ARTICLE

Discussion at Maximum Sediment Discharge Theory

Levent Yilmaz[*]

Nisantasi University, 1453 Neocampus, Civil Engineering Department, Hydraulic Division, 80626, Maslak, Istanbul, Turkey

ARTICLE INFO	ABSTRACT
	It is observed the gravel river sediment discharge with existing empirical regime relationships. The aim of the research is to give a mathematical model about the stable cross-section geometry and to determine a model for the stable slope of an alluvial channel which is in nature seldom stable. In an alluvial channel to reach an equilibrium condition, it changes its plane geometry until to have a stable condition in plane configuration. There are three different parameters in plan configuration about river behavior: width, depth and slope.

1. Introduction

The research for equilibrium state in an alluvial channel the analytical methods are investigated. For this reason, the evidence of laboratory studies and information about the sediment data is studied. The behavior distribution of meanders in nature is reviewed which has a good performance of a laboratory sand-bed channel evolution. The observation of experimental set-up is very similar with observations of a natural gravel-bed river evolution [1,7].

The meander formation is a function of the dominant discharge, grain size and sediment transport content. The Friedkin's Vicksburg experiments [8] and Inglis's [8] analysis of Indian Data are important references for understanding of alluvial flow behavior. In the last decades important research has been prepared in analytical methods. Meander migration is a significant river engineering problem [2,3].

Meander flow takes place in one single channel which ossilates more or less regularly with amplitudes that tend to increase with time. Interaction between the flow and maximum sediment transport produces channel pattern which are classified as meandering or braided.

The research deals with a solution about analytical method. In the river boundary layer two different parameters, the suspended sediment and the friction at the inner boundary layer are evaluated and found mathematical model for the evolution. Till today several researchers determined the analytical models which gave the equation for bank instability because of sedimentation [1]. Another research was about the variation of minimum stream power or about the explanation about stream power in unit discharge where a variation about basic principle is given for the channel shape. It is observed that the boundary layer changes its width, depth and slope during maximum sediment transport. The first derivatives about geometrical approaches are the shape of channel bed which boundary layer shows an acceptable equilibrium since its maximum

Corresponding Author:
Levent Yilmaz,
Nisantasi University, 1453 Neocampus, Civil Engineering Department, Hydraulic Division, 80626, Maslak, Istanbul, Turkey;
Email: levent.yilmaz@nisantasi.edu.tr

sedimentation occurs with some assumptions. For these assumptions another hypothesis become aware by Ramette [6] where there are some new principles. This work gives new relations without any comparison by sensibility analysis on different environmental data. Ramette's (1979) research has analytical conditions in minimum stream power approach [2].

The proposed mathematical model shows the similarity between Ackers and White's relationships for sedimentation in the river boundary layer and for resistance parameter of flow in the river bed by White, Paris and Bettes relationships [7]. Using these equations it is proposed having new parameters about geometric and hydraulic characteristics for a not moving boundary layer in river section. The results have been compared with practice. It is suitable while comparing the results with other river data in nature and show good approximation by using regime equations. These new inventions about river behavior on an alluvial interface show excess applications in spite using limited regime properties.

2. Formulation of Method

There are six different parameters which easily shapes the channel deformation on an alluvial boundary layer. These parameters are:

(1) The average depth, d;
(2) The slope, S;
(3) The average water velocity, V;
(4) The discharge, Q;
(5) Sediment concentration, X and
(6) The channel width.
The formulation of these variables, it is used,
(1) The continuity equation
(2) Formulas for sediment transport
(3) Formulas for flow resistance
(4) Formulation of the stream condition, that if the stream power should be minimized where maximum sediment discharge takes place in the channel boundary layer.

3. Sediment Transport

Different equations are given in the scope of the continuity equation of water flow and sedimentation, flow boundary layer resistance formula, different kind of sediment transport relationships and the rule where stream power should be minimized when the power of sediment transport must be maximized [7].

The parameters V, d, X and B are given for determination of discharge and slope of the channel where it is assumed that the flow is steady and uniform for a non cohesive boundary layer material. It is invented some

equations for determining the sediment transport concentration. This mobility at the boundary layer takes place with different kind of parameters in three values without dimension. These are :

(1) Particle size D_{gr} without dimension,
(2) Content of Sediment G_{gr} and
(3) The particle property which is not stabil and constant, F_{gr}.

This particle property is defined as the ratio of immersed weight and the ratio of shear forces which is a river boundary layer occurrence while the water flowing as a function of bed resistance.

In the river boundary layer it is given that the light sediment particles continue to flow from upstream to the downstream direction [2]. These particles show a mobility as a suspended load in sedimentation with turbulent behavior. By flowing of water the turbulence intensity is very high to carry all the particles which are finer with help of total boundary layer shear stress. It is given as the definition for particle movement [2]:

$$F_{gr} = \frac{V_*^n}{\sqrt{gD(s-1)}} \left(\frac{V}{\sqrt{32 \log\left(\frac{10d}{D}\right)}} \right)^{1-n} \tag{1}$$

For fine sediments, n=1, and n = 0 for coarse property of the sediment particles. For mean value of sediment particles n is described as a value between 0 and 1 in the transition zone, which is dependent to the parameter D_{gr}.

$$D_{gr} = D \left[\frac{g(s-1)}{v} \right]^{1/3} \tag{2}$$

where g is the gravitational constant and, v is the kinematic viscosity of the continuum medium, s is the density of coarse sediment.

$D_{gr} > 59$ gives the condition of the flume data for coarse sediments. For fine sediments the result for computation $D_{gr} < 1$. Between these values there is transition zone from fine to coarse sediments.

The cube root is identified as the ratio of immersed weight of sediment particles to viscous boundary layer forces. There is also a sensitivity analysis for different flow data for $D_{gr} > 59$ and $D_{gr} < 1$, for different kind of coarse and fine sediment particles, respectively. The transition zone takes place between above given limits. There is also a stream power definition by sedimentation process where it is combined with a mobility number of particles at the river boundary layer with a continuity parameter of sedimentation [2],

$$G_{gr} = \frac{Xd}{sD}\left(\frac{V_*}{V}\right)^n \qquad (3)$$

where a general model for a particle discharge is given as, [2]

$$G_{gr} = C\left(\frac{F_{gr}}{A} - 1\right)^m \qquad (4)$$

in which C and m are different constants for D_{gr} function, and X is the parameter for initial movement of the particles. The given threshold for changing the location of particles in the boundary layer is given with the above parameter of F_{gr}. For the paramerters n, m, G_{gr} and A is defined by transitional zones of D_{gr} between 1 and 61 [7].

$$n = 1.0 - 0.56 \log D_{gr} \qquad (5)$$

$$m = (9.66/D_{gr}) + 1.34 \qquad (6)$$

$$\log C = 2.86 \log D_{gr} - \log^2 D_{gr} - 3.53 \qquad (7)$$

$$A = \frac{0.23}{\sqrt{D_{gr}}} + 0.14 \qquad (8)$$

where for transition zone of coarse sediments, $D_{gr} > 61$ is given as [7]:

$$n = 0.11 \qquad (9)$$

$$m = 1.51 \qquad (10)$$

$$C = 0.026 \qquad (11)$$

$$A = 0.18 \qquad (12)$$

4. Frictional Characteristics

Including the Ackers sedimentation theory [1] there is another linear relationship between sediment transport and the total shear stress,

F_{fg}, is given as

$$F_{fg} = \frac{V_*}{\sqrt{gD(s-1)}} \qquad (13)$$

and the mobility, related to the effective shear stress, F_{gr}, existed with coefficients depending on D_{gr}. An extensive correlation exercise for a wide range of sediment sizes (0.05 mm to 11 mm) gave the equation

$$\frac{F_{gr} - A}{F_{fg} - A} = 1.0 - 0.76\left[1 - \frac{1}{\exp(\log D_{gr})^{1.7}}\right] \qquad (14)$$

There is traditional methods which can easily matches with data of sediment sizes between 0,04 mm to 69 mm[5].

5. Variation Principle

For solving the problem another attempt had been made with maximum or minimum parameters in the boundary layer which is given for different sediment sizes. The new hypothesis is given in the conditions of special discharge for fluvial slope where during maximum sedimentation the width of the bed boundary layer is changed till it is stable. Using stream power at the channel boundary layer if the stream power is minimum, sufficient equilibrium condition for alluvial boundary layer can be observed. The other researchers give the same observation with different analytical approaches [3,4] where the channel width is given and remains fixed during the minimization of stream power. These attempts relate the principles of minimum unit stream discharge while the occurrence of energy dissipation with minimum sediment rate. It can easily observed the same results by maximizing sedimentation and obtained a minimum slope for channel bed [5,6]. During comparison methods it is given that the maximum sediment concentration for a constant water discharge and slope, many sedimentation theories and friction relationships for bed boundary layer identifies the same parameters. It is given different diagrams for slope and sediment concentration as a function of channel width. By observations in nature both extremes occur at a width of 43 m. Since the two principles of maximizing transport rate and minimizing slope are equivalent, the work relating minimizing stream power to minimizing the rate of energy dissipation which can be used for the method of maximum sedimentation at the boundary layer. If there is not maximum transport rate conditions on the boundary layer without adjusted the alluvial fluvial bed slope with discharge. There are different solutions to the different parameters of concentration, velocity and depth. The new approaches give the solutions about different parameters which have sedimentation discharge under the maximum rates and width under the extreme values. There are another constrains with parameters of bank and bed erosion. It gives a solution about erosion parameter where the banks have more erosion property than the bed boundary layer, observed new bed deformation on alluvium with more larger curvature. This research gives the conditions about uniform flow properties without subjected the development of river plan behabiour. Only new concept about maxi-

mum sedimentation can easily determine river behavior in plan section. It is observed that only in the meandering channel development it is observed the comparison with straight channel formation where river discharge transport larger sedimentation with smaller energy. It is concluded that the plan geometry of alluvial plan behavior of meander needs maximum sediment transport rate. The comparison between theoretical study and observations in praxis has the same results. In the meandering plan geometry the uniform flow conditions produce also the same characteristic behavior.

6. Computational Procedure

There are different artificial computer intelligence software for satisfying geometric values about sedimentation density, about the size of different bed boundary layer material and about temperature conditions. These are inputs in computer software and as output the meandering boundary layer depth, water depth, mean velocity and slope for inner boundary layer which can be computed. The results have as for the sensibility analysis only 1 % deviation from observations [7]. The other researchers observed in laboratory channel a rectangular sand cross section [2,3], where it has the same computational procedure about the hydraulic radius, referring the wetted area divided into the wetted perimeter as R is the hydraulic radius, g acceleration gradient and S is the alluvial boundary layer slope, determined by the equation

$$V_* = \sqrt{gRS} \qquad (15)$$

For trapezoidal cross-sections in laboratory channel conditions the flow plan section shows an equilibrium condition for shaping its width and shape, if the cross-section slope z (defining where z is horizontal to 1 vertical) is computed for below conditions: [4]

z=0.5 if Q<1 m³/s (16)

z=0.5Q^{1/4} if Q>1 m³/s (17)

7. Evaluation of Method

By using sensitivity analysis of observations with analytical model of discharge and slope the parameters of sedimentation density, plan width and water depth were predicted. For different data another computer model is developed to determine the laboratory model discharge, Q, and sedimentation density, from which it is taken for computational procedure the different parameters as water width, water depth and boundary layer slope.

For the same data distribution there are some parameters about sediment granulometry of D_{35} size on sediment distribution curves [5], where the bank full discharge is chosen as a constrained factor. For this reason there are different data collections for evaluation about sandy boundary layer of alluvium and the gravel-bed rivers .By comparison of the results for sand channels existing regime channel relationships are compared with new approaches. It is observed that two approaches overlap in different relationships. Predictions show that the boundary layer slope is a function of sedimentation [6]. If there are deviation in the curve data of sedimentation it is given because of observation errors. Observed and calculated values may readily be compared by considering the discrepancy ratio, the ratio of the predicted to the observed value in the each data set. The mean discrepancy ratio for the slope is 2.20 with a standard deviation of 1.9. From the observed values of the discharge density in the alluvial river boundary it is given the calculation procedure for channel width determination. It showed a good agreement in the range 1> B (m)< 20 between calculated and observed values. The standard deviation is given as 0,33 with the mean discrepancy ratio of 0,96.

The results for gravel rivers in present computations are given for comparing with another scientific data [6]. The sedimentation changes between 10-50 ppm and a sediment size of 100 mm with different diagrams in cartesian coordinate systems [1]. The sensitivity analysis is not appropriate for D_{35} size and there are empirical formulas for D_{50}, D_{65} and D_{90} sizes of sedimentation with overlapping property.

The last examples for sedimentation research were taken from surface boundary layer of alluvial rivers. In gravel-bed rivers, there are different sizes in formulas except D_{35} and D_{50} which are under mean values. The other observations are obviously for computing of different properties like slope, and water depth, water boundary layer thickness with width. The prediction of slope shows a good agreement with empirical formulas. If there are not heavy sedimentation the results of formulas give more overlapping properties with observations and computation. The new methods show the tendency to under predict in low sedimentation. The deviation shows an increasing character with increasing particle property and decreased at the high sedimentation. The standard discrepancy is given as 1,1 where its deviation shows a value of 0,54. As stated earlier, the sedimentation discharge is most important factor in gravel-bed flumes. In addition, D_{35} size of material property with D_{50}, D_{65} and D_{90} is chosen for estimation of different properties.

Because of granulometry curve the computational

method shows a weak relationship in affecting the bank instability, where there exists no one relationship between size distribution of sedimentation and surface boundary layer geometry. The results for width distribution in gravel-bed flumes are not satisfactorily while the complicated procedure of computation.

The sensitivity analysis for widths does not show good agreement at the gravel boundary layer brcause of the lack of laboratory experimentation where

(1) To specify the different grain sizes at the boundary layer,

(2) To specify bed performance at the gravel bed boundary layer,

(3) It is difficult to give all parameters for a flood which is observed in the nature in exact values.

(4) There are some constraints because of the gravel-bed formations and also channel bank formations.

8. Conclusions

(1) The approaching procedure for prediction of boundary layers in a flume movement is derivation by minimum discharge parameters the maximum rates for sedimentation. This method can easily predict the unknown parameters for sand and gravel-bed flumes.

(2) The maximization method is investigated in scope of determining the minimum channel slope the sediment transport at the river valley which shows moving character in plan configuration.

(3) From comparisons with available data it has been shown that: ① Predictions of slopes show scatter when compared with observations. This is not necessarily a defi-ciency in the method. There is a slight tendency to overestimate slopes; ② predictions of widths are excellent except for very large sand channels and for meandering laboratory channels where there is a tendency to underpredict.

References

[1] Ackers, P.. Experiments on small streams in alluvium. Journal of the Hydraulics Division, ASCE, 1964, 90(HY4): 1-38.

[2] Ackers, P.. Use of sediment transport concepts in stable channel design. International Workshop on Alluvial River Problems, Roorkee, India, March, 1980.

[3] Bray, D. I.. Regime Equations for gravel bed rivers. Proceedings of the International workshop on engineering Problems in the Management of Gravel Bed Rivers, Newtown, Powys, United Kingdom, 1980.

[4] Kennedy, R. G.. On the Prevention of Silting in irrigation channels. Proceedings, Institution of Civil Engineering, 1895, 119.

[5] Lacey, G.. Stable channels in alluvium. Proceedings, Institution of Civil Engineers, 1930, 229: 259-384.

[6] Ramette, M.. A Theoretical Approach on Fluvial Processes. International Symposium on River Sedimentation, Beijing, China, 1980.

[7] Yilmaz, L.. On the problem of the meander development in alluvial channels. Bulletin of the Technical University of Istanbul, 1990, 43(4): 553-365.

[8] Yilmaz, L.. Meanderbildung, Beitrag in Türkisches Wissenschafts - Technologiezentrum e.V. Berlin [IWAWI]. Technische Universitaet Berlin, West Germany, 1989.