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EXPERIMENTAL STUDY FOR DETERMINE MANNING'S COEFFICIENT WITH DIFFERENT SLOPES AND CHANNEL BED MATERIALS

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ABSTRACT

Water resources and hydraulic engineering projects have been upward rapidly in all over the world, accordingly the prediction of roughness coefficient is essential criteria to design open channels, and related hydraulic structures. The aims of this research are to find out the effect of changing beds materials and discharge on coefficient of roughness (n), the beds that used in the tests are smooth which represented by original channel bed (steel plate), rough bed material which is a gravel bed and waved bed .The experimental work was performed in a rectangular flume with dimension of (15 m* 0.3 m* 0.45 m) long, wide and deep, respectively with different value of slope (1:200 and 1:500) to analyze slope effect on coefficient of roughness in addition to the effect of channel bed material. The experimental work showed that The coefficient of roughness reduced when the discharge increases for specified slope and channel bed, The slope of the channel and bed roughness is the main factors affected on determining coefficient of roughness and when the channel slope increases the coefficient of roughness increases, the coefficient of roughness is decreased when using smooth bed and it is increased when channel bed is waved. The percentage change in the Manning coefficient due to changing in slope and channel bed is (112.6%) when slope equal to (1/200) and the channel bed changed from smooth to rough , (184%) when the bed changed from rough to waved, and (33.6%) when channel bed changed from rough to waved. And for (1/500) slope, the percentage change in the Manning coefficient equal to (33.5%) when the bed changed from smooth to rough, (80%) when changed from smooth to waved, and (33.1%) when changed from rough to waved.

KEYWORDS: manning coefficient, channel slope, channel bed material, and roughness

دراسة مختبرية باختلاف ميول ومواد قاع القناة

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الخلاصة

إن المشاريع الخاصة بهندسة المنشآت الهيدروليكية والموارد المائية قد تطورت وبشكل سريع في مختلف أنحاء العالم وكنتيجة لذلك ولتصميم العديد من المنشآت الهيدروليكية كالقنوات المفتوحة, يتطلب معرفة كاملة بكيفية إيجاد معامل مااننغ والعوامل المؤثرة عليه. إن الغرض من هذا البحث هو معرفة التأثير الناتج من تغير أرضية وميل القناة واستخدام تصاريف مختلفة على معامل ماننغ, حيث تم استخدام أرضية ناعمة ممثلة بأرضية القناة الأصلية والمصنوعة من الفولاذ, وأرضية خشنة باستخدام حصى متدرج الأحجام وكذلك استخدام أرضية متموجة. أما التغيير في الميل فتم استخدام ميول بمقدار(1:200 و 1:500). تم إجراء التجارب العملية في قناة مفتوحة أبعادها هي (15*0.3*0.45) متر لكل من الطول, العرض والعمق على التوالي، لقد أوضحت التجارب العملية إن معامل الخشونة (ماننغ) يقل عندما يزداد التصريف لميل وأرضية قناة معينة وان ميل القناة وخشونة قعر القناة هي من العوامل الأساسية المؤثرة في تحديد معامل ماننغ, وعندما يزداد الميل يزداد معامل ماننغ, وجد ان اقل قيمة لمعامل ماننغ عند استخدام أرضية ناعمة واكبر قيمة عند استخدام أرضية مموجة.

1. INTRODUCTION

Recently water resources and hydraulic engineering projects have been upward rapidly in all over the world, accordingly the prediction of roughness coefficient is essential criteria to design open channels, and related hydraulic structure.

Roughness coefficient (n), defined as a parameter expresses' the channel roughness and flow resistance. Previous studies showed that there is many significant factors affecting on the velocity in a certain channel such as water area, wetted perimeter, maximum surface velocity, slope of water surface, maximum depth, roughness coefficient, and water temperature (Huthoff and Augustijin, 2005). In the beds of rivers, when the shape of the bed are dunes or ripples the flow resistance is essentially caused by roughness element forms. However, in rivers that have composed bed due to different materials will have main effects on roughness resistance to flow, which have been studied by many researchers such as (Arcement and Schnider, 1989), (Collins and Dunne, 1990), (Down, 1995), (Leopoled, 1994), and (Ringman, 2004).

(Christodoulou, 2014) made experiments for flow with channel slope of 16.5% with different type of underwater non-natural large size roughness elements.

(Sadeque et al., 2009) analyzed the results for experimental study of flow with cylindrical material on a rough surface in an open channel.

The main parameters which have an effect on the coefficient of roughness (n) are the roughness shape and spacing, channel shape, stage and alignment. In this study the effect of bed roughness materials and channel slope will be considered by changing it in an experimental work to compute Manning coefficients and its effect on discharge.

2. THE EQUATION OF FLOW RESISTANCE

(Limerinos, 1970) and (Griffiths, 1981) intended to ***link*** hydraulic coefficients each other to find out general equation, such as slope, flow rate or depth, river width roughness of bed, ***to*** bed and flow characteristics.

The resistance of flow in open channel can be represented by Manning coefficients of roughness (n). Flow resistance can be defined as “the force to defeat or the necessary work to be prepared to oppose the action of the flexible, rigid, or moving the boundary on the flow” (Yen, 2002).

Manning equation identified as the most suitable formulae that can represent the applications of flow in open channel. The outcome of Manning's equation an indirect calculation of stream flow, which include many applications such as flood-plain administration, bridges and highways design which across submerge plains, and flood studies. The Manning's coefficient (n) of the bed, can be determined by realignment the Manning formula (1) into (2).

$$\boldsymbol{Q} = \frac{1}{n} \boldsymbol{R}^{\frac{2}{3}} \boldsymbol{S}^{\frac{1}{2}} \boldsymbol{A} \quad (1)$$

$$\boldsymbol{n} = \frac{1}{Q} \boldsymbol{R}^{\frac{2}{3}} \boldsymbol{S}^{\frac{1}{2}} \boldsymbol{A} \quad (2)$$

Where:

Q: is the flow rate in (m^3/s),

R: is the hydraulic radius in (m),

S: is the channel slope,

A: is the channel cross section area in (m^2), and

n: is the Manning's coefficient of roughness($m^{1/6}$).

3. EXPERIMENTAL WORK

Experimental work was performed in a rectangular flume with dimensions of (15 m* 0.3 m* 0.45 m) long, wide and deep, respectively was used to carry out the tests. Acrylic glass is the material that the flume wall made of to grant visual observation, with stainless steel bed. An electrical control unit is located at the upstream of the flume to control the slope and the pump changing system.

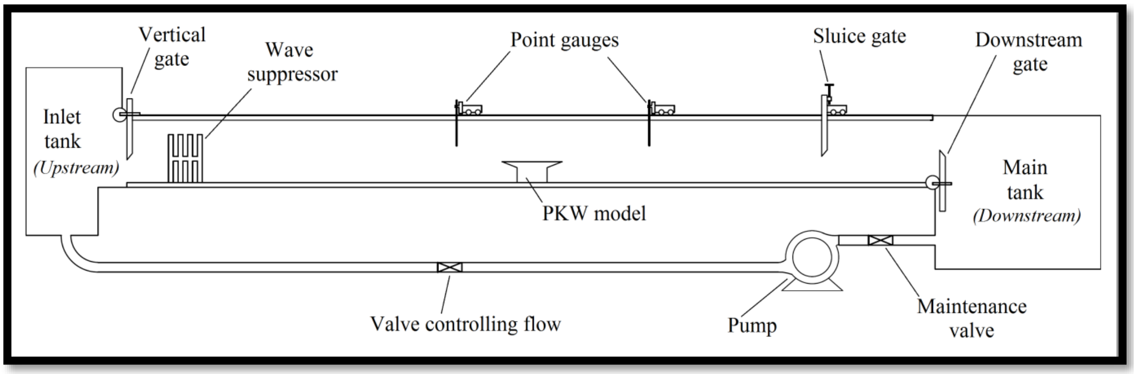

Fig. 1. The details of experimental flume.

Fig. 1 shows the details of the flume in graphic form; the Figs. 2, 3, and 4 represented the flume. Throughout all the tests in this research. There is a vertical sluice gate used to manage the water level located at the beginning of the flume, was kept open.

Fig. 2. The experimental flume.

4. TEST PROCEDURE

1. Place the sharp crested rectangular weir at the downstream of the channel as shown in Fig. 5, to determine flow-rate by using the following formula:

$$Q = \mu * h * \acute{b} * \sqrt{2gh}$$

where:

Q: is the flow-rate measured using the rectangular weir (m^3/sec).

μ: is the discharge coefficient which varies as a function of the form taken on by the flowing vein (0.385 – 0.433 – 0.46 – 0.497 – 0.554) which is taken equal to (0.433) according to the User's Manual and Exercise Guide H91.8D/15, (code 934206) for the experimental flume.

$\acute{b}$: is the width of the threshold (0.3) m.

h: is the difference between the level of the threshold and the surface of the current as the latter begins to approach the outlet (m).

g: is the acceleration of gravity(m/sec^2).

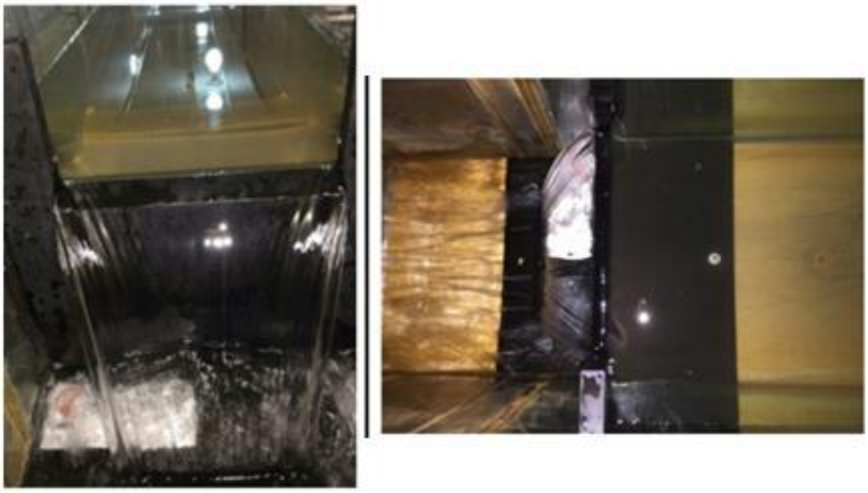

Fig. 3. Sharp crested rectangular weir.

2. Arrange the channel in sloped position which was (1/200, 1/500)
3. Start the electrically operated pump from the control panel.
4. Work on the throttle valve and the upstream gate until the desired flow-rate is obtained.
5. Waiting steady flow and measure (h) over the weir from its crest to the water surface.
6. Calculating the flow rate by $Q = \mu * h * \acute{b} * \sqrt{2gh}$
7. Applying Manning equation (2).

This procedure used for each thirty test that done in this research for smooth channel bed represented by origin channel bed, rough surface by using gravel bed surface and the waved surface by using waved plate as shown in Fig. 4 and 5.

Table 1. Conditions of Experiments.

Type of bed	Test	Slope
Smooth (stainless steel)	1	
Rough (gravel)	2	1:200
Waved	3	
Smooth (stainless steel)	4	
Rough (gravel)	5	1:500
Waved	6	

Fig. 4. Channel beds material.

Fig. 5. Channel beds.

5. RESULTS AND DISCUSSION

5.1. Effect of slope on roughness coefficient

The results of test 1 and 4 were compared to study the effect of slope on roughness for smooth surface and the results of smooth surface are plotted in Fig. 6.

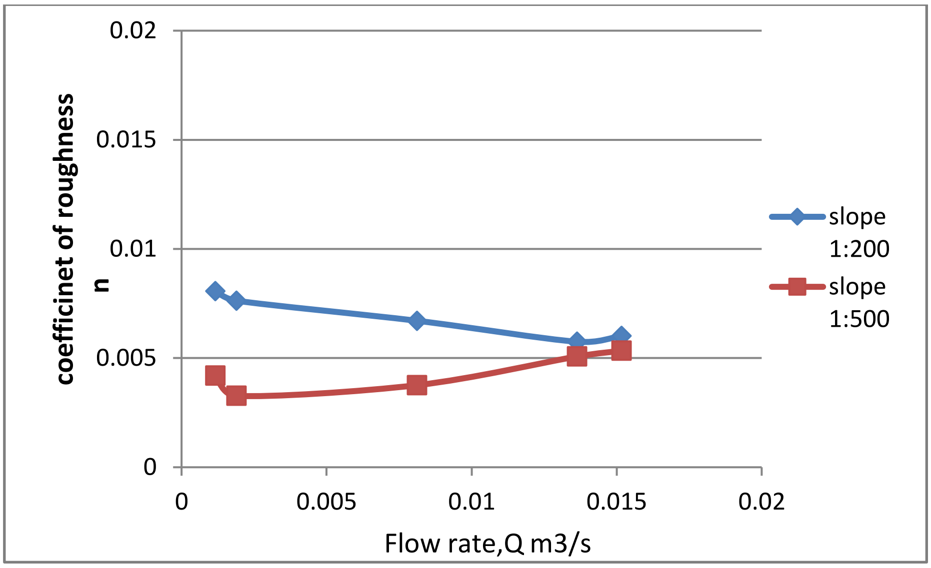

Fig. 6. Manning's coefficient (n) against discharge Q for smooth (stainless steel bed).

As shown in Fig. 6, the amount of Manning's coefficient (n) is decreasing from steeper to flatter which agreement with Manning's theory (Lau and Afshar, 2013). Thus the roughness of coefficient for channel slope equal to 1:200 is higher when comparing with channel slope of 1:500, it was noticed that the effect of manning coefficient for roughness decreases when getting closer to a flatter slope (1:500). From Fig. 6 the difference of Manning's coefficient (n) between the slope 1:200 and 1:500 for (0.00117m3/s) discharge is (0.00386) in summary, the effect of channel slope on roughness is reduction step by step for flatter slope. Also, the results with rough and waved beds were presented in to Figs. 7 and 8, test 2 and 5 used to show slope effect on coefficient of roughness for rough bed, while test 3and 6 used to study influence of slope on coefficient of roughness for waved bed.

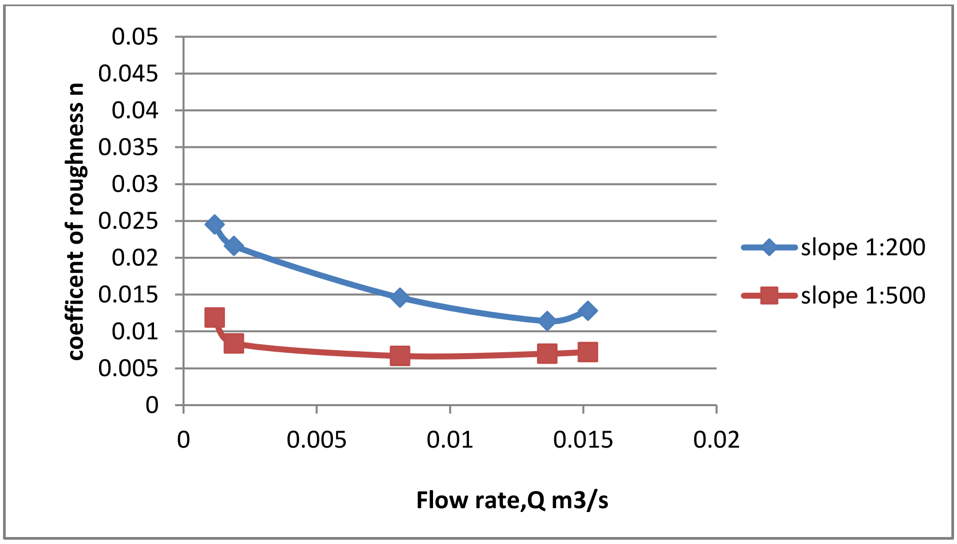

Fig. 7. Manning's coefficient (n) against discharge Q for rough bed.

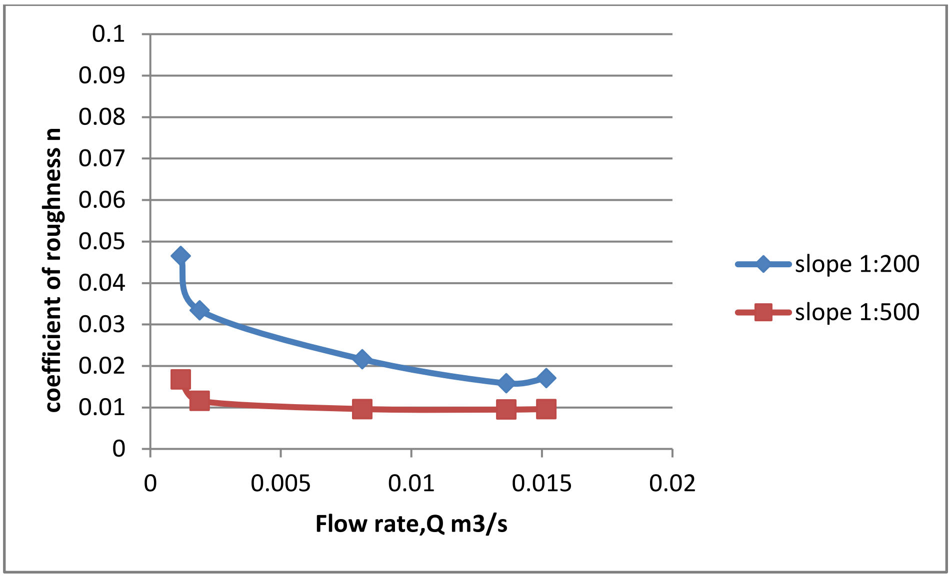

Fig. 8. Manning's coefficient (n) against discharge Q for waved bed.

5.2. effect of various type of bed material on coefficient of roughness

Test 1 and 4 with smooth roughness was analyze to find out the relationship between the bed roughness and coefficient of roughness for a steeper slope (1:200). Fig. 9 indicate roughness coefficients almost stay constant during the experiments when experienced with various flow rate. For example, the maximum and minimum value of manning's coefficient (n) are (0.00806, 0.00575) respectively for test 1 (smooth channel bed) so the different between them is (0.00231) only which is small along the experiment. The same thing for other tests which observed ***that manning's coefficient will not show a big different while the discharge increased for the same test.*** Fig. 9 showed that bed roughness have influence on manning's coefficient and discharge. For example, smooth bed (test1) have a lesser coefficient of roughness comparing with rough bed (test 2) and waved bed (test 3), ***when the channel bed having high roughness material the coefficient of roughness will be higher.*** Table 2 show the average values of manning's n for slope (1:200).

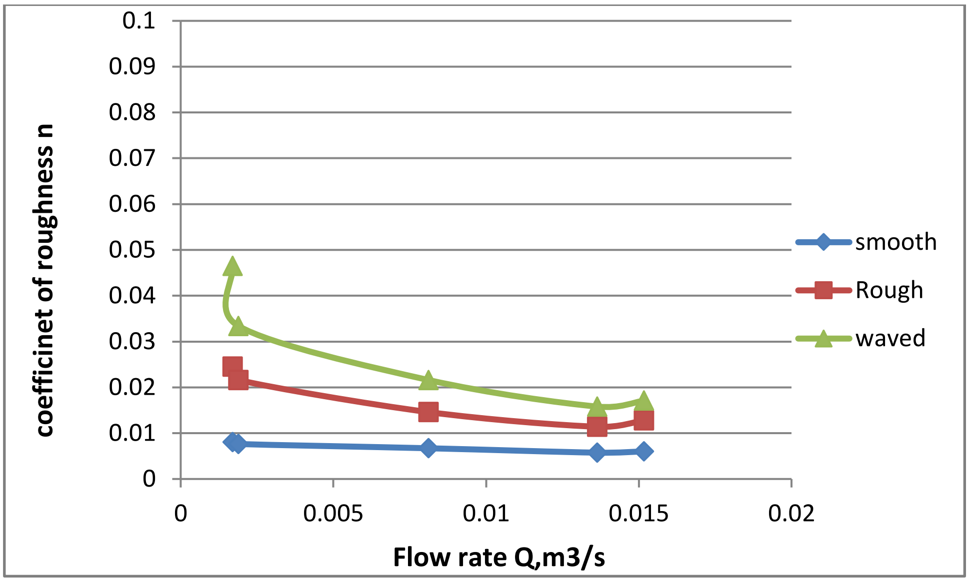

Fig. 9. Manning's coefficient (n) versus discharge Q for slope 1:200.

Table 2. Average coefficient of roughness of various channel bed for slope 1:200.

Beds material	Flow rate Q (m3/s)					Range (n)	Average (n)
	0.00117	**0.00189**	**0.00812**	**0.01364**	**0.01517**		
Smooth	0.00806	0.00763	0.00671	0.00575	0.00602	0.00806--(0.00575)	0.01767
Rough	0.0245	0.0216	0.0146	0.0114	0.0128	0.0245--(0.0114)	0.01698
waved	0.0465	0.0334	0.0216	0.0158	0.0171	0.0465--(0.0158)	0.02688

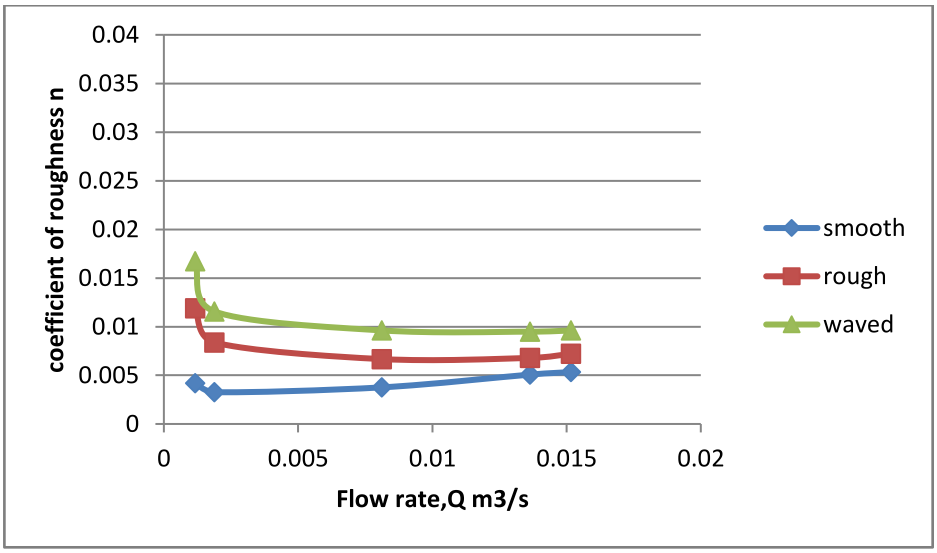

Fig. 10. Manning's n versus discharge Q for slope 1:500.

Fig. 10 presented that the manning's coefficient remain the same or doesn't show more difference with the discharge changing for the tests (2 and 5) but its show an obvious different when changing beds material (test 4, 5 and 6), the ranges of manning's coefficient are organized in Table 3.

Table 3. Average coefficient of roughness of various channel bed for slope 1:500.

Beds material	Flow rate Q (m3/s)					Range (n)	Average (n)
	0.00117	**0.00189**	**0.00812**	**0.01364**	**0.01517**		
Smooth	0.0042	0.0033	0.0038	0.0051	0.0053	0.0053-0.0033	0.0043
Rough	0.0119	0.0084	0.0067	0.0069	0.0072	0.0119-0.0067	0.0093
waved	0.0167	0.0116	0.0096	0.0095	0.0096	0.0167-0.0095	0.0131

The percentage change in the Manning coefficient as a result of the change in slope and channel bed is shown in the table below:

Table 4. Percentage change % of Manning coefficient due to changing in slope and channel bed for slope 1/200.

Flow rate (m3/s)	percentage change% of Manning coefficient when bed changed from smooth to rough	percentage change% of Manning coefficient when bed changed from smooth to waved	percentage change% of Manning coefficient when bed changed from rough to waved
0.00117	203.9	476.9	89.8
0.00189	183.0	337.7	54.6
0.00812	117.5	275.6	47.9
0.01364	98.0	98.2	38.5
0.01517	112.6	184.0	33.6

Table 5. Percentage change% of Manning coefficient due to changing in slope and channel bed for slope 1/500.

Flow rate (m3/s)	percentage change% of Manning coefficient when bed changed from smooth to rough	percentage change% of Manning coefficient when bed changed from smooth to waved	percentage change% of Manning coefficient when bed changed from rough to waved
0.00117	183.3	298.6	40.7
0.00189	156.4	253.5	37.9
0.00812	77.2	155.4	44.2
0.01364	37.3	86.9	36.1
0.01517	33.5	80.0	33.1

6. CONCLUSIONS

Many conclusions can be notified;

1. The coefficient of roughness reduced when the discharge increases for specified slope and channel bed.
2. The slope of the channel and bed roughness is the main factors affected on determining coefficient of roughness, coefficient of roughness for 1:200 slope is higher than 1:500.
3. Coefficient of roughness increases when the channel slope increases, but the proportion of increase is not linearly to slope increases.
4. For the same bed roughness, the increase in discharge will not have that more effect on coefficient of roughness.
5. Lower coefficient of roughness and less effect on discharge can be gets when the channel bed is smooth.
6. Waved bed material give higher coefficient of roughness.
7. The percentage change in the Manning coefficient as a result of the change in slope and channel bed is (112.6%) when slope equal to (1/200) and the channel bed changed from smooth to rough , (184%) when the bed changed from rough to waved, and (33.6%) when channel bed changed from rough to waved.

8. The percentage change in the Manning coefficient as a result of the change in slope and channel bed is (33.5%) when slope equal to (1/500) and the channel bed changed from smooth to rough , (80%) when the bed changed from rough to waved, and (33.1%) when channel bed changed from rough to waved.

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