MODIFYING BAGNOLD'S EQUATION AND DETERMINING RIPPLE FACTOR FOR MONSOON SEASON, SAVKHEDA GAUGING STATION OF TAPI RIVER

Prof. S. M. Yadav [1] and Dr. B. K. Samtani [2]

[1] Lecturer, S.V. National Institute of Technology, Surat -395 007, Gujarat, India
E-mail: shivnam27@yahoo.co.in
[2] P. G. Incharge (WRE), S.V. National Institute of Technology, Surat -395 007, Gujarat, India
E-mail: samtanibk@yahoo.com

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 like correction to hydraulic mean depth, deduction of wall shear find the total shear (suggested by Jhonson), using the number of coefficients obtained graphically (as in Einstein's equation). However, all these correction factors are based on particular characteristics grain size of particle. 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, where as 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, Monsoon season, Savkheda gauging station. The majority of the bed load formulae represent a functional relation between bed load discharge and shear stress. The formulae are characterized by three aspects namely the basic function $q_b = A\, f\,(t_0 - t_c)$, the characteristic grain-size to be used and the correction applied to bed load equations. The main objectives of this paper are to estimate bed load of monsoon season, to analyze the sediment load during monsoon, using various measured parameters determine q_b, t_0 and t_c and to develop modified bed load equation for Bagnold's approach. The bed load equation can be approximated in exponential form as $Y = a\, X^{b}$. For this purpose bed load, shear stress and critical shear stress are computed. Bed load obtained by these equations is converted in the form of volume (q_{bv}). The statistical analysis, multiple regression and curve fitting (by nonlinear square fitter) is carried out by using allometric function of Microcal Origin 6.1. The modified bed load equation of Bagnold for Tapi river, Monsoon season and for Savkheda gauging station is $Y = X^{1.55373}$. The value of Ripple factor obtained by above analysis is 0.01593 and the value of index is 1.55373.

INTRODUCTION

The subject of sediment transport and flow in alluvial streams are gaining importance with the increasing utilization of water resources, considerable development has taken place in the field of fluvial hydraulics which is considered as complicated branch of engineering.

Valuable information are available in numerous journals, monographs and research publications on sediment transport relating to the problems of incipient motion, flow regimes, resistance to flow bed load, suspended load, total load transport and flow of sediment in pipes etc. based on various approaches and concepts used by various research scientists and thousands of equations are developed.

The majority of the bed load formulae represent a functional relation between bed load discharge and shear stress. The formulae are characterized by three aspects:

(i) The basic function $q_b = A\, f\,(t_0\text{-}t_c)$.
(ii) The characteristic grain-size to be used.
(iii) The correction of the bed load equations.

This means that the formulae cannot be compared easily. The transport of sediment defined as a volume transported per unit width and time as if it were settled has advantages over real volume or mass. The main advantage lies in the fact the formulae are mainly used to predict sedimentation and erosion. By using bulk volume (i.e. including pores) in the formulae this link can easily be made.

The correction factor 'μ' allows also known as Ripple factor, for the fact that only part of shear stress is used for transport and it also acts as a correction factor to adopt the basic formula to transport measurements.

OBJECTIVES

The main objectives of this paper are:

(i) To estimate bed load of monsoon season
(ii) To analyze the sediment load during monsoon.
(iii) Using various measured parameters determine q_b, t_0 and t_c.
(iv) To develop modified bed load equation for Bagnold's approach.

STUDY AREA AND DATA COLLECTION

Tapi is the second largest westward flowing river of peninsular India. The total length of the river is 724 kms from origin to Arabian Sea. The Tapi basin is situated between latitudes 20^o N to 22^o N, 80% of the basin lies in Maharashtra and the balance in the state of Madhya Pradesh and Gujarat as shown in Figure 1.

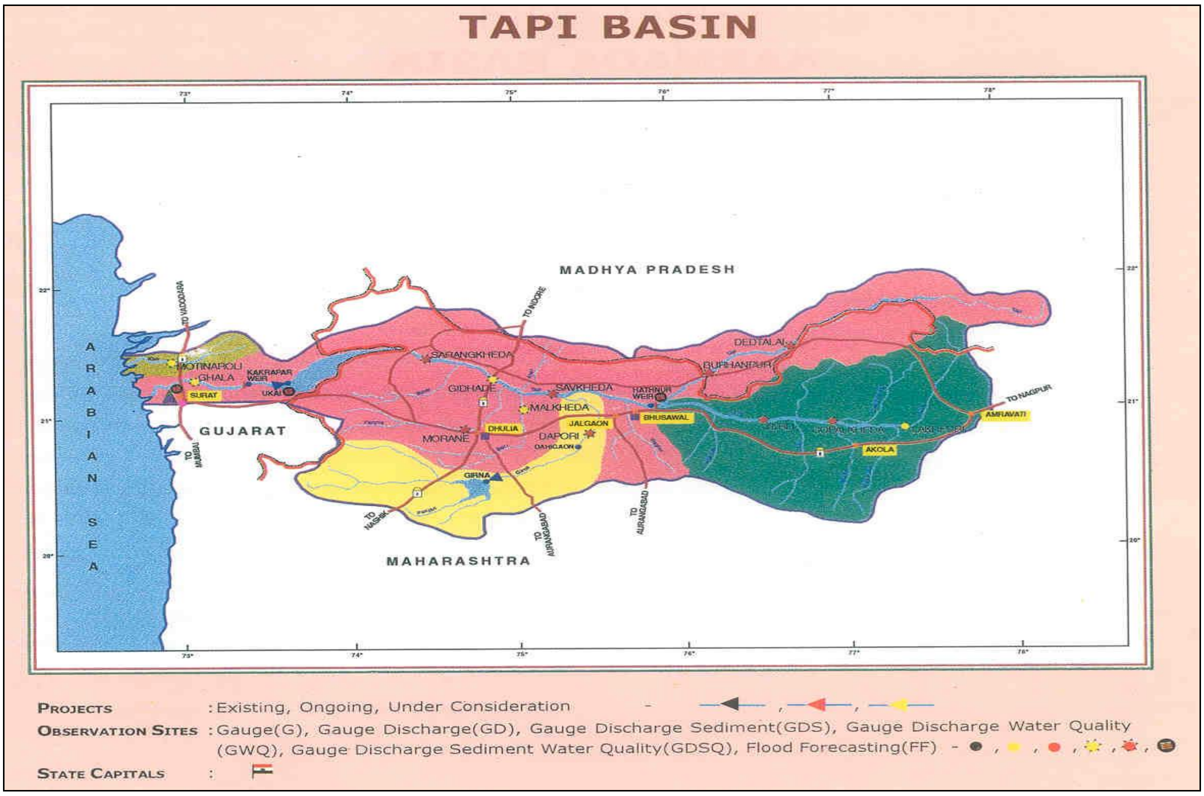

Fig. 1 Map of Study Area

Central Water Commission, Tapi Division, Surat is regularly collecting daily data of discharge and sediment at gauging site Savkheda on river Tapi. Savkheda 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. Bed load data (seasonal) from 1981 - 95 and suspended load data from 1984 - 94 are collected for study.

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 IS1192:1981. 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.

METHOD OF ANALYSIS

The function $q_b = A\ f\ (t_0 - t_c)$ can be approximated by an exponential function $Y = a\ X^{\ b}$. Majority of the bed load equations follow three different approaches viz. empirical, dimensional consideration and semi theoretical approach which are based on mainly four different concepts like excess shear stress, fall velocity criteria, turbulence modern theory and stream power concept of dispersion of solid particles under shear. The Bagnold equation follows semi theoretical approach based on fall velocity criteria. The equation is converted in to *X-Y* form (non dimensional) so that they can be easily compared.

Bagnolds has given the following bed load equation:

$$\frac{q_B}{\gamma_S d \sqrt{\left(\frac{\rho_S}{\rho_f}-1\right) gd \cos\theta}} = AB_b \left\{ \frac{\tau_0}{(\gamma_S-\gamma_f) d \cos\theta} - \frac{\tau_{0c}}{(\gamma_S-\gamma_f) d \cos\theta} \right\} \times \left\{ \frac{\tau_0}{(\gamma_S-\gamma_f) d \cos\theta} \right\}^{\frac{1}{2}} \quad (1)$$

In which θ is the inclination of the bed with the horizontal, A = 9.0 and B_b is a parameter defined by the relationship

$$B_b = \frac{\sqrt{\frac{2\tan\phi}{3\mathrm{C_D}}}}{\left(1-\frac{\tan\theta}{\tan\phi}\right)} \approx \sqrt{\frac{2\tan\phi}{3\mathrm{C_D}}} \quad (2)$$

In which θ is the angle of repose of the material and C_D is the drag coefficient of the sediment particle (which must be corrected for the effect of sediment concentration).

COMPUTATION OF BEDLOAD AND RELATED PARAMETERS

From the observed and calculated daily data like discharge, area, velocity, wetted perimeter, hydraulic mean depth, Manning's and Chezy's constants, average diameter of sediment, mean diameter of sediment etc. are grouped under mainly five heads i.e., monthly, pre-monsoon, monsoon, post-monsoon and yearly to facilitate the use of these data in analysis. In this paper the discussion is done for monsoon season and for Bagnold's approach only.

For the purpose of analysis, the above equation is used to find bed load, shear stress and critical shear stress. Bed load obtained by these equations is converted inform of volume (q_{bv}).

This function can be approximated in exponential form as:

$$Y = a\,X^{\,b} \quad (3)$$

The statistical analysis, multiple regression and curve fitting (by nonlinear square fitter) is carried by using allometric function of Microcal Origin 6.1.

RESULT ANALYSIS

During monsoon, the computed values of bed load discharge, shear stress and critical shear stress obtained using Bagnold's approach are plotted as shown in Fig. 2. The statistical analysis is carried out using Microcal Origin 6.1. The modified bed load equation and value of Ripple factor *a* is given below.

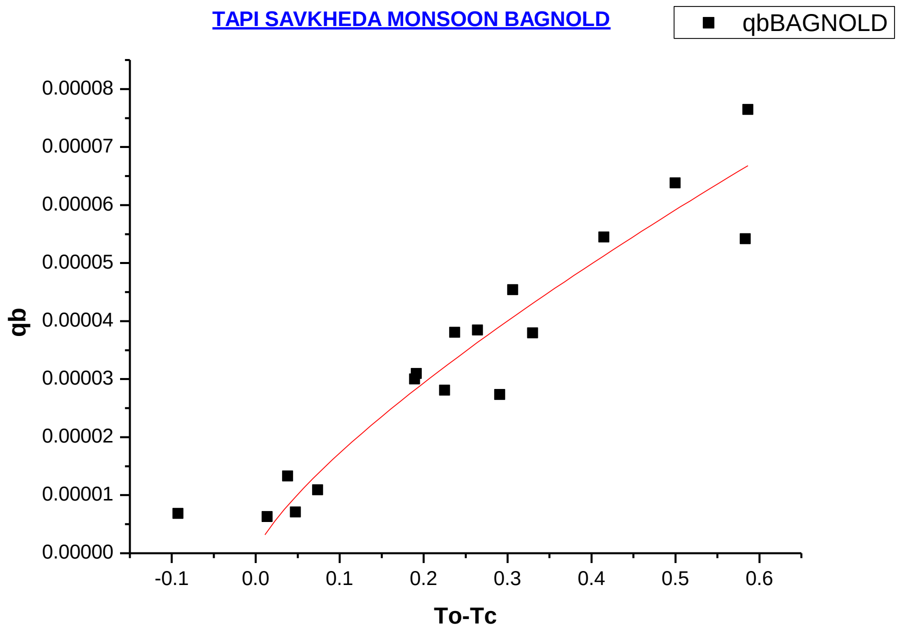

Fig. 2 The relationship between bed load discharge, shear stress and critical shear stress

Model: Allometric1

Equation:
$Y = a*X^b$

Weighting:
Y No weighting

Chi^2/DoF	R^2
4.017E-11	0.90985

Parameter	Value	Error
a	0.0001	9.3491E-6
b	0.7649	0.08922

The value of ripple factor comes out to be 0.0001 while value of b = 0.7649.

The above equation can be used to calculate the correct bed load transported by Tapi River in case of Monsoon season for Savkheda gauging station.

CONCLUSION

The modified bed load equation of Bagnold for Tapi river, Monsoon season and for Savkheda gauging station is $Y = 0.0001\ X^{0.7649}$. The value of Ripple factor obtained by above analysis is 0.0001 and the value of index is 0.7649.

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