Development of Sediment Transport Equations for Selected Rivers in Malaysia

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ABSTRACT

Sediment transport in rivers involves complex interaction between numerous inter-related variables. Empirical methods explain only on a certain number of parameters that are considered to be relevant by the developers. Multiple linear regression technique has been used to predict sediment transport equations. This paper aims to discuss the development of sediment transport equations for selected rivers in Malaysia. The four rivers that were observed for their hydraulics and sediment discharges are Pari River, Riai River in Perak, Kerayong River in Kuala Lumpur and Kulim River in Kedah. From analysis, two equations gave satisfactory performance with R^2 values close to 1. Thus, the developed equations can be used as a basis for design and analysis. Further improvement on the derived equations requires a larger data set. Degree of accuracy of the derived equations was measured using the discrepancy ratio and this is the ratio of the predicted values to the measured values.

Keywords: Sediment transport, multiple linear regression, discrepancy ratio

1 Introduction

Regression techniques have been used widely to estimate sediment discharge in rivers. Laursen (1958) proposed a relationship that give both quantity and quality of total, suspended and bed loads as functions of stream and sediment characteristics. Colby (1965) developed graphical solutions for total load based on laboratory and field data. Chang *et al* (1965) computed the load as the sum of bed load and suspended load. Shen and Hung (1972) derived a regression equation based on laboratory data for the sand-sized particles. Using the same concept, Ackers and White (1973) defined his sediment transport functions in terms of three dimensionless groups namely, size, mobility and transport rate of sediments. His functions are based on flume data carried out with uniform or near uniform sediments with flow depths up to 0.4 meters. Brownlie (1982) succeeded in obtaining an improved solution of the one-dimensional equation of Shen and Hung (1972). Karim and Kennedy (1990) derived a relation between flow velocity, sediment discharge, bed-form geometry and friction factor of alluvial rivers using the nonlinear form of the multiple linear regression model. Their analysis were based on both river and flume data. Yang (1996) derived his sediment concentration functions using multiple linear regression analysis of laboratory data, based on his unit stream power theory. He presented a formula to estimate total bed-material load in a sediment-laden river with high concentrations of fine materials. Molinas and Wu (2001) developed his sediment transport equation based on universal stream power derived from the energy concept that has the advantage of eliminating the energy slope as a parameter. In Malaysia, research in sediment transport has been done by JICA (1995), Ab Ghani *et al* (1996), Abu Hasan (1998), Yahaya (1999) and Ariffin *et al* (2001).

This paper discusses the development of total sediment load equations for 108 observed data obtained from four rivers in Malaysia namely Pari River, Riai River in Perak, Kerayong River in Kuala Lumpur and Kulim River in Kedah.

2 The Data

A total of 108 observations were obtained from the four rivers namely, Pari River, Riai River, Kerayong River and Kulim River. The summary for the river data is given in Table 1.

Here B is the river width in m, Q is the flow discharge in m^3/s, V is the average flow velocity m/s, Y_0 is the flow depth in m, S_0 is the energy slope and d_{50} is the sediment diameter in mm where 50% of bed material is finer.

3 The Model

The variables used in modeling are (i) transportation parameters such as ϕ, the transport parameter and C_v, the volumetric concentration of sediment (ppm) (ii) mobility parameters such as $V/\sqrt{g(S_s-1)d_{50}}$, where V is the average flow velocity, g is the acceleration due to gravity, S_S is the specific gravity of sediment, d_{50} is the sediment diameter where 50% of bed material is finer (iii) sediment parameters such as D_{gr}, the dimensionless grain size (iv)flow parameter such as ψ and (v) hydraulic parameters such as R/d_{50},the relative roughness on the bed, B/y_0,the stream width ratio and U_*/W_s, the ratio of shear velocity and fall velocity. The dependent variable for the model is $V/\sqrt{g(S_s-1)d_{50}}$ .Two sets of models were obtained depending on the width and depth of the river. The first set contains 58 data while the second set contains 50 data.

Table 1 Summary of the river data.

River	No. of Data	B (m)	Q (m^3/s)	V (m/s)	Y_0 (m)	S_0	d_{50} (mm)
Pari	24	15.5 – 18.0	4.341 – 24.346	0.461 – 1.079	0.52 – 1.30	0.00125	1.80 – 3.10
Kinta	20	25.2 – 28.0	3.798 – 9.645	0.420 – 0.651	0.30 – 0.58	0.00340	0.40 – 1.00
Raia	21	18.5 – 25.6	3.603 – 8.463	0.512 – 0.719	0.22 – 0.62	0.00270	0.62 – 1.60
Kerayong	27	18.0	0.854 – 6.075	0.218 – 0.586	0.22 – 0.59	0.00125	1.80 – 3.00
Kulim	16	14.0 – 18.0	1.394 – 11.138	0.303 – 0.872	0.31 – 0.84	0.00096	3.00 – 4.00

4 Results

Table 2 below shows the best regression models when the first set of 58 data was used.From Table 2, it can be seen that the highest discrepancy ratio which can be achieved is 30% with R^2=0.573. Further tests shows that the data consist of influential outliers which could be omitted from the analysis. The result is given in Table 3.

From Table 3, Equation 6 gives the highest discrepancy ratio of 36% with R^2=0.780.

Table 4 below shows the best regression models when the second set of 50 data was used. From Table 4, it can be seen that the highest discrepancy ratio which can be achieved is 47% with R^2=0.901. Further tests shows that the data consist of influential outliers which could be omitted from the analysis. The result is given in Table 5. From, Table 5, Equation 14 with omitted influential outliers has produced a better model with the value of the discrepancy ratio increasing to 55% and with R^2 =0.934.

Table 2 Regression Models For The First Set of 58 Data

No	Regression Model	R^2	Discrepancy Ratio	Eqn no.
1	$45.79(C_v)^{0.127}(D_{gr})^{-0.421}$	0.573	30%	1
2	$7.50(C_v)^{0.066}\left(U_*/W_S\right)^{0.464}$	0.595	18%	2
3	$507.76\left(B/y_0\right)^{-0.651}(C_v)^{0.0025}\left(W_S d_{50}/v\right)^{-0.469}$	0.840	2%	3
4	$1305.05\left(B/y_0\right)^{-0.684}(C_v)^{0.0141}(D_{gr})^{-0.919}\left(U_*/W_S\right)^{-0.140}$	0.853	2%	4
5	$2160.29\left(B/y_0\right)^{-0.686}(C_v)^{0.013}(D_{gr})^{-2.595}\left(U_*/W_S\right)^{-0.123}\left(W_S d_{50}/v\right)^{-0.468}$	0.863	0%	5

Table 3 Regression Models For First Data Set (with outliers removed).

No	Regression Model	Data	R^2	Discrepancy Ratio	Eqn no.
1	$47.75(C_v)^{0.134}(D_{gr})^{-0.425}$	52	0.740	36%	6
2	$8.58(C_v)^{0.081}\left(U_*/W_S\right)^{0.446}$	55	0.684	20%	7
3	$676.55\left(B/y_0\right)^{-0.684}(C_v)^{0.022}\left(W_S d_{50}/v\right)^{-0.468}$	56	0.870	7%	8

Table 4 Regression Models For The Second Set Of 50 Data.

No	Regression Model	R^2	Discrepancy Ratio	Eqn no.
1	$0.120(C_v)^{0.060}\left(R/d_{50}\right)^{0.695}$	0.796	17%	9
2	$0.099(C_v)^{0.037}\left(y_0/d_{50}\right)^{0.686}$	0.782	8%	10
3	$0.128\left(B/y_0\right)^{-0.017}(C_v)^{0.060}\left(R/d_{50}\right)^{0.694}$	0.796	17 %	11
4	$0.026(C_v)^{0.087}\left(R/d_{50}\right)^{0.979}\left(U_*/W_S\right)^{-0.384}$	0.834	18%	12
5	$0.00021(C_v)^{0.150}\left(B/y_0\right)^{0.498}\left(R/d_{50}\right)^{1.532}\left(U_*/W_S\right)^{-1.111}$	0.901	47%	13

Table 5 : Regression Models For Second Data Set (with outliers removed)

No	Regression Model	Data	R^2	Discrepancy Ratio	Eqn no.
1	$0.00014(C_v)^{0.186}\left(\frac{B}{y_0}\right)^{0.575}\left(\frac{R}{d_{50}}\right)^{1.613}\left(\frac{U_*}{w_S}\right)^{-1.212}$	47	0.934	55%	14

5 Conclusions

This research has developed sediment transport equations for selected rivers in Malaysia namely Pari and Riai River in Perak, Kerayong River in Kuala Lumpur and Kulim River in Kedah. The total number of data collected was 108. The data was split into two with (i) the first set containing 58 data and (ii)the second set containing 50 data. For the first set of 58 data, the best equation obtained is

$$\frac{V}{\sqrt{g(S_S-1)d_{50}}} = 47.75(C_v)^{0.134}(D_{gr})^{-0.425}$$

with discrepancy ratio of 36%. For the second set of 50 data, the best equation obtained is

$$\frac{V}{\sqrt{g(S_S-1)d_{50}}} = 0.00014(C_v)^{0.186}\left(\frac{B}{y_0}\right)^{0.575}\left(\frac{R}{d_{50}}\right)^{1.613}\left(\frac{U_*}{w_S}\right)^{-1.212}$$

with a discrepancy ratio of 55%. It is hoped that the derived equations can be used as a basis for design and analysis. However, the proposed equation can be further improved on their performances with larger data set.

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