Effect of Roughness on Conveyance of Channel

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Abstract: - The effect of surface roughness (i.e. Manning's roughness coefficient, Darcy Weisbach resistance coefficient) is studied on conveyance or channel carrying capacity of channel. Also the effect of roughness due to size of the roughness material is seen on conveyance on channel. Velocity is much reduced with respect to Darcy Weisbach resistance coefficient as compared to Manning's roughness coefficient.

Keywords: **Surface roughness; Size of the roughness material; Mean depth of flow; Conveyance; Mean velocity of flow Flume.**

I. INTRODUCTION

Darcy Weisbach resistance coefficient is found from $f = \frac{8\,gRs}{V^2}$ and $n = \frac{1.49R^{2/3}S^{1/2}}{V}$

f = Darcy Weisbach resistance coefficient, g=Acceleration due to gravity into account because depth of flow increases due to roughness. R= Hydraulic radius to be taken into account because roughness is more effective in lesser depth of flow and hydraulic radius is lesser than mean depth of flow. S= Channel slope. V=Mean Velocity of flow in m/sec. n=Manning's roughness coefficient. There is much reduction in mean velocity of flow for Darcy Weisbach resistance coefficient. Mean depth of flow depends upon mean velocity of flow hence mean depth of flow is less and discharge of flow is less. Hence, conveyance is lesser for Darcy Weisbach resistance coefficient as compared to conveyance of a channel found with respect to Manning's roughness coefficient.

II. EXPERIMENTAL SETUP & PROCEDURES

Data were obtained for 0.75-inch roughness bed.

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

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

III. RESULTS AND ANALYSIS

(Refer Appendix 1 - Observation Tables for data)

$$K = \frac{1.114\,A\,(d)^{0.898}}{n} \qquad - \qquad (1)$$

$$K = \frac{1.114\,A\,(d)^{0.898}}{f} \qquad - \qquad (2)$$

Where K = Conveyance or channel carrying capacity. A= low Cross Sectional Area = Wd where W=Width of Channel = 1.168m, d = Mean depth of flow in meters. n=Manning's roughness coefficient, f=Darcy Weisbach resistance coefficient.

Since conveyance increases, it shows that mean depth of flow increases hence flow across sectional area & mean depth of flow are taken in numerator. And as surface roughness increases i.e. n & f increases, the velocity of flow decreases and channel carrying capacity or conveyance decreases. Hence, n & f are taken in denominator. Substituting the average values of different parameters in equation (1) and (2) of 0.75-inch roughness bed flume data, we have K=0.0358 m^3/sec from equation (1) and from equation (2), K=0.0042 m^3/sec. Velocity is much reduced with respect to Darcy Weisbach resistance coefficient as compared to Manning's roughness coefficient because power of V is two in f and power of V is unity in n. Mean depth of flow is much reduced for Darcy Weisbach resistance coefficient as compared to Manning's roughness coefficient since mean depth of flow depends upon mean velocity of flow. Hence conveyance K is lesser for f as compared to n.

Similarly

$$K = \frac{1.079\,A\,(b)^{0.927}}{n}\,x\,W \qquad - \qquad (3)$$

$$K = \frac{1.079\,A\,(b)^{0.927}}{f}\,x\,W \qquad - \qquad (4)$$

Where b = Function of effective roughness concentration depending upon Wetted frontal cross sectional area.

From equation (3), by substitution of average values of different parameters for 0.75-inch roughness bed we have K= 0.469m^3/sec and K = 0.0548 m^3/sec from equation (4) since we get less K in case of f. Here, increase in mean depth of flow is concerned for function of effective roughness concentration. Here the value of K is more for (3) & (4) as compared to equation (1) and (2)

Similarly

$$K = \frac{1.114\,A\left(\frac{d}{S_{50}}\right)^{0.898}}{f}\,x\,W \qquad - \qquad (5)$$

Where $\frac{d}{S_{50}}$ = Relative submergence and from equation (5), K = 0.374m^3/sec.

Also

$$K = \frac{1.114\,A\left(\frac{d}{S_{50}}\right)^{0.898}}{n}\,x\,W \quad - \quad (6)$$

$\frac{d}{S_{50}}$ = Relative submergence where S_{50} = The size of the short axis which isbigger than or equal to 50% of short axis.

From equation (6), K = 3.195m^3/sec. Here, the submergence ofroughness material is concerned. Here, value of conveyance is more as compared to mean depth of flow and function of effective roughness concentration.

Also conveyance with respect to size of roughness material:-

$$K = 1.114(A)\,(d)^{0.898}\,x\,\frac{d}{D_{50}} \quad - \quad (7)$$

As d increases, $\frac{d}{D_{50}}$ increases. Here size of the roughness material is fixed i.e. 0.75-inch roughness bed is taken. Here roughness $\frac{d}{D_{50}}$ and $\frac{d}{D_{84}}$ depends upon mean depth of flow. D_{50}= The size of the median axis which is greater than or equal to 50% of median axis = 0.013 metre for 0.75-inch roughness bed. D_{84}= The size of the median axis which is greater than or equal to 84% of median axis. D_{84} =0.0193 metre.

From equation (7), K=0.0052m^3/sec and also with respect to $\frac{d}{D_{84}}$ the equation is

$$K = 1.114\,A\,(d)^{0.898}\,x\,\frac{d}{D_{84}} \quad - \quad (8)$$

Hence from equation (8), K = 0.0035m^3/sec

Since size of D_{84} is more than D_{50}hence there is more reduction in mean velocity of flow. There is decrease in depth of flow since depth of flow depends upon mean velocity of flow. Hence we get lesser value of K from equation (8) as compared to equation (7).

$\frac{d}{D_{50}}$ and $\frac{d}{D_{84}}$ represent the roughness due to size of the roughness material. Here we can say there is much reduction in mean velocity of flow with respect to size of the roughness material as compared to surface roughness (n & f). And mean depth of flow depends upon mean velocity of flow. Hence channel carrying capacity or conveyance is lesser with respect to size of the roughness material as compared to surface roughness.

Similarly with respect to function of effective roughness concentration:-

$$K = 1.079\,A\,(b)^{0.927}\,x\,W\,x\,\frac{d}{D_{50}} \quad - \quad (9)$$

and from equation (9) , K = 0.0684 m^3/sec.

Here, as mean depth of flow increases $\frac{d}{D_{50}}$ and $\frac{d}{D_{84}}$ increases because $\frac{d}{D_{50}}$ and $\frac{d}{D_{84}}$ depend upon mean depth of flow because size of the roughness material is fixed i.e. 0.75 inch roughness bed is taken. Here $\frac{d}{D_{50}}$ and $\frac{d}{D_{84}}$ are taken in numerator in the equation of conveyance. We get more conveyance with respect to function of effective roughness concentration as compared to mean depth of flow.

Hence, we can say that size of the roughness material is more effective as compared to surface roughness to reduce more velocity of flow.

$$K = 1.079\,A\,(b)^{0.927}\,x\,W\,x\,\frac{d}{D_{84}} \quad - \quad (10)$$

K= 0.0461m^3/sec.

Similarly

$$K = 1.114\,A\left(\frac{d}{S_{50}}\right)^{0.898} x\,W\,x\,\frac{d}{D_{50}} \quad - \quad (11)$$

K=0.4665m^3/sec

Also

$$K = 1.114\,A\left(\frac{d}{S_{50}}\right)^{0.898} x\,W\,x\,\frac{d}{D_{84}} \quad - \quad (12)$$

K=0.2690m^3/sec

IV. CONCLUSION

The size of the roughness is more effective as compared to surface roughness. Hence, there is more decrease in mean velocity of flow due to size of the roughness material and depth of flow depends upon mean velocity of flow. Conveyance is lesser with respect to size of the roughness material as compared to surface roughness. Also function of effective roughness concentration depends upon Wetted frontal cross sectional area or increase in depth of flow due to roughness in high velocity of flow. And relative submergence depends upon submergence of roughness material. Hence, we get more conveyance for function of effective roughness concentration and relative submergence as compared to mean depth of flow.

V. APPENDIX 1 – OBSERVATION TABLES

Table 1 : Flume data for 0.75 inch roughness bed.

Sl. No. (1)	Channel Slope (2)	Discharge in cubic meters per second (3)	Mean depth d in meters (4)	Mean velocity 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: Flume data for 0.75 inch roughness bed

Sl. No. (1)	Hydraulic radius R (2)	Manning's roughness coefficient n (3)	Darcy Weisbach resistance co-efficient f (4)	Depth d' of bed datum in meters (5)	Relative roughness area $\frac{Aw}{Wd'}$ (6)	Function of effective roughness concentration (b) (7)
1.	0.021	0.071	0.708	0.0282	0.2081	0.397
2.	0.028	0.055	0.375	0.0349	0.1696	0.480
3.	0.040	0.050	0.294	0.0495	0.1146	0.660
4.	0.054	0.051	0.270	0.0642	0.0801	0.846
5.	0.063	0.050	0.255	0.0746	0.0641	0.975
6.	0.013	0.078	1.046	0.0204	0.3052	0.269
7.	0.019	0.065	0.591	0.0262	0.2411	0.349
8.	0.029	0.053	0.345	0.0360	0.1709	0.482
9.	0.035	0.045	0.234	0.0426	0.1433	0.560
10.	0.041	0.043	0.209	0.0491	0.1156	0.655
11.	0.044	0.042	0.195	0.0536	0.1090	0.693
12.	0.009	0.096	1.731	0.0159	0.4031	0.189
13.	0.014	0.063	0.617	0.0211	0.3253	0.255
14.	0.019	0.069	0.680	0.0258	0.2222	0.370
15.	0.029	0.049	0.289	0.0363	0.1742	0.477
16.	0.035	0.043	0.221	0.0435	0.1382	0.575
17.	0.037	0.043	0.218	0.0450	0.1285	0.605

Table 3: Flume data for 0.75 inch roughness bed:-

S_{50}=0.008m, D_{50}=0.013m,D_{84}=0.0193m

Sl. No. (1)	$\frac{d}{S_{50}}$ (2)	$\frac{d}{D_{50}}$ (3)	$\frac{d}{D_{84}}$ (4)
1.	2.790	1.715	1.155
2.	3.626	2.231	1.503
3.	5.482	3.377	2.275
4.	7.383	4.546	3.062
5.	8.728	5.369	3.617
6.	1.768	1.085	0.731
7.	2.484	1.531	1.031
8.	3.736	2.300	1.549
9.	4.557	2.808	1.891
10.	5.428	3.338	2.249
11.	5.965	3.669	2.472
12.	1.190	0.731	0.492
13.	1.776	1.092	0.736
14.	2.505	1.538	1.036
15.	3.743	2.300	1.549
16.	4.682	2.885	1.943
17.	4.905	3.015	2.031

VI. APPENDIX 2 - NOTATIONS

The following symbols are used in this paper:-

A = Flow cross sectional area = Wd.

A_w = Wetted Cross Sectional area

b = Function of effective roughness concentration.

d = Mean depth of flow in meters.

d' = Depth of bed datum in meters.

D_{50} = The size of median axis which is bigger than or equal to 50% of median axis.

D_{84} = The size of median axis which is bigger than or equal to 84% of median axis.

f = Darcy Weisbach resistance coefficient

g = Acceleration due to gravity

k = Conveyance in m^3/sec

n = Manning's roughness coefficient .

P = Wetted Perimeter.

R = Hydraulic radius $= \frac{A}{p} = \frac{Wd}{W+2d}$

S = Channel slope.

S_{50} = The size of the short axis which is bigger than or equal to 50% of short axis.

$\frac{d}{S_{50}}$ = Relative submergence.

Q = Discharge in cubic meters per second.

V = Mean velocity of flow in meters per second.

W = Width of the channel = 1.168m

VII. APPENDIX 3 – FORMULAE USED

$$V = \frac{1.49}{n} R^{2/3} S^{1/2}$$

$$\left(\frac{8}{f}\right)^{1/2} = \frac{V}{(gRS)^{1/2}}$$

$$A + A_w = Wd'$$

$$\frac{A_w}{Wd'} = \left(\frac{w}{d}\right)^{-b}$$

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