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FRICTION FACTOR IN OPEN CHANNEL

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ABSTRACT

There is reduction in mean velocity of flow in steep slope for larger size of roughness material. There is more roughness for larger size of roughness material with respect to Darcy Weisbach resistance coefficient as compared to Manning's roughness coefficient. There is more roughness for larger size of roughness material with respect to $\frac{d}{D_{50}}$ as compared to $\frac{d}{D_{84}}$.

Subject Headings: Boulders, Channels, Drag, Flow Resistance, Flumes

KEYWORDS: Friction Factor, Hydraulic Geometry, Roughness

INTRODUCTION

2.0 inch roughness bed provides large scale roughness and 0.75 inch roughness bed provides intermediate scale roughness.

For large scale roughness $\frac{d}{D_{50}} < 2$ and $\frac{d}{D_{84}} < 1.2$ and for intermediate scale roughness $2 < \frac{d}{D_{50}} < 7.5$ and $1.2 < \frac{d}{D_{84}} < 4$.

Experimental Setup and Procedures: Data were obtained for 0.75 inch and 2.0 inch roughness bed.

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

Experimental Procedure: For each bed, 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. In flows with large scale roughness, the cross sectional area of flow is significantly affected by the projections of the elements into the flow.

Roughness depends upon $\frac{d}{D_{50}}$ and $\frac{d}{D_{84}}$. For large scale roughness $\frac{d}{D_{50}} < 2$ and $\frac{d}{D_{84}} < 1.2$ where d is the mean depth of flow and D_{50}= the size of the median axis which is bigger than or equal to 50% of median axis. Similarly

D_{84} = The size of the median axis which is bigger than or equal to 84% of median axis. Similarly for Intermediate Scale roughness $2 < \frac{d}{D_{50}} < 7.5$ and $1.2 < \frac{d}{D_{84}} < 4$.

Table 1: Flume Data for 0.75 Inch Roughness Bed

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

Table 2: Flume Data for 0.75 Inch Roughness Bed: D_{50}=0.013m, D_{84}=0.0193m

Sl. No. (1)	Hydraulic Radius $R=\frac{A}{P}=\frac{Wd}{W+2d}$ in Meters (2)	$\frac{d}{D_{50}}$ (3)	$\frac{d}{D_{84}}$ (4)	Manning's Roughness Coefficient n (5)
1	0.021	1.715	1.155	0.071
2	0.028	2.231	1.503	0.055
3	0.040	3.377	2.275	0.050
4	0.054	4.546	3.062	0.051
5	0.063	5.369	3.617	0.050
6	0.013	1.085	0.731	0.078
7	0.019	1.531	1.031	0.065
8	0.029	2.300	1.549	0.053
9	0.035	2.808	1.891	0.045
10	0.041	3.338	2.249	0.043
11	0.044	3.669	2.472	0.042
12	0.009	0.731	0.492	0.096
13	0.014	1.092	0.736	0.063
14	0.019	1.538	1.036	0.069
15	0.029	2.300	1.549	0.049
16	0.035	2.885	1.943	0.043
17	0.037	3.015	2.031	0.043

Table 3: Flume Data for 0.75 Inch Roughness Bed

Sl. No. (1)	Darcy Weisbach Resistance Coefficient F(2)	Depth d' of Bed Datum in Meters (3)
1	0.708	0.0282
2	0.375	0.0349
3	0.294	0.0495
4	0.270	0.0642
5	0.255	0.0746
6	1.046	0.0204
7	0.591	0.0262
8	0.345	0.0360
9	0.234	0.0426
10	0.209	0.0491
11	0.195	0.0536
12	1.731	0.0159
13	0.617	0.0211
14	0.680	0.0258
15	0.289	0.0363
16	0.221	0.0435
17	0.218	0.0450

Table 4: Flume Data for 0.75 Inch Roughness Bed. M=1.696, C=0.822

Sl. No. (1)	$\frac{b}{m}$ (2)	$\frac{b}{c}$ (3)	Relative Roughness Area $\frac{Aw}{Wd'}$ (4)	Function of Effective Roughness Concentration (b) (5)
1	0.234	0.483	0.2081	0.397
2	0.283	0.584	0.1696	0.480
3	0.389	0.803	0.1146	0.660
4	0.499	1.029	0.0801	0.846
5	0.575	1.186	0.0641	0.975
6	0.159	0.327	0.3052	0.269
7	0.206	0.425	0.2411	0.349
8	0.284	0.586	0.1709	0.482
9	0.330	0.681	0.1433	0.560
10	0.386	0.797	0.1156	0.655
11	0.409	0.843	0.1090	0.693
12	0.111	0.230	0.4031	0.189
13	0.150	0.310	0.3253	0.255
14	0.218	0.450	0.2222	0.370
15	0.281	0.580	0.1742	0.477
16	0.339	0.700	0.1382	0.575
17	0.357	0.736	0.1285	0.605

Table 5: Flume Data for 2.0 Inch Roughness Bed

Sl. No. (1)	Channel Slope (2)	Discharge in Cubic Meters per Second (3)	Mean Velocity in Meters per Second (4)	Mean Depth d in Meters (5)
1	0.02	0.00329	0.100	0.0282
2	0.02	0.00837	0.189	0.0378
3	0.02	0.01158	0.227	0.0436
4	0.02	0.02541	0.377	0.0578

Table 5: Contd.,

5	0.02	0.04047	0.519	0.0668
6	0.02	0.04949	0.601	0.0705
7	0.05	0.00329	0.132	0.0213
8	0.05	0.00713	0.214	0.0285
9	0.05	0.01413	0.337	0.0359
10	0.05	0.02068	0.431	0.0411
11	0.05	0.02941	0.542	0.0465
12	0.05	0.04368	0.643	0.0582
13	0.08	0.00247	0.162	0.0130
14	0.08	0.00565	0.205	0.0236
15	0.08	0.1077	0.313	0.0295
16	0.08	0.02187	0.515	0.0363
17	0.08	0.03249	0.637	0.0437
18	0.08	0.03724	0.712	0.0448

Table 6: Flume Data for 2.0 Inch Roughness Bed. C = 0.939 D_{50} = 0.043 m, D_{84} = 0.047m

Sl. No. (1)	$\frac{d}{D_{50}}$ (2)	$\frac{d}{D_{84}}$ (3)	Manning's Roughness Coefficient n (4)	Darcy Weisbach Resistance Coefficient F(5)	$\frac{b}{c}$ (6)
1	0.656	0.600	0.186	4.463	0.234
2	0.879	0.804	0.120	1.654	0.299
3	1.014	0.928	0.109	1.323	0.345
4	1.344	1.230	0.078	0.639	0.459
5	1.553	1.421	0.061	0.390	0.514
6	1.640	1.500	0.055	0.307	0.518
7	0.495	0.453	0.190	4.796	0.175
8	0.633	0.606	0.139	2.437	0.232
9	0.835	0.764	0.103	1.245	0.300
10	0.956	0.874	0.087	0.870	0.333
11	1.081	0.989	0.075	0.621	0.371
12	1.353	1.238	0.073	0.553	0.476
13	0.302	0.277	0.141	3.092	0.089
14	0.549	0.502	0.164	3.522	0.171
15	0.686	0.628	0.123	1.892	0.222
16	0.844	0.772	0.085	0.860	0.246
17	1.016	0.930	0.078	0.676	0.284
18	1.042	0.953	0.070	0.554	0.332

Table 7: Flume Data for 2.0 Inch Roughness Bed

Sl. No. (1)	Hydraulic Radius $\frac{Wd}{W+2d}$ in Meters (2)	Relative Roughness Area $\frac{Aw}{Wd'}$ (3)	Depth d' of Bed Datum in Meters (4)	Function of Effective Roughness Concentration (b) (5)
1	0.027	0.4413	0.0505	0.220
2	0.036	0.3814	0.0611	0.281
3	0.041	0.3443	0.0665	0.324
4	0.053	0.2735	0.0795	0.431
5	0.060	0.2511	0.0892	0.483
6	0.063	0.2553	0.0947	0.486
7	0.021	0.5179	0.0442	0.164
8	0.027	0.4450	0.0513	0.218
9	0.034	0.3750	0.0575	0.282

Table 7: Contd.,

10	0.038	0.3508	0.0633	0.313
11	0.043	0.3252	0.0688	0.348
12	0.053	0.2617	0.0788	0.447
13	0.013	0.6842	0.0411	0.084
14	0.023	0.5330	0.0505	0.161
15	0.028	0.4646	0.0551	0.208
16	0.034	0.4483	0.0659	0.231
17	0.041	0.4155	0.0747	0.267
18	0.041	0.3615	0.0701	0.312

Table 8: Flume Data for 2.0 Inch Roughness Bed m=1.483

Sl. No. (1)	$\frac{b}{m}$ (2)
1	0.148
2	0.189
3	0.218
4	0.291
5	0.326
6	0.328
7	0.111
8	0.147
9	0.190
10	0.211
11	0.235
12	0.301
13	0.057
14	0.109
15	0.140
16	0.156
17	0.180
18	0.210

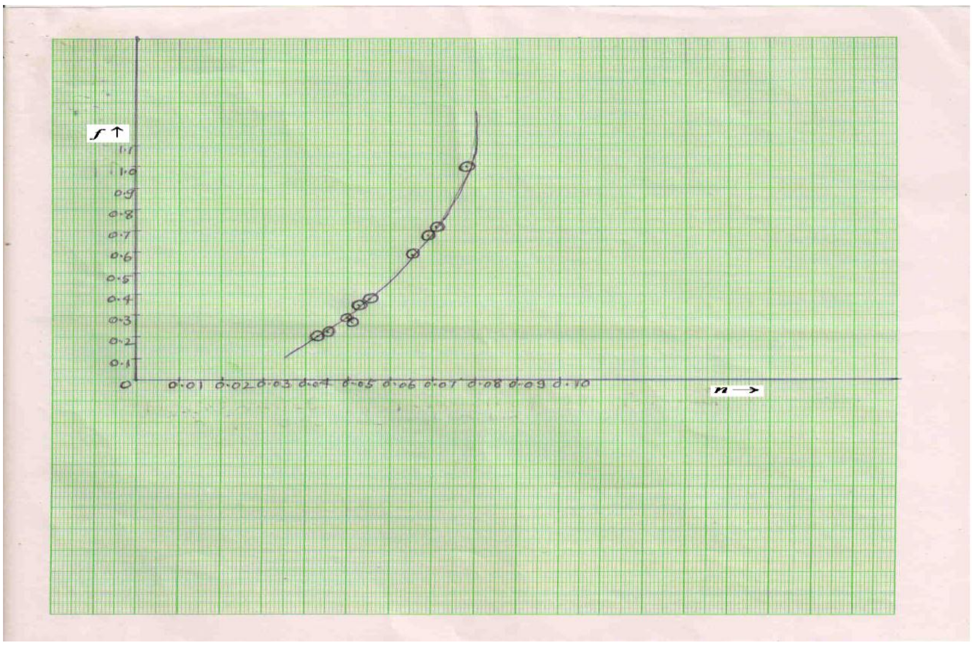

Figure 1: Variation of Parameter f with Parameter n for 0.75 Inch Roughness

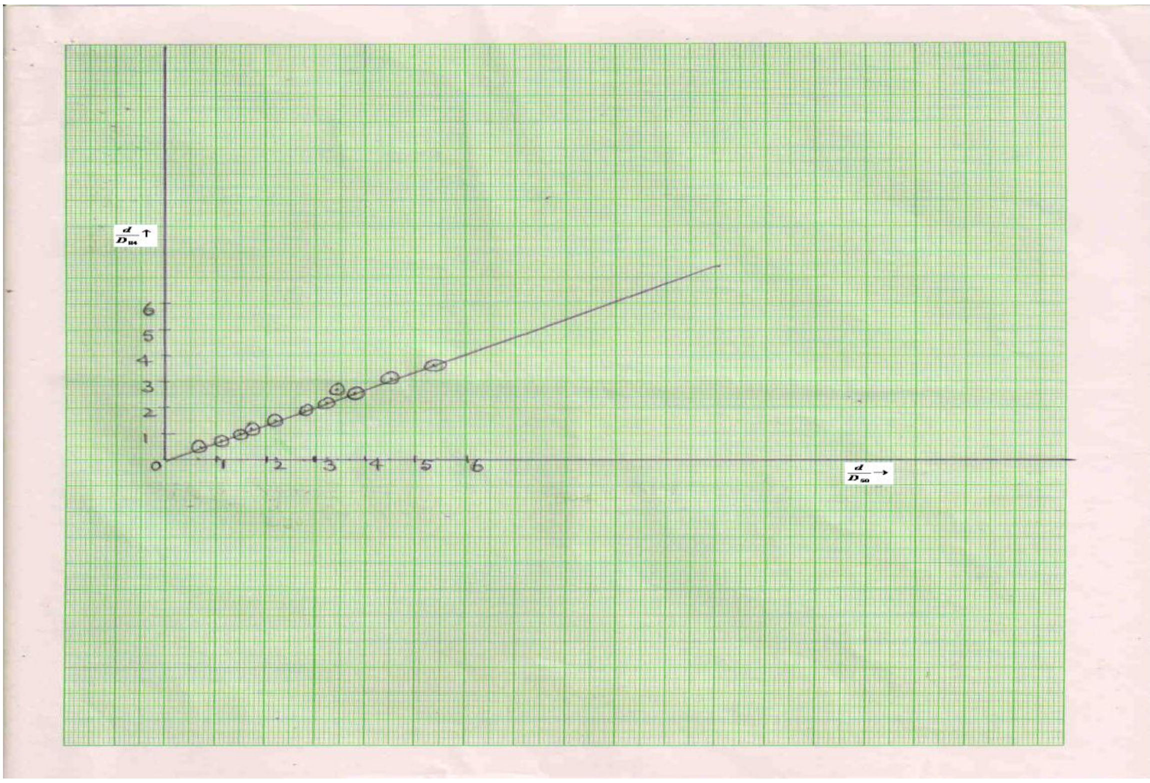

Figure 2: Variation of Parameter $\frac{d}{D_{84}}$ with Parameter $\frac{d}{D_{50}}$ for 0.75 Inch Roughness Bed

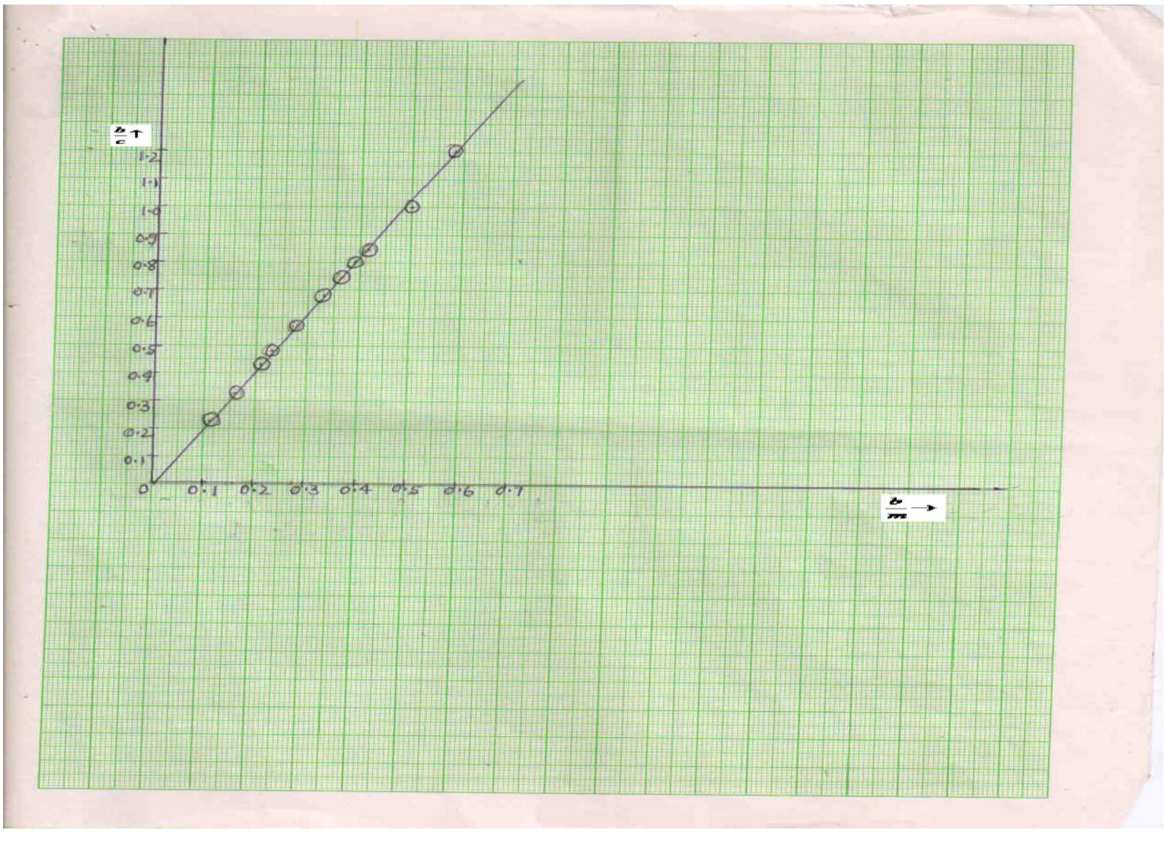

Figure 3: Variation of Parameter $\frac{b}{c}$ with Parameter $\frac{b}{m}$ for 0.75 Inch Roughness Bed

RESULTS AND ANALYSIS

0.75 Inch Roughness Bed

Average mean velocity in step slope = 0.650 m/sec

Average $\frac{b}{c}$ = 0.632

Average n= 0.057

Average f= 0.487

Average $\frac{b}{m}$ = 0.306

Average $\frac{d}{D_{50}}$ = 2.561

Average $\frac{d}{D_{84}}$ = 1.725

2.0 Inch Roughness Bed

Average mean velocity of flow in steep slope = 0.424 m/sec

Average $\frac{b}{c}$ =0.311

Average n = 0.108

Average f= 1.661

Average $\frac{b}{m}$ = 0.197

Average $\frac{d}{D_{50}}$ = 0.939

Average $\frac{d}{D_{84}}$ = 0.859

Average reduction in mean velocity in steep slope for 2.0 inch roughness bed i.e. for large scale roughness is 1.533 times more as compared to 0.75 inch roughness bed i.e. for intermediate scale roughness hence erosion of the channel bed is much reduced in steep slope for large scale roughness.

There is 1.894 times more roughness for 2.0 inch roughness bed as compared to 0.75 inch roughness bed with respect to n.

There is 3.411 times more roughness for 2.0 inch roughness bed compared to 0.75 inch roughness bed with respect to f. Since V $=\frac{1.49}{n}R^{2/3}S^{1/2}$ and $\left(\frac{8}{f}\right)=\left[\frac{V}{(gRS)^{1/2}}\right]^2$ hence there is more roughness for 2.0 inch roughness bed with respect to n.

There is 2.727 times more roughness for 2.0 inch roughness bed as compared to 0.75 inch roughness bed with respect to $\frac{d}{D_{50}}$.

There is 2.008 times more roughness for 2.0 inch roughness bed as compared to 0.75 inch roughness bed with respect to $\frac{d}{D_{84}}$. Since $D_{50} < D_{84}$ hence more roughness for 2.0 inch roughness bed with respect to $\frac{d}{D_{84}}$.

Lesser value of $\frac{d}{D_{50}}$ and $\frac{d}{D_{84}}$ indicates more roughness since larger size has more roughness. Hence D_{50} and D_{84} are more for larger size of roughness material hence lesser value of $\frac{d}{D_{50}}$ and $\frac{d}{D_{84}}$ indicate more roughness.

There is 1.553 times more $\frac{b}{m}$ for 0.75 inch roughness bed as compared to 2.0 inch roughness bed since mean velocity of flow is more for 0.75 inch roughness bed and roughness is more effective in high velocity of flow to get more wetted frontal cross sectional area hence functions of effective roughness concentration b is more for 0.75 inch roughness bed hence $\frac{b}{m}$ is more for 0.75 inch roughness bed. Since m is constant depends upon roughness material.

Similarly there is 2.032 times more $\frac{b}{c}$ for 0.75 inch roughness bed as compared to 2.0 inch roughness bed. Since b is more for 0.75 inch roughness bed due to high velocity of flow. C is constant depends upon roughness material.

Since m = 1.696 for 0.75 inch roughness bed and c = 0.822 for 0.75 inch roughness bed. Hence there is more increase in $\frac{b}{c}$ for 0.75 inch roughness bed as compared to $\frac{b}{m}$ with respect to 2.0 inch roughness bed.

0.75 Inch Roughness Bed

Relationship for $\frac{b}{c}$ with n, f, $\frac{b}{m}$, $\frac{d}{D_{50}}$ and $\frac{d}{D_{84}}$

$$\frac{b}{c}=0.996\left(\frac{d}{D_{50}}\right)^{1.113}-0.930(n)^{1.075}-0.708(f)^{1.412}-0.928\left(\frac{b}{m}\right)^{1.077}-0.898\left(\frac{d}{D_{84}}\right)^{1.114} \quad (1)$$

Relationship for $\frac{b}{c}$ with n, f, $\frac{b}{m}$ and $\frac{d}{D_{50}}$

$$\frac{b}{c} = 0.418\left(\frac{d}{D_{50}}\right)^{1.113} - 0.930(n)^{1.075} - 0.708(f)^{1.412} - 0.928\left(\frac{b}{m}\right)^{1.077} \tag{2}$$

Relationship for $\frac{b}{c}$ with n, f, and $\frac{b}{m}$

$$\frac{b}{c} = 3.336\left(\frac{b}{m}\right)^{1.077} - 0.930(n)^{1.075} - 0.708(f)^{1.412} \tag{3}$$

Relationship for $\frac{b}{c}$ with $\frac{b}{m}$ and n

$$\frac{b}{c} = 2.418\left(\frac{b}{m}\right)^{1.077} - 0.930(n)^{1.075} \tag{4}$$

Relationship for $\frac{b}{c}$ with n & f

$$\frac{b}{c} = 1.867\,(f)^{1.412} - 0.930(n)^{1.075} \tag{5}$$

Relationship for $\frac{b}{c}$ with n

$$\frac{b}{c} = 13.669\,(n)^{1.075} \tag{6}$$

Relationship for $\frac{b}{c}$ with f

$$\frac{b}{c} = 1.748\,(f)^{1.412} \tag{7}$$

Relationship for $\frac{b}{m}$ with $\frac{b}{c}$ n, f, $\frac{d}{D_{50}}$ and $\frac{d}{D_{84}}$

$$\frac{b}{m} = 1.247\left(\frac{d}{D_{50}}\right)^{0.912} - 1.078\left(\frac{b}{c}\right)^{0.928} - 0789(n)^{1.267} - 0.480(f)^{2.081} - 1.096\left(\frac{d}{D_{84}}\right)^{0.912} \tag{8}$$

Relationship for $\frac{b}{m}$ with $\frac{b}{c}$, n, f and $\frac{d}{D_{50}}$

$$\frac{b}{m} = 0.693\left(\frac{d}{D_{84}}\right)^{0.912} - 1.078\left(\frac{b}{c}\right)^{0.928} - 0.789(n)^{1.267} - 0.480(f)^{2.081} \tag{9}$$

Relationship for $\frac{b}{m}$ with $\frac{b}{c}$, n & f

$$\frac{b}{m} = 0.664\left(\frac{b}{c}\right)^{0.928} - 0.789(n)^{1.267} - 0.480(f)^{2.081} \tag{10}$$

Relationship for $\frac{b}{m}$ with $\frac{b}{c}$ and n

$$\frac{b}{m} = 0.500\left(\frac{b}{c}\right)^{0.928} - 0.789(n)^{1.267} \tag{11}$$

Relationship for $\frac{b}{m}$ with $\frac{b}{c}$

$$\frac{b}{m} = 0.469\left(\frac{b}{c}\right)^{0.928} \tag{12}$$

Relationship for $\frac{b}{m}$ with n and f

$$\frac{b}{m} = 1.467\,(f)^{2.081} - 0.789(n)^{1.267} \tag{13}$$

Relationship for $\frac{b}{m}$ with $\frac{d}{D_{50}}$ and $\frac{d}{D_{84}}$

$$\frac{b}{m} = 0.894\left(\frac{d}{D_{50}}\right)^{0.912} - 1.096\left(\frac{d}{D_{84}}\right)^{0.912} \tag{14}$$

Relationship for n with $\frac{b}{m}$, $\frac{b}{c}$, f, $\frac{d}{D_{50}}$ and $\frac{d}{D_{84}}$

$$n = 0.951\left(\frac{d}{D_{50}}\right)^{1.148} - 0.871\left(\frac{d}{D_{84}}\right)^{1.148} - 0.925\left(\frac{b}{m}\right)^{1.081} - 0.924\left(\frac{b}{c}\right)^{1.082} - 0.770(f)^{1.299} \tag{15}$$

Relationship for f with n, $\frac{d}{D_{50}}$ and $\frac{d}{D_{84}}$

$$f = 0.523\left(\frac{d}{D_{50}}\right)^{1.673} - 0.598\left(\frac{d}{D_{84}}\right)^{1.673} - 0.672\left(\frac{b}{c}\right)^{1.487} - 0.673\left(\frac{b}{m}\right)^{1.485} - 1.140(n)^{0.877} \tag{16}$$

Most Appropriate Equation for $\frac{b}{m}$

From (1) equation

$$\frac{b}{m} = 2.940 - 0.704\text{-}0.021\text{-}0.107\text{-}1.802$$

=2.940-2.634 =0.306

which is equal to $\frac{b}{m}$ = 0.306

Hence equation (1) is most appropriate equation for $\frac{b}{m}$.

From equation (2)

$$\frac{b}{m} = 1.139\text{-}0.704\text{-}0.021\text{-}0.107$$

=1.139-0.832 = 0.307

Hence this equation (2) is not so much appropriate as compared to equation (1).

From equation (3)

$$\frac{b}{m} = 0.434\text{-}0.021\text{-}0.107$$

=0.434-0.128 = 0.306

Hence this equation is also appropriate

From equation (4)

$$\frac{b}{m} = 0.327\text{-}0.021\text{=}0.306$$

This is also appropriate

From equation (5)

$$\frac{b}{m} = 0.306$$

From equation (6)

$$\frac{b}{m} = 0.328\text{-}0.021$$

= 0.307

From equation (7)

$\frac{b}{m}$ = 2.108-1.802

=0.306

Mathematical Formulation for $\frac{d}{D_{50}}$

$$Since\frac{b}{c} = 0.996\left(\frac{d}{D_{50}}\right)^{1.113} - 0.930(n)^{1.075} - 0.708(f)^{1.412} - 0.928\left(\frac{b}{m}\right)^{1.077} - 0.898\left(\frac{d}{D_{84}}\right)^{1.114} \quad (1)$$

$$Again\frac{b}{c} = 0.418\left(\frac{d}{D_{50}}\right)^{1.113} - 0.930(n)^{1.075} - 0.708(f)^{1.412} - 0.928\left(\frac{b}{m}\right)^{1.077} \quad (2)$$

Hence from (1) & (2)

$$0.996\left(\frac{d}{D_{50}}\right)^{1.113} - 0.043 - 0.256 - 0.259 - 1.648 = 0.418\left(\frac{d}{D_{50}}\right)^{1.113} - 0.043 - 0.256 - 0.259$$

Now

$$0.996\left(\frac{d}{D_{50}}\right)^{1.113} - 2.206 = 0.418\left(\frac{d}{D_{50}}\right)^{1.113} - 0.558$$

$$Or\, 0.996\left(\frac{d}{D_{50}}\right)^{1.113} - 0.418\left(\frac{d}{D_{50}}\right)^{1.113}$$

=-0.558+2.206

=1.648

$$Or\, 0.996\left(\frac{d}{D_{50}}\right)^{1.113} - 1.191 = 1.648$$

$$Or\, 0.996\left(\frac{d}{D_{50}}\right)^{1.113} = 2.839$$

$$Or\left(\frac{d}{D_{50}}\right)^{1.113} = 2.850$$

$$Or\left(\frac{d}{D_{50}}\right) = (2.850)^{\frac{1}{1.113}}$$

= $(2.850)^{0.898}$

=2.561

Hence this combination is most appropriate.

Mathematical formulation for $\dfrac{d}{D_{50}}$ with other equations:-

$$\frac{b}{c} = 0.418\left(\frac{d}{D_{50}}\right)^{1.113} - 0.930(n)^{1.075} - 0.708(f)^{1.412} - 0.928\left(\frac{b}{m}\right)^{1.077} \tag{1}$$

$$\frac{b}{c} = 3.336\left(\frac{b}{m}\right)^{1.077} - 0.930(n)^{1.075} - 0.708(f)^{1.412} \tag{2}$$

Hence 0.418 $\left(\dfrac{d}{D_{50}}\right)^{1.113}$ -0.043-0.362 -0.259

=0.932-0.043-0.256

Or 0.418 $\left(\dfrac{d}{D_{50}}\right)^{1.113}$ -0.664 = 0.633

Or 0.418 $\left(\dfrac{d}{D_{50}}\right)^{1.113}$ = 1.297

$\therefore$ $\left(\dfrac{d}{D_{50}}\right)^{1.113}$ = 3.103

$$\therefore \left(\frac{d}{D_{50}}\right) = (3.103)^{\frac{1}{1.113}}$$

= $(3.103)^{0.898}$

=2.765

Hence this combination is not so appropriate.

Mathematical Formulation for $\frac{b}{m}$

$$\frac{b}{c} = 3.336\left(\frac{b}{m}\right)^{1.077} - 0.930(n)^{1.075} - 0.708(f)^{1.412} \tag{1}$$

$$\frac{b}{c} = 2.418\left(\frac{b}{m}\right)^{1.077} - 0.930(n)^{1.075} \tag{2}$$

Hence from (1) & (2)

$3.336\left(\frac{b}{m}\right)^{1.077}$ -0.043-0.256

=0.675-0.043

Or $3.336\left(\frac{b}{m}\right)^{1.077}$ -0.299 = 0.632

Or $3.336\left(\frac{b}{m}\right)^{1.077}$ = 0.931

Or $\left(\frac{b}{m}\right)^{1.077}$ = 0.279

$\therefore \quad \left(\frac{b}{m}\right) = (0.279)^{\frac{1}{1.077}}$

= $(0.279)^{0.929}$

=0.305

≈0.306

Hence equation is satisfied.

Mathematical formulation for n

$$\frac{b}{c} = 2.418\left(\frac{b}{m}\right)^{1.077} - 0.930(n)^{1.075} \tag{1}$$

$$\frac{b}{c} = 1.867\,(f)^{1.412} - 0.930(n)^{1.075} \tag{2}$$

Or 0.675-0.930$(n)^{1.075}$ =0.676-0.043

Or -0.930$(n)^{1.075}$ =0.633-0.675

=-0.042

$\therefore\ (n)^{1.075}$ =0.045

Or n $(0.045)^{\frac{1}{1.075}}$

=$(0.045)^{0.930}$

=0.056 ≈ 0.057

Hence equation is satisfied.

Mathematical Formulation for f

$$\frac{b}{c}=1.867\,(f)^{1.412}-0.930(n)^{1.075} \tag{1}$$

$$\frac{b}{c}=13.669\,(n)^{1.075} \tag{2}$$

From (1) & (2)

1.867$(f)^{1.412}$-0.043

Or (f) = $(0.359)^{\frac{1}{1.412}}$ =0.628

=$(0.359)^{0.708}$

=0.484≈0.487

Mathematical Formulation for $\frac{d}{D_{84}}$

$$\frac{b}{c}=0.996\left(\frac{d}{D_{50}}\right)^{1.113}-0.930(n)^{1.075}-0.708(f)^{1.412}-0.928\left(\frac{b}{m}\right)^{1.077}-0.898\left(\frac{d}{D_{84}}\right)^{1.114} \tag{1}$$

$$\frac{b}{c}=0.418\left(\frac{d}{D_{50}}\right)^{1.113}-0.930(n)^{1.075}-0.708(f)^{1.412}-0.928\left(\frac{b}{m}\right)^{1.077} \tag{2}$$

From (1) & (2)

2.837-0.043-0.256-0.259-0.898 $\left(\frac{d}{D_{84}}\right)^{1.114}$ = 1.191-0.043-0.256-0.259

Or 2.837-0.558-0.898 $\left(\frac{d}{D_{84}}\right)^{1.114}$ = 1.191-0.558

Or 2.837-0.898 $\left(\frac{d}{D_{84}}\right)^{1.114}$ = 1.191

Or -0.898 $\left(\frac{d}{D_{84}}\right)^{1.114}$ = 1.191-2.837

=-1.646

Or $\left(\frac{d}{D_{84}}\right)^{1.114}$ = 1.833

Or $\left(\frac{d}{D_{84}}\right)^{1.114}$ = $(1.833)^{\frac{1}{1.114}}$

= $(1.833)^{0.898}$

=1.723 ≈1.725

Hence equation is satisfied.

Mathematical Formulation for $\frac{b}{c}$

$$\frac{b}{m} = 1.247\left(\frac{d}{D_{50}}\right)^{0.912} - 1.078\left(\frac{b}{c}\right)^{0.928} - 0.789(n)^{1.267} - 0.480\left(f\right)^{2.081} - 1.096\left(\frac{d}{D_{84}}\right)^{0.912} \quad (1)$$

$$\frac{b}{m} = 0.693\left(\frac{d}{D_{84}}\right)^{0.912} - 1.078\left(\frac{b}{c}\right)^{0.928} - 0.789(n)^{1.267} - 0.480\left(f\right)^{2.081} \quad (2)$$

From (1) & (2)

2.940-1.078 $\left(\frac{b}{c}\right)^{0.928}$ -0.021 -0.107-1.802 = 1.139-0.704-0.021-0.107

Or 2.940-1.930-1.078 $\left(\frac{b}{c}\right)^{0.928}$ = 1.139-0.832

Or 1.010-1.078 $\left(\frac{b}{c}\right)^{0.928}$ =0.307

Or -1.078 $\left(\frac{b}{c}\right)^{0.928}$ =-0.703

Or $\left(\frac{b}{c}\right)^{0.928}$ =0.652

Or $\frac{b}{c}$ = $(0.652)^{\frac{1}{0.928}}$

=(0.652)1.078

=0.631

≈ 0.632

Hence equation is satisfied.

CONCLUSIONS

Large size of roughness material reduces mean velocity of flow in steep slope hence erosion is prevented and soil conservation is obtained. Since mean velocity of flow is more for 0.75 inch roughness bed and roughness is more effective is high velocity of flow to get more wetted frontal cross sectional area hence function of effective roughness concentration is more for 0.75 inch roughness bed as compared to 2.0 inch roughness bed.

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. SOC Civ. Eng. 105 (HY 9), 1103 - 1122
5. Griffiths, G.A.(1981) “Flow resistance in course gravel bed rivers “J. Hydraulic Div. An soc. Civ. Eng. 107 (HY – 7), 899 – 918
6. Hey R.D (1979) “Flow resistance in gravel bed rivers “J Hydraulic Div Am SOC CIV Eng, 105 (HY – 4), 365 – 379.
7. James C. Batharst (December 1981) “Resistance Equation for Large Scale Ranghnen” Journal of the Hydraulics Division, American Society of Civil Engineers, Vol. 107 NO HY 12, PP 1593-1613.
8. James C. Bathurst (December 1978) “ Flow resistance of large-scale roughness”
9. Journal of the Hydraulic Division vol 104NO12PP1587-1603
10. Lovera, F. and kennedy J.F (1969) “Friction factors for flat – bed flows in sand channel” J Hydraulic Div, Am. Soc. Civ Eng 95 (HY 4) 1227 – 1234.

11. Petryk, S. and shen, H.W (1971) "Direct measurement of sheer strem in a flume, "J Hydraulic Div. Am. SOC. Civ. Eng. 97(HY – 6), 883 – 887

APPENDICES: NOTATION

The following symbols are used in this paper:-

$\frac{A_w}{Wd'}$ = Relative roughness area

A_w = Wetted cross sectional area

b = Function of effective roughness concentration

c = constant varying with bed material properties

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

m = Constant varying with bed material properties.

n = Manning's roughness coefficient

P = Wetted Perimeter

Q = Discharge in cubic meters per second

R = Hydraulic radius = $\frac{A}{p}$

S = Channel slope

V = Mean velocity of flow in meters per second.

W = Width of the channel = 1.168m

Formula Used

$$m = 1.025\left(\frac{W}{Y_{50}}\right)^{0.118}$$

Where W = width of the channel = 1.168m

Y_{50} = The cross stream axis is assumed to have been the average of the long

L_{50} and median axis D_{50} for 0.75 inch roughness bed

Y_{50}= 0.0164m

W=1.168m

Hence m=1.696

For 2.0 inch roughness bed:-

Y_{50}=0.051m

m=1.483

C=constant varying with bed material properties

$C=0.648\sigma^{-0.134}$

σ=standard deviation of distribution = log $\left(\dfrac{D_{84}}{D_{50}}\right)$

For 0.75 inch roughness bed

C=0.822

For 2.0 inch roughness bed

C=0.939

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

Where A_w=wetted cross sectional area

d'=depth of bed datum in meters

W=width of the channel = 1.168m

$\dfrac{A_w}{Wd'}$ =Relative roughness area.

W=width of the channel = 1.168m

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

f=Darcy Weisbach resistance coefficient

g=Acceleration due to gravity

R=Hydraulic radius

S=Channel slope

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

$$R=\frac{A}{P}=\frac{Wd}{W+2d}$$

$A+A_w=Wd'$

A=Flow cross sectional area

A_w=Wetted cross sectional area