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A Case Study of Ripple Factor with Special Reference to Boundary Reynold Number for Tapi River

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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. The effect of non uniformity of bed material on the sediment transport has been studied by various investigators in the past. They developed the transport rate equation for particular size of sediment in a non uniform bed material, whereas the influence of other sizes of sediments has been neglected. 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 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 Brown Formula, Duboy's formula, Shield's Formula and, Bagnold's formula and Kalinske's formula. The variation of ripple factor with Boundary Reynolds number is studied for the three seasons of the year for the period of 15 years. In E. Brown's approach variation of correction factor with Boundary Reynolds number for all season is similar in nature. In Duboy's approach monsoon and post monsoon season shows similar variation in the nature of curve where the value falls up to 150 Boundary Reynolds no. and than further there is a rise in the value of correction factor with the increase in the value of Boundary Reynold no. where as for pre monsoon season it shows that the value of correction marginally increases. In Shield's approach monsoon season shows fall in the value of correction factor up to 200 Boundary Reynold no. and than there is rise in the value. For post monsoon season there is a constant fall in the value of correction factor upto 150 and than increases and for pre monsoon season value of ripple factor increases after 175. In Meyer Peter's approach monsoon season shows gradual rise in the value of ripple factor till 200 Boundary Reynold no. and than the value falls where as the post monsoon season shows constant rise in the value of correction factor and for pre monsoon season value falls up to 80 Boundary Reynold no. and than shows rises in the value of ripple factor with the increase in the value of Boundary Reynold no. In Bagnold's approach all the three seasons there is similar variation in the nature that is value falls constantly with the initial rise. However monsoon season has initial same value as post monsoon season but finally high value of correction factor than post monsoon season where as pre monsoon season has maximum value among the three seasons. In Kalinske's approach all the three approach shows different nature of curve that is for monsoon season value of correction factor falls with the increase in Boundary Reynold no. where as for post monsoon season the value of correction factor falls up to 50 Boundary Reynold no. and than the value rise for higher Boundary no. and for pre monsoon season there is a gradual rise in the value of correction factor. For multiple regression curve the value of correction factor decreases marginally with increased Boundary Reynolds no. between 60 to 150 values while for other range increases marginally.

Key words: Ripple factor . boundary reynold number . multiple regression . mathematical model . armouring

INTRODUCTION

Sarangkheda is one of the gauging stations on river Tapi. In the present paper the last 15 years data collected from this gauging station is used to compute ripple factor. The ripple factor is computed for three seasons in a year namely monsoon, post monsoon and pre monsoon. There are number of approaches used to compute ripple factor. In this paper E. Brown equation, Duboy's formula, Shields formula, Meyer Peter

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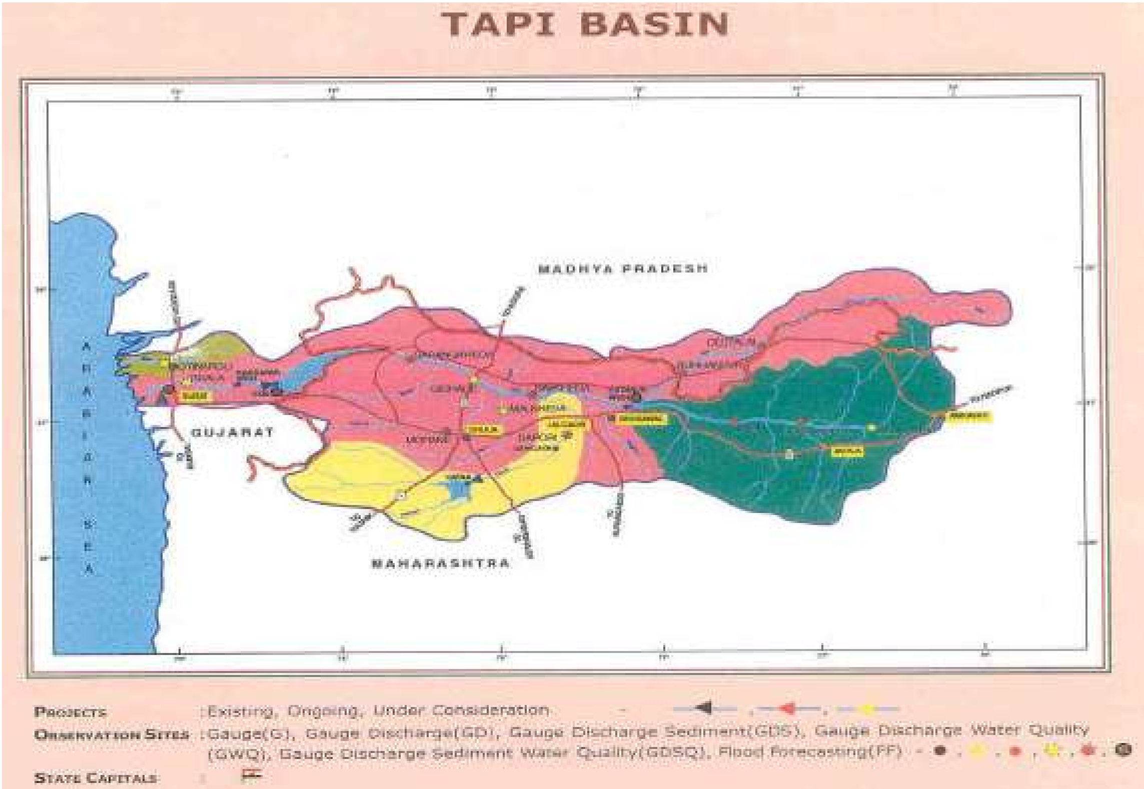

Fig. 1: Map showing study area

formula, Bagnold's formula, Kalinske formula, Average of all the above formula and Ripple factor from multiple regressions 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 analysis of the data. The relationship between Ripple factor and Boundary 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.

Study area: The river Tapi is the second largest west flowing rivers of India. The Tapi its source at Multai ("Mool Tapi" means the original Tapi) in Betul District of Madhya Pradesh in Latitude 21°43' N and Longitude 78°16' E. The river has a total length of 724 km of which 282 km in the Madhya Pradesh, 228 km in the Maharashtra and the last lap of the 214 km a Gujarat and ultimately meets the Arabian Sea in the Gulf of Cambay approximately 19.2 km west of Surat (Fig. 1). The river has four distinct reaches during its course. In the initial reach of 240 km the river flows through area covered with dense forest of Madhya Pradesh. The river then emerges into a narrow plain which starts widening out at Burhanpur. In this reach the river has average bed slope of 1 in 460. The river after gradually widening out near Burhanpur leaves Madhya Pradesh and enters Maharashtra. It is swelled by several of its large tributaries on both the sides in Maharashtra. The river has high banks and rocky outcrops in the bed below Bhusawal. The length of the river in this section is about 288 km. The bed gradient in this reach is of 1 in 1900. In the third section, i.e. between 528 and 608 km the river enters the hilly country covered with thick forest. Here the hills on the north bank are fairly close to the river whereas the hills on the south bank gradually recede away. In this reach, the river has more or less uniform section with the bed-width of 333 to 350 mt and steep banks. The average slope of the river in this reach is about 1 in 1760 in the last reach downstream of Ukai, the river enters the flat and fertile lands of Gujarat. Low banks beyond Kakrapar cause periodic overflow resulting in extensive flood damages. The deltaic conditions are formed many times with increasing zone of flood damages. Between Kakrapar and Piparia, the river drops by about 27.43 m in a length of 25.6 km. The river bed is fairly flat beyond Piparia.

Data analysis: The field daily data of Sarangkheda gauging station of river Tapti are collected for 15 years as sown in Table 1. The daily data is first converted to

Table 1: Data collection

		Bed load sediment			Suspended load sediment		
Sr. No.	Name of river	Pre monsoon	Monsoon	Post monsoon	Pre monsoon	Monsoon	Post monsoon
1.	Tapi	1981-95	1980-95	1980-95	1985-95	1985-94	1985-95

monthly data by taking average of all the parameter. The monthly data is then converted to seasonal data by taking average of monthly data. The seasonal data is for monsoon, post monsoon and pre monsoon seasons. The seasonal data so obtained is used for carrying out multiple regressions over various parameters and a final relation ship between various parameters and ripple factor is established. The seasonal data further converted in to yearly data and the multiple regression analysis is carried out on this to establish relationship between ripple factor and the various parameters. The value of ripple factor is computed using E.Brown equation, Duboy's formula, Shields formula, Meyer Peter formula, Bagnold's formula, Kalinske's formula, Average of all the above formula and multiple regressions. The values of ripple factor obtained by above methods are averaged and a new parameter ripple factor average is compared with the various parameters obtained as stated above. The values so obtained are presented graphically season wise. These values are compared among themselves and compared with ripple factor obtained from the field data.

RESULT ANALYSIS

Boundary Reynold number is a function of shear velocity and the diameter of the particle.

The most of the bed load equations can be reduced to one of the following forms:

$$q_B = Af(\tau_0 - \tau_{0c})$$

$$q_B = Af(q - q_c)$$

$$q_B = Af(U - U_{cr})$$

In which the quantities with subscript c or cr refer to the incipient condition and A is a constant related to sediment and fluid characteristics, which is known as Ripple factor.

Ripple factor is the correction factor applied to bed load transport rate obtained using E. Brown, Duboy's, Shields, Meyer Peter, Bagnold's, Kalinske's, Average of all the above and from the multiple regression obtained from the field data. In the present paper relationship between Boundary Reynold number and

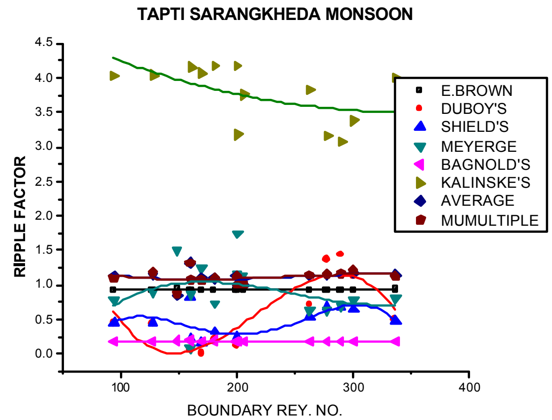

Fig 2: Variation of ripple factor v/s boundary reynold no for monsoon season

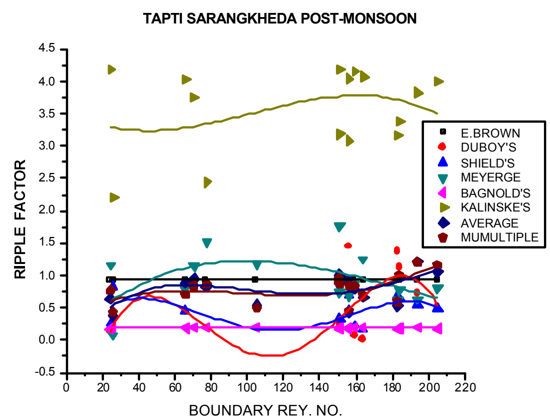

Fig. 3: Variation of ripple factor v/s boundary reynold no for post monsoon season

Ripple factor (Correction Factor) is developed for three different seasons using origin software. The mathematical models developed for Boundary Reynolds number and Ripple factor is presented in Table 2-4. Boundary Reynolds number is useful in finding out whether the bed will be Armored or not.

The relationship obtained between Boundary Reynolds no and Ripple factor is shown in Fig. 2 for monsoon season, Fig. 3 for post monsoon season and Fig. 4 for pre monsoon season. In E. Brown's approach variation of correction factor with Boundary Reynolds number for all season is similar in nature. In Duboy's approach monsoon and post monsoon season shows

Table 2: Mathematical models for boundary reynold number and ripple factor for monsoon season

Sr. No.	Name of scientist	Model	Equation	a	b	c	d	e
1	E. Brown	Cubic	y = A + B*x + C*x^2 + D*x^3	0.91639	0.00015	-4.61E-07	4.58E-10	-
2	Buboy's	Cubic	y = A + B*x + C*x^2 + D*x^3	6.37449	-0.10422	0.00054	-8.20E-07	-
3	Shield's	Poly 4	y = A0 + A1*x + A2*x^2 + A3*x^3 + A4*x^4	-4.76839	0.12681	-0.00106	3.66E-06	-4.40E-09
4	Meyer Ge	Cubic	y = A + B*x + C*x^2 + D*x^3	-1.17069	0.03125	-0.00014	1.86E-07	-
5	Bagnold's	Cubic	y = A + B*x + C*x^2 + D*x^3	0.11349	-0.00125	-6.24E-06	9.29E-09	-
6	Kalinske's	Parabola	y = A + B*x + C*x^2	4.95568	-0.00833	0.00001	-	-
7	Average	Cubic	y = A + B*x + C*x^2 + D*x^3	1.57611	-0.00711	0.00003	-4.25E-08	-
8	Mu Multiple	Cubic	y = A + B*x + C*x^2 + D*x^3	1.51063	-0.00637	0.00003	-4.06E-08	-

Table 3: Mathematical models for boundary reynold number and ripple factor for post monsoon season

Sr. No.	Name of scientist	Model	Equation	a/A0	b/A1	c/A2	d/A3	e/A4
1	E. Brown	Poly4	y = A0 + A1*x + A2*x^2 + A3*x^3 + A4*x^4	0.96038	-0.00205	0.00004	-2.54E-07	5.63E-10
2	Buboy's	Poly4	y = A0 + A1*x + A2*x^2 + A3*x^3 + A4*x^4	-2.54977	0.17553	-0.00315	0.00002	-4.56E-08
3	Shield's	Poly4	y = A0 + A1*x + A2*x^2 + A3*x^3 + A4*x^4	-5.15937	0.37525	-0.00704	0.00005	-1.05E-07
4	Meyer Ge	Cubic	y = A + B*x + C*x^2 + D*x^3	0.04523	0.02688	-0.00018	3.26E-07	-
5	Bagnold's	Poly4	y = A0 + A1*x + A2*x^2 + A3*x^3 + A4*x^4	0.21151	-0.0013	0.00002	-1.45E-07	3.09E-10
6	Kalinske's	Cubic	y = A + B*x + C*x^2 + D*x^3	3.54441	-0.01518	0.00022	-6.97E-07	-
7	Average	Poly4	y = A0 + A1*x + A2*x^2 + A3*x^3 + A4*x^4	-0.23487	0.04215	-0.00055	2.79E-06	-4.59E-09
8	Mu Multiple	Poly4	y = A0 + A1*x + A2*x^2 + A3*x^3 + A4*x^4	0.29493	0.01736	-0.00021	9.78E-07	-7.66E-10

Table 4: Mathematical models for boundary reynold number and ripple factor for post monsoon season

Sr. No.	Name of scientist	Model	Equation	a/A0	b/A1	c/A2	d/A3	e/A4
1	E. Brown	Asympotic1	y = a-b*c^x	0.93155	0.14491	0.79896	-	-
2	Buboy's	-	-	-	-	-	-	-
3	Shield's	-	-	-	-	-	-	-
4	Meyer Ge	Cubic	y = A + B*x + C*x^2 + D*x^3	3.5159	0.08599	-0.0007	-1.76E-06	-
5	Bagnold's	Cubic	y = A + B*x + C*x^2 + D*x^3	0.19355	0.00071	-6.00E-06	1.41E-08	-
6	Kalinske's	Allometric1	y = a*x^b	3.33E-07	3.13567	-	-	-
7	Average	Poly4	y = A0 + A1*x + A2*x^2 + A3*x^3 + A4*x^4	0.48259	0.01946	-0.00056	4.60E-06	-1.11E-08
8	Mu Multiple	Poly4	y = A0 + A1*x + A2*x^2 + A3*x^3 + A4*x^4	0.49343	0.0197	-0.00059	4.92E-06	-1.20E-08

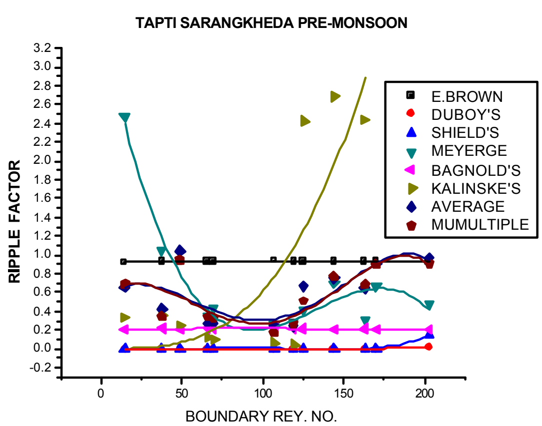

Fig. 4: Variation of ripple factor v/s boundary reynold. No for pre monsoon season

similar variation in the nature of curve where the value falls up to 150 Boundary Reynolds no. and than further there is a rise in the value of correction factor with the increase in the value of Boundary Reynold no. Where as for pre monsoon season it shows that the value of correction marginally increases.

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CONCLUSION

The Boundary Reynold Number increases with increase in the particle diameter for all seasons. In case of Kalinske's approach the value of Ripple factor is very high compare to all other approaches for all the seasons. The wide variation is observed in case of Duboy's approach between Ripple factor and Boundary Reynold. Hence, these formulas can not be used to compute bed load transport rate in case of river flow.In case of Shields, E.Brown's and Meyer Peter formula, it can not be applied directly to compute the bed load transport rate for river flows as large variation is observed between Ripple factor and Boundary Reynold Number. While the Ripple factor obtained from multiple regression formula can be used to find out actual bed load transport rate of River Tapi. Armoring of bed, can be predicted from the curves developed. Further, the curves developed for Ripple factor and Boundary Reynold Number, also guide to find out minimum size of the bed material or lining stone that will remain at rest in a channel and to determine actual bed load transported in a channel. The above curves are an useful tool for predicting armoring of bed, determining minimum size of particle that will remain at rest and to correct bed load transported by the channel.

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