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Manning's roughness coefficient in a truncated triangular open-channel flow section

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ABSTRACT

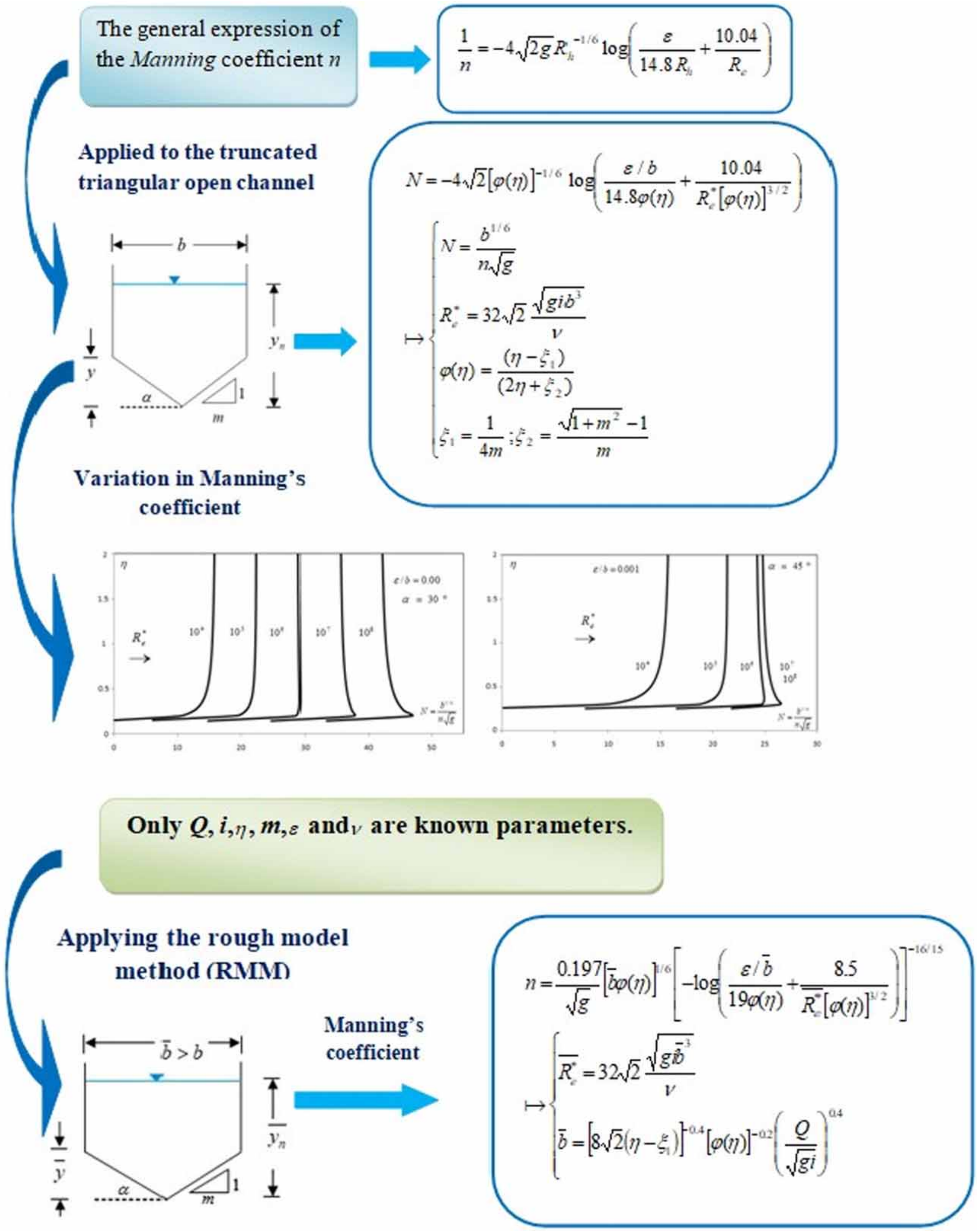
In uniform flows, Manning's roughness coefficient *n* plays an important role in the calculation of the normal depth in the open channels. When calculating uniform flows in open conduits and channels, Manning's coefficient is arbitrarily chosen. This arbitrary choice is not physically justified because the coefficient *n* must be determined according to the parameters that influence the flow, particularly the normal depth sought. In this paper, a new method is presented to compute Manning's coefficient in a truncated triangular channel section. In the first step, the study proposes to establish the general relationship that allows computing Manning's coefficient in this type of channel. The relationship is presented in dimensionless terms, giving it a character of general validity, including the dimensionless Manning's resistance coefficient, denoted as *N*. The latter is shown to depend on the aspect ratio of the wetted area, the side slope of the channel, the relative roughness and the modified Reynolds number, which is physically justified since flow resistance is closely related to flow depth. In the second step, the rough model method is proposed to express Manning's coefficient when the horizontal dimension of the channel is not a given data of the problem.

Key words: discharge, Manning's resistance coefficient, open channel, rough model method (RMM), truncated triangular channel, uniform flow

HIGHLIGHTS

- The general expression of *n* is set with different geometric profiles of conduits and channels, mainly the truncated triangular open channel flow section.
- Explicit relation of the *n* in the turbulent flow using the RMM.
- The coefficient *n* can be determined independently of the horizontal dimension *b* using the RMM.
- The study of variation of *nt* as a function of the parameters that influence the flow makes.

GRAPHICAL ABSTRACT



1. INTRODUCTION

The calculation of uniform flows in conduits and channels occupies an important place in the practice of hydraulic engineering. In uniform flows, *Chezy's* and *Manning's* equations are two important formulas used to determine the velocity and discharge. For open channel turbulent flow calculations, the *Manning* formula is the most commonly used resistance equation. Manning's coefficient n is an empirically derived coefficient that depends especially on the surface roughness. The greatest difficulty in applying the *Manning* formula is determining the roughness coefficient n because there is no exact method of determining the n value (Chow 1959).

In the past, the coefficient n has always been regarded as a constant whose value comes from tables that may be obtained in the literature according to the type of material composing the pipe or the channel (Chow 1959; Henderson 1966; Streeter 1971). However, 76 years ago, Camp (1946) showed that the Manning roughness coefficient n is not a constant and that it depends on several parameters, especially the depth of the flow. In the recent past, this observation has been confirmed with different shapes of artificial channels (Swamee & Rathie 2004; Achour & Bedjaoui 2006; Meky *et al.* 2015). More recently, Swamee & Rathie (2004) suggested a new general relationship for Manning's roughness coefficient, which is applicable for all forms of channels and conduits. This formula is very complete as it contains the longitudinal slope of the channel i, hydraulic radius R_h, absolute roughness ε, kinematic viscosity ν, and acceleration due to gravity g. Thus, it can be applied to the whole domain of turbulent flow. However, this relation is implicit when the linear dimension of the channel is not provided, or in regard to determining the normal flow depth.

For circular, trapezoidal or rectangular channels, some authors have proposed analytical relationships for estimating Manning's coefficient (Achour 2014; Achour & Amara 2020a, 2020b). However, no study has been published on truncated triangular channel sections despite their extensive use in practice as irrigation and drainage channels.

The purpose of this study is to show how to calculate Manning's resistance coefficient in a truncated triangular channel section. In the first step, the dimensionless Manning's coefficient is expressed to give it a general validity character. The expression of this dimensionless coefficient is deduced from the comparison between *Manning's* relationship and the general formula of the discharge proposed by Achour & Bedjaoui (2006). This relationship is valid for all geometric profiles and established in all turbulent flow regimes, which is applied to the truncated triangular channel section. In the second step, the calculation approach is based on the rough model method (RMM), which has been proven in the recent past by successfully contributing to the design of conduits and channels and to the calculation of normal depth (Achour 2014; Achour & Sehtal 2014). An explicit method of calculating Manning's resistance coefficient is proposed when the horizontal dimension of the channel is not a given data of the problem, taking into account the required hydraulic parameters, namely, the aspect ratio, the discharge, the longitudinal slope, the side slope of the channel, the absolute roughness of the internal walls of the channel and the kinematic viscosity of the liquid.

In the third step, curves showing the variation in the dimensionless Manning coefficient will be elaborated as a function of the aspect ratio in a truncated triangular channel section. The variation in the coefficient N in this type of channel will be studied not only as a function of the aspect ratio but also as a function of other flow parameters such as the side slope of the channel, the relative roughness and the modified Reynolds number, and thus the kinematic viscosity. The detailed study of these curves leads to interesting results.

Through a detailed practical example, how to calculate Manning's resistance coefficient in a truncated triangular channel section with minimum practical data is shown.

2. METHODOLOGY

2.1. Geometric characteristics

The truncated triangular channel section is displayed in Figure 1. This is characterized by the three geometric elements b, y and y_n corresponding to the horizontal dimension, the vertical dimension and the normal depth, respectively. The bottom of the channel has a triangular shape with a side slope of m horizontal to 1 vertical.

The wetted cross-sectional area A and the wetted perimeter P can be formulated as a function of the aspect ratio $\eta = y_n/b$.

$$A = b^2(\eta - \xi_1) \tag{1}$$

$$P = b(2\eta + \xi_2) \tag{2}$$

where

$$\xi_1 = \frac{1}{4m} \tag{3}$$

$$\xi_2 = \frac{\sqrt{1+m^2} - 1}{m} \tag{4}$$

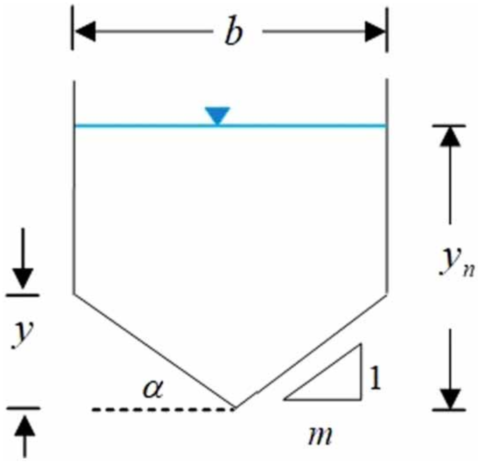


Figure 1 | Flow in a truncated triangular channel section.

The hydraulic radius $R_h = A/P$:

$$R_h = b\varphi(\eta) \tag{5}$$

where

$$\varphi(\eta) = \frac{(\eta - \xi_1)}{(2\eta + \xi_2)} \tag{6}$$

2.2. General expression of Manning's resistance coefficient

For the uniform flow of open channels, *Manning's* formula can be written as:

$$Q = \frac{1}{n} A R_h^{2/3} \sqrt{i} \tag{7}$$

where n is the resistance coefficient of Manning and i is the longitudinal slope of the channel.

In this formula, the resistance coefficient to flow n in Equation (7) varies as a function of the aspect rate η. This means that this coefficient is not a known data of the problem.

For all the geometrical shapes of the channels, Achour & Bedjaoui (2006) gave a general relationship of the discharge Q according to all parameters influencing the flow. This relationship applies to all turbulent flow regimes, namely, smooth, rough and transitional, such as:

$$Q = -4\sqrt{2g} A \sqrt{R_h i} \log\left(\frac{\varepsilon}{14.8R_h} + \frac{10.04}{R_e}\right) \tag{8}$$

where ε is the absolute roughness of the channel internal wall and R_e is a Reynolds number given by the equation:

$$R_e = 32\sqrt{2}\frac{\sqrt{gR_h^3 i}}{\nu} \tag{9}$$

where ν is the kinematic viscosity. Inserting Equation (5) into Equation (9) results in:

$$R_e = 32\sqrt{2}[\varphi(\eta)]^{3/2}\frac{\sqrt{gib^3}}{\nu} \tag{10}$$

Equation (9) can be rewritten as follows:

$$R_e = R_e^*[\varphi(\eta)]^{3/2} \tag{11}$$

where R_e^* is a modified Reynolds number and is written by

$$R_e^* = 32\sqrt{2}\frac{\sqrt{gib^3}}{\nu} \tag{12}$$

By comparing relations (7) and (8), we can deduce that the general expression of the Manning coefficient is such that:

$$\frac{1}{n} = -4\sqrt{2g}R_h^{-1/6}\log\left(\frac{\varepsilon}{14.8R_h} + \frac{10.04}{R_e}\right) \tag{13}$$

Taking into account Equations (5) and (11), Equation (13) is reduced to:

$$\frac{1}{n} = -4\sqrt{2g}b^{-1/6}[\varphi(\eta)]^{-1/6}\log\left(\frac{\varepsilon/b}{14.8\varphi(\eta)} + \frac{10.04}{R_e^*[\varphi(\eta)]^{3/2}}\right) \tag{14}$$

The dimensionless parameter is set as follows:

$$N = \frac{b^{1/6}}{n\sqrt{g}} \tag{15}$$

In dimensional terms, Equation (14) becomes

$$N = -4\sqrt{2}[\varphi(\eta)]^{-1/6}\log\left(\frac{\varepsilon/b}{14.8\varphi(\eta)} + \frac{10.04}{R_e^*[\varphi(\eta)]^{3/2}}\right) \tag{16}$$

It thus appears that n depends on the relative roughness ε/b, the aspect ratio η, and the modified Reynolds number R_e^*. When these parameters are provided, relation (16) allows the coefficient n to be determined explicitly. However, in regard to designing the channel, b is not a given data, and only Q, i, η, m, ε and ν are known parameters. In this case, relation (16) does not allow the explicit determination of the coefficient n. However, this problem can be solved using the RMM.

2.3. Manning's resistance coefficient calculation using the RMM

The symbol '$-$' distinguishes each of the rough model's geometric and hydraulic properties. The referential rough model of the same shape is defined by the horizontal dimension $\overline{b}$ greater than b, the vertical dimension $\overline{y}$ and the normal depth $\overline{y_n}$, a side slope 'm' vertical to 1 horizontal and a longitudinal slope $\overline{i} = i$ (Figure 2). The flow characterized by the relative roughness is $\overline{\varepsilon}/\overline{D_h} = 0.037$ arbitrarily chosen in the fully rough regime, where $\overline{D_h}$ is the hydraulic diameter (Achour 2014). Thus, the friction coefficient $\overline{f} = 1/16$ according to the Colebrook–White equation (Colebrook 1939) for Reynolds number $R_e = \overline{R_e}$ converges to infinitely large values. In the rough model, the discharge is $\overline{Q} = Q$, the kinematic viscosity is ν and the aspect ratio is $\overline{\eta} = \eta$.

The flow in the rough model, Manning's equation, is written as follows:

$$\overline{Q} = Q = \frac{1}{\overline{n}}\overline{A}\overline{R_h}^{2/3}\sqrt{i} \tag{17}$$

Manning's resistance coefficient in the rough model is:

$$\overline{n} = \frac{\overline{R_h}^{1/6}}{\overline{C}} \tag{18}$$

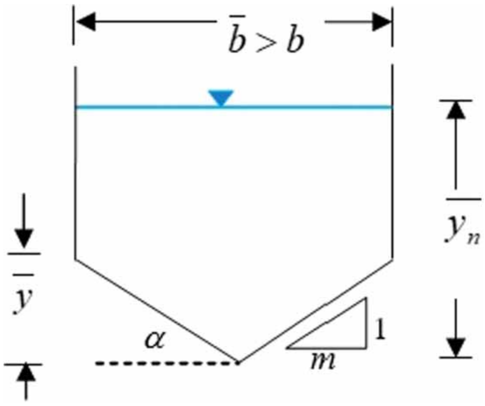


Figure 2 | Flow in the rough model of a truncated triangular channel section.

Chezy's coefficient C is provided according to the *RMM* as follows (Achour & Sehtal 2014):

$$\overline{C} = 8\sqrt{2g} \tag{19}$$

Substituting relation (19) into (18), we thus deduce

$$\overline{n} = \frac{\overline{R_h}^{1/6}}{8\sqrt{2g}} \tag{20}$$

Between the water areas A and the hydraulic radius R_h of the flow in the channel and their homologs of the reference rough model $\overline{A}$ and $\overline{R_h}$, one can write the following equations (Achour & Sehtal 2014):

$$A = \psi^2\overline{A} \tag{21}$$

$$R_h = \psi\overline{R_h} \tag{22}$$

where ψ is a dimensionless parameter determined by the following expression (Achour & Bedjaoui 2006):

$$\psi = 1.35\left[-\log\left(\frac{\varepsilon/\overline{R_h}}{19} + \frac{8.5}{\overline{R_e}}\right)\right]^{-2/5} \tag{23}$$

where $\overline{R_e}$ is the Reynolds number in the rough model given by the following relationship:

$$\overline{R_e} = \overline{R_e^*}[\varphi(\eta)]^{3/2} \tag{24}$$

Thus, according to relation (5), we can write:

$$\overline{R_h} = \overline{b}\varphi(\eta) \tag{25}$$

Taking into account relations (21) and (22), Equation (7) is written as follows:

$$Q = \frac{1}{n}\psi^{8/3}\overline{A}\overline{R_h}^{2/3}\sqrt{i} \tag{26}$$

By comparing Equations (17) and (26), we can write

$$n = \psi^{8/3}\overline{n} \tag{27}$$

Taking into account Equation (20), Equation (27) is written as follows:

$$n = \frac{\psi^{8/3}\overline{R_h}^{1/6}}{8\sqrt{2g}} \quad (28)$$

Inserting Equations (24) and (25) into Equation (23) leads to

$$\psi = 1.35\left[-\log\left(\frac{\varepsilon/\overline{b}}{19\phi(\eta)} + \frac{8.5}{\overline{R_e^*}[\phi(\eta)]^{3/2}}\right)\right]^{-2/5} \quad (29)$$

The following explicit expression of Manning's coefficient n is obtained by combining Equations (25), (28) and (29):

$$n = \frac{0.197}{\sqrt{g}}[\overline{b}\phi(\eta)]^{1/6}\left[-\log\left(\frac{\varepsilon/\overline{b}}{19\phi(\eta)} + \frac{8.5}{\overline{R_e^*}[\phi(\eta)]^{3/2}}\right)\right]^{-16/15} \quad (30)$$

The Reynolds number $\overline{R_e^*}$ is given by Equation (12) as follows:

$$\overline{R_e^*} = 32\sqrt{2}\frac{\sqrt{gi\overline{b}^3}}{\nu} \quad (31)$$

Equation (30) will be used when the horizontal dimension b of the channel is not a given data of the problem. The coefficient n is explicitly calculated, provided that the discharge Q, the slope i, the absolute roughnessε, the side slope of the channel m and the aspect ratioη are known. To express the horizontal dimension $\overline{b}$, *Manning's* relation to the rough model is applied.

Using Equation (1) for the rough model results in:

$$\overline{A} = \overline{b}^2(\eta - \xi_1) \quad (32)$$

With the aid of Equations (20), (25) and (32), Equation (17) becomes

$$\overline{b} = \left[8\sqrt{2}(\eta - \xi_1)\right]^{-0.4}[\phi(\eta)]^{-0.2}\left(\frac{Q}{\sqrt{gi}}\right)^{0.4} \quad (33)$$

Since the problem's known parameters are Q, i, m and η, relation (33) allows for a direct determination of the horizontal dimension $\overline{b}$. As a result, all relationships are made for the explicit calculation of Manning's coefficient n through the following steps, provided Q, i, m and η are given:

1. With the known value of m, compute ξ_1 and ξ_2 using Equations (3) and (4), respectively.
2. According to Equation (6), compute $\phi(\eta)$.
3. Compute the horizontal dimension $\overline{b}$ of the rough model using Equation (33).
4. For the given values of $\overline{b}$, i, g and ν, Equation (31) gives the modified *Reynolds* number $\overline{R_e^*}$.
5. Finally, using Equation (30), *Manning's* coefficient n can be worked out for the known values of $\overline{b}$, ε, $\overline{R_e^*}$, η and g.

The solving procedure is schematically shown in Figure 3.

3. RESULTS AND DISCUSSION

3.1. Variation in Manning's coefficient

According to Equations (3), (4), (6) and (16), the dimensionless Manning's coefficient N depends on four variables, namely, the relative roughness ε/b, the side slope m of the channel, the aspect ratio η and the modified Reynolds number R_e^*.

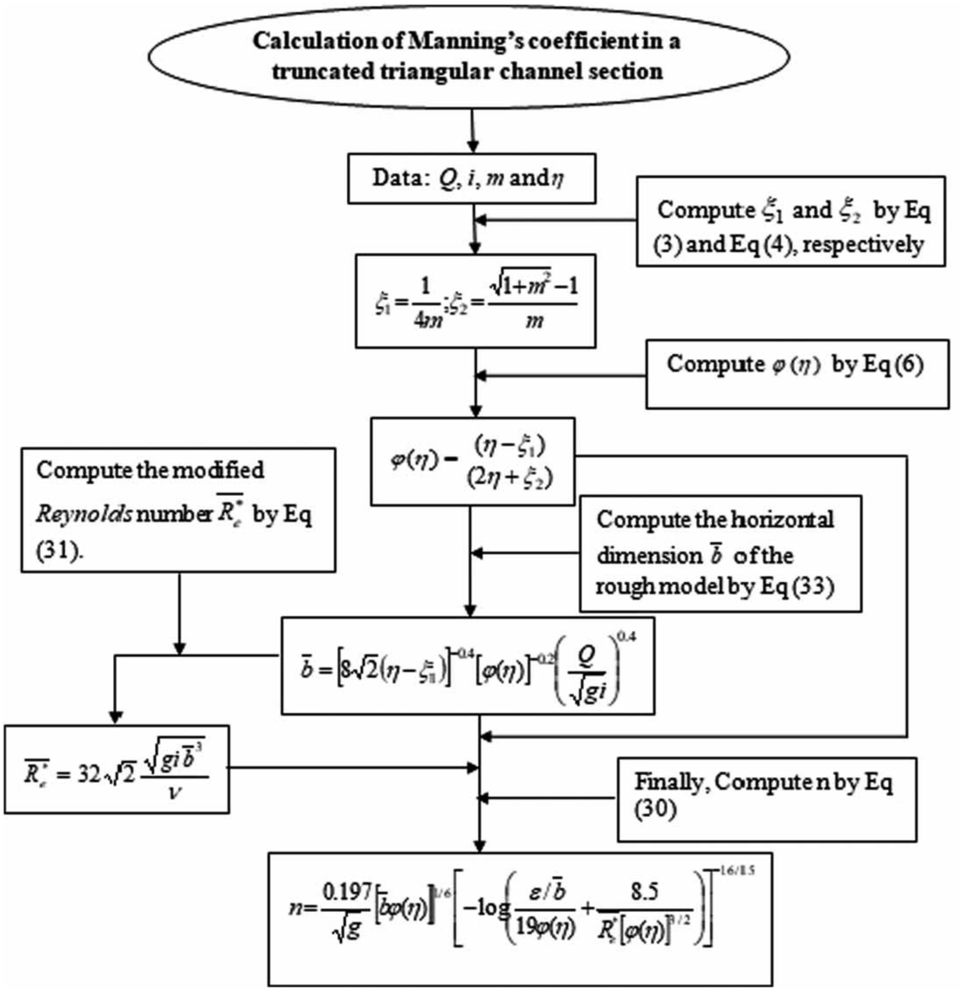


Figure 3 | Calculation procedure diagram.

According to relation (16), the study of the variation of N as a function of the aspect ratio η requires the drawing of the indicative curves for different values of relative roughness ε/b, the side slope m of the channel and by varying values of the modified Reynolds number R_e^* between 10^4 and 10^8.

Three figures have been made, exposing this variation for different side slopes of the truncated triangular channels section, one for the side slope m $(\alpha = 30°) = 1.73205081$, the second for the side slope m $(\alpha = 45°) = 1$, and the third for the side slope m $(\alpha = 60°) = 0.57735027$.

In all figures, the variation of N versus the aspect ratio η and the modified Reynolds number R_e^* are translated for $\varepsilon/b = 0$ corresponding to a smooth inner wall of the channel and for ($\varepsilon/b = 0.001$ and $\varepsilon/b = 0.01$) corresponding to a state of the rough inner wall of the channel.

In all curves, the coefficient N undergoes an increase for low filling rates η of the channel; for $\eta > 0.2$, the coefficient N undergoes a very small variation and becomes constant at the increase of η; hence, the variation η has little influence on the value of the coefficient N. The constancy of the parameter N is remarkable for the value $R_e^* \geq 10^5$. Beyond this value, the curves begin to be concave.

In Figures 4–6, for a fixed value of η, the coefficient N increases with the increasing of the *Reynolds* number. That is for a known horizontal dimension b of the channel, the increase in the dimensionless parameter N means that $1/n$ increases or Manning's resistance coefficient n decreases.

With the increase in the relative roughness ε/b, the curves tend to lose their concavity for values of $R_e^* > 10^5$. The coefficient N decreases as ε/bincreases, regardless of the value of the modified Reynolds number R_e^*. This amounts to saying that $1/n$ increases or that the coefficient n decreases, for which the horizontal dimension b is fixed.

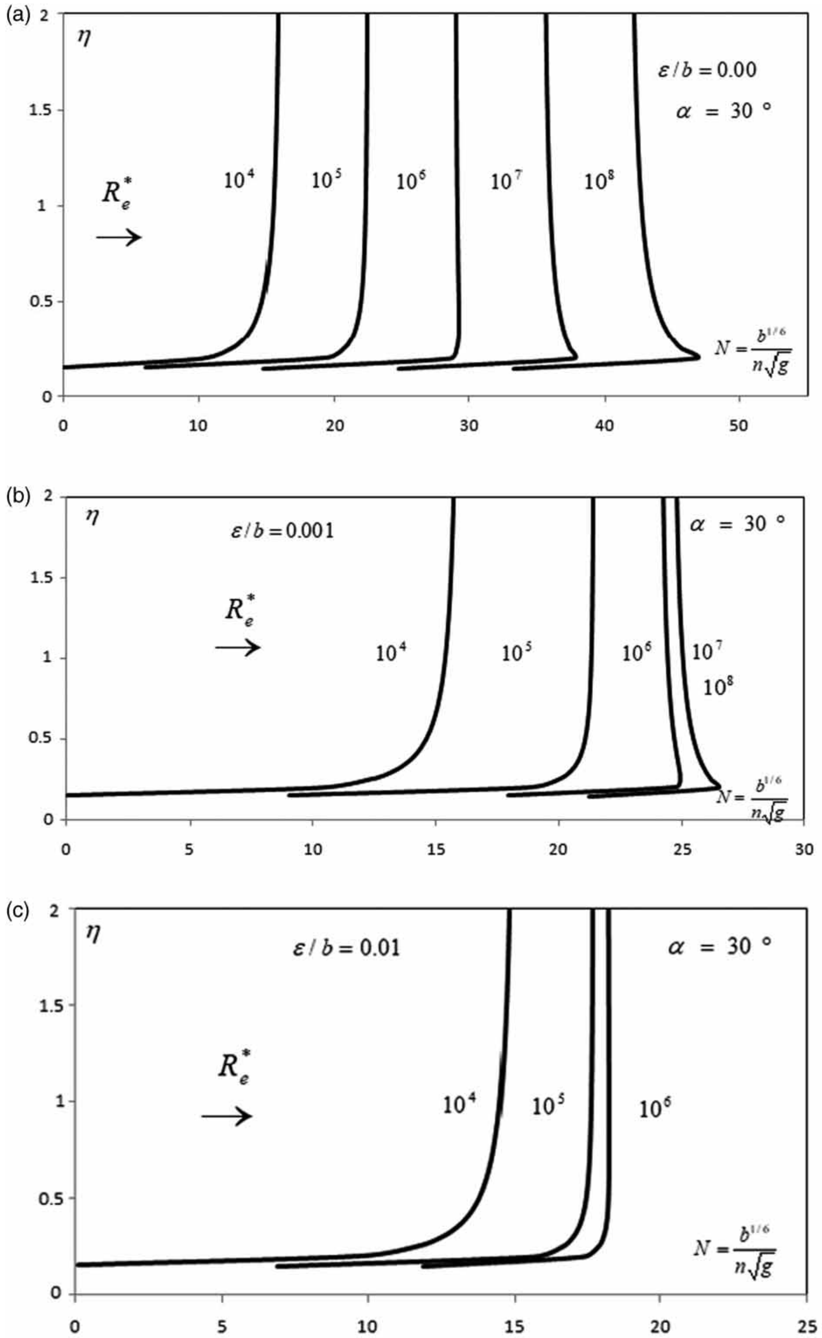


Figure 4 | Variation of N as a function of the filling rate η and the Reynolds number R_e^* for the side slope m ($\alpha = 30°$) = 1.73205081, according to Equation (16) for fixed values of the relative roughness: (a) $\varepsilon/b = 0$, (b) $\varepsilon/b = 0.001$ and (c) $\varepsilon/b = 0.01$.

With the simultaneous increase in the relative roughness ε/b and the Reynolds number R_e^*, the curves of Figures 4(b), 5(b) and 6(b), corresponding to relative roughness $\varepsilon/b = 0.001$, come closer and tend to become confounded for the values of $R_e^* \geq 10^7$. Beyond this value, the modified Reynolds number R_e^* has no influence on the variation of the dimensionless parameter N, which means that the kinematic viscosity ν of the flowing liquid does not play any role. The rough turbulent state of the flow is therefore reached for $R_e^* = 10^7$. Only the shape parameter $\eta = y_n/b$ influences the variation of N.

For higher relative roughness $\varepsilon/b = 0.01$, the curves of Figures 4(c), 5(c) and 6(c), tend to become confounded for the values of $R_e^* \geq 10^6$. This reflects the fact that the rough turbulent regime is reached for $R_e^* = 10^6$, and there is no influence of the modified Reynolds number R_e^*, or the kinematic viscosity ν of the flowing liquid, on the variation of N.

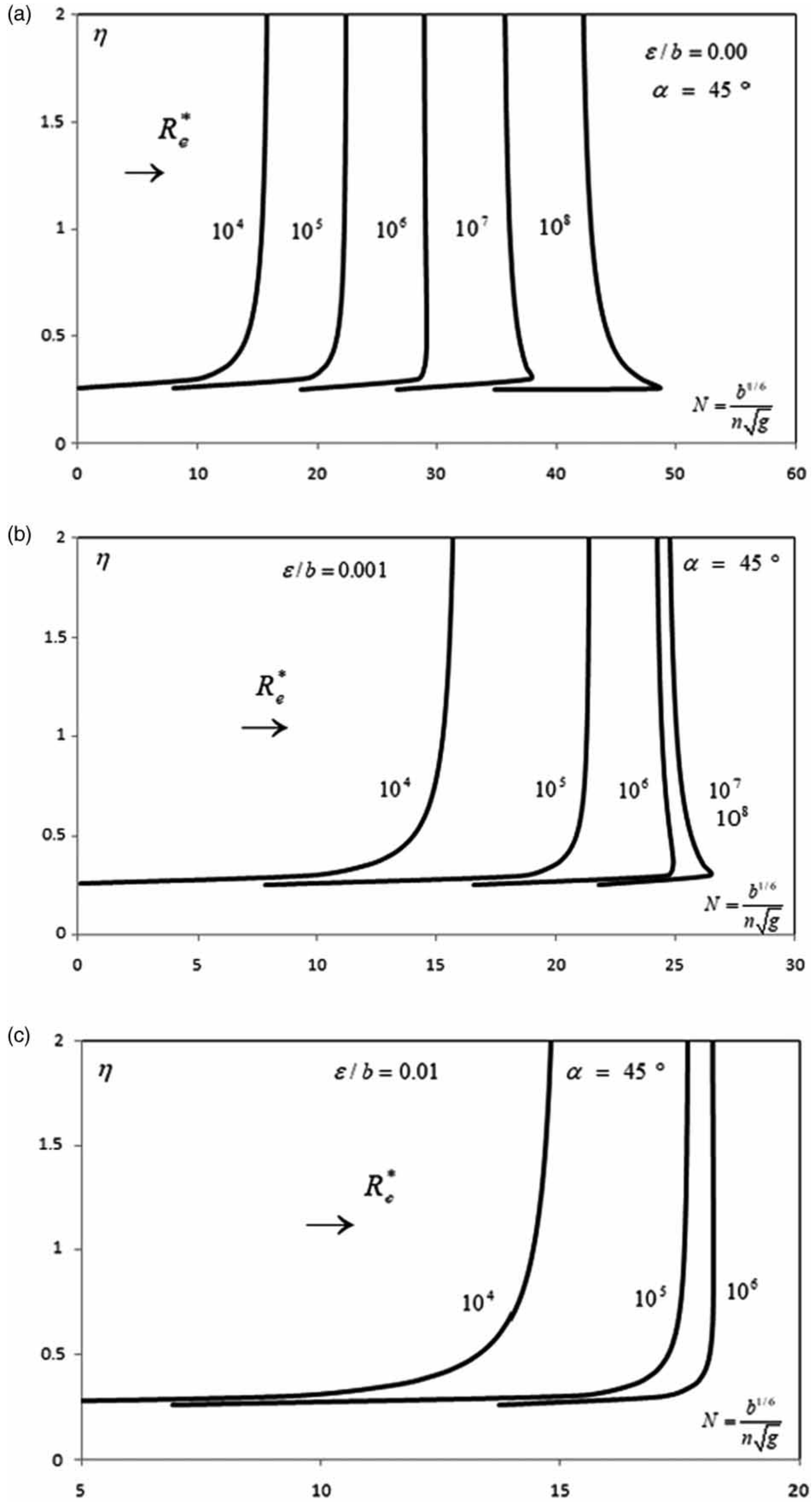


Figure 5 | Variation of N as a function of the filling rate η and the Reynolds number R_e^* for the side slope m ($\alpha = 45°$) $= 1$, according to Equation (16) for fixed values of the relative roughness: (a) $\varepsilon/b = 0$, (b) $\varepsilon/b = 0.001$ and (c) $\varepsilon/b = 0.01$.

3.2. Computation of Manning's resistance coefficient by the RMM

Equation (30) is established using the RMM to directly calculate n as a function of the parameters η, $\overline{b}$, ε and $\overline{R_e^*}$ without knowing the horizontal dimension b of the channel. This calculation is clearly shown in the following example.

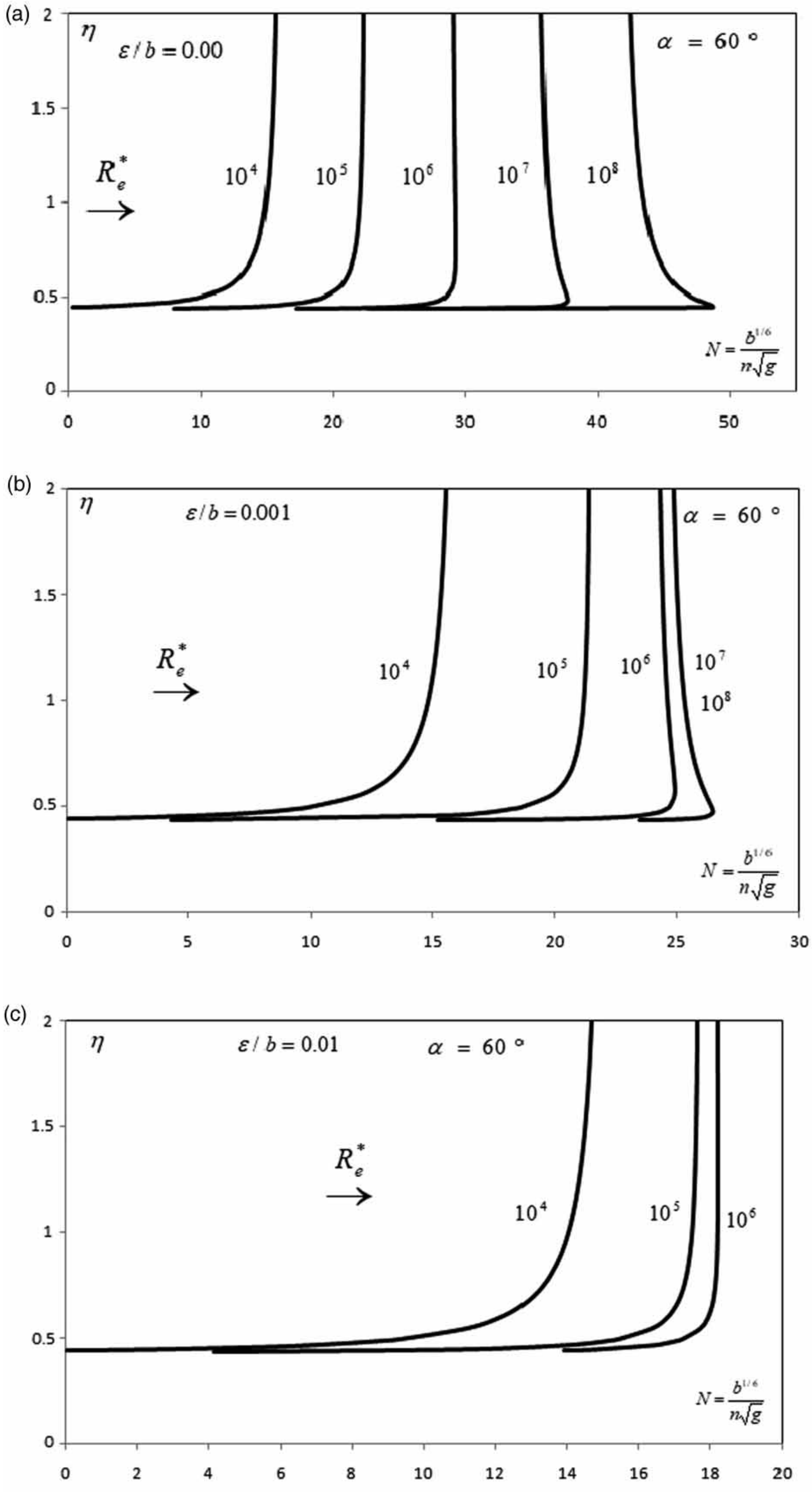


Figure 6 | Variation of N as a function of the filling rate η and the Reynolds number R_e^* for the side slope m ($\alpha = 60°$) $=$ 0.57735027, according to Equation (16) for fixed values of the relative roughness: (a) $\varepsilon/b = 0$, (b) $\varepsilon/b = 0.001$ and (c) $\varepsilon/b = 0.01$.

Example

Compute Manning's resistance coefficient n for the following data:

$$Q = 3m^3/s,\ \eta = 0.9,\ i = 10^{-3},\ \varepsilon = 10^{-3},\ \alpha = 30°(m = 1.73205081),\ \nu = 10^{-6}m^2/s.$$

1. According to Equations (3), (4) and (6), ξ_1, ξ_2 and $\phi(\eta)$ are, respectively:

$$\xi_1 = \frac{1}{4m} = \frac{1}{4 \times 1.73205081} = 0.14433757$$

$$\xi_2 = \frac{\sqrt{1+m^2}-1}{m} = \frac{\sqrt{1+1.73205081^2}-1}{1.73205081} = 0.57735027$$

$$\varphi(\eta) = \frac{(\eta - \xi_1)}{(2\eta + \xi_2)} = \frac{(0.9 - 0.14433757)}{(2 \times 0.9 + 0.57735027)} = 0.31785911$$

2. In accordance with the relation (33), the horizontal dimension $\overline{b}$ of the rough model is

$$\overline{b} = \left[8\sqrt{2}(\eta - \xi_1)\right]^{-0.4} [\phi(\eta)]^{-0.2} \left(\frac{Q}{\sqrt{gi}}\right)^{0.4} = \left[8\sqrt{2}(0.9 - 0.14433757)\right]^{-0.4} [0.31785911]^{-0.2} \left(\frac{3}{\sqrt{9.81 \times 0.001}}\right)^{0.4}$$

$$\overline{b} = 2.085905561\ m$$

3. Applying Equation (31), the modified Reynolds number $\overline{R_e^*}$ is then:

$$\overline{R_e^*} = 32\sqrt{2}\frac{\sqrt{gi\overline{b}^3}}{\nu} = 32\sqrt{2}\frac{\sqrt{9.81 \times 0.001 \times 2.085905561^3}}{10^{-6}} = 13503347.46$$

4. Finally, according to relation (30), Manning's resistance coefficient n is

$$n = \frac{0.197}{\sqrt{g}}[\overline{b}\varphi(\eta)]^{1/6}\left[-\log\left(\frac{\varepsilon/\overline{b}}{19\varphi(\eta)} + \frac{8.5}{\overline{R_e^*}[\varphi(\eta)]^{3/2}}\right)\right]^{-16/15}$$

$$= \frac{0.197}{\sqrt{9.81}} \times [2.085905561 \times 0.31785911]^{1/6}$$

$$\times \left[-\log\left(\frac{0.001/2.085905561}{19 \times 0.31785911} + \frac{8.5}{13503347.46 \times [0.31785911]^{3/2}}\right)\right]^{-16/15}$$

$$= 0.013102311 s/m^{-1/3}$$

5. This step aims to verify the validity of the calculations by determining the discharge Q using Equation (26).
   i. The water area $\overline{A}$ of the rough model is:

$$\overline{A} = \overline{b}^2(\eta - \xi_1) = 2.08590556\ 1^2 \times (0.9 - 0.14433757) = 3.28788876\ m^2$$

   ii. The wetted perimeter $\overline{P}$ in the rough model is as follows:

$$\overline{P} = \overline{b}(2\eta + \xi_2) = 2.08590556\ 1 \times (2 \times 0.9 + 0.57735027) = 4.95892814\ 8\ m$$

   iii. According to Equation (25), the hydraulic radius $\overline{R_h}$ is then:

$$\overline{R_h} = \overline{b}\phi(\eta) = 2.08590556\ 1 \times 0.31785911 = 0.66302407\ 8\ m$$

   iv. Thus, the *Reynolds* number $\overline{R_e}$ that characterizes the flow in the rough model is

$$\overline{R_e} = \frac{4Q}{\overline{P}\nu} = \frac{4 \times 3}{4.958928148 \times 10^{-6}} = 2419877.773$$

v. Using Equation (23), the nondimensional correction factor of linear dimension ψ is as follows:

$$\psi = 1.35\left[-\log\left(\frac{\varepsilon/\overline{R_h}}{19}+\frac{8.5}{\overline{R_e}}\right)\right]^{-2/5} = 1.35\times\left[-\log\left(\frac{0.001/0.66302407\ 8}{19}+\frac{8.5}{2419877.773}\right)\right]^{-2/5}$$
$$= 0.769142409$$

vi. Finally, Equation (26) gives the discharge Q as:

$$Q = \frac{1}{n}\psi^{8/3}\overline{AR_h}^{2/3}\sqrt{i} = \frac{1}{0.013102311}\times 0.769142409^{8/3}\times 3.28788876\times 0.663024078^{2/3}\times\sqrt{0.001}$$
$$= 2.9964481 \approx 3m^3/s$$

Thus, the calculated discharge corresponds to the discharge given in the problem statement, confirming the validity of the calculations.

4. CONCLUSION

The expression of Manning's coefficient n for a truncated triangular channel section was established by using the general discharge relationship. The obtained expression clearly showed that n depends on the relative roughness-ε/b, the filling rate η and the modified Reynolds number R_e^*. This, in turn, depends on the slope i, the horizontal dimension b of the channel, the side slope of the channel m and the kinematic viscosity ν. All parameters influencing the flow are represented in the expression of n, unlike current relationships. When all these parameters are given, the resulting expression is used to explicitly calculate the required value of n. However, in the case where the horizontal dimension b of the channel is not given of the problem, the explicit calculation of n is still possible through the use of the RMM. The coefficient n is then expressed as a function of the known parameters of the flow in the rough model. In this case, the calculation of n requires the discharge Q, the slope i, the absolute roughnessε, the side slope of the channel m, the filling rate η and the kinematic viscosity ν.

The paper was completed by the study of the dimensionless Manning coefficient N. The graphical representation showed that N increases for low filling rates η of the channel. For a fixed value of η, the coefficient N decreases as the relative roughness ε/b increases, regardless of the value of the modified Reynolds number R_e^*.

At the end of this study, we can propose to use general relation (13) to calculate the Manning coefficient in artificial waterways (open channel, a culvert).

The RMM can be used in practice to calculate the Manning coefficient for artificial channels when the dimensions cannot be measured or when there is a lack of information. It can also be used to calculate the dimensions of channels with a free surface flow.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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