# STUDY RELATIONSHIP OF BED CHANNEL CONFIGURATION AND BED ROUGHNESS COEFFICIENT NON MATERIAL COHESIVE

Wibowo [1], Suripin [2], Kodoatie [2], Isdiayana

*[1].Student of Doktoral Program on University of Diponegoro,50241 Semarang*
*[1]Water Resources Engineering Department, University of Tanjungpura, 78115 Pontianak, Indonesia.*
*[2] Civil Engineering, University of Diponegoro,50241 Semarang.*
*[3]River Balai, Water Resources Research Center, Balitbang the Ministry of Public Works*
*e-mail:* ***Hariwibowo13@yahoo.com***

**ABSTRACT :** Resistance to the flow is very important and is the main parameter in determining the elevation of the water surface. Resistance flow in alluvial channel changes with the flow and sediment transport conditions can cause changes in the bedform. Various forms of the bedform, especially in the lower flow regime (lower regime) have an influence on the bed roughness. Due to the complexity of the development of bedform, some existing methods may differ drastically from each other in predicting the shape of the bedform. In this paper, conducted laboratory experiments to investigate the geometry of the sand hill in the bed channels and its effect on the flow resistance in the channels. Experiments performed in the hydraulic laboratory flume at the Balai River of Solo and some secondary data using sand particles. Simple relationship is sought to dimension through some basic configuration parameters of dimensions. The results obtained between roughness basic and basic shapes expressed in the form n '/ n' = 18.198 (Δ/h) + 0.426 with a correlation coefficient of ($R^2$) = 0.742.

**Keywords -** flow resistance, bedform, flow regime

## I. INTRODUCTION

The elevation of the water surface is very important in determining the limits of the floodplain and river structures such as the design of the flood control structures, dams, pier, hydropower generation projects, and bridges. The water surface elevation is closely related to the flow resistance in the alluvial bed easily eroded and carried by the flow of water (Simons & Richardson, 1966; Simons and Senturk, 1992; Talebbydokhti, et al., 2006; Garde, 2006; Yang & Tan, 2008; Bilgin & Altun, 2008; Bose & Dey, 2010; Greco et al., 2014; Mirauda & Greco, 2014; Wibowo, 2015).

Resistance flow in alluvial channel changes with the flow and sediment transport conditions can cause deformation bedform (Bose & Dey, 2012; Simons and Senturk, 1992; Simons & Richardson, 1966). Form the bed configuration changes that occur in the lower flow regime described in lower flow regime and on upper flow regime and transition (Simons & Richardson, 1961; Lewis, 1984). In both these flow regime, has a characteristic shape that is similar to the basic configuration, mode of sediment transport, energy dissipation process, the phase relationship between surface water and basic channels (Simons & Richardson, 1966; Lewis, 1984; Simons and Senturk, 1992). Various forms of the bed configuration, the lower regime flow starting from ripples, and gradually increase the speed of shear stress or water, into a mound of dunes. Upper regime flow in the form of erosion of sand dunes, flat bed, antidunes, and astanding wave (Simons and Richardson, 1966; Simons and Senturk, 1992; Holmes, 2003; Talebbydokhti, et al., 2006; Garde, 2006; Yang & Tan, 2008; Bose & Dey, 2010; Wibowo, 2015).

Resistance flow in the alluvial channel changes can be due to two roughness. First, because the grain roughness, which in turn depends on size bed grain , and secondly, the roughness shape, which depends on the dimensions of the bedform and the depth of flow (Rouse, 1965; Morva et al., 2008; Kodoatie, 2009). As has been known that almost ninety percent of the total base flow resistance may be caused by a form of resistance, the influence of the roughness of this form should not be overlooked (Kazemipour & Apelt, 1983; Talebbydokhti, et al., 2006). Therefore, it can be concluded that the need for a method to predict the accurate dimensions of the bedform. Furthermore, the accurate prediction of dimensional bedform is very important to avoid potential problems in the building engineering water. Knowledge of basic geometric shapes also allows one to estimate the bed load of sediment transport in the continuity equation of elementary particles (Fredsϕe, 1982; Yang, 1996, Shimizu and Giri, 2007; Van Duin et al., 2013).

Development and verification of the results of research that has been done is still very necessary. This is because a lot of the flow behavior and form the bed channel or river that must be considered, such as due to iteration of water flow (turbulence), secondary currents, and bed roughness channel. In addition, also the influence of the side walls and shear stress is not evenly distributed in the cross section of the river which caused sedimentation and erosion that can change the shape of the riverbed. Besides the separation zone (separation zone) in the downstream and upstream on the basic geometric shapes that form the horizontal direction causes the vortex flow. Sediment will accumulate in the area of separation (separation zone). The greater the accumulated sediment causing the flow velocity in the front area of separation will increase. With increasing velocity causes scouring increases. Such behavior would lead to the longer scour bed channel. By paying attention to the flow behavior and form the basis of the channel is expected to be used as a reference in the engineering stream (Alice et al., 2013; van der Mark, 2009; Paarlberg, 2008).

The development of the bedforms continue to be made, especially with regard to the bed roughness channel or flow resistance coefficients, which are widely used in hydraulic engineering. Bed roughness covered are basic Manning roughness coefficient (n). This coefficient was first disclosed by Robert Manning (1891). Manning coefficient (n) is the roughness or friction is applied in a uniform open channel flow, which is used to calculate the average flow velocity (Bilgil, 2002; Bahramifar et al., 2012). Manning roughness forms the basis of the channel that will be developed in the form of a linear separation concept. The concept of separation of the flow on the flow resistance carried out by Bojurunas (1952). Bojurunas expressed linear separation of the Manning roughness coefficient into 2 (two) parts: first, bed grains channel resistance associated friction on the surface (skin friction) known as the grain roughness ($n'$), the basic flow resistance in relation to the existence of basic forms and amendments known as the roughness shape ($n''$). Furthermore Talebbydokhti, et al. (2006) who developed a comparative study roughness shape and roughness of granules in relation to the bedforms, roughness mutually agree on the assumption that the bedform is the decomposition of the total bed roughness of the bed due to grain roughness ($n'' = n - n'$). In relation to the roughness of the form (n ") approaches do not yet fully examined in detail from a theoretical standpoint, so it is necessary to develop the form of bottom friction is related to the basic configuration of the channel..

Therefore in this paper will be discussed on the modeling of bedforms the bed roughness associated with the channel in the flow regime under which led to changes in the basic shape of the channel. The purpose of this paper is the first to look for empirical relationship between the shape of the basic configuration and basic roughness coefficient; both develop models bedform of the channel by channel basis coefficients

## II. MATERIALS

### 2.1 Summation of the Resistance at Various Elements Roughness

Roughness equivalent on the bed of the movement caused by waves of sand or vegetation. Equivalent roughness can be attributed to two factors: (1) the surface resistance of resistance generated by the boundary surface and depending on the depth of the flow relative to the size of the element surface roughness along the boundary; and (2) the resistance form (form drag) caused by waves of sand or plants which regulate the circulation of eddy currents in the secondary. In Figure (1) shows the the bed of two-dimensional bedform, where λ = wavelength of sand; Δ = high basic form; h = depth of flow; λ"= length of the separation zone behind the sand waves; and λ'= long dominated by friction grains. In the long λ", turbulent energy is mainly transmitted by large eddies in the lee surface of the sand waves. Loss of energy in the long λ' this caused by small eddies behind the base load particles. Thus, the total the bed of roughness Manning during sand waves can be expressed as Equation (1)

$$n = n' + n'' \quad \text{......................................................................(1)}$$

Where $n'$ 'is the resistance due to friction surfaces (skin friction) or the roughness of granules, and $n''$ ' 'is the resistance that is due to bedform drag (form drag) or roughness bedform.

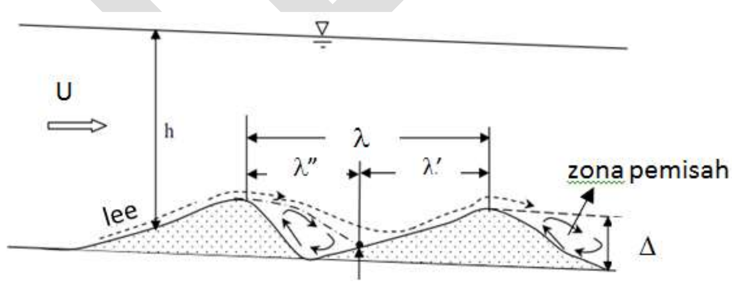


Figure 1 Sketch of two-dimensional bedform (Yang & Tan , 2008 ; Karim , 1999)

- **Resistance due to friction Granular.**

Resistance due to friction surfaces (skin friction), formulation expressed in Equation (2)

$$\frac{n'}{R^{1/6}}\sqrt{g} = \frac{\sqrt{\tau_0'/\rho}}{U} = \frac{u_*'}{U} \quad \text{......................................................(2)}$$

Keulegan (1938) shows a theoretical the bed of for the channel in the plane parallel to the wall with a limited extend to the roughness of the particles. Englund and Hansen (1967) stated Eq (1) in the form of Equation (3)

$$\frac{U}{u_*'} = \frac{1}{\kappa}\ln\left(11\frac{R'}{k_s}\right) = \frac{1}{\kappa}\ln\left(11\frac{0{,}368R'}{z_0}\right) = \frac{U}{u_*'} = 6{,}0 + 5{,}75\log\left(\frac{R'}{k_s}\right) \ldots\ldots\ldots\ldots(3)$$

Results of research Sheng-fa et al. (2011) shows the relationship between $R'$ 'and $R$ in the form of Equation (4)

$$R' = 0{,}6434R + 0{,}0012 \ldots\ldots\ldots\ldots(4)$$

With mensubtitusikan Equation (3) depth of Equation (2), it will obtain the relationship between the $n'$ and $u'$ which is expressed in bedform Equation (5)

$$n' = \frac{R^{1/6}}{\left[6{,}0+5{,}75\log\left(\frac{h'}{k_s}\right)\right]\sqrt{g}} \ldots\ldots\ldots\ldots(5)$$

**• Resistance Granular Due to Bedform**

Resistance bedform can be approximated by the equation (6).

$$\frac{n''}{R^{1/6}}\sqrt{g} = \frac{\sqrt{\tau_0''/\rho}}{U} = \frac{u_*''}{U} \ldots\ldots\ldots\ldots(6)$$

The application of the force parallel to the bed of that produces balance equation developed by Engelund and Fredsϕe (1976), Bridge and Dominic (1984), and Griffiths (1989), which was developed on the bed of Manning coefficient equation with the basic shape (Wibowo, 2015) obtained equation (7) on the bed of Manning coefficient equation with the bedforms obtained by Equation (7).

$$n'' = \frac{k_f\,\tau_*''\left(\frac{1}{\kappa}\ln\left(\frac{R'}{k_s}\right)\right)^2 n'^2}{2g\lambda d\,(S_r-1)(\cos\alpha\tan\emptyset-\sin\alpha)} \ldots\ldots\ldots\ldots(7)$$

Where $\tau_*''$ is the shear stress relative due to the basic form ($\tau_*'' = \tau_* - \tau_*'$ ), $\tau_* = hS/(\rho_s - \rho)d_s$ , $\tau_*' = \frac{\tau_*''n'}{n''}$', ks is the equivalent roughness $d_{50}$ and $k_3$ is the correction factor (0.20 to 0.90), tan$\emptyset$ is dynamic friction coefficient and α is the angle of the bed channel.

**Table 1.** Value Factor Correction on Alluvial Material (Corey, 1956)

| Number | Shape material | Shape Factor |
|---|---|---|
| **1** | □ | 0,20 – 0,39 |
| **2** | o | 0,40 – 0,59 |
| **3** | ● | 0,60 – 0,79 |
| **4** | ▪ | 0,80 – 0,99 |
| **5** | Δ | 1,00 |

**Table 2.** Angle Angle pupose ($\emptyset$) on Non Cohesive Soil (Piere, 2010)

| Number | Class name | ϕ (deg) |
|---|---|---|
| **1** | Sand Very Coarse | 32 |
| **2** | Sand Coarse | 31 |
| **3** | Sand medium | 30 |
| **4** | Sand Fine | 30 |
| **5** | Sand Very Fine | 30 |

**• Effect of Sidewall**

Problems in separating the shear stress and the side walls are important in almost all studies on open channel flow. Shear stress distribution on a cross-boundary around wet in open channels are known depending on the shape of the cross section. The importance of understanding the limits of shear stress distribution is shown by the use of local limit or the average shear stress, which has been widely used in the hydraulic equations regarding the problem of resistance to the flow and sediment transport. Thus the need for corrections in the sidewalls that are often required in laboratory flume studies on the velocity profile, bedform the basic configuration and sediment transport. By performing this wall shear stress correction will evaluate the hydraulic roughness due to some irregularities bedform the bed of configuration of the channel. Roughness coefficient because of their sidewalls, expressed in bedform Equation (8).

$$n_w = \frac{R^{1/6}}{\sqrt{g}}\left(\frac{u_{*w}}{\bar{U}}\right) \quad \text{and } u_{*w} = \sqrt{\tau_w/\rho} \quad \text{......(8)}$$

- **Equation of Average Bed and Sidewall Shear Stress**

Shear stress bed ($\overline{\tau_b}$) and sidewalls average $\overline{\tau_w}$ can be formulated to implement using the overall balance of force in the direction of flow (Guo & Pierre, 2005). As defined in Equation (9)

$$2h\overline{\tau_w} + b\overline{\tau_b} = \rho g S A_b = \rho g S\, bh \quad \text{......(9)}$$

where the amount of shear stress bed ($\overline{\tau_b}$) by formulated by Javid & Mohammadi (2013) as Equation (10a) and (10b)

$$\frac{\overline{\tau_b}}{\rho g H S} = \exp\left(-0{,}57\frac{h}{b}\right) - 0{,}33\frac{h}{b}exp\left(-0{,}57\frac{h}{b}\left(4{,}25 + 3{,}04\ln\left(\frac{h}{b}\right)\right)\right) \quad \text{......(10a)}$$

$$\frac{\overline{\tau_w}}{\rho g H S} = 0{,}5\frac{b}{h}\left(1 - \frac{\overline{\tau_b}}{\rho g H S}\right) \quad \text{......(10b)}$$

- **Area of the cross section Channels**

Keulegan (1938) suggested that the bisectors of the internal angles of the polygonal channels can be used as a dividing line to illustrate the extent of the the bed of and side wall area. as Equation (11).

$$A = A_b + A_w \quad \text{......(11)}$$

The drainage area of the bed ($A_b$) formulated by Javid & Mohammadi (2013) as Equation (12a) and drainage area of the side wall ($A_w$) in Equation (12b)

$$A_b = 2\int_0^h y\,dz = 1{,}7544b^2[1 - \exp(-0{,}57\ h/b)] \quad \text{......(12a)}$$

$$A_w = bh - A_b; \quad A_w = bh - \int_0^h y\,dz = 1{,}7544b^2[1 - \exp(-0{,}57\ h/b)] \quad \text{......(12b)}$$

**2.2 Dimensional Analysis on Bed Configuration Channels**

Influencing parameters in this study from Simon and Richadson (1966) were as Equation (13)

Bed configuration = f (U, h, b, S, ρ, μ, g, ds, ρs, σ) ...... (13)

Bed configuration parameters (Δ) or higher is a basic form of parameter to be searched. By describing Equation (14) in the analysis of the dimensions of the obtained equation (14)

$$\frac{\Delta}{h} = f_2\left(\frac{\rho_s}{\rho},\ {}^{\nu}/_{Uh},\ b/h,\ gh/U^2,\ \frac{h}{ds}, \sigma, S\right) \quad \text{......(14)}$$

Where Δ / h is relatively high mound, h = depth of flow, $d_s$ = roughness of granules, ν /Uh = inverse of the Reynolds number, S is the slope; ν = kinematic viscosity of the fluid, ρ = density of the fluid mass, ρs = mass density of granules, and g = acceleration due to gravity, $d_s$ / h is the relative roughness and ρs / ρw = $G_s$ is a density value of sediment to water.

**2.3 Dimensional Analysis on Bed Roughness.**

A phenomenon characteristic parameters of consideration on the issue on the basis of channel roughness in the variables stated in (τ, h, d_s, ρ, ρs, G, U, and ν). By using dimensional analysis will be obtained Equation (15)

$$\frac{n''}{n'} = \phi_1\left(\frac{u_*.d_s}{\upsilon}, \tau_*, \frac{h}{d_s}, F_r\right) \quad \text{......(15)}$$

where $\phi_1$ = function unspecified / unknown, because the fully developed turbulent flow conditions are assumed, the effect of viscosity can be neglected and the reduction in Equation (16) into Equation (16)

$$\frac{n''}{n'} = \phi_2\left(\tau_*, \frac{h}{d_s}, F_r\right) \quad \text{......(16)}$$

When the flow is sub critical, Fr = 1 can also be ignored (Yalin, 1977). The equation would be Equation (17).

$$n'' = n'\left(1 + \frac{\tau_*''}{\tau_*'}\right) = n'\left(1 + \phi_2\left(\tau_*, \frac{h}{d_s}, F_r\right)\right) \quad \text{......(17)}$$

**2.4 Performance Model**

Performance models used to measure the accuracy of the model. In this paper, the performance of the model is used to determine the degree of correspondence between the actual data with the results of forecasting used measure of correlation coefficient, with the formula in Equation (18).

$$R = \frac{\sum xy}{\sqrt{\sum x \sum y}} \quad \text{.....(18)}$$

Where $x = X - \bar{X}$, X is the actual discharge, $\bar{X}$ is the average value of X, $y = Y - \bar{Y}$, Y is a debit or a simulation result of forecasting, $\bar{Y}$, is the average value of the Y value of correlation can be seen in **Table 3.**

**Table 3 Value Correlation Coefficient**

| Correlation Coefficient (R) | interpretation |
|---|---|
| 0 | There is no linear relationship |
| 0 < R ≤ 0,25 | very weak correlation |
| 0,25 < R ≤ 0,5 | correlation enough |
| 0,50 < R ≤ 0,75 | strong correlation |
| 0,75 < R ≤ 0,99 | very strong correlation |
| 1 | perfect correlation |

Cource : Soewarno, 1995

The median square error (mean square error, MSE). MSE is a measure of the accuracy of the model by squaring the error for each point of data in a data set and then obtain the average or median value of the sum of the squares. The formulation of MSE as Equation (19)

$$MSE = \frac{\sum_{i=1}^{N}(y_i - \hat{y}_i)^2}{N} = \frac{\sum_{i=1}^{N} e_i^2}{N} \quad \text{.....(19)}$$

where $y_i$ is the actual value of data, $(\hat{y}_i)$ is the value of the results of forecasting, N is the number of data observations, and $e_i$ is per-point error data. Then used a common procedure error calculating per-point data, which for the time series followed formulation is: data = pattern + errors for easy, error (error) is written with an e, the data with the data pattern of X and X. In addition, the *subscript i* (i = 1,2,3, ..., n) are included to show the data point to-i, so written $e_i = X_i - \bar{X}$ If you just want to know the magnitude of the error regardless of the direction it is called absolute error or $e_i = X_i - \bar{X}$ Another criterion is the accuracy of the model or Nash Sutcliffe Model Efficiency Coefficient (NSE) by Nash and Sutcliffe (1970). Nash gives a good indication for matching of 1: 1 between simulations and observations. Formulation of Nash as Equation (20).

$$NSE = 1 - \left[\frac{(Q_{obs} - Q_{sim})^2}{(Q_{obs} - \bar{Q}_{obs})^2}\right] \quad \text{.....(20)}$$

Where $Q_{obs}$ are observational data, $\bar{Q}_{obs}$ is the average from observational data and $Q_{sim}$ is the value of the simulation results. NSE value criteria can be seen in Table (4).

**Table 4 Criteria Value Efficiency Model Nash Sutcliffe Coefficient (NSE).**

| **Nilai *Nash Sutcliffe Model Efficiency Coefficient* (NSE).** | **Interpretasi** |
|---|---|
| **NSE > 0,75** | good |
| **0,36 <NSE ≤ 0,75** | satisfy |
| **NSE ≤ 0,36** | Not satisfy |

*Source : Motovilov et al., 1999.*

Normal distribution calculation performed to perhitung prediction accuracy using the average normal faults (MNE), namely:

$$MNE = \frac{100}{N}\sum_{i=1}^{N}\frac{|X_{ci} - X_{mi}|}{X_{mi}}, \quad \text{.....(21)}$$

## III METHODS

### 3. 1 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 maxsimum grain diameter of 0,25 mm to 0,5 mm. Picture design can be found at Fig.2

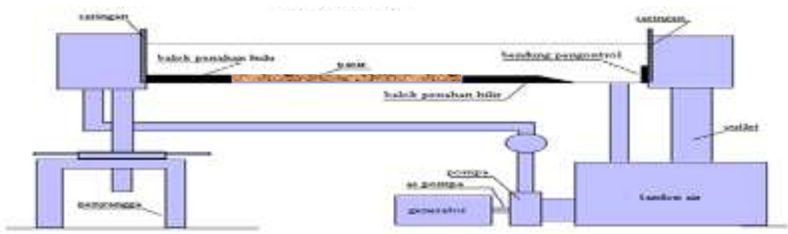

Figura 2. Flume Conditions along with Additional Equipment used

### 3.2 Experiment Data.

The data will be used by the laboratory results of several researchers and the results of its own research, the data include:

1. Data experimental Wang and White (1993)
2. The result of experiments Guy et al. (1966)
3. Research data Sisingih (2000).
4. The result of the experiment Wibowo (2015).

Collection of data from the above study are shown in Table 5.

**Table 5**. Results of Research Data

| Slope (S) | Discharge (Q) $M^3$/second | Ratio (b/h) | Velocity(V) m/detik | Reynolds Numbers (Re) | Froude Numbers (Fr) | Fricative (τ) | Roughness coefficient (n) |
|---|---|---|---|---|---|---|---|
| 0,00015-0,0101 | 0,028 – 0,643 | 2,247-42,105 | 0,212-1,898 | 2,157-98,753 | 0,089-1,714 | 0,0015-1,734 | 0,010-0,040 |
| 0,006-0,0100 | 0,003-0,008 | 3,587-9,524 | 0,132-0,411 | 14,446-50,29 | 0,152-0,324 | 0,291-0,842 | 0,011-0,026 |
| 0,007-0,013 | 0,003-0,006 | 0,667-1,000 | 0,214-0,429 | 0,003-29,211 | 0,194-0,353 | 0,727-1,982 | 0,012-0,042 |
| 0,00001-0,00305 | 0,024-0,410 | 3,288-19,335 | 0,105-1,318 | 4,35-11,42 | 0,073-1,049 | 0,021-4,685 | 0,015-0,028 |

## IV. RESULTS AND DISCUSSION

### 4.1 Decline Geometry Empirical Formula based on Bedform.

**a. Geometry Bedform**

The high bedform (H or Δ) is defined as the vertical distance from crest to trough of the basic form. Long basic form (L or λ) is the horizontal distance between the trough to trough forms the basis of the adjacent bedform (Simons et al., 1965a; Lin, 2011). At the bed of the sand waves, ks " will be associated with the geometry of the bedform. Yalin (1972), assumes the functions related as Equation (22) and Figure (3).

$$k_s'' = f(\Delta, \frac{\Delta}{\lambda}) \qquad (22)$$

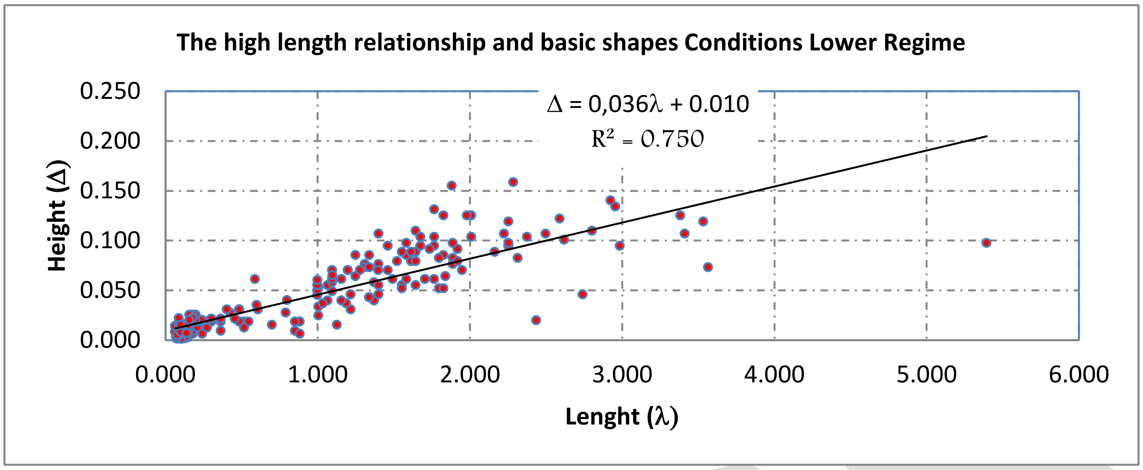


Figure 4. Height and Length Relationship condition Configuration Lower Regime

**b. Relatively Height Dunes** ***(Δ /h)***

Dimensional shape analysis as in Equation (23).

$$\frac{\Delta}{h} = f\ (\text{Re, Fr}, \frac{b}{h}\ \frac{h}{ds}, \sigma, S) \quad (23)$$

Results of analysis of the dimensions of Equation (23) will result in the empirical formula as Equation (24)

$$\frac{\Delta}{h} = 0{,}8768\ \text{Fr} - 0{,}0734\ \ (R^2 = 0{,}453) \quad (24)$$

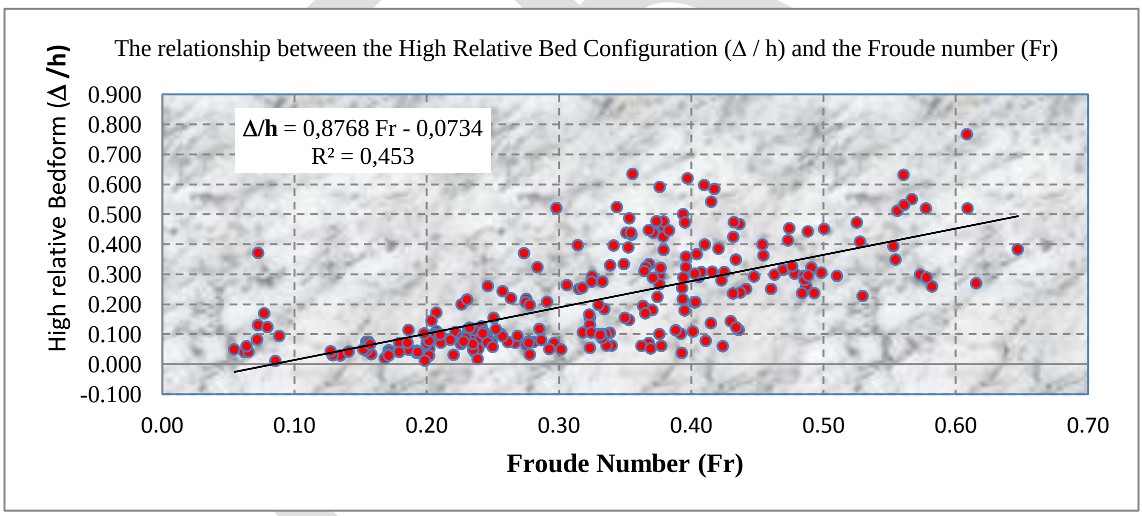


Figure 4. Relatively High relations Bed Configuration and the Froude number

Similarly, on the other parameters, as the following table:

Table 6 Bedform Relationship between Relative (Δ / h) and the Independent Variable

| No | Model | $R^2$ | MNE | MSE | NSE |
|---|---|---|---|---|---|
| 1 | $\frac{\Delta}{h} = = 1{,}155\ (F_r)^{1{,}77}$ | 0,496 | 78,836 | 0,788 | 0,471 |
| 2. | $\frac{\Delta}{h} =$ -0,105 -1.1E-05$\left(\frac{h}{d_s}\right)$+0,972 Fr | 0,474 | 62,398 | 0,049 | 0,913 |
| 3. | $\frac{\Delta}{h} =$ 0,094-4,592 S +0,952 Fr | 0,477 | 63,621 | 0,049 | 0,895 |

| | | | | | |
|---|---|---|---|---|---|
| **4.** | $\frac{\Delta}{h} = -0{,}162 + 1{,}007\mathrm{F}_r + 0{,}0185\sigma$ | 0,474 | 80,827 | 0,068 | 0,475 |
| **5.** | $\frac{\Delta}{h} = -0{,}149 + 0{,}909\mathrm{F}_r + 0{,}007\frac{b}{h}$ | 0,509 | 60,415 | 0,047 | 0,814 |
| **6.** | $\frac{\Delta}{h} = -0{,}074 + 0{,}909\mathrm{F}_r - 0{,}029\,\tau_*$ | 0,502 | 64,204 | 0,050 | 0,958 |

Based on the results in Table (6) shows the relationship between height sand dune relation to variables that affect the formation and development forms the basic configuration consisting of sediment diameter ($d_{50}$), sediment distribution (σ), the density of the sediment (ρs), flow depth (h) , the flow velocity (V), the density of water (ρw), the viscosity of water (which includes water temperature) μ, the slope of energy, (Sw), and the acceleration of the earth (g). Obtained good form at high relationship basic shapes and Froude number and depth-width ratio, which shows a strong correlation (R2> 0.50) or in other words that the accuracy of the linear regression model between observations with the forecast of 0,509. Average normal fault (MNE) amounted to 60.415% indicates that the value has a model fit proportion of 60.41% (satisfactory). With a margin of error (MSE) of 0.047 means that the smaller the error rate, the better the model created. Value Efficiency Model Nash Sutcliffe Coefficient (NSE) of 0.814 indicates a very good interpretation of the model (NSE> 0.75).

**c. Relative dunes length (λ / h).**

Comparison of the relative wavelength (λ / h) typically found on dunes in the range of 4 to 7 (Yalin,, 1977; Van Rijn, 1984; Karim, 1999). In the study, the ratio (λ / h) acquired approximately 0.423 to 3.585 (the ripples) and 3.269 to 10.9 (the dunes). Application of empirical formula would be made to establish a relationship between the length of the basic shape relative geometry and other parameters, as shown between (λ / h) as the dependent variable and (h / d_50), (F_r) and S as the independent variable. As Table (7).

Table 7 Bedform Relationship between Relative (λ / h) and independent variables

| No | Model | $R^2$ | MNE | MSE | NSE |
|---|---|---|---|---|---|
| 1 | $\frac{\lambda}{h} = 22{,}837F_r + 3{,}42156$ | 0,578 | 91,650 | 4,850 | 0,838 |
| 2. | $\frac{\lambda}{h}$=-3,145$-0{,}00025\frac{h}{d_s} + 22{,}674\,F_r$ | 0,575 | 90.421 | 4,859 | 0,576 |
| 3. | $\frac{\lambda}{h}$=-2,674$-148{,}654S + 21{,}969\,F_r$ | 0,455 | 91,164 | 4,748 | 0,589 |
| 4. | $\frac{\lambda}{h}$=-3,878+23,122 $F_r$+0,187 □ | 0,571 | 92,171 | 4,940 | 0,834 |
| 5. | $\frac{\lambda}{h}$ = -4,071+21,440 $F_r$+0,139$\frac{b}{h}$ | 0,605 | 86,158 | 4,567 | 0,846 |
| 6. | $\frac{\lambda}{h}$ = -2,00745+20,506 $F_r$- 0,991$\tau_*$ | 0,652 | 82,335 | 4,014 | 0,865 |

Based on the results in Table (7), which is best demonstrated relationship between the wavelength of the basic shape and the Froude number and sliding. Namely

$$\frac{\lambda}{h} = -2{,}00745+20{,}506\,F_r - 0{,}991\tau_* \qquad (R^2 = 0{,}652)$$

**4.2 Empirical formula based decrease in Roughness Effect Shape**

Manning equation has been used extensively by most hydraulic engineer for different purposes. We have used the Manning coefficient, n, as a basis for comparison between forms of roughness (n ") and the amount of roughness (n). By using Equation (5), (7) and (17), it can show the relationship basic roughness and (Δ/h) Based on data from the study, forms the basic roughness (n '/ n') and (Δ/h) obtained by as a linear regression equation (25).

$$n''/n' = 18{,}198(\Delta/h) + 0{,}426 \quad \text{.............................................}(25)$$

or

$$n'' = n'\,(18{,}198(\Delta/h) + 0{,}426\ ) \text{ with } n' = \frac{R^{1/6}}{\left[6{,}0+5{,}75\log\left(\frac{h'}{k_S}\right)\right]\sqrt{g}}$$

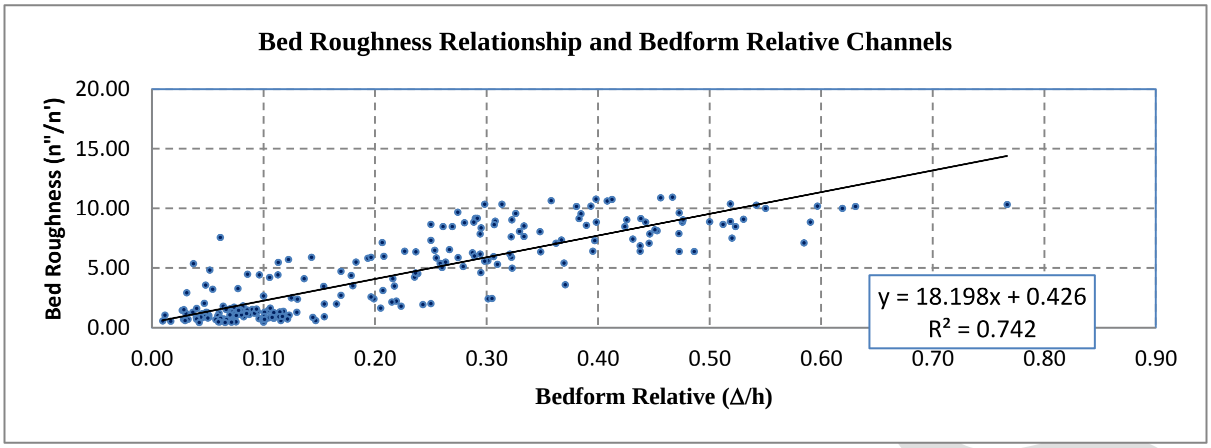


**Figure 5. Height Relations Bedform and Bed Roughness Relative**

The correlation coefficient (R2) of 0.742 (R2> 0.50) showed a strong correlation, or in other words that the accuracy of the linear regression model between observations with the forecast of 0.742. Average normal fault (MNE) amounted to 60.817% indicates that the value has a model fit proportion of 60.817% (satisfactory). With a margin of error (MSE) of 2.965% means it is still within the error tolerance level (<5%). Value Efficiency Model Nash Sutcliffe Coefficient (NSE) of 0.742 indicates a satisfactory interpretation of the model (NSE <0.75).

Form the basis of the relative roughness by converting the basic shape relative value as Equation (26)

$$n"/n' = 0{,}0054(b/h) + 0{,}397(\tau^*) - 0{,}0176 \quad \text{with } R^2 = 0{,}761 \text{ ..............(26)}$$

**4.3 Applications in Flow.**

Discharge or magnitude of the flow of the river / canal is flowing through the volume flow through a river cross section / channel per unit time (Chow, 1959; Soewarno, 1995; Wibowo, 2013). The total discharge and all average speeds in excess can be calculated using Equation (27).

$$Q = V_b A_b + V_w A_w \text{ ..................(27)}$$

$$V = \frac{1}{n} R^{2/3} \sqrt{S} \text{ ..................(28)}$$

Then obtained a relationship with simulation and discharge in flume as in Figure (6).

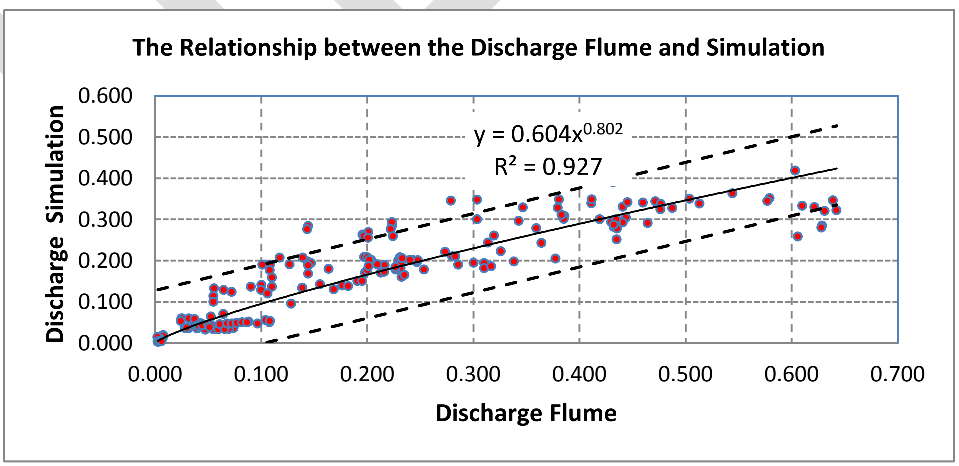


**Figure 6 The Relationship between the Discharge Flume and**

**V. CONCLUSION**

Based on the results of the above description, the is taken conclusions as follows

- Effect of resistance form can not be ignored $n"/n'$ = -17,316 $n$ + 0,6807, meaning that large more and more roughness value relative basis, the value of the Manning roughness coefficient (n) small more and more thus obtained a large flow rate.
- There is a relationship between koefsien high roughness and geometry form the basis of a relative basis ( $n"/n' = 18{,}198(\Delta/h)$+ 0,426).
- Combinations of dimensions and regression analysis gives satisfactory results in the error rate and suitability models from the right formula for the ratio (Δ/h).
- Equation (25) gives us a simple relationship for calculating the roughness forms the basis of the low flow regime (lower flow regime) are useful in the process of trial and error.
- The relative influence of shear stress and depth-width ratio is more dominant in Ratios (Δ/h) than others. This is caused by the sliding on the base will affect the basic shapes that occur as well as the influence of the sidewall to the width of a small flume.
- existing methods provide the difference in approach to the prediction dimension mound.

**ACKNOWLEDGMENTS**

Experimental work carried out in the Central Solo River, Indonesia. The author would like to thank the Balai of Solo River in Central Java province, which has been providing information and data - the data to support this research and The author would like to acknowledge the assistance of Suripin, Robert Kodoatie, Isdiyana, Kirno and Family in conducting experiments too. Special thanks to Hanif ,Uray Nurhayati , Ajeng and Amira for their help during the work.

**REFERENCES.**

1. Simons, D.B., and Richardson, E.V., 1966. " Resistance to Flow in Alluvial Channels". *U.S. Geol.Survey Prof. Paper 422-J61p.*
2. Simons, D.B. and Senturk, F., 1992. " Sediment Transport Technology – Water and Sediment Dynamics ", *Water Resources Publications*, Littleton, Colorado.
3. Talebbeydokhti, N., Hekmatzadeh, A.A., and Rakhshandehroo, G. R., 2006." Experimental Modeling of Dune Bedform in A Sand Bed Channels ", Iranian Journal of Science & Technology, Volume 30, Number B4, pp 503-516 .
4. Garde, R.J., 2006. " River Morphology *", New Age International (P) Ltd., Publishers,* New Delhi, ISBN (13) : 978-81-224-2841-4.
5. Yang, S.Q., and Tan, S.K., 2008. " Flow Resistance over Mobile Bed in an Open-Channel Flow ",*Journal of Hydraulic Engineering, ASCE*, Vol. 134,No. 7,pp. 937-947.
6. Bilgil, A and Altun, H., 2008. " Investigation of Flow Resistance in Smooth Open Channels using Artificial Neural Networks". Flow Meas Instrum 19:404–408.
7. Bose and Dey, S., 2012. " Instability Theory of Sand Ripples Formed by Turbulent Shear Flows ".*Journal of Hydraulic Engineering*, Vol. 138, No. 8, August 1, 2012. ASCE, ISSN 0733-9429/2012/8-752–756.
8. Greco, M., Mirauda., D., and Plantamura, V. A., 2014." Manning's Roughness Through the Entropy Parameter for Steady Open Channel Flows In Low Submergence" 2th International Conference on Computing and Control for the Water Industry, CCWI2013, ScienceDirect. Procedia Engineering 70 .pp773 –780.
9. Mirauda., D., and Greco, M. 2014. " Assessment of Rating Curve Through Entropy-Based Manning's Equation **",** Latest Trends in Energy, Environment and Development, ISBN: 978-960-474-375-9,Pp. 141-147.
10. Wibowo, H., 2015. " Manning Roughness Coefficient Study on Bed Materials Non-Cohesive with Parameters Using Entropy to Open Channel Flow", *Proceedings of International Conference : Issues, Management And Engineering In The Sustainable Development On Delta Areas Semarang, Indonesia – February 20th, 2015 Paper No. XXX (The number assigned by the OpenConf System).*
11. Wibowo, H., Suripin, Kodoatie, R., and Isdiyana., 2015." Comparing the Calculation Method of the Manning Roughness Coefficient in Open Channels". *Proceedings of International Conference*,The 1st Young Scientist International Conference of Water Resources Development and Environmental Protection, Malang, Indonesia.
12. Simons, D.B, and Richardson. E.V., 1961. " Forms of Bed Roughness In Alluvial Channels ", *Proc. ASCE,87 (HY3)*, p.87-105.
13. Lewis, D.W., 1984. " Practical Sedimentology ". *Hutchinson Ross, Stroudsburg, 229p*
14. Rouse, H., 1965. ''Critical Analysis of Open-Channel Resistance.*'' J. Hydraul. Div., Am. Soc. Civ. Eng.,91(HY4), 1–25.*

15. Morvan, H., D. Knight, N. Wright, X. Tang, and A. Crossley., 2008. " The concept of Roughness In Fluvial hydraulics and Its Formulation in 1D, 2D and 3D numerical simulation models", *Journal of Hydraulic Research*, 46 (2), pp.191-208.
16. Kodoatie, R. J., 2009. " Hidrolika Terapan, Aliran pada Saluran Terbuka dan Pipa*". Edisi Revisi Cetakan ke IV, Penerbit. C.V Andi Offset,* Yogyakarta.
17. Holmes, R. R., 2003. " **Flow Field Over Bedforms In the Lower Missouri River ",** *In Seventh Annual Missouri River Natural Resources Conference, Atchison,* Kansas.
18. Mark. V.D., 2009." A Semi-Analytical Model For Form Drag Of River Bedforms*",* "*Dissertasion of Universiteit Delft, Edited by Gildeprint Drukkerijen, The* Netherlands.
19. Alice Lefebvre, Andries J. Paarlberg, and Christian Winter., 2013. "Flow separation in the lee of bedforms: a numerical study on the influence of bedform height and length ",7 th International Conference on Coastal Dynamics, Bordeaux University-SHOM,France
20. Kazemipour, A. K. & Apelt, C. J. (1983). Effects of irregularity of form on energy losses in open channel flow. Australian Civil Eng. Transactions, I.E. Aust., CE25, 294-299.
21. Yang, C.T., 1996, " *Sediment Transport Theory And Practice ",* The McGraw-Hill Companies, Inc., New York.
22. Giri, S., and Y. Shimizu., 2006." Computation Of Flow, Turbulence And Bed Evolution With Sand Waves ", Annual Journal of Hydraulic Engineering, JSCE, 50, 169-174.
23. Giri, S. and Y. Shimizu., 2006. " Numerical Computation of Sand Dune Migration With Free Surface Flow. *Water Resources Research*, 42 (W10422), doi:10.1029/2005WR004588.
24. Duin, O. J.M.V, Ribberink, J.S., Dohmen-Janssen C.M., and Hulscher, S.J.M.H., 2013. " Modelling Sediment Pick-p And Deposition In a Dune Model ",*Marine and River Dune Dynamics – MARID IV – 15 & 16 April 2013 - Bruges,* BelgiumAlicw
25. Paarlberg, A.J., Dohmen-Janssen, C.M., Hulscher, S.J.M.H., and Termes, P., 2009. "Modeling River Dune Evolution Using A Parameterization Of Flow Separation ", *Journal of Geophysical Research 114,* F01014.
26. Bilgil, A., 2003. "Effect of Wall Shear Stress Distribution on Manning Coefficient of Smooth Open Rectangular Channel Flows ",Turkish J. Eng. Env. Sci.27 , pp. 305 – 313
27. Bahramifar, A, Shirkhanib,R., and Moham madic, M., 2013. " An ANFIS-based Approach for Predicting the Manning Roughness Coefficient in Alluvial Channels at the Bank-full Stage ",IJE Transactions B: Applications Vol. 26, No. 2, pp.177-186.
28. Keulegan, G. H., 1938. " Laws of Turbulent flow in Open-Channels." Natl. Bur. Stand. Circ. (U.S.), 21, 709–741.
29. Einstein, H A., and Barbarossa, 1952. " River Channels Rougness ." *Trans. ASCE, 117, pp.1121-1132*.
30. Englund, F. and E. Hansen, 1967, " Investigation of Flow in Alluvial Stream", *Bulletin, No. 9, Hyd.Laboratory,Technical university of Denmark*.
31. Motovilov, Y.G., Gottschalk, L., Engeland, K. & Rodhe, A. 1999. Validation of a Distributed Hydrological Model Against Spatial Observations. Elsevier Agricultural and Forest Meteorology. 98, pp. 257-277.
32. Soewarno, 1995. " Hidrologi Aplikasi Metode Statistik untuk Analisa Data, Jilid 1 dan 2 " , Penerbit Nova Bandung.
33. Engelund, F., and Freds0e, J. (1976). "A sediment transport model for straight alluvial channels." *Nordic Hydr.*, Denmark, 7, 293-306.
34. Bridge, J. S., and Dominic, D. F. (1984). "Bedload Grain Velocities and Sediment Transport Rates." *Water Resour. Res.*, 20(4), 476-490.
35. Griffiths., G. A., 1989. " Form Resistance In Gravel Channels With Mobile beds ".*Journal of Hydraulic Engineering,* Vol. 115, No. 3,© ASCE. Paper No. 23245.pp 340-355.
36. Guo, J. and Julien, P.Y., 2005. "Shear Stress in Smooth Rectangular Open-Channel Flows", *Journal of Hydraulic Engineering, ASCE,* Vol. 131 , No. 1,pp. 30–37.
37. Julien, P. Y. 2010. " *Erosion and Sedimentation, 2nd Edition* ". Published in the United States of America by Cambridge University Press, New York
38. Karim, F., 1999. " Bedform Geometry In Sand-Bed Flows ", *Journal of Hydraulic Engineering*, 125 (12), pp. 1253-1261.
39. Javid, S., and Mohammadi, M., 2012. " International Journal of Engineering, Transactions B. Vol. 25 no 4, 323-331.
40. Wibowo, H., 2013." Geometic Mathematics Model Of River to Base Flow Discharge", Jurnal Eco Rekayasa.Vol.9.No.2. Halaman: 186-194 Universitas Muhammadiyah Solo.
41. Wibowo, H.2013." Analisa Perubahan Geometri Penampang Sungai Menggunakan HEC-6 untuk Menaksir Debit Sedimen pada Sungai Citanduy di Jawa Barat ", Jurnal Media Komunikasi Teknik Sipil.Volume 19, No 2, Halaman 191-197. Universitas Diponegoro Semarang