Civil and Project Journal, 2022, 4(7), 11-16
https://doi.org/10.22034/CPJ.2022.365058.1162

Civil and Project Journal
http://www.cpjournals.com/

Research Article

A Study of Calculation Manning Roughness Methods: The Case of a Small River in Southwestern Iran

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Received: 09 October 2022; Revised: 27 October 2022; Accepted: 27 October 2022; Published: 27 October 2022

Abstract

Affected by numerous elements, the estimation of manning's roughness coefficient is of great importance and sensitivity. In the present study a reach of 56 km from beshar river in kohgiluyeh and boyer-ahmad province was studied. The selected reach was divided into 12 sub-reaches based on similar characteristics. Experimental and quasi-experimental methods, tables, and cowan's method were used to estimate manning's coefficient. The estimation results were compared with stage-discharge rating curves from two hydrometric stations located in the selected reach. The 'inverse solution' was proved to be the best method to estimate manning's coefficient in the river under study followed by bruschin and cowan's method with an average error of 0.237 and 0.241, respectively.

Keywords:

Manning's coefficient, Inverse solution method, Beshar river, HEC-RAS.

Cite this article as: Rasooli SMS, Bazaee A, Aghamajidi R. (2022). A Study of Calculation Manning Roughness Methods: The Case of a Small River in Southwestern Iran. Civ Proj J;4(7):11–6. https://doi.org/10.22034/cpj.2022.365058.1162.

ISSN: 2676-511X /

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1. Introduction

Manning's roughness coefficient considers all the effective factors in the flow resistance of a channel bed, representing a flow's energy-loss intensity. In this regard, estimating the proper value of Manning's coefficient plays a significant role in water level estimation and is of special importance. Identifying the factors affecting Manning's coefficient is an acceptable method to estimate this coefficient more accurately. These factors include channel bed roughness, channel material, irregularities in cross section, vegetation (type and density), type of path (direct or meandering), obstructions in the flow path, and even the flow depth and discharge, some of which partially have to do with the losses due to flow variation (local losses) , while others have to do with the frictional loss in the flow path.

Shiri et al. (2018) examined the existing relevant relationships to determine the best relation for estimating the initial value of Manning's coefficient in Baneh River. After applying the inverse solution method and checking the results from various methods by HEC-RAS software, they selected Bruschin method as the best one with the least error. Using HEC-RAS software and providing output in GIS, Arman and Salajegheh (2017) conducted a flood zoning in a reach of Karaj River. They concluded that due to the steep slope of the selected reach, raising the flood height in this river does not have any significant effect on expansion of the flood zone. Using HEC-RAS hydraulic model, Hosseinzadeh and Tabar Ahmadi (2015) conducted a flood zoning and estimated the flood damages. They found that the Geographic Information System (GIS) and the HEC-RAS model are powerful tools to analyze the flood areas. Shakouri (2017) compared the effectiveness of various methods including three general approaches of using tables, experimental techniques, and direct techniques in estimating roughness coefficient and concluded that the direct technique is the most accurate method. Using HEC-RAS model, Adam (2016) investigated the changes in velocity and Froude number for two types of forested and non-forested streams by comparing the effect of vegetation on their flow regime and physical behavior. They found that the HEC-RAS model can provide researchers with suitable numerical values to study a stream regime and other hydraulic properties. As a part of a study, Zapp et al. (2015) investigated the effect of rock fragments in soil matrix with various content volumes ranged up to 40% on roughness coefficient and suggested that when rock fragments are floating in a turbulent flow, the roughness coefficient is the same for different amounts of rock fragments. In an experiment with the same soil and no/little rock fragments, they also showed that a narrow rill is formed, in which it’s the sediment yield is considerably higher than that in soil containing rock fragments. Jetten and Guanghui (2013) conducted some experiments to estimate Manning's roughness coefficient in steep slopes and noted that for erodible croplands, there is an apparent linear increase in Manning's roughness coefficient with increasing slope, but for woodlands, which have non-erodible soil, velocity increases with slope, while Manning's roughness coefficient remains constant. By conducting a case study along Soreq Stream in Israeli-occupied Palestine, Azmon (2010) used field data to compare various methods of calculating Manning's coefficient with table values and found that the values determined in the tables cause considerable errors. Azmon also investigated the relation between Manning's roughness coefficient, slope, and hydraulic radius and discovered a direct relation between Manning's roughness coefficient and these two factors. Zhe Li and Juntao Zhang (2009) proposed an analytical method called YSM to calculate Manning's roughness coefficient for border irrigation, and by comparing the results via testing with the field data obtained from various regions and different soil types, they found the proposed model as an accurate method for short borders (<100 m) in that particular field situation.

The present study aims to select the best relation for estimating Manning's roughness coefficient of Beshar River in Kohgiluyeh and Boyer-Ahmad Province. Due to the occurrence of multiple floods in this river and the following damages, it is of great importance to estimate this parameter properly in order to determine bed boundary and river flood fringe.

The following methods are applied in the present study.

1- Experimental relations: these relations, which are obtained through experimental methods are mostly in the form of an exponential relation between Manning's coefficient and characteristic diameter of bed particles. Some of these relations, which are applied in the present study are listed in Table 1.

Table 1 Experimental Methods Used In The Present Study

Researcher(s)	Formula No.	Formula	Particle size unit
Strickler (1923)	(1-1)	$n=.0473d_{50}^{0.166}$	m
Meyer (1948)	(1-2)	$n=.0384d_{90}^{0.166}$	m
Julian (2002)	(1-3)	$n=0.062d_{50}^{0.166}$	m
Keulegan (1949)	(1-4)	$n=.021d_{50}^{0.166}$	ft
Sabramania	(1-5)	$n=.047d_{50}^{0.166}$	m
Guard & Raju	(1-6)	$n=.039d_{50}^{0.166}$	m

2- Semi-experimental relations

Group 1: relations in which Manning's coefficient is affected by mean depth and d_{50}. An example is Berry's relation:

$$n=0.113y^{.166}/\left(1.09+2.2\log\left[y/d_{50}\right]\right) \quad (2\text{-}1)$$

Group 2: relations in which Manning's coefficient is affected by hydraulic radius and d_{50}. An example is Limerinous's relation:

$$n=(0.113R^{0.166})/\left(0.35+2\log(\frac{R}{d_{50}})\right) \quad (2\text{-}2)$$

Group 3: relations in which Manning's coefficient is affected by slope, as well as hydraulic radius and d_{50}. One of these relations is Bruschin's relation:

$$n=(d_{50}^{0.166}/12.38)(R.S/d_{50})^{0.137} \quad (2\text{-}3)$$

In these relations, y is mean depth (m), d_{50} is the diameter from which 50% of soil particles are smaller (m), and R is hydraulic radius (m).

Using tables: according to bed material and considering various factors and conditions, many researchers proposed different tables to estimate roughness coefficient. In the present study, tables provided by Chow and Plan and Budget Organization are investigated.

3- The method of determining Manning's coefficient by considering a series of factors, or Cowan's method:

$$n=(n_0+n_1+n_2+n_3+n_4)m_5 \quad (2\text{-}4)$$

Where n_0 is a base roughness coefficient, which is selected according to the channel material. n_1 to m_5 are correction factors, which represent the effects of surface irregularities, variations in cross section, obstructions in channel path, vegetation, and degree of meandering, respectively. In various references, different values are recorded for these coefficients.

2. Methods and Materials

The reach under study is located in an area with coordinates ranged from 3392082 NL and 549953 EL to 3425647 NL and 524953 EL in UTM. The river bottom heights are 1728.47m and 1466.44m in the upstream and the downstream of the reach, respectively. Therefore, the height difference in the starting and ending points of the reach is 262m, and the river's mean slope is 4.7%.

The river has vast floodplains in many reaches, and the adjacent lands are not much higher than the river bottom. Farmlands, industrial zones, fish farms, and rural areas are built in these reaches. According to the results from the sieve analysis conducted in 5 stations on this reach, the bed materials are nearly similar i.e., coarse gravel, though due to land use, the fringe materials are different in the floodplain i.e., mostly rocks or granules with rather dense vegetation.

In the present study, calculation of Manning's coefficient for the river was conducted using field observations, sieve analysis, and experimental tables and calculations. Moreover, cross sections were provided using the region's topographic maps. Then, water level was obtained in various cross sections using HEC-RAS software based on discharge, geometric characteristics, and Manning's roughness coefficient resulting from different methods. Accordingly, stage-discharge rating curves for each method were obtained and compared with the actual stage-discharge rating curve from the two stations located in the corresponding reach. Then, the best method was selected based on the minimum error by observing the results and measuring the errors using root-mean-square error (RMSE) method.

The method with the least error was naturally selected as the best method to estimate roughness coefficient in the river under study.

3. Results And Discussion

In this section, various methods of determining roughness coefficient are compared, and the results of these calculations along with the related errors for different reaches are listed in the following tables.

Table 2 Values Of Manning's Coefficient Obtained From Experimental Methods

Relation	Parameter	Sample No.1	Sample No.2	Sample No.3	Sample No.4	Sample No.5
Strickler	d_{50}(mm)	12	25	21	28	9
	n	0.0227	0.0256	0.0249	0.0261	0.0216
Meyer	d_{90}(mm)	35	59	59	60	35
	n	0.022	0.024	0.024	0.0241	0.022
Julian (2002)	d_{50}(mm)	12	25	21	28	9
	n	0.030	0.0336	0.0326	0.0342	0.0284
Keulegan (1938)	d_{50}(mm)	12	25	21	28	9
	n	0.012	0.014	0.013	0.014	0.012
Sabramania	d_{50}(mm)	12	25	21	28	9
	n	0.0225	0.0255	0.0247	0.026	0.021
Guard & Raju	d_{50}(mm)	12	25	21	28	9
	n	0.0187	0.0211	0.020	0.0215	0.018

Table 3 Values Of Manning's Coefficient Obtained From Semi-Experimental Methods

Relation	Parameter	Sample No.1	Sample No.2	Sample No.3	Sample No.4	Sample No.5
Berry	d_{50}(mm)	12	25	21	28	9
	n	0.0214	0.024	0.0233	0.0244	0.0207
Bruschin	d_{50}(mm)	12	25	21	28	9
	n	0.0412	0.0431	0.0421	0.0423	0.0425
Limerinous	d_{50}(mm)	12	25	21	28	9
	n	0.0264	0.0298	0.0305	0.0305	0.0253

Table 4 Values Of Manning's Coefficient Obtained From Semi-Experimental Methods

Relation	Reach No.1	Reach No.2	Reach No.3	Reach No.4	Reach No.5	Reach No.6	Reach No.7	Reach No.8	Reach No.9	Reach No.10	Reach No.11	Reach No.12
Chow	0.040	0.035	0.035	0.035	0.040	0.050	0.035	0.030	0.030	0.030	0.030	0.030
Plan and Budget Organization	0.028	0.028	0.037	0.037	0.035	0.035	0.038	0.038	0.026	0.026	0.026	0.026

Table 5 Values Of Manning's Coefficient Obtained From Methods Under The Effect Of A Series Of Factors

Relation	Reach No.1	Reach No.2	Reach No.3	Reach No.4	Reach No.5	Reach No.6	Reach No.7	Reach No.8	Reach No.9	Reach No.10	Reach No.11	Reach No.12
Cowan	0.033	0.046	0.038	0.040	0.050	0.048	0.045	0.038	0.038	0.038	0.038	0.038

The stage-discharge rating curves from the calculation of Manning's coefficient by different methods are compared with the actual stage-discharge rating curves from the hydrometric stations. The errors of each method are obtained using RMST statistical technique and diagrams. The following methods provide the most accurate estimations: (a) semi-experimental Bruschin's method, which considers the effect of bed slope in addition to hydraulic radius and d_{50}, and coming next with a slight margin, (b) Cowan's method, which considers various factors such as variations in cross section, obstructions, vegetation in path, and degree of river meandering in addition to bed gradation. Table 6 lists the error values for each method in an ascending order.

Table 6 Error Values For Various Methods In An Ascending Order

Method	Error in Station No.1	Error in Station No. 2
Bruschin	0.219115	0.25414
Cowan	0.221706	0.260625
Chow	0.306987	0.372507
Plan and Budget Organization	0.404784	0.440567
Julian	0.473228	0.494769
Limerinous	0.503628	0.683837
Strickler	0.592749	0.800269
Sabramania	0.598388	0.809891
Meyer	0.639124	0.88264
Berry	0.673841	0.92398
Guard & Raju	0.849919	1.041828
Keulegan	0.946157	1.259351

4. Conclusions

Since various factors have an effect on Manning's coefficient and since calculating this coefficient is highly sensitive, and considering that there is no specific method to calculate this coefficient in every river, it is suggested that the inverse solution method along with a process of trial and error yields the best value for this coefficient, as it minimizes the difference between observational and calculational values.

Based on the good approximations obtained in this study, the semi-experimental Bruschin method and the Cowen method can be suggested to determine roughness values, which take a range of valid factors for the Manning coefficient and allow for a good initial estimate of the Manning coefficient in coarse gravel-bed rivers.

The experimental methods lack sufficient precision because they ignore the influence of various factors other than bed material on the Manning coefficient. Hence, the coefficient can be estimated by comparing the stage-discharge rating curves of these methods in HEC-RAS with the actual ones.

5. Acknowledgements

This research article is excerpted from a thesis implemented in Islamic Azad University Yasuj Branch. In addition, Reginal Water Company of Kohgiluyeh and Boyer-Ahmad Province is greatly appreciated for their collaboration.

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