>
<td>0.893</td>
</tr>
<tr>
<td>Riekenmann (1994)</td>
<td>39.989</td>
<td>0.877</td>
</tr>
<tr>
<td>Riekenmann (2005)</td>
<td>68.551</td>
<td>0.846</td>
</tr>
<tr>
<td>Chiari dan Rickenmann 2007</td>
<td>61.168</td>
<td>0.894</td>
</tr>
<tr>
<td>Metode Entropi - Wibowo</td>
<td>82.189</td>
<td>0.925</td>
</tr>
<tr>
<td>Wibowo (2015)</td>
<td>69.058</td>
<td>0.859</td>
</tr>
</tbody>
</table>

Results of analysis of the Manning roughness coefficient calculation (n) obtained the highest and lowest values of n for each method, for empirical method obtained the lowest n = 0.0008 and n highest n = 0.0071, this shows that by using laboratory data obtained results are still within reach Manning roughness table for sand = 0.020. On the condition of with the natural channel data highest n= 0.0590 and lowest n = 0.0027 (In natural conditions n = 0.025-0.033).

In the study of the entropy formula, bojorunas and Wibowo, for the Manning roughness values using laboratory data the highest n = 0.012 and the lowest n = 0.027.
For the third method in the Manning roughness coefficient results showed results that approached with the table Manning to a grain of sand \( (n = 0.020) \). While the field data showed that are less good results.

Similarly to the empirical formula. This is because the analysis used in the form of uniform flow, while the flow field is not uniform.

Formulation development Manning coefficient of linearseparation in relation to the flow rate can be seen in Figure 5. Table 8 presents a comparison of MNE from all studies show varying results between 39.989% - 82.220%. In the method of data Limerinos and Entropy Method shows the model fit a large proportion of the 82% which means the value is quite satisfactory, because it is still the case that small forecasting error of 18%.

From Table 9, it is also seen that, the correlation coefficient between the actual and the forecast has a direct relationship Strong positive as indicated by the value of \( R^2 \) ranging from 0.681 to 0.926. If used best linear fitting as shown in Figure 2, obtained the highest coefficient of determination Limerinos method that \( R^2 \) approximately 0.926; or in other words that the accuracy of the linear regression model between observation is very strong with a forecast of 0.926.

V. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

In the discussion of the previous chapter, we conclude some results as follows:

- Effect of resistance form can not be ignored \( n''/n' = -17.316 n + 0.6807 \), meaning that large semangkit roughness value relative basis, the value of the Manning roughness coefficient (n) small semangkin thus obtained a large flow rate.
- The value of the roughness coefficient (n) obtained from Manning in some formulations are obtained empirical method for the lowest n = 0.008 and highest n = 0.090. and the condition of with the natural channel data n highest and lowest namely 0.0590 and 0.0027.
- obtained simulating the relationship between Q and Q flume \( Q_{\text{sim}} = 0.436Q_{\text{flume}}^{0.8834} \) with \( R^2 = 0.859 \) which shows the model results correlate very well.
- By using the relationship obtained by the method Nash \( Q_{\text{sim}} = 0.950Q_{\text{flume}} + 0.0012 \) with \( R^2 = 0.9797 \), which shows a very good correlation results.
- In a study of entropy formula, bojorunas and Wibowo, for the Manning roughness values using the highest laboratory data n = 0.0256 and the lowest n = 0.0171, which results still meet the requirements for the value of non-cohesive material.
- Development of the Manning formula can be applied in the field by the presence of a correction value.
- Results between the discharge and discharge measurement results correlated linearseparation is good, which is shown by the correlation coefficient \( R^2 = 0.859 \).
- In the method of data Limerinos and Entropy Method shows the model fit a large proportion of the 82% which means the value is quite satisfactory, because it is still the case that small forecasting error of 18%.
- Linear separation method by taking into account the basic shape can be used in predicting the flow in natural river.
5.2 Recommendations

- To obtain optimal results in the research study, the Manning coefficient should be used as much as possible the data.
- The amount of data retrieved should be quite a lot, both with respect to the number of observation points and the number density of the vertical point of channel cross section.
- Development research can be carried out with the assumption of cross-channel conditions in other places.

IV. ACKNOWLEDGEMENT

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I. REFERENCES


