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Application of bed geotechnical parameters and flow cross section hydraulic parameters for calculating for calculating Manning's roughness coefficient in Colorado River

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Abstract: Rivers are considered as one of the main sources of surface water and important habitant of aquatic animals from effective inland ecosystems. River water, in addition to participation in Earth's climate cycle, is considered as one of the most important factors in the erosion of the planet Earth. In recent decades, significant progresses have been achieved in the engineering science. But in some cases, such as sediment transport, turbulent flows, flood control, and river response to environmental factors, engineers' society are still looking forward to precise method for calculating. The river network is defined as set of waterways that, in the basin level , discharges surface flows. Some of these waterways are as perennial rivers, and seasonal rivers, and some other as watercourse that only during rainfall, a flowing body of water follows. In order to provide mathematical model in determining Manning's roughness coefficient for mountainous range on the basis of existing field data, hydraulic and geotechnical information for 20 American river and 75moiuntain ranges related to Mr. Jarrett researches were collected. This is considered in choosing mentioned rivers that the sections have been placed on the mountainous range of the river, and the slope of the river at that location is more than 1%. The results obtained from the study, suggests that unlike Jarrett's proposed relations, soil mechanics factors are also have significant effects on the accuracy of the Manning's roughness coefficient, which is directly tangible in the results.
Keywords: Mountainous, Manning's roughness coefficient, Colorado rivers, bed geotechnical parameters, flow section hydraulic parameters.

Introduction

Mountainous river is referred to a waterway system having the slope over 0.002 during its mountain range. In addition to the steep slope, these rivers have high substrate roughness, rapid and severe spatial displacement, in substrate surface morphology. High speed and low depth of flow can be noted as other characteristics of these rivers. A significant portion of energy distribution on free surface flow is caused by bed frictional resistance against flow. Many theories presented in there regard, have therefore been focused on the parameters influencing the friction between the fluid and its bed. Existing relations and equations have greatest emphasis on bed roughness and the crystallization of the role of roughness in significant size is also considered as constituent materials of substrate surface. In this study, a mathematical model of Manning's roughness coefficient on mountain ranges (with slope more than 1%) on the basis of geotechnical data (uniformity of aggregates, aggregation coefficient of aggregate, relative softness), and flow hydraulic data (friction slope and hydraulic radius) will be developed using Minitab software. Mountain river is defined as waterway system with slope more than 0.002 over its mountain range. In addition to high slope, these rivers have characteristics including high substrate roughness caused by bedrock and coarse particles. Various

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displacement and in contrast little time changes in substrate bed morphology has also developed very high resistance against floods during floods that retains the stability almost after the flood occurred. Other characteristics can be noted as high speed, low depth, united waterway canal consisting of rubble and rock and catchment of several dozen square kilometers. In these waterways, substrate surface is covered with uniform distribution of aggregates, and in most cases the aggregate size varies from 16 to 128. By increasing the slope, fine materials are washed and larger particles remain in waterway, consequently leading to more turbulence. The increased resistance therefore leads to increased frictional slope (Bathurst, 1985, 625 – 643). Seams and gaps in bed rocks (caused by difference between characteristic of different rocks) causes to limit changes in lower surfaces that ultimately leads to control and division of longitudinal profiles. Unlike alluvia river in which the highest energy flow are associated with high flow cross section, increased depth in mountain rivers causes to increased flow rate, and ultimately increased flow energy (Bathurst, 1985, 625 – 643). It may be also said that this theory is derived from flow resistance rules of boundary layers which is applied for flow inside the pipes. In channels, friction in boundary layers creates a shear layer, which is similar to boundary layers and associated theory. In fact, this theory with little changes can be used for channels that is considered as an appropriate basis for development of a theory concerning flow resistance in channels (Hey, 1983). According to what was said:

(1) $$\bar{u}^2 = \frac{8\tau_0}{\rho . f} = \frac{8u_*^2}{f}$$

: $\bar{u}$ Average speed

: τ_0 Boundary shear stress

: ρ Fluid density

: u_* speed of density

: f Darcy–Weisbach coefficient

Rivers as natural canals for passing water, and sediments considering the condition and substance of edges, and shape of the river in plan and section, show resistance against flow and erosion and sedimentation processes. Interaction between driving forces and resisting forces, adjusts geometry of rivers. The sheer stress caused by flow in channel boundaries and in the opposite direction, is defined as flow resistance. Flow resistance can be divided into three categories:

1- Surface resistance: This resistance is caused by the roughness of material surfaces or vegetation.
2- Internal resistance: This resistance is caused by vortex flows, secondary flows, curves in the flow, scattered rubbles on the bed and its final shape.
3- Falling resistance: This resistance is caused by gradually varied flow and The deceleration versus acceleration contrast of fluid occurring in its path. This resistance has a local mode.

Flow resistance in moving bed, increases with the development of bed shape. Although flow resistance for a constant bed shape, is reduced with reduced flow turbulence. In rivers with sand bed, surface resistance is the dominant resistance against the flow which is effective along waterway. Falling resistance, however, occurs locally and due to the bed shape, internal resistance is reduced. Falling resistance and fluid's internal resistance can be therefore ignored. Generally, flow resistance depends on factors such as static particles in bed, bed load on the verge of movement, bed shape (form), presence of sediment masses, river route on plan, the condition of edges, flow geometry, and roughness changes in cross section (figure1) (Iman Sho'ar, 2006).

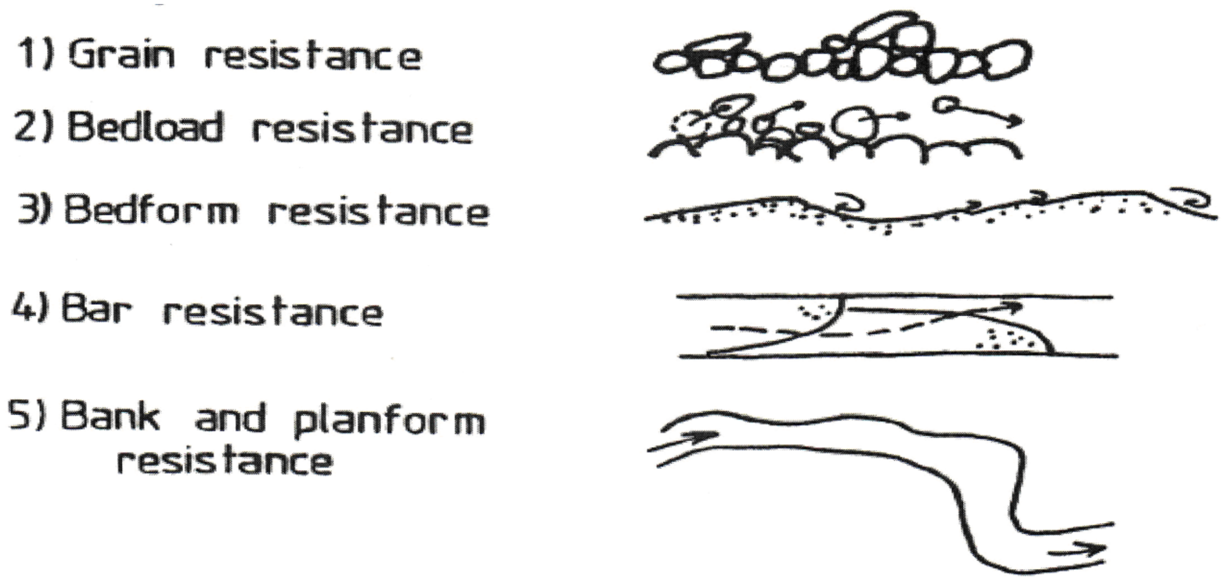

Figure 1 Shear stress components of borders

Materials and methods

In order to provide mathematical model in determining Manning's roughness coefficient for mountainous range on the basis of existing field data, hydraulic and geotechnical information for 20 American river and 75moiuntain ranges related to Mr. Jarrett researches were collected. This is considered in choosing mentioned rivers that the sections have been placed on the mountainous range of the river, and the slope of the river at that location is more than 1%.

<u>Parametric methods for estimating Manning's roughness coefficient:</u>

Another method in determining n , particularly for rivers is using empirical relations for river engineering. These relations generally depend on the diameter of particles forming wall and waterway bed. Many famous relations are given below:

1. In 1923, Strikler proposed following relation for estimating Manning's roughness coefficient:

(2) $n = 0.047 d_{50}^{1/6}$

Where d_{50} is the is the hypothetical size in mm through which50% of material can pass. He believed that roughness coefficient is independent from flow depth and is defined as a function of bed particle size. His equation and other equation are based on this basis, with specific user limitation, since only when the flow is turbulent and the loss is entirely caused by the roughness in bed materials, it is not applicable. (Yen, 2002)

2. In 1938, Keulegan subsequently proposed a relation close to the previous work:

(3) $$n = \frac{d_{50}^{1/6}}{46.9} = 0.021 d_{50}^{1/6}$$

Where d_{50} is measured in terms of feet.

3. In continuation of previous work, Keulegan proposed another concept of bed resistance against flow in form of two equations:

(4) $$\frac{u}{u*} = 8.12\left(\frac{R}{K_s}\right)^{1/6}$$

And also:

(5) $$\frac{u}{u*} = 5.75\log\left(\frac{R}{Ks}\right) + 6.25$$

Where K_s is the roughness equal to Nicholas Tse and is considered equal to d_{85}.

4. In 1946, Lacey proposed the following equation based on frictional slope (nguyen, 2004):

(6) $$n = 0.0928 S_f^{\frac{1}{6}}$$

On the other hand, in order to consider the impacts of other sizes of aggregation in alluvia material (Keulegan, 1947) has added two following equations to the previous set:

(7) $$n = \frac{d_{90}^{1/6}}{49} = 0.02 d_{90}^{1/6}$$

(8) d_{90} $$n = \frac{d_{65}^{1/6}}{29.3} = 0.034 d_{65}^{1/6}$$

d_{65} is measured in terms of foot.

5. In metric unit, Meyer-Peter & Muller (1948) have proposed the following equation:

(9) $$n = 0.0385 d_{90}^{1/6}$$

Where d_{90} is measured in terms of foot. This equation can be used when the bed is covered with rubble (Shafaei Bejestan, 1384, 470).

6. In 1949, Irmay proposed the following equation in metric unit (Rahmeyer, 2006):

(10) $$n = \frac{d_{65}^{1/6}}{24}$$

7. In research similar to what is noted above, through study on the channels in San Lu valley with rubble bed, the following equation to estimate the roughness is proposed by Lane & Karl son (1953) (Shafaei Bejestan, 1384, 470)

(11) $n = 0.026 d_{75}^{1/6}$

d_{75} is measured in terms of inch.

8. In 1965, Henderson proposed an equation similar to equation (2-47):

(12) $n = 0.034 d_{50}^{1/6}$

d_{50} is measured by foot.

9. After a comprehensive discussion concerning the size of aggregates forming waterway bed in order to calculate the roughness coefficient while applying d_{63} in mm, Raudkivi (1967) suggests that:

(13) $n = 0.013 d_{63}^{1/6}$

Equation (12), in a research conducted by Iman Sho'ar and Taher Shams on the accuracy of existing relations in estimating the roughness coefficient in rivers, has given more reasonable results. The concluded that these relations are consistent with climate of European rivers. Therefore, in order to apply it in Iranian rivers, changes should be done to be consistent with our climactic conditions and environment (Iman Sho'ar, 2007).

10. In 1968, Anderson et al proposed the following equation (Rahmeyer, 2006):

(14) $n = \frac{d_{50}^{1/6}}{20.5}$

11. In 1970, Limerinos reused hydraulic radius in order to estimate roughness coefficient. The particles that he had considered in the following formula, was generally coarse- grained (Rice, 1998). Then, he propose the following equation:

(15) $n = \frac{0.0926 R^{1/6}}{1.16 + 2\log\left(\frac{R}{d_{84}}\right)}$

In 1976, Burkham and Dawdy indicated that this equation can also be used for sandy river.

12. By examining a series of alluvial rivers, in 1975 Chiemeka proposed an equation, using shear stress, to calculate *n* (Chiemeka, 1957)

(16) $f = 0.017\exp(0.4\frac{\tau''_0}{\tau'_0})$

(17) $\frac{\tau''_0}{(\gamma_s - \gamma_w)D_{50}} = 0.0246(\frac{\tau_0}{\tau_c})$

(18) $\tau_0 = \gamma_w RS$

(19) $\tau'_0 = \tau_0 - \tau''_0$

(20) $n = 0.012R^{\frac{1}{6}}\exp(0.2\frac{\tau''_0}{\tau'_0})$

13. In 1976, Riggs proposed the following equation by considering area, hydraulic radius and water level slope (nguyen, 2004):

(21) $n = \frac{1}{1.55}A^{-0.33}R^{\frac{2}{3}}S_w^{0.45+0.056\log S_w}$

14. In Simons & Senturk's research works (1976), it can be observed that:

(22) $n = 0.047d_{50}^{1/6}$

Where d_{50} is measured in terms of m. They concluded that the equation are not applicable in flows with moving bed (Van Rijn, 1993).

15. Garde & Raju by expressing the fact that Mr. Strickler has analyzed the data with various flows in Switzerland where bed materials are rough and without wave-like movement (Soleimani, 2005, 140), proposed the following equation:

(23) $n = 0.039d_{50}^{1/6}$

d_{50} is measured in terms of foot.

16. The equation corrected by Hey in 1979, is proposed as the following:

(24) $$\frac{u}{u*} = 5.62\log\left(\frac{5.85R}{3.5d_{84}}\right) + 2.85$$

17. Bray in 1982 only by considering water level slope, obtained the following equation (nguyen, 2004):

(25) $$n = 0.104S_w^{0.177}$$

In 1982, Subramanya has noted an equation as:

(26) $$n = 0.0474d_{50}^{1/6}$$

d_{50} is measured in terms of m.

18. In 1983, Brownie succeeded to propose a formula in English unit, based on his researches fir both upper and lower regime in channels (Rahmeyer, 2006):

- For lower regime, where $F_g \leq F'_g$, we have:

(27) $$n = \left[1.694\left(\frac{R}{d_{50}}\right)^{0.1374} S^{0.1112}\sigma^{0.1605}\right]0.034d_{50}^{0.167}$$

And for upper regime where ($F_g > F'_g$), we also have:

(28) $$n = \left[1.0213\left(\frac{R}{d_{50}}\right)^{0.0662} S^{0.0395}\sigma^{0.1282}\right]0.034d_{50}^{0.167}$$

(29) $$\sigma = 0.5\left(\frac{d_{84}}{d_{50}} + \frac{d_{50}}{d_{16}}\right)$$

(30) $$F_g = \frac{V}{\sqrt{(S-1).g.d_{50}}}$$

(31) $$F'_g = \frac{1.74}{\sqrt{S}}$$

19. In 1985, Thorne & Zevenberg, based on a series of tests, succeeded to propose the following equation where f, V and n are in relation with each other (Throne, 1985):

$$(32)\ \frac{V}{\sqrt{gRS}} = \left(\frac{8}{f}\right)^{0.5} = \frac{R^{\frac{1}{6}}}{n\sqrt{g}}$$

They believed that this equation cannot be verified in mointain rivers, since:

- Bed materials in mountain rivers are coarse-grained, while the rivers in foothills are generally sandy and fine-grained.
- Bed slope in mountain rivers is higher than that of foothill rivers.
- Relative buoyancy ($\frac{D}{d_{84}}$)in mountain rivers is higher than that of foothill rivers.

20. Madrid by considering the ratio of also proposed the $\frac{R}{d_{84}}$, proposed the Froude number and bed slope of the following equations (Papanicolaou, 2004):

$$(33)\ n = \left(0.183 + \ln\left(\frac{1.7462 S^{0.1581}}{F_d^{\ 0.2631}}\right)\right) \times \frac{d_{84}^{\frac{1}{6}}}{\sqrt{g}} \qquad \frac{R}{d_{84}} > 1$$

$$(34)\ n = \left(0.183 + \ln\left(\frac{1.3014 S^{0.0784} R^{0.0211}}{F_d^{\ 0.205} d_{84}^{0.2011}}\right)\right) \times \frac{d_{84}^{\frac{1}{6}}}{\sqrt{g}} \qquad 1 < \frac{R}{d_{84}} < 12.5$$

21. Then, in 1994 Miller and Quick based on their findings, also suggested that (Rahmeyer, 2006):

$$(35)\ n = \frac{K_n R^{\frac{1}{6}}}{\sqrt{g}\, 5.75 \log\left(12.2 \frac{Y_0}{3.5 D_{90}}\right)}$$

22. In 1997, Dingman and Sharma proposed equations similar to Manning equation (Dingman, 1997):

$$(36)\ n = \frac{1}{1.564} A^{-0.173} R^{0.267} S_w^{\ 0.5+0.0543\log S_w}$$

In order to develop a mathematical equation for roughness coefficient in mountain ranges with supercritical slope, Grant in 1997 proposed hypothesis on interaction between hydraulic parameters of waterway and bed form, based on his observation on rivers with sandy and how to form bed forms and then to generalize these observation into steep slope rivers with coarse and rough grain (Mahpour, 2006, 110). In this hypothesis, a stream can precisely adapt its longitudinal bed slope over time, so that it can provide by flow rate and other dominant characteristics existed in waterway, the speed required for transforming the sediment produced by catchment.

He obtained the following equation by concluding from his observation, while applying Keulegan's resistance equation (1938) and Shields criterion for movement threshold of bed materials:

(37) $$Fr = 2.18\left[\ln\left(1.65\frac{\tau_{cr}^{*}}{s}\right)+1.35\right]g^{0.5}$$

Where τ_{cr}^{*} , based on Shields diagram and flow rate forming rivers with sandy bed, is equal to 0.06. He demonstrated that by combinig one of the equations propose for n and equation (2-23), the following equation, to estimate the roughness coefficient in these streams where the interaction between bed and hydraulic waterway causes the Froude number not to exceed 1, it can be proposed (Yen, 2002):

(38) $$n = \frac{d^{1/6}}{2.18\left[\ln\left(1.65\frac{\tau_{cr}^{*}}{s}\right)+1.35\right]g^{0.5}}$$

It should be noted that although the equation (38) is an appropriate and logical basis for estimating the roughness coefficient in mountain ranges with supercritical slope, it can be summed up by comparing mentioned equations that most researchers considers the significant size of the grains in alluvial materials to be the most important factor to flow resistance, and do not consider other geotechnical parameters in alluvial materials. It seems, however, that other gradation characteristics of constituent materials of bed, including curvature coefficient, and or uniformity coefficient shall also be considered in such equations. The roughness of aggregate surface can also be important and effective on roughness coefficient in Manning's equation. Although in many ranges of downstream in rivers, aggregates forming bed sediment are rounded, the aggregates in mountain ranges, due to a large amount of debris on one hand, and being close to headwater on the other hand, are relatively sharp and angular. The geometry of aggregates or the amount of surface roughness in aggregates may be therefore considered as an important factor in resistance against flow. Consequently, according to the author of the thesis, the difference between equations proposed by different researchers is rooted in the fact that a single size of aggregates cannot solely reflect the impact of bed materials on roughness coefficient.

23. Sauer (1998), by considering parameters of hydraulic radius and water surface slope important, proposed the following equation (nguyen, 2004):

(39) $$n = 0.11S_{w}^{0.18}\left(\frac{R}{0.3048}\right)^{0.08}$$

24. Marrion et al (1998) based on his experiences, also proposed the following equation (Hatami, 2006, 140):

(40) $$n = \frac{d_{90}^{1/6}}{26}$$

25. Chin & Mai (1998) obtained the following equation by investing on yellow river:

(41) $$n = \frac{d_{65}^{1/6}}{19}$$

The compatibility of observed data to develop mathematical models

Hydraulic data

In order to perform hydraulic calculation in rivers, some characteristics of sections that are most needed and used, are as follows:

- Flow cross-section (A): It is referred to a place where the area of cross section are perpendicular to general direction of flow.
- Free surface width (T): It is referred to the length of cross section that is in contact with open air.
- Wetted perimeter (P): if the free surface width is subtracted from total perimeter of flow cross section, wetted perimeter is obtained that indicates contact scope of flow with channel bed.
- Hydraulic radius (R) : According to the definition of flow cross-section ratio, the wetted perimeter are called hydraulic radius, in other words:

(42) $R = \frac{A}{P}$

- Hydraulic depth (D): It is referred the ratio of flow cross section to water free surface width:

(43) $D = \frac{A}{T}$

The above information is related to geometric characteristics of cross sections and items such as flow velocity, flow friction slope and water surface slope shall also be calculated in order to be used in Manning equation. After reviewing the required information and calculation, the results are collected in Table 1.

Table 1 Hydraulic data

site	Sf	D(ft)	D(m)	R(m)	R(ft)	n
1	0.026	3.61	1.1003	0.99	3.24	0.142
	0.023	4.66	1.4204	1.22	3.99	0.132
	0.021	5.22	1.5911	1.36	4.46	0.112
	0.025	5.75	1.7526	1.48	4.85	0.11
	0.026	6.58	2.0056	1.68	5.51	0.086
2	0.015	1.02	0.3109	0.31	1.02	0.138
	0.017	1.54	0.4694	0.46	1.5	0.084
	0.018	2.08	0.634	0.61	2	0.084
	0.019	2.71	0.826	0.79	2.6	0.067
3	0.03	0.88	0.2682	0.27	0.9	0.159
	0.034	1.24	0.378	0.37	1.2	0.097
	0.033	1.43	0.4359	0.46	1.51	0.052
	0.03	2.03	0.6187	0.56	1.85	0.058
4	0.003	0.73	0.2225	0.22	0.72	0.045
	0.004	1.27	0.3871	0.39	1.27	0.046
	0.004	1.7	0.5182	0.52	1.7	0.041
	0.004	2.34	0.7132	0.68	2.24	0.028
5	0.003	1.21	0.3688	0.37	1.21	0.054
	0.004	1.36	0.4145	0.41	1.35	0.051
	0.004	1.44	0.4389	0.43	1.42	0.052
	0.004	2.02	0.6157	0.62	2.02	0.05

	0.004	3.54	1.079	1.07	3.51	0.041
	0.004	4.09	1.2466	1.23	4.03	0.037
6	0.003	0.54	0.1646	0.18	0.6	0.057
	0.003	0.7	0.2134	0.21	0.7	0.044
	0.002	1.17	0.3566	0.36	1.17	0.03
7	0.003	0.66	0.2012	0.18	0.6	0.058
	0.004	1.46	0.445	0.46	1.5	0.052
	0.006	2.28	0.6949	0.7	2.3	0.034
	0.006	3.02	0.9205	0.91	2.98	0.044
8	0.011	0.48	0.1463	0.15	0.5	0.109
	0.016	1.09	0.3322	0.32	1.05	0.062
	0.014	1.5	0.4572	0.43	1.42	0.042
9	0.019	2.3	0.701	0.68	2.23	0.087
	0.014	2.87	0.8748	0.87	2.85	0.052
	0.014	3.07	0.9357	0.92	3.03	0.054
	0.014	3.14	0.9571	1.02	3.36	0.049
10	0.019	1.28	0.3901	0.37	1.2	0.098
	0.023	2.3	0.701	0.65	2.12	0.062
	0.024	2.72	0.8291	0.77	2.53	0.056
11	0.026	0.59	0.1798	0.18	0.6	0.117
	0.026	0.82	0.2499	0.24	0.8	0.108
	0.025	1.49	0.4542	0.43	1.4	0.082
	0.021	2.02	0.6157	0.59	1.92	0.105
12	0.004	3.84	1.1704	1.16	3.8	0.034
	0.004	4.1	1.2497	1.23	4.03	0.037
13	0.004	0.89	0.2713	0.27	0.89	0.058
	0.004	2.98	0.9083	0.91	2.97	0.041
	0.003	4	1.2192	1.21	3.98	0.035
14	0.002	1.69	0.5151	0.53	1.73	0.044
	0.002	1.74	0.5304	0.55	1.8	0.041
	0.003	2.32	0.7071	0.71	2.32	0.043
	0.003	3.29	1.0028	1	3.29	0.032
15	0.008	3.33	1.015	1.02	3.34	0.042
	0.007	3.44	1.0485	1.05	3.43	0.038
16	0.009	0.98	0.2987	0.3	0.98	0.087
	0.007	2.45	0.7468	0.74	2.44	0.043
	0.007	3.61	1.1003	1.07	3.52	0.052
17	0.016	0.5	0.1524	0.15	0.5	0.089
	0.017	0.61	0.1859	0.18	0.6	0.065

	0.016	0.76	0.2316	0.24	0.8	0.053
	0.013	1.19	0.3627	0.34	1.13	0.033
	0.013	1.64	0.4999	0.48	1.57	0.064
18	0.027	1.59	0.4846	0.5	1.63	0.103
	0.031	2.16	0.6584	0.57	1.87	0.074
19	0.002	2.52	0.7681	0.55	1.8	0.039
	0.003	3.14	0.9571	0.94	3.1	0.034
	0.004	3.31	1.0089	0.99	3.25	0.035
20	0.006	0.93	0.2835	0.27	0.9	0.074
	0.006	1.36	0.4145	0.4	1.3	0.047
	0.005	2.43	0.7407	0.73	2.4	0.041
	0.005	2.66	0.8108	0.81	2.66	0.032

Soil mechanic data

The results obtained from mechanical analyses such as grading test are usually drawn on a semi-logarithmic paper, that is called soil gradation curve. The diameter of grains and shall be placed on the logarithmic vertical axis, and the relevant passing percentage shall be placed on non-logarithmic vertical axis. This curve can be used to compare different soils. Two basic parameters used for classification of granular soils which can be determined by grading curve, are as follows:

(44) $$C_u = \frac{D_{60}}{D_{10}}$$

(45) $$C_c = \frac{D_{30}^2}{D_{10} \times D_{60}}$$

Where

C_u = Soil uniformity coefficient

C_c = Soil gradation coefficient

D_{10} = Diameter for passing percentage of 10% on gradation curve

D_{30} = Diameter for passing percentage of 30% on gradation curve

D_{60} = = Diameter for passing percentage of 60% on gradation curve

Diameter of particles can be determined with regard to passing percentage, using bed-material gradation curve. This is important since in most equation for determining Manning's roughness coefficient – particularly Strikler's equations and other equations derived from them – the effective diameter of particles is required that researchers, in different cases, have chosen different diameters as effective diameter based on their observations. The effective diameter of particles generally exist in mountain rivers d_{84}. This means that 84% of particles have lower diameter. The particles are defined by different names based on their diameters and the given range. In 1953, Wellman proposed a table where the position of each particle is determined according to its diameter (Jarrett, 1984), Table 2. Table 3 show calculated geotechnical parameters for each section, the information in one of the sites for soil mechanical data are not available that it can be therefore removed from calculation.

Table 2 Classification of particles based on diameter

Group	(mm) Size of particles	
Sand and Silt	<	2
Gravels	2 -	4
	4 -	6
	6 -	8
	8 -	12
	12 -	16
	16 -	24
	24 -	32
	32 -	48
	48 -	64
Cobbles	64 -	96
	96 -	128
	128 -	192
	192 -	256
Boulders	256 -	384
	384 -	512
	512 -	1024
	1024 -	2048
	2048 -	4096
Bedrock	>	4096

Table 3 Soil mechanical data of bed materials for Colorado rivers

site	d_{100}	d_{90}	d_{80}	d_{63}	d_{60}	d_{50}	d_{30}	d_{20}	d_{15}	d_{10}	d_0	Cc	Cu	e	S_{90}
1	1.272	0.975	0.799	0.538	0.502	0.427	0.329	0.198	0.15	0.142	0.124	1.53	3.55	32.9	0.001
2	1.099	0.701	0.491	0.247	0.219	0.183	0.065	0.044	0.03	0.029	0.019	0.67	7.52	30.6	0.002
3	0.828	0.64	0.427	0.243	0.22	0.152	0.082	0.061	0.05	0.042	0.03	0.72	5.24	29.8	0.002
4	0.26	0.213	0.183	0.144	0.138	0.122	0.085	0.073	0.061	0.061	0.053	0.87	2.25	28.5	0.005
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

	3	5	3	9	6	2	3	3			4				4
7	0.563	0.457	0.37	0.259	0.243	0.213	0.129	0.105	0.094	0.085	0.069	0.81	2.86	29.7	0.002
8	0.675	0.427	0.368	0.18	0.162	0.091	0.067	0.039	0.029	0.027	0.019	1.02	5.96	29.8	0.003
9	0.654	0.488	0.416	0.283	0.265	0.244	0.135	0.107	0.089	0.086	0.068	0.8	3.09	30.1	0.002
10	0.84	0.671	0.544	0.376	0.352	0.305	0.183	0.148	0.12	0.119	0.095	0.8	2.97	30.5	0.002
11	0.62	0.427	0.316	0.179	0.161	0.122	0.073	0.042	0.029	0.027	0.021	1.22	5.98	30.7	0.003
12	0.48	0.36	0.26	0.18	0.16	0.12	0.02	0.01	0.01	0.01	0.00	0.42	15.6	30.4	0.00
13	0.197	0.183	0.146	0.113	0.108	0.091	0.069	0.061	0.055	0.051	0.044	0.86	2.12	27.9	0.006
14	0.34	0.305	0.23	0.193	0.184	0.152	0.128	0.1	0.09	0.086	0.074	1.04	2.15	29.2	0.004
15	0.56	0.36	0.27	0.14	0.13	0.12	0.04	0.03	0.02	0.02	0.01	0.7	6	29.6	0.00
16	0.427	0.305	0.274	0.19	0.177	0.152	0.092	0.074	0.06	0.059	0.048	0.8	3	29.1	0.004
17	0.211	0.152	0.13	0.086	0.08	0.061	0.038	0.03	0.027	0.024	0.018	0.78	3.38	27.8	0.007
18	1.00	0.61	0.47	0.25	0.22	0.21	0.11	0.05	0.02	0.02	0.02	2.12	8.14	33.5	0.00
19	0.122	0.091	0.085	0.061	0.061	0.061	0.035	0.03	0.027	0.025	0.021	0.82	2.46	27.4	0.011
20	0.515	0.335	0.257	0.142	0.128	0.122	0.045	0.03	0.027	0.022	0.016	0.71	5.7	29.5	0.003

Results and discussion

The Manning's roughness coefficient shall be first calculated using new model for rivers of Colorado, Karaj and Greenville. The results obtained from the study, compared with roughness observed from Manning equation, certainly show incompatibility that shall be evaluated using statistical method. For this purpose, two standards including sum of squared errors (SSE) and mean squared error (MSE) can be used. Therefore:

$$(46)\ SSE = \sum (n - n_j)^2$$

$$(47)\ MSE = \frac{\sum (n - n_j)^2}{N}$$

Where n_j is the manning's roughness coefficient estimated using the desired model and N is the estimations.

Examination of Colorado River

The Manning's roughness coefficient should be first calculated using proposed new model (equation $n = 0.255 S_f^{0.197} C_c^{0.274} C_u^{-0.068} (\frac{D}{d_{84}})^{-0.5} R^{0.19}$). The existing errors in estimating the roughness coefficient calculated, shall be then interpreted and investigated using the model. Table (4) indicates calculated values based on proposed formula, as well as the amount of computational errors.

Table (4) calculation of n for Colorado river using new model

Site	$n=0.255S_f^{0.197}C_c^{0.274}C_u^{-0.068}(D/d_{84})^{-0.5}R^{0.19}$	n	SE
1	0.1085	0.1420	0.001123022
	0.0970	0.1320	0.001226238
	0.0919	0.1120	0.000404728
	0.0921	0.1100	0.000321419
	0.0889	0.0860	8.12823E-06
2	0.0926	0.1380	0.002059694
	0.0833	0.0840	5.29653E-07
	0.0765	0.0840	5.6922E-05
	0.0711	0.0670	1.68738E-05
3	0.1026	0.1590	0.003176641
	0.0941	0.0970	8.46288E-06
	0.0908	0.0520	0.00150408
	0.0776	0.0580	0.000385125
4	0.0503	0.0450	2.79912E-05
	0.0450	0.0460	1.02305E-06
	0.0411	0.0410	4.80723E-09
	0.0368	0.0280	7.80716E-05
5	0.0496	0.0540	1.96546E-05
	0.0505	0.0510	2.98025E-07
	0.0495	0.0520	6.35907E-06
	0.0448	0.0500	2.72145E-05
	0.0375	0.0410	1.20772E-05
	0.0358	0.0370	1.32858E-06
7	0.0723	0.0580	0.000204434
	0.0615	0.0520	8.99332E-05
	0.0577	0.0340	0.000562478

	0.0527	0.0440	7.59086E-05
8	0.1072	0.1090	3.2865E-06
	0.0884	0.0620	0.000698855
	0.0777	0.0420	0.001272334
9	0.0764	0.0870	0.000112923
	0.0675	0.0520	0.000239126
	0.0659	0.0540	0.000142216
	0.0665	0.0490	0.000305447
10	0.1056	0.0980	5.76059E-05
	0.0910	0.0620	0.000842983
	0.0872	0.0560	0.000972041
11	0.1196	0.1170	6.86359E-06
	0.1072	0.1080	6.94052E-07
	0.0881	0.0820	3.76117E-05
	0.0777	0.1050	0.000747048
12	0.0280	0.0340	3.61621E-05
	0.0274	0.0370	9.23942E-05
13	0.0458	0.0580	0.00014912
	0.0315	0.0410	8.9848E-05
	0.0271	0.0350	6.18099E-05
14	0.0439	0.0440	1.82159E-08
	0.0435	0.0410	6.42884E-06
	0.0429	0.0430	1.73914E-08
	0.0384	0.0320	4.11983E-05
15	0.0456	0.0420	1.31382E-05
	0.0440	0.0380	3.55849E-05
16	0.0671	0.0870	0.000396212
	0.0479	0.0430	2.44266E-05
	0.0424	0.0520	9.28891E-05
17	0.0677	0.0890	0.000453105
	0.0642	0.0650	5.95147E-07
	0.0601	0.0530	4.97507E-05
	0.0492	0.0330	0.000263109
	0.0448	0.0640	0.000369926
18	0.1173	0.1030	0.000203565
	0.1060	0.0740	0.001023617
19	0.0206	0.0390	0.000339771
	0.0221	0.0340	0.000141692
	0.0230	0.0350	0.000143953

20	0.0577	0.0740	0.0002642
	0.0515	0.0470	1.98437E-05
	0.0416	0.0410	4E-07
	0.0406	0.0320	7.37176E-05

Correlation coefficient between calculated and observed n and for Colorado rivers is 0.67 in this model. SSE = 0.021 and MSE = 0.03. Arithmetic mean for difference percentage is 42.89, that is varied from 18.3% to 182/08%. This suggests that this model tends to overestimate in estimation of n, while this error rate is lower according to the model proposed by Jarrett. The proposed mother therefore have more reliability and accuracy in estimating the Manning's roughness coefficient.

Conclusion

By using Table (4) which derived from the investigation and field data processing of the United States, the results obtained from the current study suggests that unlike Jarrett's proposed relations, soil mechanics factors are also have significant effects on the accuracy of the Manning's roughness coefficient, which is directly tangible in the results.

References

Iman Sho'ar. F. (2006) study on the equation of river regime, master's thesis of water and hydraulic civil engineering, Amirkabir University of Technology.

Soleimani. K. (2005), Rivers: "The forms and the process of alluvial channels"

Shafaei Bejestan. M. (2004), Hydraulic sediment, Shahid Chamran University press

Mahpour, Y (2006) study on roughness in rivers with steep slope, master's thesis of water and hydraulic civil engineering, Amirkabir University of Technology.