Formation of Non-Linear Equation for Mean Depth of Flow and Discharge of Flow

Dr. Birendra Kumar Singh

Civil Engineering Department, Birla Institute of Technology, Mesra, Ranchi-835215 (Jharkhand), India

Abstract: **-The relationship between mean depth of flow and discharge of flow in non-linear form is obtained. And we find that after adjusting the coefficient used in equation, we get the appropriate relationship between mean depth of flow and discharge of flow in non-linear form.**

Keywords: **Mean depth of flow, Discharge of Flow, Non-linear form, Maximum depth of flow.**

I. INTRODUCTION

After adjusting the coefficient of discharge of flow in the developed equation betweenmean depth of flow and discharge of flow we get appropriate value of mean depth of flow compared to any 0.75-inch roughness bed flume data.

II. EXPERIMENTAL SETUP & PROCEDURES

FlumeData were obtained for 0.75-inch roughness bed.

Flume: -The flume is open and it is 1.168m wide and 9.54m long. Roughness bed was obtained by smearing masonite boards with fiberglass resin. The boards were screwed to the bed of the flume.

Experimental Procedure: -Five to seven flows were taken for three different slopes (2, 5 and 8%). At each flow, depth was measured at a single cross section, so that channel properties could be calculated.

III. OBSERVATIONS

(Note: *For data collected, refer to section of Observation tables below*)

For a relation of type $y = ax^b$

$$\log(y) = \log(a) + b\log(x)$$

This is non-linear relation: -

Relationship between mean depth of flow and discharge of flow: -

x = Discharge of flow in m^3/sec

y = Mean depth of flow in meter

Σx = 0.44345 m^3/sec

Σy = 0.6093 meter

Σxy = 0.01901

Σx^2 = 0.0173

Σy^2 = 0.02313

$$\log(a) = \frac{\left(\sum y \sum x^2 - \sum x \sum xy\right)}{\left(N\sum x^2 - (\sum x)^2\right)}$$

$$= \frac{(0.6093\times 0.0173 - 0.44345\times 0.0190)}{\left[17\times 0.0173 - (0.44345)^2\right]}$$

$$= \frac{0.0105 - 0.00843}{0.2941 - 0.1966}$$

$$= \frac{0.0021}{0.0975} = 0.0215$$

$$a = \frac{\sum yi \sum xi^2 - \sum xi \sum xiyi}{N\sum xi^2 - (\sum xi)^2}$$

$$b = \frac{N\sum xiyi - \sum xi \sum yi}{N\sum xi^2 - (\sum xi)^2}$$

Where N = total no of S. No.'s

a = 0.0215

log 10^a = 0.0215

a = $10^{0.0215}$

= 1.0508

$$b = \frac{\left(N\sum xy - \sum x \sum y\right)}{\left(N\sum x^2 - (\sum x)^2\right)}$$

$$= \frac{[17\times 0.01901 - 0.44345\times 0.6093]}{17\times 0.0173 - (0.44345)^2} = 0.5436$$

Hence the developed equation is

$$\frac{d}{d_{\max}} = x \times 1.0508\left(\frac{Q}{Q_{\max}}\right)^{0.5434}$$

x factor is taken to balance L.H.S. = R.H.S. considering same unit in both side.

Hence

$$\frac{0.0333}{0.0698} = x \times 1.0508\left(\frac{0.0261}{0.05460}\right)^{0.5434}$$

$$or\ 0.4771 = x \times 1.0508(0.4780)^{0.5434}$$

= $x \times 1.508$ (0.6696)

= $x \times 0.7036$

$\therefore x$ = 0.6781

Hence required equation is

$$\frac{d}{d_{\max}} = 0.678 \times 1.0508\left(\frac{Q}{Q_{\max}}\right)^{0.5434}$$

$$or\ \frac{d}{d_{\max}} = 0.7125\left(\frac{Q}{Q_{\max}}\right)^{0.5434} \qquad -(1)$$

Check for S. No. (4) [0.75-inch roughness bed data]

$$\frac{d}{0.0698} = 0.7125\left(\frac{0.04047}{0.05460}\right)^{0.5434}$$

$$\frac{d}{0.0698} = 0.7125(0.7412)^{0.5434}$$

=0.7125 x 0.8498

$$\therefore \frac{d}{0.0698} = 0.6055$$

$\therefore$ d = 0.0423 meter ≈ 0.0591 meter

Hence equation (1) is the required equation in the form of $y = ax^b$.

IV. CONCLUSION

The relationship for mean depth of flow and discharge of flow is obtained in non-linear from and we observe that after adjusting the coefficient of discharge of flow we get appropriate value of mean depth of flow compared to any S. No. of 0.75-inch roughness bed data.

V. OBSERVATION TABLES

Table 1: 0.75-inch roughness bed flume data.

Sl. No. (1)	Channel Slope (2)	Discharge of flow in cubic meters per second (3)	Mean depth of flow d in meters (4)	Mean velocity of flow in meters per second (5)
1.	0.02	0.00580	0.0223	0.222
2.	0.02	0.01181	0.0290	0.348
3.	0.02	0.02482	0.0439	0.484
4.	0.02	0.04047	0.0591	0.586
5.	0.02	0.05348	0.0698	0.656
6.	0.05	0.00381	0.0141	0.230
7.	0.05	0.00843	0.0199	0.363
8.	0.05	0.02037	0.0299	0.583
9.	0.05	0.03333	0.0365	0.782
10.	0.05	0.04586	0.0434	0.904
11.	0.05	0.05460	0.0477	0.979
12.	0.08	0.00207	0.0095	0.186
13.	0.08	0.00631	0.0142	0.380
14.	0.08	0.01007	0.0200	0.430
15.	0.08	0.02825	0.0299	0.807
16.	0.08	0.04518	0.0375	1.032
17.	0.08	0.04879	0.0392	1.064

Table 2: 0.75-inch roughness bed flume data.

Sl. No. (1)	Manning's roughness coefficient n (2)	Chezy's resistance factor C (3)	Hydraulic radius R in meter (4)
1.	0.071	10.832	0.021
2.	0.055	14.706	0.028
3.	0.050	17.112	0.040
4.	0.051	17.758	0.054
5.	0.050	18.481	0.063
6.	0.078	9.021	0.013
7.	0.065	11.777	0.019
8.	0.053	15.310	0.029
9.	0.045	18.693	0.035
10.	0.043	19.966	0.041
11.	0.042	20.872	0.044
12.	0.096	6.932	0.009
13.	0.063	11.355	0.014
14.	0.069	11.029	0.019
15.	0.049	16.754	0.029
16.	0.043	19.503	0.035
17.	0.043	19.557	0.037

Table 3: 0.75-inch roughness bed flume data

The summation of discharge of flow in m^3/sec = 0.44345 m^3/sec = Σx

Sum of mean depth of flow in m = 0.6093 meter = Σy

S. No.	Discharge of flow in cubic meters per second (x)	Mean depth of flow d in meters (y)	x^2	y^2	(x) (y)
1.	0.00580	0.0223	0.00003	0.00050	0.00013
2.	0.01181	0.0290	0.0001	0.00084	0.00034
3.	0.02482	0.0439	0.00062	0.0019	0.0011
4.	0.04047	0.0591	0.00164	0.0035	0.0024
5.	0.05348	0.0698	0.00286	0.0049	0.0037
6.	0.00381	0.0141	0.000015	0.0002	0.00005
7.	0.00843	0.0199	0.00007	0.0004	0.00017
8.	0.02037	0.0299	0.00041	0.0009	0.00061
9.	0.03333	0.0365	0.0011	0.0013	0.0012
10.	0.04586	0.0434	0.0021	0.0019	0.0020
11.	0.05460	0.0477	0.0030	0.0023	0.0026
12.	0.00207	0.0095	0.000004	0.00009	0.00002
13.	0.00631	0.0142	0.00004	0.00020	0.00009
14.	0.01007	0.0200	0.00010	0.00040	0.0002
15.	0.02825	0.0299	0.00080	0.00090	0.0008
16.	0.04518	0.0375	0.0020	0.00140	0.0017
17.	0.04879	0.0392	0.0024	0.0015	0.0019

VI. NOTATIONS

The following symbols are used in this paper: -

A = Flow cross sectional area = Wd.
d = Mean depth of flow in meters.
n = Manning's roughnesscoefficient.
P = The Wetted Perimeter.
Q = Discharge of flow in cubic meters per second.
R = Hydraulic radius $= \frac{A}{p} = \frac{Wd}{W+2d}$
S = Slope of channel.
V = Mean velocity of flow in meters per second.
W = Width of channel equal to 1.168m

REFERENCES

[1]. A Caroglu, E.R (1972), "Friction factors is solid material systems "J. Hydraulic Div. Am. SOC.Civ.Eng, 98(HY 4),681 – 699
[2]. Alam, A.M.Z. and Kennedy J.F (1969)," Friction factors for flow in sand bed channels "J Hydraulic Div. Am. SOC Civ. Eng 95(HY 6), 1973 – 1992
[3]. Ben Chie Yen F. (January 1.2002), "Open channel flow resistance" Journal of the Hydraulic Engg. Vol 128, No – 1 ASCE, PP,20 – 39
[4]. Bray, D.I. (1979), "Estimating average velocity in gravel bed – rivers "J Hydraulic Div. Am. SOCCiv. Eng. 105 (HY 9), 1103 – 1122
[5]. Bathurst, J.C., Flow Resistance of Large-Scale Roughness," Journal of the Hydraulics Division, ASCE, Vol. 104, No. HY12, Paper 14239, Dec., 1978, pp.1587.
[6]. Bathurst, J.C., Li, R-M., and Simsons, D.B., Hydraulics of Mountains Rivers, Report No.CER7879JCB-RML-DBS55, Civil Engineering Department, Colorado State University, Fort Collins, Colo.,1979.
[7]. Bathurst, J.C., "Flow Resistance in Boulder-Bed Streams," 22-28, 1980. University East Anglia/Institute Hydrology/Colorado State University International Workshop on Engineering Problems in the Management of Gravel Bed Rivers, held at Gregyong, Newtown, Wales, U.K. (Proceedings to be Published by John Wiley and Sons, Inc., New York, N.Y.)
[8]. Charlton, F.G., Brown, P.M., and Benson, R.W., "The Hydraulic Geometry of Some Gravel Riversin Britain." Report No. ITI80. Hydraulics Research Station Wallingford, U.K., July 1978.
[9]. Day, T., "The channel Geometry of Mountain Streams." Mountains Geomorydlogy Olav Slaymaker and H.J. McPherson, eds, Tantalus Research Ltd., B.C., 1972, pp. 141-149.
[10]. Day, T.T., discussion of "Resistance Equation for Alluvial-Channel Flow," by D.E. Burkham And D.R. Dawdy, Journal of the Hydraulics Division, ASCE, Vol. 103, No. HY5. Proc. Paper 12896,May, 1977, pp. 582-584.
[11]. Dey S, Raikar R.V. (2007), "Characteristic of loose rough boundary streams at near threshold" Journal of Hydraulic Engg. ASCE 133(3), 288-304
[12]. Flammer, G.H., Tullis,J. Mason, E.S., "Free Surface Velocity Gradient Flow Past Hemisphere," Journal of the Hydraulics Division, ASCE, Vol. 96, No.HY7, ProcPaper 7418, July, 1970, pp.1485-1502.
[13]. Golubtsov, V.V., "Hydraulic Resistance and Formula for Computing the Average Flow Velocity of Mountain Rivers," Soviet Hydrology: Selected Papers, American Geophysical Union, No. 5, 1969,pp. 500-511.
[14]. Griffiths, G.A. (1981), "Flow resistance in course gravel bed rivers "J. Hydraulic Div. And soc.Civ.Eng. 107 (HY – 7), 899 – 918
[15]. Hartung, F., and Scheuerlein. H., "Macroturbulent Flow in Steep Open Channels with High Natural Roughness," Proceedings of the Twelfih Congress of the International Association for Hydraulic Research, Fort Collins, Colo., Vol, 1, Sept., 1967, pp, 1-8.
[16]. Herbich, J.B., and Shulits, S., "Large-Scale Roughness in Open Channel Flow," Journal of The Hydraulics Division, ASCE, Vol. 90, No. HY6, Proc. Paper 4105, Nov., 1964, pp, 203-230.
[17]. Hey, R.D., "Flow Resistance in Gravel-Bed Rivers," Journal of the Hydraulics Division, ASCE, Vol.105, No. HY4, Proc. Paper 14500, Apr., 1979, pp, 365-379.
[18]. Hey R.D (1979) "Flow resistance in gravel bed rivers "J HydraulicDiv Am SOC CIV Eng, 105 (HY –4), 365 – 379.
[19]. Johansson, C.E., "Orientation of Pebbles in Running Water," Geografiska Anneler, Vol. 45, Stockholan, Sweden, 1963, pp,85-112.
[20]. Judd, H.E., and Peterson, D.F.., "Hydraulics of Large Bed Element Channels," Report No. PRWG17-6, Utah Water Research Laboratory, Utah State University, Logan, Utah, 1969.
[21]. James C. Bathurst (December 1981), "Resistance Equation for Large Scale Roughness "Journal ofthe Hydraulics Division, ASCE, Vol 107 NOHY-12, pp 1593-1613.
[22]. James C. Batharst (December 1981), "Resistance Equation for Large Scale Roughness" Journal of the Hydraulics Division, American Society of Civil Engineers, Vol. 107 NO HY 12, PP 1593-1613.
[23]. James C. Bathurst (December 1978),"Flow resistance of large-scale roughness "Journal of the Hydraulic Division Vol 104NO12PP1587-1603
[24]. J. Aberle and G.M. Smart (2003), "The influence of roughness structures on flow resistance on steep slopes", Journal of Hydraulic Research Vol 41, Issue 3, Available online 01 Feb 2010,259-269

[25]. Kellerhals, R., "Runoff Routing Through Steep Natural Streams," Journal of the Hydraulics Division, ASCE, Vol. 96, No. HY11, Proc. Paper 7666, Nov., 1970, pp, 2201-2217.

[26]. LI, R-M., Simons, D.B., Ward, T.J., and Steele, K.S., "Phase 1 Report: Hydraulic Model Study of Flow Control Structures," Report No. CER77-78RML-DBS-TJW, KSS15, Department of Civil Engineering, Colorado State University, Fort Collins, Colo., Nov., 1977.

[27]. Lovera, F. and kennedy J.F (1969), "Friction factors for flat – bed flows in sand channel" J Hydraulic Div, Am. Soc. CivEng 95 (HY 4) 1227 – 1234.

[28]. Miller, J.P., "High Mountain Streams: Effects of Geology on Channel Characteristics And Bed Material," Memoir No. 4, State Bureau of Mines and Mineral Resources, New Mexico Institute of Mining and Technology, Socorro, N.M., 1958.

[29]. Peterson, D.F., and Mohanty, P.K., "Flume Studies of Flow in Steep, Rough Channels,"Journal ofthe Hydraulics Division, ASCE, Vol. 86, HY9, Proc. Paper 2653, Nov., 1960, pp 55- 76.

[30]. Petryk, S. and shen, H.W (1971), "Direct measurement of shear stream in a flume, "JHydraulic Div. Am. SOC. Civ. Eng. 97(HY – 6), 883 – 887

[31]. Thompson, S.M. and Campbell, P.L. (1979), "Hydraulics of a large channel paved withboulders" J. Hydraulics Research, 17(4), 341-354

[32]. Van RiJn, L.C. (1982), "Equivalent roughness of alluvial bed" J Hydraulics Div, Am, SOC.Civ.Eng.108 (HY10), 1215-1218

[33]. Whiting P.J; and Dietrich W.E. (1990), "Boundary Shear Stress and roughness over mobile alluvial beds" J Hydraulic Engg 116(12), 1495-01511