Mathematical Relationship Between Particle Reynolds Number and Ripple Factor using Tapi River Data, India.

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ABSTRACT

The computation of bed load allows for the fact that only part of the shear stress is used for transport of sediments and some of the shear stress is wasted in overcoming the resistance due to bed forms therefore the total shear stress developed in the open channel requires correction in the form of correction factor called ripple factor. Different methods have been followed for correcting the actual shear stress in order to compute the sediment load. Correction factors are based on particular characteristics grain size of particle. In the present paper the ripple factor has been obtained for non uniform bed material considering the various variables like discharge, hydraulic mean depth, flow velocity, bed slope, average diameter of particle etc. by collecting the field data of Tapi river for 15 years for a particular gauging station. The ripple factor is obtained using Meyer Peter and Muller formula, Einstein Formula, Kalinske's formula, Du Boy's formula, Shield's formula, Bagnold's formula, average of six formulae and multiple regression analysis. The variation of ripple factor with particle Reynolds Number is studied. The ripple factor obtained by different approaches are further analyzed using Origin software and carrying out multiple regression on the 15 years of data with more than 10 parameters, ripple factor by multiple regression has been obtained. These values are further analysed and giving statistical mean to the parameters a relationship of power form has been developed. The ripple factor increases with the increase in the value of Particle Reynolds number. The large deviation is observed in case of Kalinske's approach when compare with other approaches

1. INTRODUCTION

Sarangkheda is one of the gauging stations on river Tapi. In the present paper the last 15 year data collected from this gauging station is used to compute ripple factor. The ripple factor is computed for monsoon season. There are number of approaches used to compute ripple factor but in this paper six approaches are used to compute ripple factor. The field data of 15 years has been analyzed and computer programming in Ms-excel and origin has been used to carry out analysis of the data. The relationship between Ripple factor and Particle Reynolds number has been established. The graphs are plotted for the above parameters using origin software and on the obtained results statistical analysis is carried out.

2. OBJECTIVES

The main objectives of this paper are:

(i) Using various measured parameters determine Ripple factor.

(ii) To develop mathematical model relating Particle Reynolds's number and Ripple factor.

3. STUDY AREA AND DATA COLLECTION

Tapi is the second largest westward flowing river of peninsular India. Total length of the river is 724 kms from origin to Arabian sea. The Tapi basin (fig.2)is situated between latitudes 200 N to 220 N, 80% of the basin lies in Maharashtra and the balance in the state of Madhya Pradesh and Gujarat. Central Water Commission, Tapi Division, Surat is regularly collecting daily data of discharge and sediment at gauging site Sarangkheda on river Tapi (fig.3). Sarangkheda is situated at a distance of about 488 kms from origin. The daily data during monsoon are

collected for 15 years period from 1981 to 1995 and 2000-2005. Bed load data (seasonal) from 1981 - 95 are collected for study from the central water commission data books (1980-1995, 2000- 2005)

4. DISCHARGE AND SEDIMENT OBSERVATIONS

Discharges are observed once in a day at 08:00 hours at all the sites and calculated by area-velocity methods. Cross-section is divided into 15 to 25 segments as per S1192:1981.Depths are measured by sounding rods as per IS 3912:1966.Necessary air and wet line corrections are done as per IS 1192:1981.Velocity is measured by cup-type current meter as per 3910:1966 suspended sediment samples are collected in Punjab Bottle Samplers at a depth of 0.6 D from the water surface.

Particle Reynolds Number

The particle Reynolds number is related to the fall velocity of the particle.

$$= \frac{wD_S}{\nu} \quad (1)$$

Where, w is the fall velocity of the solid particle with diameter D_S. This dimensionless number is extensively used in the study of the dynamic properties of submerged solid particles and in resistance relations.

Ripple Factor

The computation of bed load allows for the fact that only part of the shear stress is used for transport of sediments and some of the shear stress is wasted in overcoming the resistance due to bed forms therefore the total shear stress developed in the open channel requires correction in the form of correction factor called Ripple factor.

Meyer – Peter and Muller formulae (1984)

In the Meyer – Peter and Muller formulae can be expressed as shown below in its basic form Basic form

$X = 13.3\,(Y^{-1} - 0.047)^{3/2}$ (2)

The Ripple factor as suggested by Meyer – Peter and Muller formulae is given below

Ripple factor $\mu = (C/C')^{3/2}$ C' based on D_{90}

The characteristics of above equation is discussed as below Characteristics grain size $D = D_i = \Sigma\,(p_i/D_i)\ \Sigma p$

Characteristics: The formula is mainly of an experimental nature. The experiments were carried out for D >= 0.4 mm for cases I which suspended load was absent. The formula has been extensively tested and used for rivers with coarse bed material. The table 1.1 presents the approach, concept and features of Meyer Peter's formulae.

Relationship Based on Estimated and Computed Parameters

The method used for estimation of ripple factor depends upon many variables. The seasonal average values of these parameters calculated by all the six methods are based on different approaches.

It is observed that all the six methods used for the study are well known, widely used and involves all-important hydraulic parameters and sediment parameters. Hence the comparisons of Ripple Factor calculated for developing the sediment transport characteristics of this river are compatible. Looking to the above fact average of six methods can be used as base without any loss of accuracy.Therefore average values of ripple factor, estimated by six methods is considered as a reliable base for the comparison of data collected and relation between ripple factor and various non dimensional parameters are established.

Multiple Regression Analysis

A multiple regression analysis is carried out between the measured and calculated basic data, viz., bed width discharge per unit width, flow area, hydraulic mean depth, velocity of flow, bed slope, avg. diameter of sediments with calculated average values of q_{bv}, , μ.

Finally equations are derived of the following form using Tables 4.1 to 4.12 for each river.

$$\mu_{\cdot multi} = C + C_1 \times q + C_2 A + C_3 \times S + C_4 \times B + C_5 \times V + C_6\,HMD + C_7\,Da. \quad (3)$$

$\mu_{\cdot multi}$ = bed load discharge in terms of volume on the basis of submerged weight

q_{bw} = is bed load discharge for river under consideration on the basis of submerged weight.

q	=	discharge per meter width
A	=	Cross section area of flow
S	=	Bed slope
B	=	bed width of stream
V	=	Velocity of flow
HMD	=	Hydraulic Mean Depth
Da	=	Diameter of sediment C, C1, C2, C3,C4,C5,

C6, C7 are multiplying constants for – q, A,S,B,V,HMD, & Da. The statistical analysis is carried out between Ripple factor, bed load discharge and various variables by using multiple regressions and the non linear square fitter of Micro cal Origin 7.5 has been used to obtain the base fit curve.

5. DATA ANALYSIS

In this paper 15 years field data of Sarangkheda gauging station of river Tapi River is analyzed.

Step: 1 The daily discharge data is converted in to monthly data.

Step: 2 The monthly data is then converted to seasonal data by taking average of monthly data so obtained is converted in to seasonal data. i.e. monsoon, post monsoon and pre monsoon seasons.

Step: 3 The seasonal data is converted in to yearly data.

Step: 4 The value of ripple factor obtained using six approaches.

Step: 5 After carrying out multiple regressions on this data results are obtained for three seasons.

Step: 6 Origin software is used to develop mathematical model to co relate Particle Reynolds number and Ripple Factor for each approach, average and multiple regression ripple factor

6. RESULT ANALYSIS

Almost for all the methods the variation of ripple factor calculated at particular station is almost uniform. An attempt is made under this study to develop simple equations which are best suited for the river under consideration the values used on the basis of average of six different methods can be used without mush loss of accuracy. The pattern of variation of hydraulic parameters or variables follows particular path. Following this path a multiple regression equation is developed for Ripple factor. The variation of hydraulic parameters is such that ripple factor shows very large variation during monsoon. Looking to such distribution, the best-fit curve based on least square method does not give the satisfactory results or very good value of co-efficient of determination on yearly basis. Therefore, an attempt is made to study seasonal variation of ripple factor. Ripple factor takes into account the effect of non-uniformity of flow. This non-uniformity can be correlated with bed conditions, flow conditions, dynamic conditions etc. and the relation between ripple factor and various non dimensional parameters can be established for given conditions of specific weight of sediment, diameter and sediment characteristics. However, it is very difficult to correlate all the parameters affecting the ripple factor. But depending upon local conditions the correlation can be made between ripple factor and the variables affecting the sediment transportation. Origin software is used to develop mathematical model to co relate Particle Reynolds number and Ripple Factor for each approach, average and multiple regression ripple factor. Table 1.2 represents the developed mathematical models. The statistical analysis of curve plotted between ripple factor and Particle Reynolds number is done by using non-linear-square-fitter to obtain the best fit curve.From the figure no.4 depicting Particle Reynolds number vs. Ripple factor, it is observed that the pattern of variation is same for all methods except Meyer Peter and Kalinske's. Comparison of all the six methods shows that Meyer Peter and Kalinske's equations deviate maximum. The pattern of variation for averaged and multiple regression Ripple factor curves appear similar. Comparison of all the six methods with corrected averaged Ripple factor curve and multiple regression curves shows that Ripple factor by Meyer Peter and Kalinske's Ripple factor gives more deviation. An extremely large deviation is observed in case of Kalinske's Ripple factor curve.

Sr.	Scientist	Approach	Concept	Features
1	Duboy's	Empirical	Excess Shear Stress	(1) Effect of bed forms is not considered
				(2) Bed Load moves in series of parallel layers and velocity of lowest layer =0
				(3) Assume linear variation of velocity
				(4) For critical condition entire bed moves as a single layer.
				(5) Developed for uniform material with different densities of sediments.
2	Shield's	Dimensionless Considerations	Excess Shear Stress	(1) Based on sediment site varying between 1.56mm to 2.47mm and sp. Gravity varying between 1.6 to 4.2
				(2) Variation of results up to 200%
3	Meyer- Peter Muller	Empirical	Excess Shear Stress	(1) Effect of Bed form considered
				(2) Total Shear Stress is partially utilize for over coming the firm resistance of undulation
				(3)Bed load transport is function of shear stress due to grains
				(4) Channel slope is divided into two parts (a) S' (slope required to overcome the resistance of grains) (b) S" (Slope required to overcome resistance of bed regularities)
				(5) Values of constants are different for uniform and non uniform material.
				(6) Used for rivers carrying coarse bed material
				(7) Results by this equation almost coincides with Einstein equation which is complicated
4	Einstein Brown	Semi Theoretical	Fall Velocity Criteria	(1) Contains no explicit correction for the shear stress, using fall velocity of particles but temperature effects are taken into kinematics viscosity.
5	Kalinske	Semi theoretical	Turbulence modern theory	(1) Bed Load transported is linked with characteristics of turbulent flow and uniform bed materials
				(2) Assume Gaussian distribution for flow velocity near bed
6	Bagnold	Semi Theoretical	Stream power concept	(1) Used concept of dispersion of solid particles under shear
				(2) Total Shear Stress= Shear stress at boundaries of shear stress due to collision of particles
				(3) Shear stress due to collision of particles depends upon normal force on particles and angle of internal friction.

7. DISCUSSION ON RESULTS

Following findings can be summarized from above study.

1. The extremely large deviation observed in case of Kalinske's approach as his formula consider uniform bed material which is not possible in case of river flow.
2. The pattern of variation of Particle Reynold's number with Ripple factor is same for all methods except Meyer Peter and Kalinske's.
3. The variation of Ripple factor with Particle Reynolds number for averaged and multiple regression Ripple factor curves appear similar.

8. REFERENCE

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Table.1.2 Mathematical models for Particle Reynolds Number
Tapi-Sarangkheda-Monsoon Season

Sr.No	NAME OF SCIENTIST	MODEL	EQUATION	a	b	c	d	e	Chi^2	R^2
1	E.BROWN	Asymptotic1	y = a-b*c^x	0.933	0.017	0.99529	-	-	4.3188E-9	0.99898
2	DUBOY'S	Allometric1	y = a*x^b	0.430	0.1705				0.89291	0.94374
3	SHIELD'S	Cubic	y = a + b*x + c*x^2 + d*x^3	3.057	-0.018	0.00004	-2.19E-08	-	0.04348	0.97888
4	MEYER	Poly4	y = a + b*x + c*x^2 + d*x^3 + e*x^4	-10.89	0.108	-0.00035	4.81E-07	-2.36E-10	0.08997	0.86823
5	BAGNOLD'S	Cubic	y = a + b*x + c*x^2 + d*x^3	0.246	-0.0037	7.45E-07	-4.77E-10	-	5.5092E-10	0.94379
6	KALINSKE'S	Allometric1	y = a*x^b	1.0258	0.19466			-	0.00362	0.81133
7	AVERAGE	Poly4	y = a + b*x + c*x^2 + d*x^3 + e*x^4	4.299	-0.03	0.0001	-1.41E-07	7.08E-11	0.00741	0.81235
8	MU MULTIPLE	Poly4	y = a + b*x + c*x^2 + d*x^3 + e*x^4	3.536	-0.022	0.00008	-1.07E-07	5.36E-11	0.00836	0.81746

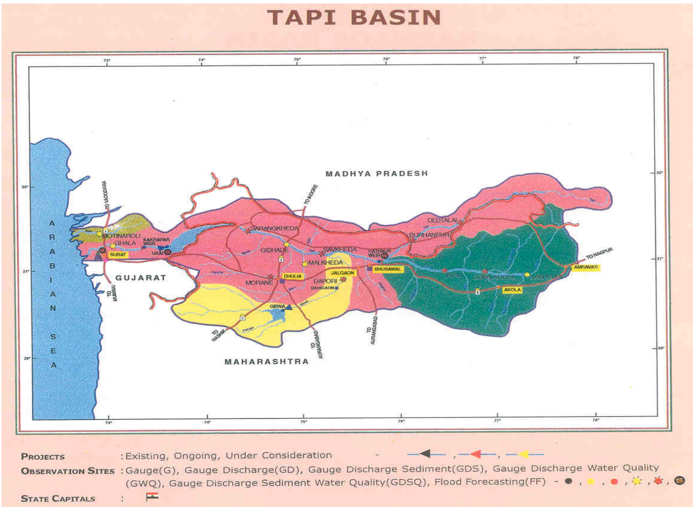

Fig.2 Tapi Basin.

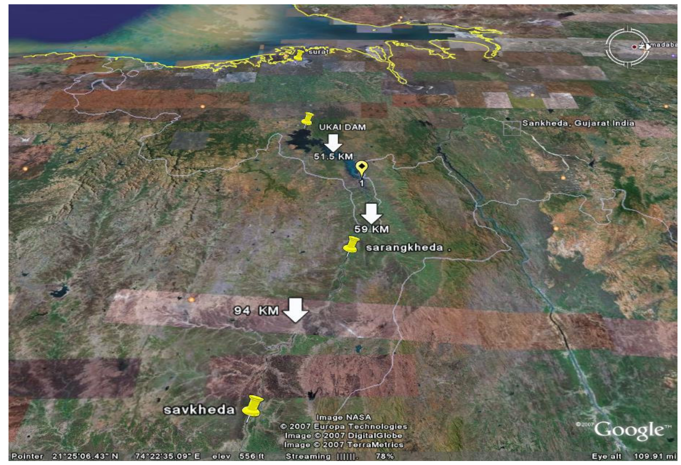

Fig.3 Savkheda, Sarangkheda gauging stations and Ukai dam.

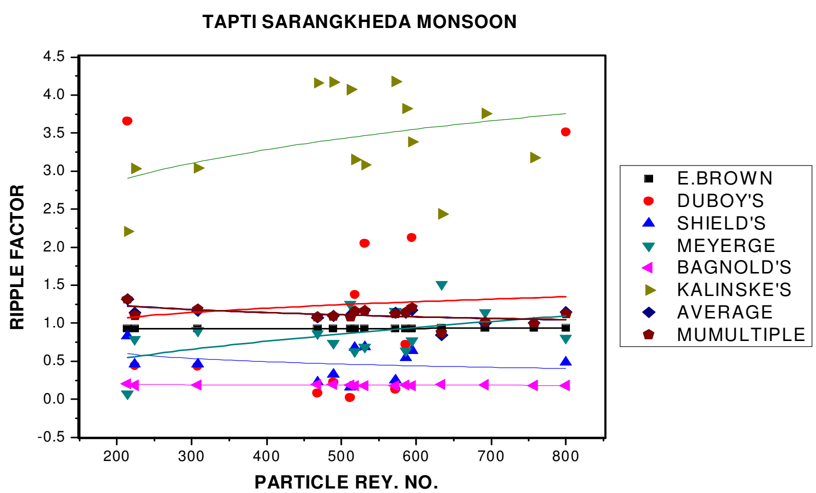

Figure.4 Particle Reynolds Number versus Ripple Factor