Global Journal of Researches in Engineering: E
Civil And Structural Engineering
Volume 15 Issue 1 Version 1.0 Year 2015
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

Effect of Different Bed Configuration on Flow Resistance under Different Flow Regimes in an Open Channel

By Muhammad Yaseen, Muhammad Afzal & Khalida Khan
University of the Punjab, Pakistan

Abstract- This study was conducted to evaluate the effect of different bed configuration/bed-forms on flow resistance for different flow conditions in an open channel. The study was limited to investigate whether the flow resistance increases or decreases. The inter-relationship of flow discharge on the friction factor (f) and their quantitative relationship was also determined. A physical model was constructed in the Model Tray Hall of Centre of Excellence in Water Resource Engineering (CEWRE), University of Engineering & Technology Lahore, Pakistan. The sediment commonly available in rivers of Pakistan was used in the channel as bed load under different scenarios. The sediments as bed load were used having the size ranging from 0.5 to 1.2 mm. The bed-forms were predicted using the Athaullah, Simons, Richardson and Van Rijn's Approach. Darcy–Weisbach equation was used to compute the friction factor (f). The results showed that the friction factor (f) in clear water decreased with increase of discharge upto 18 liter per second and a plane bed type was formed. For flow of 18 to 25 liter per second, a ripple bed type was formed due to increase in friction factor. For flow rate of 25 to 40 liter per second the friction factor decreased and dune bed type was formed.

Keywords: bed-forms; channel capacity; friction factor; open channel; suspended sediment.

GJRE-E Classification : FOR Code: 090599

EFFECTOFDIFFERENTBEDCONFIGURATIONONFLOWRESISTANCEUNDERDIFFERENTFLOWREGIMESINANOPENCHANNEL

Strictly as per the compliance and regulations of :

© 2015. Muhammad Yaseen, Muhammad Afzal & Khalida Khan. This is a research/review paper, distributed under the terms of the Creative Commons Attribution-Noncommercial 3.0 Unported License http://creativecommons.org/ licenses/by-nc/3.0/), permitting all non commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

Effect of Different Bed Configuration on Flow Resistance under Different Flow Regimes in an Open Channel

Muhammad Yaseen [α], Muhammad Afzal [σ] & Khalida Khan [ρ]

Abstract- This study was conducted to evaluate the effect of different bed configuration/bed-forms on flow resistance for different flow conditions in an open channel. The study was limited to investigate whether the flow resistance increases or decreases. The inter-relationship of flow discharge on the friction factor (f) and their quantitative relationship was also determined. A physical model was constructed in the Model Tray Hall of Centre of Excellence in Water Resource Engineering (CEWRE), University of Engineering & Technology Lahore, Pakistan. The sediment commonly available in rivers of Pakistan was used in the channel as bed load under different scenarios. The sediments as bed load were used having the size ranging from 0.5 to 1.2 mm. The bed-forms were predicted using the Athaullah, Simons, Richardson and Van Rijn's Approach. Darcy–Weisbach equation was used to compute the friction factor (f). The results showed that the friction factor (f) in clear water decreased with increase of discharge upto 18 liter per second and a plane bed type was formed. For flow of 18 to 25 liter per second, a ripple bed type was formed due to increase in friction factor. For flow rate of 25 to 40 liter per second the friction factor decreased and dune bed type was formed.

Keywords: bed-forms; channel capacity; friction factor; open channel; suspended sediment.

I. Introduction

Knowledge of flow resistance for different flow conditions helps in better understanding of flood routing, backwater curve computation and scouring. Flow resistance may be caused by roughness of the grain surface and form resistance. The resistance in open channel depends on the dimensions of the streams and roughness of its sides as well as on the shape of the channel, the degree of saturation of the stream with suspended sediments and in case of alluvial channels, dunes formed as a result of interaction between the stream flow and channel under erosion. The sediments can be transported either as bed load or suspended load or both. The bed load is the material which rolls, slides or bounces by saltation along the bed almost without leaving the bed whereas the suspended load consists of the particles which remain in suspension in the flow. In steady uniform flow in rigid boundary as well as in alluvial streams, there is a relationship between the mean velocity of flow U, the water surface slope S, the hydraulic radius R, and the characteristics of the channel boundary. Such a relationship is commonly known as flow resistance equation. A resistance equation is essential in the design of irrigation channels, river enhancement works, sediment transport studies, etc. However, the problem of predicting the resistance to flow and velocity distribution in alluvial streams are elaborated by two factors. Firstly, the configuration of the bed changes with changes in flow conditions. This changing bed condition makes it very complicated to describe the resistance due to these bed forms by a constant resistance coefficient. Secondly, under certain conditions, a part of the sediment load is transported in suspension. The material that goes into suspension changes the flow and fluid characteristics and this has large effect on velocity distribution and hence on the mean velocity. The friction factor (f) increases with increasing concentration of the suspended sediment (Yaseen et al., 2010).

The values of friction factors in sand bed rivers depend primarily on bed-form configuration which may change from plane bed, to ripples and dunes, to upper-regime plane bed and antidunes. The specific effects of bed-forms in terms of classification characteristics and resistance to flow can be found in Simons and Richardson (1963), Engelund and Hansen (1967). Specific studies on the geometry of sand dunes and resistance to flow can be found in Vanoni and Hwang (1967), Engelund (1977) and Van Rijn (1982, 1984).

In studies of flow with suspended sediment two issues often raised are the effect of suspended sediment on velocity distribution and flow resistance. Flow computations in rigid-boundary channels and alluvial channels need information on boundary friction. Accurate flow resistance values may improve the channel design and help in deciding depths of the channels. Proper channel design reduces the overtopping and loss of water in irrigation channels. The overall objective of this study was to enhance the understanding regarding flow resistance due to formation of different bed configuration under flow regimes in small channel and hence improve the design parameters of these channels.

Author α: Centre for Integrated Mountain Research (CIMR), University of the Punjab, Lahore, Pakistan.
Author σ: Centre of Excellence in Water Resources Engineering, University of Engineering and Technology, G.T. Road, Lahore, Pakistan. e-mail: afzelbutt@yahoo.com

© 2015 Global Journals Inc. (US)

II. Materials and Methods

Experiments were conducted in the Model Tray Hall of Centre of Excellence in Water Resources Engineering in the rectangular lined channel. The length of the channel is 40 m and its depth is 0.6 m. Bed width of the channel is 0.75 m and its bed slope is 0.35 percent. To measure the average flow depth, water measuring scales were installed at head, middle and tail ends of the channel. The sediments as bed load were used having the size ranging from 0.5 to 1.2 mm. For measurement of discharge in the experimental channel; a 90^0 v-notch weir of length 2 feet at u/s of the experimental channel was installed. The Francis Formula ($Q=0.0138H^{5/2}$) for measurement of discharge (Q in liter per second and H is in cm) was used. Sieved sand (0.5 mm to 1.2 mm) was spread over the bed of the channel. The thickness of the sediment layer was 10 cm. The bed surface was made plain with the help of a wooden template before starting the experiment. Observed the bed form after 30 minutes water runs. Repeat the above procedure for different discharges.

a) *Experimental Scenarios*

Various combinations of discharge were used in the present study. A series of experiments were conducted in sediment free (i.e. clear) water in the channel to determine value of the friction factor 'f_0'. With this setup, 9 different flow rates were used for clear water in the channel ranging from 12 to 39 liter per second for each scenario.

b) *Computation of Flow Resistance (f)*

The ASCE Task Force on Friction Factors in Open Channels (1963) expressed its belief in the general utility of using the Darcy-Weisbach formulation for resistance to flow in open channels, noting that it was more fundamental, and was based on more fundamental research. Darcy–Weisbach equation was used to calculate the friction factor given as:

$$f = \frac{8g\,R_b S}{U^2} \tag{1}$$

Where f is the friction factor, g is the acceleration due to gravity (m/sec²), S is the bed slope of the channel (in fraction), U is the mean flow velocity of the channel (m/sec), R_b is the hydraulic radius with respect to bed (m). Williams's formula was used to compute the hydraulic radius with respect to bed as:

$$R_b = \frac{h}{\left(1 + \frac{0.055h}{b^2}\right)} \tag{2}$$

Where h is the flow depth (m) and b is the channel width (m).

c) *Method of Bed Forms Prediction*

The flow in channels composed of erodible granular material. A strong physical interrelationship exists between the friction factor, the sediment transport rate and the geometric configuration assumed by the surface. The changes in bed forms result from the interaction of the flow, fluid and bed material. Thus the resistance to flow and sediment transport are the functions of the slope and the depth of the stream, the viscosity of the fluid and the size distribution of the bed material. To predict the bed forms following approaches were used.

i. *Simons and Richardson's Approach*

By this approach bed form was predicted in terms of the median fall diameter of bed material in the sand sized range and the stream power from graphical relationship which was developed by Simons and Richardson (1977);

Stream power is the product of shear stress, τ_0 and the mean velocity, U

$$\text{Stream power} = \tau_0 \times U \tag{3}$$

Shear stress can be computed by using the following relation

$$\tau_0 = \gamma DS \tag{4}$$

Where

γ =Specific weight of water (lbs/ft³)

D=Depth of flow (ft)

S = Bed slope (in fraction)

ii. *Athaullah's Approach*

By this approach bed form was predicted in terms of different flow regime based on the Froude number and the relative roughness from graphical relationship which was developed by Athaullah (1968);

Froude number was by using the relation

$$F_r = \frac{U}{\sqrt{gD}} \tag{5}$$

Relative roughness is ratio of the Hydraulic radius, R and the median bed- material size, d.

$$\text{Relative roughness} = \frac{R}{d} \tag{6}$$

iii. *Van Rijn's Approach*

By this approach bed form was predicted in terms of a dimensionless particle parameter, d_* and a transport –stage parameter T from graphical relationship which was developed by Van Rijn (1984);

The dimensionless particle parameter was computed as

$$d_* = d\left[\frac{(\rho_s - \rho)g}{\rho v^2}\right]^{1/3} \tag{7}$$

© 2015 Global Journals Inc. (US)

Where

D = Median size of bed material (m)

ρ = Mass density of fluid (kg/m^3)

ρ_s = Mass density of sediment (kg/m^3)

g = gravitational acceleration (m/sec^2)

υ = Kinematic viscosity (m^2/sec)

The transport-stage parameter was computed by using the following relation;

$$T = \frac{(U_*^{/})^2 - (U_{*c})^2}{(U_{*c})^2} \quad (8)$$

Where

U_{*c} = critical bed shear velocity (m/sec)

$U_*^{/}$ = bed shear velocity related to grain roughness (m/sec)

The critical bed shear velocity was computed as

$$U_{*c} = \left(\frac{\tau_c}{\rho}\right)^{1/2} \quad (9)$$

The critical shear stress was computed from the shields diagram and the bed shear velocity related to grain roughness was computed by following Chezy-type equation;

$$U_*^{/} = \frac{g^{0.5} U}{18 \log\left(12R_b / 3d_{90}\right)} \quad (10)$$

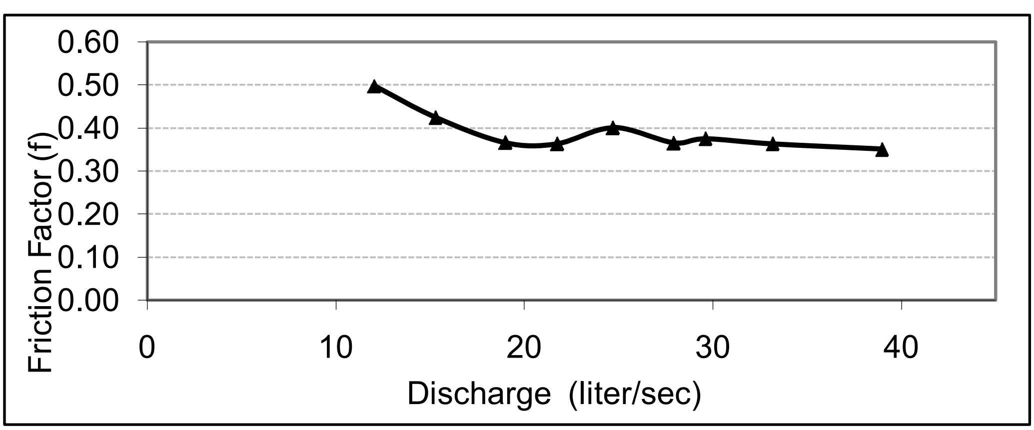
Hydraulic radius with respect to bed was computed by using the equation (2).

III. Results and Discussion

The computation procedure to predict the bed forms by different approaches and their results under discharges are shown in Table 1. All bed forms which were predicted from prediction approaches have the same results and match with physically observed bed forms.

Values of the friction factor in clear water decreases with increase of discharge as shown in Figure 1. The trend of this relation first decreased up to 18 liter per second discharge. In this range of discharge, a plane bed type was formed and the flow resistance decreased. The value of the friction factor (f) in this range of discharge can be computed by using the empirical relation (f = 0.7201- 0.0189 Q). The plane bed formed at smaller velocity ranging from 0.4 to 0.8 ft/sec and smaller and Froude number ranging from 0.14 to 0.23. The friction factor varies from 0.5 to 0.36 over the plane bed. From 18 to 25 liter per sec discharges, the trend of discharge and friction factor (f) relationship increase and in this range of discharge a ripple bed type is formed and friction factor increases. The value of friction factor (f_0) in this range of discharge can be compute by using the relation (f = 0.245 + 0.0061Q). The friction factor shows erratic behavior at discharge rate of 25 l/s but thereafter it again decreases with increase of discharge from 25 to 40 l/s. But rate of decrease in the value of "f" is smaller than the one observed at the smaller flow rates (05-18 l/s). Thus from these results, it can be safely concluded that "f" decreases with increase of discharge but the rate of decrease may be different at different flow rate. For the flow rates of 25 to 40 l/s, the friction factor decreased as also stated earlier. The value of the friction factor (f_0) in this range of discharge can be computed by using the relation (f_0 = 0.4501- 0.0026 Q). The value of the friction factor (f_0) is 0.498 which is maximum at 12 l/s and the value of 0.351 is minimum at discharge of 39 l/s. The bed form dune formed when the flow velocity and Froude number exceed from 0.8 ft/sec and 0.25 respectively. The flow resistance over the dune bed is proportional to stream power.

Figure 1 : Relationship between discharge and friction factor (f_0) for sediment free water



Global Journal of Researches in Engineering (E) Volume XV Issue I Version I Year 2015

© 2015 Global Journals Inc. (US)

Table 1 : Prediction of Bed-Forms by Athaullah's Approach, Simons and Richardson's Approach and Van Rijn's Approach

						Athaullah's Approach			Simons and Richardson's Approach				Van Rijn's Approach	
Sr. No	Discharge	Depth of flow	Velocity	Shear Velocity	Hydraulic Radius	Froud No	Ratio R/d	Bed Forms	Median Fall Diameter	Bed Shear Stress	Stream Power	Bed Forms	Transport-stage parameter	Bed Forms
	Q (liter/sec)	h (m)	U (m/sec)	U_* (m/sec)	R (m)	Fr	R/d		D_{50} (mm)	σ (ft-lb/sec)	σU (ft-lb/ft-sec)		T	
1	5	0.070	0.117	0.049	0.057	0.14	76	Plane	0.75	0.041	0.016	Plane	-4.55	Plane
2	12	0.089	0.222	0.055	0.069	0.24	92	Plane	0.75	0.049	0.036	Plane	-0.69	Plane
3	15	0.099	0.253	0.058	0.075	0.26	100	Ripples	0.75	0.054	0.044	Ripples	-0.35	Ripples
4	19	0.109	0.285	0.061	0.080	0.28	107	Dunes	0.75	0.058	0.053	Dunes	-0.09	Dunes
5	22	0.119	0.299	0.064	0.086	0.28	114	Dunes	0.75	0.061	0.060	Dunes	-0.02	Dunes
6	25	0.134	0.302	0.068	0.093	0.26	124	Dunes	0.75	0.067	0.066	Dunes	-0.04	Dunes
7	28	0.141	0.324	0.070	0.096	0.28	129	Dunes	0.75	0.069	0.073	Dunes	0.08	Dunes
8	30	0.148	0.328	0.071	0.100	0.27	133	Dunes	0.75	0.071	0.076	Dunes	0.09	Dunes
9	33	0.158	0.344	0.074	0.104	0.28	139	Dunes	0.75	0.075	0.083	Dunes	0.15	Dunes
10	39	0.174	0.367	0.077	0.111	0.28	148	Dunes	0.75	0.079	0.095	Dunes	0.23	Dunes

© 2015 Global Journals Inc. (US)

References Références Referencias

1. ASCE Task Force on Friction Factors in Open Channels. (1963). "Friction factors in open channels." J. Hydraulics Div. ASCE 89, 97–143.
2. Engelund, F. and Hansen, E. (1967). ''A monograph on sediment transport in alluvial streams.'' Teknisk Forlag, Copenhagen, 62 p.
3. Engelund, F. (1977). ''Hydraulic resistance of flow over dunes.'' *Progress Rep. No. 44*, Institute Hydraulics and Hydraulic Engineering, Tech. Univ., Denmark.
4. Julien, P. Y., and Klaassen, G. J. (1995). ''Sand-dune geometry of large rivers during floods.'' *J. Hydraul. Eng.,* 121(9), 657–663.
5. Simons, D. B., and Richardson, E. V. (1963. ''Forms of bed roughness in alluvial channels.'' *Trans. Am. Soc. Civ. Eng.,* 128(1), 284–323.
6. Simons, D. B., and Richardson, E. V. (1966). ''Resistance to flow in alluvial channels.'' *Prof. Paper 422 J*, U.S. Geological Survey, Center, Miss.
7. Simons, D.B., and Seinturk, F. (1977). "Sediment Transport Technology." Water Resources Publication, Fort Collins Colorado80522.USA, pp 284-299.
8. Van Rijn, L. C. (1984). ''Sediment transport, part III: Bed forms and alluvial roughness.'' *J. Hydraul. Eng.,* 110(12), 1733–1754.
9. Van Rijn, L. C. (1993). "*Principles of sediment transport in rivers, estuaries and coastal seas"*. Aqua Publications, the Netherlands.
10. Yaseen, M., Latif, M., and Nabi, N. (2011). "Effect of suspended sediment on flow resistance for different condition in an open channel." Proceedings Of International Conference On Water Resources Engineering & Management, Lahore Pakistan, 7-8 March 2011, pp. 211-216.

© 2015 Global Journals Inc. (US)

Global Journals Inc. (US) Guidelines Handbook 2015

www.GlobalJournals.org