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Satbayev University

ХАБАРЛАРЫ

ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ
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NAS RK is pleased to announce that News of NAS RK. Series of geology and technical sciences scientific journal has been accepted for indexing in the Emerging Sources Citation Index, a new edition of Web of Science. Content in this index is under consideration by Clarivate Analytics to be accepted in the Science Citation Index Expanded, the Social Sciences Citation Index, and the Arts & Humanities Citation Index. The quality and depth of content Web of Science offers to researchers, authors, publishers, and institutions sets it apart from other research databases. The inclusion of News of NAS RK. Series of geology and technical sciences in the Emerging Sources Citation Index demonstrates our dedication to providing the most relevant and influential content of geology and engineering sciences to our community.

Қазақстан Республикасы Ұлттық ғылым академиясы «ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы» ғылыми журналының Web of Science-тің жаңаланған нұсқасы Emerging Sources Citation Index-те индекстелуге қабылданғанын хабарлайды. Бұл индекстелу барысында Clarivate Analytics компаниясы журналды одан әрі the Science Citation Index Expanded, the Social Sciences Citation Index және the Arts & Humanities Citation Index-ке қабылдау мәселесін қарастыруда. Webof Science зерттеушілер, авторлар, баспашылар мен мекемелерге контент тереңдігі мен сапасын ұсынады. ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы Emerging Sources Citation Index-ке енуі біздің қоғамдастық үшін ең өзекті және беделді геология және техникалық ғылымдар бойынша контентке адалдығымызды білдіреді.

НАН РК сообщает, что научный журнал «Известия НАН РК. Серия геологии и технических наук» был принят для индексирования в Emerging Sources Citation Index, обновленной версии Web of Science. Содержание в этом индексировании находится в стадии рассмотрения компанией Clarivate Analytics для дальнейшего принятия журнала в the Science Citation Index Expanded, the Social Sciences Citation Index и the Arts & Humanities Citation Index. Web of Science предлагает качество и глубину контента для исследователей, авторов, издателей и учреждений. Включение Известия НАН РК. Серия геологии и технических наук в Emerging Sources Citation Index демонстрирует нашу приверженность к наиболее актуальному и влиятельному контенту по геологии и техническим наукам для нашего сообщества.

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ANALYSIS OF EXISTING METHODS FOR CALCULATING THE ROUGHNESS COEFFICIENT OF CHANNELS ALONG THE PERIMETER OF THE CHANNEL

Abstract. The scientific work examines the issues of the channel roughness coefficient and the uniform movement of water in channels with bottom roughness. The analysis of existing methods for calculating the roughness coefficient of channels along the perimeter of the channel is given. The methods of determining the roughness coefficient of famous scientists such as P.N. Belokon, G.K. Lotter, N.N. Pavlovsky for channels consisting of two or three slopes along the perimeter of the channel are presented and analyzed. When designing channels with a soil base, the reduced roughness coefficient of the channel, which forms the basis of the resistance of the plantar structure along the length of the channel, plays a decisive role. Currently, there are a number of computational relationships proposed for hydraulic calculations of water flow along the perimeter of the channel. A number of researchers claim that the soil of the channel bottom simulates the flow movement in different channels with the flow movement under the ice layer. But, it should be borne in mind that the soil of the channel bottom has its own characteristic (specific) features of water movement in open channels with different roughness and under ice cover. The calculation formulas proposed by a number of authors for channels with different lengths along the perimeter cannot be used directly for hydraulic calculations of the flow under the ice cover, and vice versa, the equations of water flow under the ice cover do not apply even for channels with different roughness along the perimeter.

In general, the solution to the main computational relationship is to determine the perimeters and areas included in separate disparate sections. Determining the perimeters of individual parts does not create any special difficulties and is defined as the corresponding face of a geometric figure. Taking into account the fact that the edge of the wall should lie on the considered sole of the channel. But to determine the area of the figures adjacent to the walls in an individual appearance is quite a complicated matter. Approaches of well-known scientists in the scientific literature, such as P.N. Belokon, G.K. Lotter, N.N.Pavlovsky and E.E. Schiperko are based on the phenomenon of flow and large assumptions about the equality of the hydraulic radii of individual parts and the whole channel, as well as the equality of the average speeds of individual parts and the whole flow, but in fact they are not. Current measurements in the laboratory, performed by us and other authors, show that they differ in magnitude and allow significant errors in calculations. Thus, we came to the conclusion that an attempt to solve the problem of the reduced roughness coefficient using generally accepted approaches did not allow us to obtain the desired results: it is not enough to use only the equation of uniform motion, and, therefore, it is necessary to consider other ways to solve the problem. In our opinion, the simplest method is used by all authors who have dealt with the calculation of channels of varying degrees of complexity.

Key words: channel, uniform motion, roughness coefficient, steady motion, average velocity, channel perimeter, channel cross-section, hydraulic radius.

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ПЕРИМЕТРІ БОЙЫНША КАНАЛДАРДЫҢ БҰЖЫРЛЫҚ КОЭФФИЦИЕНТІ ӘРТҮРЛІЛІГІН ЕСЕПТЕУДІҢ ҚОЛДАНЫСТАҒЫ ӘДІСТЕРІН ТАЛДАУ

Аннотация. Ғылыми мақалада табаны бұжырлы каналдардағы бірқалыпты қозғалыс және арнаның бұжырлық коэффициентін (коэффициент шероховатости) анықтау мәселелері қарастырылады. Периметрі бойынша каналдардың бұжырлық коэффициенті әртүрлілігін есептеудің қолданыстағы әдістерін талдау жүргізіледі. Белгілі ғалымдар - П.Н. Белоконь, Г.К. Лоттер, Н.Н. Павловскийлердің периметрі бойынша екі-үш бөліктен тұратын жақтаулы арналар үшін бұжырлық коэффициентін анықтаудың әдістері келтіріледі. Топырақ арнада өтетін каналдарды жобалау кезінде, канал ұзындығы бойымен табаны құрылымының қарсылығы негізін құрайтын арнаның келтірілген бұжырлық коэффициенті шешуші рольді атқарады. Қазіргі уақытта, арнаның периметрі бойынша су ағынының гидравликалық есептеулері үшін ұсынылатын бірқатар есептеу байланыстылықтары бар. Бірқатар зерттеушілер, арнасының бұжырлығы әркелкі каналдардағы ағын қозғалысын, мұз қабаты астындағы ағын қозғалысымен ұқсатады. Бірақ, мынаны ескере кету керек, арна бұжырлығы әртүрлі ашық каналдардағы және мұз қабаты астындағы су қозғалысының өзіндік тән (спецификалық) ерекшеліктері болады. Периметрі бойынша бұжырлығы әртүрлі арналар үшін бірқатар авторлармен ұсынылған есептік формулалар – мұз қабаты астындағы ағынды гидравликалық есептеулер кезінде тікелей пайдаланылуы мүмкін емес, және керісінше периметрі бойынша бұжырлығы әртүрлі арналар үшін де мұз қабаты астындағы су ағыны қозғалысы теңдеулері қолданылмайды.

Жалпы айтқанда, негізгі есептік байланыстылықты шешу, жеке бұжырлық мәнді қималарға енетін суланған периметрлер мен аудандарды анықтаудан тұрады. Жеке бөліктердің суланған периметрлерін анықтау, аса көп қиыншылықтар туғыза қоймайды және олар геометриялық фигураның тиісті қыры ретінде анықталады. Мынаны ескере кету керек, қабырға қыры арнаның қарастырылатын табанына жатуы тиіс. Бірақ, жеке бұжырлықтағы қабырғаларға түйісетін фигуралар ауданын анықтау, өте қиын мәселе. Ғылыми әдебиеттердегі белгілі – П.Н. Белоконь, Г.К. Лоттер, Н.Н. Павловский және Е.Э. Шиперколардың тәсілдері, ағынның құбылысына және жеке бөліктер мен тұтас арнаның гидравликалық радиусы теңдігі және де жеке бөліктер мен тұтас ағынның орташа жылдамдықтары теңдігі туралы үлкен рұқсат берулерге (допущения) негізделген, бірақ олар іс жүзінде ондай болмайды. Біз және де басқа авторлармен орындалған лабораториялық жағдайлардағы ағымдағы өлшеулер көрсеткендей, олар едеуір шек шамасында ерекшеленеді және олар есептеулер кезінде айтарлықтай қателіктерге жол береді. Сонымен, мынадай қорытындыға келеміз, жалпы қабылданған тәсілдерді қолдана отырып, келтірілген бұжырлық коэффициенті туралы мәселені шешуге талпыныс жасау, бізге қажет нәтижелерді алуға жол бермеді: бірқалыпты қозғалыс теңдеуін ғана пайдалану жеткіліксіз, және соған орай, қойылған мәселені шешудің басқа да жолдарын қарастыру керек. Біздің ойымызша, әртүрлі бұжырлықтағы арналарды есептеу мәселелерімен айналысқан барлық авторлар жүгінетін ең қарапайым әдіс.

Түйінді сөздер: канал, бірқалыпты қозғалыс, бұжырлық коэффициенті, орныққан қозғалыс, орташа жылдамдық, арна периметрі, арнаның өтім (көлденең) қимасы (поперечное сечение), гидравликалық радиус.

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АНАЛИЗ СУЩЕСТВУЮЩИХ МЕТОДОВ РАСЧЕТА КОЭФФИЦИЕНТА ШЕРОХОВАТОСТИ КАНАЛОВ ПО ПЕРИМЕТРУ РУСЛА

Аннотация. В научной работе рассматриваются вопросы коэффициента шероховатости русла и равномерное движение воды в каналах с шероховатостью дна. Дан анализ существующих методов расчета коэффициента шероховатости каналов по периметру русла. Приводится и дается анализ методов определения коэффициента шероховатости известных ученых, таких как П.Н. Белоконь, Г.К. Лоттер, Н.Н. Павловский для русел, состоящих из двух-трех откосов по периметру русла. При проектировании каналов с грунтовым основанием определяющую роль играет приведенный коэффициент шероховатости канала, составляющий основу сопротивления подошвенной конструкции по длине канала. В настоящее время существует ряд расчетных связей, предлагаемых для гидравлических расчетов расхода воды по периметру канала. Ряд исследователей утверждает, что грунт дна канала имитирует движение потока в разных каналах с движением потока под слоем льда. Но следует учитывать, что грунт дна канала имеет свои характерные (специфические) особенности движения воды в открытых каналах с различной шероховатостью и под ледяным покровом. Расчетные формулы, предложенные рядом авторов для каналов с разной протяженностью по периметру, не могут быть использованы непосредственно при гидравлических расчетах потока под ледяным покровом, и, наоборот, уравнения движения потока воды под ледяным покровом не применяются даже для каналов с разной шероховатостью по периметру.

В общем, решение основной расчетной взаимосвязи заключается в определении периметров и площадей, входящих в отдельные разрозненные сечения. Определение периметров отдельных частей не создает особых сложностей и определяется как соответствующая грань геометрической фигуры. С учетом того, что ребро стены должно лежать на рассматриваемой подошве канала. Но определить площадь фигур, примыкающих к стенам в индивидуальном облике, – дело довольно сложное. Подходы известных в научной литературе ученых, таких как П.Н. Белоконь, Г.К. Лоттера, Н.Н. Павловский и Е.Э. Шиперко основаны на явлении потока и больших допущениях о равенстве гидравлических радиусов отдельных частей и целого канала, а также равенстве средних скоростей отдельных частей и целого потока, но на самом деле они это не так. Текущие измерения в лабораторных условиях, выполненные нами и другими авторами, показывают, что они различаются по величине и допускают значительные ошибки при расчетах. Таким образом, мы пришли к выводу, что попытка решить вопрос о приведенном коэффициенте шероховатости с использованием общепринятых подходов не позволила нам получить желаемые результаты: недостаточно использовать только уравнение равномерного движения, и, следовательно, необходимо рассмотреть другие пути решения поставленной задачи. На наш взгляд, самый простой метод, к которому прибегают все авторы, занимавшиеся вопросами расчета каналов различной степени сложности.

Ключевые слова: канал, равномерное движение, коэффициент шероховатости, установившееся движение, средняя скорость, периметр русла, поперечное сечение русла, гидравлический радиус.

Introduction. In principle, most channels and canals used in hydraulic engineering have the same stiffness coefficient of the frame and base. As a result of long-term operational use, it is possible that the roughness coefficient along the perimeter of the channel will change due to changes in flow during the growing season.

The coefficient of stiffness of the bottom and frame of the channel, as well as the water permeability and filtration properties of the base layer are also affected. The main goal of our research is to determine the roughness coefficient on the perimeter of the channel in a common way (Altshul et al, 1973).

Due to the fact that large main canals built for inter-basin distribution of river flow are designed in earthen channels, protection of canals from wave actions of various types (due to wind, ship traffic, wave movement) becomes more relevant. One of the reinforcement measures for channel frames is covering them with protective covers, which, in addition to protecting the banks from wave erosion, can also solve the design stability problems of the channel, and are more economical compared to unreinforced channels with a cross-section through overgrown with vegetation, loose soils and in deep excavations, especially on alignments allows designing effective channels (Imanaliyev et al, 2022).

When designing canals passing through a soil channel with a small part of the cross-section fixed, the coefficient of stiffness of the channel, which forms the basis of the resistance of the base structure along the length of the channel, plays a decisive role (Chow, 1969). Currently, there are a number of computational relationships proposed for hydraulic calculations of water flow along the perimeter of the channel. A number of researchers compare the flow movement in channels of different channel stiffness with the flow movement under the ice sheet. However, it should be noted that water movement in open channels with different channel thicknesses and under the ice layer has its own characteristic (specific) features (Koibakov et al, 2020). Calculation formulas proposed by many authors for channels with different stiffness along the perimeter cannot be directly used in hydraulic calculations of the flow under the ice sheet, and on the contrary, the equations of water flow under the ice sheet are not used for channels with different stiffness along the perimeter. Allowances (admissions) made during the compilation of these formulas cannot be accepted (Koibakov et al, 2020).

Materials and methods. The research method is theoretical, and processing of existing materials was carried out.

Method of roughness averaged over the perimeter of the channel. The meaning of this method is that, knowing the values of the individual parts of the channel along the perimeter (n1 and n2) and the corresponding wetted perimeters, the roughness coefficient of such a channel can be determined by the following expression (Altshul et al 1984):

$$n_{np} = \frac{(n_1\chi_1 + n_2\chi_2)}{(\chi_1 + \chi_2)} \qquad (1)$$

This method is considered very rough and approximate. The resulting roughness coefficient of the channel is more dependent on the hydraulic radius than the wetted perimeter of the channel (Baizhigitova, 2020).

G.K. Lotter's method. G.K. Lotter (Altshul et al, 1973) uses the composite channel calculation method when calculating channels with different stiffness along the channel perimeter. The water flow of the composite channel is equal to:

$$Q = Q_1 + Q_2 \qquad (2)$$

where: Q_1 and Q_2 – flows in the first and second parts of the flow. We can express the flow of water using the Schezi formula:

$$\omega \cdot C_{np} \cdot \sqrt{R \cdot J} = \omega_1 \cdot C_1 \cdot \sqrt{R_1 \cdot J_1} + \omega_2 \cdot C_2 \cdot \sqrt{R_2 \cdot J}_2$$

where: ω – cross-sectional area; R – hydraulic radius of the entire cross-sectional area; C_{np} – the appropriate quoted Schezi coefficient for the entire cross-section (Baizhigitova, 2020);

ω_1 and ω_2 – areas of cross-sections of flow parts located in the region of influence of homogeneous stiffness;

R_1 and R_2 – hydraulic radii of sections 1 and 2 of the cross section;

C_1 and C_2 – Shezi coefficients of parts 1 and 2 of the cross section;

J - piezometric slope.

Since the movement in the first and second parts of the channel cross-section and due to the effect of the slope is the same, the previous equation can be written as (Altshul et al, 1973):

$$C_{np}\chi R^{3/2} = C_1\chi_1 R_1^{\ 3/2} + C_2\chi_2 R_2^{\ 3/2} \tag{3}$$

where: x - wetted perimeter of the entire cross section; x_1 and x_2 - wetted perimeters in sections 1 and 2 of the cross section.

Dividing the given equation into two parts and denoting the / ratio by a, we get:

$$C_{np} = \frac{C_1 R^{3/2} + aC_2 R_2^{3/2}}{R^{3/2}(1+a)} \tag{4}$$

As we can see from equation (4), to find “C_pr” it is necessary to know the hydraulic radii of individual parts of the cross-section, in addition to the wetted perimeters of parts with different thicknesses (Altshul et al, 1973). In this case, the hydraulic radii of individual parts of the cross section are determined as found for the composite channel (Ibrayev, 2022). For very wide channels, the wetted perimeter may be assumed to equal to the width of the channel, and the hydraulic radius to be equal to the average depth of water in the area under consideration. In this case, equation (4) is written as follows (Baizhigitova, 2020):

$$Q = \left(C_1 b_1 h_1^{3/2} + C_2 b_2 h_2^{3/2}\right)\sqrt{J} \tag{5}$$

where b_1 and b_2- are the widths of compartments 1 and 2, respectively, and are the water depths in compartments 1 and 2, respectively.

For channels covered with an ice layer, G. K. Lotter (Altshul et al, 1973) takes the hydraulic radii of individual parts of the flow as equal to the hydraulic radius of the entire flow:

$$R_1 = R_2 = R \tag{6}$$

Since the wet perimeter of the channel is and the ice perimeter is equal, the hydraulic radius of the entire section is equal:

$$R = \frac{\omega}{\chi_1 + \chi_2} \tag{7}$$

In this case, equation (7) becomes:

$$C_{np} = \frac{C_1 + aC_2}{(1+a)} \tag{8}$$

In addition, the methods of P. N. Belokon and N. N. Pavlovsky (Altshul et al, 1987) were published independently (Grishanin, 1992).

P.N. Belokon's method.

We consider the channel section of any shape, we take the roughness of the wetted perimeter in the first part as n_1 and in the second part as n_2 (Haicai et al, 2018).

We find the backflow (fall) per unit length of the channel by the following formula (Koibakov and et all, 2020).

$$J = \frac{F}{\gamma\omega} \tag{9}$$

where: *F* - the sum of fictitious friction forces on the channel walls. We denote the average false friction force per 1 m^2 area of the channel wall by τ_1 in the first part and τ_2 in the second part, respectively (Altshul et al, 1973).

$$F = \tau_1\chi_1 + \tau_2\chi_2 \tag{10}$$

Then equation (11) can be written as follows:

$$\frac{\tau_1\chi_1}{\gamma} + \frac{\tau_2\chi_2}{\gamma} = \omega J$$

If $\chi_1 = a\chi$ and $\chi_2 = a\chi$, we can get it there: $a_1\frac{\tau_1}{\gamma} + a_2\frac{\tau_2}{\gamma} = \frac{\omega}{\chi}J = RJ$.

In case of turbulent steady motion, it taken as follows, i.e

$\frac{\tau_1}{\gamma} = \frac{\upsilon_1^2}{C_1^2}$ and $\frac{\tau_2}{\gamma} = \frac{\upsilon_2^2}{C_2^2}$

where: υ_1 and υ_2 - are average velocities in the first and second parts of the flow. Then the previous equations become:

$$a_1\frac{\upsilon_1^2}{C_1^2} + a_2\frac{\upsilon_2^2}{C_2^2} = RJ \tag{16}$$

If C_1 and C_2 are expressed by Manning's formula, then equation (16) takes the following form

$$a_1 \frac{n_1^2 \upsilon_1^2}{R_1^{1/3}} + a_2 \frac{n_2^2 \upsilon_2^2}{R_2^{1/3}} = RJ \qquad (17)$$

This relationship $\frac{n_2}{n_1} = \psi$ if we mark it, we get it:

$$n_1^2 \left(a_1 \frac{\upsilon_1^2}{R_1^{1/3}} + \psi^2 a_2 \frac{\upsilon_2^2}{R_2^{1/3}} \right) = RJ \qquad (11)$$

Further, P. N. Belokon wrote: if we say that, the ratio of cross-sectional areas according to (Altshul et al, 1973) sections of different stiffness is equal, then $\frac{\omega_1}{\omega_2} = \theta$. Then $\omega_1+\omega_2=\omega$ when, $\omega_1 = \frac{\theta}{1+\theta}$ and $\omega_2 = \frac{\theta}{1+\theta}\omega$.

P.N. Belokon gets the values of R_1 and R_2 from the following expressions:

$$R_1 = \frac{\omega_1}{\chi_1} = \frac{\theta}{a_1(1+\theta)} R \text{ and } R_2 = \frac{\omega_2}{\chi_2} = \frac{\theta}{a_2(1+\theta)} R \qquad (12)$$

Full settlement will be equal: $Q = Q_1 + Q_2$.

We can express the flux with the Chezy-Manning formula:

$$Q_1 = \frac{1}{n_1} \omega_1 R_1^{2/3} J^{1/2} \text{ and } Q_2 = \frac{1}{n_2} \omega_2 R_2^{2/3} J^{1/2} \qquad (13)$$

Since the slopes of the first and second parts of the cross section are the same, we divide the first part of the equation (13) by the second and get it: $\frac{Q_1}{Q_2} = \frac{n_1}{n_2} \cdot \frac{R_1^{2/3}\omega_1}{R_2^{2/3}\omega_2}$ or we can put ω_1, ω_2 және R_1, R_2 found above in this equation (Altshul et al, 1973):

$$\frac{Q_1}{Q_2} = \psi \left(\frac{a_2}{a_1} \right)^{2/3} \theta^{2/3}$$

After converting the equations, the resulting roughness coefficient is equal to:

$$n = n_1 \left(a_1 + a_2 \psi^{3/2} \right)^{3/2} \qquad (14)$$

N.N. Pavlovsky's method.

N.N. Pavlovsky summarizes the coefficient of stiffness, the form shown below, obtained from the basic equation of steady motion for open channels (Altshul et al, 1984):

$$RJ = \frac{\tau}{\gamma} \tag{15}$$

When the walls of the channel are different, this equation should replace by another one, for this, it is necessary to separate the liquid between the two sections and formulate the equation of motion for the given part by directing the acting forces in the direction of the flow. Then, instead of equation (16), we get (Jafari and et all, 2018).

$$RJ = \frac{\tau_1 + a\tau_2}{\gamma(1+a)} \tag{16}$$

where: τ_1 and τ_2 – and the average resistivity in the wall sections, respectively, α – apparently, the ratio of the wetted perimeters in the two parts to each other, ie $a = \frac{\chi_2}{\chi_1}$ (Altshul et al, 1984).

When the walls are homogeneous, the magnitude of the average resistivity related to the average depth by the following dependence $\frac{\tau}{\gamma} = \frac{\upsilon^2}{C^2}$.

Accordingly, τ_1 and τ_2 can written as follows:

$$\frac{\tau_1}{\gamma} = \frac{\upsilon^2}{C^2}, \qquad \frac{\tau_2}{\gamma} = \frac{\upsilon^2}{C^2}. \tag{17}$$

N.N. Pavlovsky assumes that the average speeds of each part are equal throughout the flow before taking the connection $\upsilon = \upsilon_1 = \upsilon_2$.

We find the equation (17) by substituting the following equation (16):

$$RJ = \frac{\upsilon^2}{1+a}\left(\frac{1}{C_1^2} + \frac{a}{C_2^2}\right), \text{ that follows } \upsilon = C_1 C_2 \sqrt{\frac{1+a}{aC_1^2 + C_2^2}} \cdot \sqrt{RJ} \tag{18}$$

Here, N.N. Pavlovsky $\sqrt{RJ}$ The quantity in front of it is called the “quoted coefficient of Shezi” and it C_{np} indicates that, therefore, equation (19) can be written as follows (Altshul et al, 1984):

$$\upsilon = C_{np} \cdot \sqrt{RJ} \tag{19}$$

where $C_{np} = C_1 C_2 \sqrt{\frac{1+a}{aC_1^2 + C_2^2}}$.

C_1 and C_2 to determine the values, it is necessary to know the values of the corresponding hydraulic radiios R_1 and R_2. To determine them, N.N. Pavlovsky considers that the size of the cross-sectional area of individual parts of the channel is proportional to the size of the wetted perimeter, then (Altshul et al, 1984):

$$\frac{\omega_1}{\omega_2} = \frac{\chi_1}{\chi_2}, \text{ that follows } \frac{\omega_1}{\omega} = \frac{\chi_1}{\chi}, \ \frac{\omega_1}{\omega} = \frac{\chi_1}{\chi} \tag{20}$$

Then we can:

$$R_1 = \frac{\omega_1}{\chi_1} = \frac{\omega}{\chi} = R, \ R_2 = \frac{\omega_2}{\chi_2} = \frac{\omega}{\chi} = R \tag{21}$$

Then, $R_1 = R_2 = R$ (22)

Knowing the value of the hydraulic radius and one of the well-known formulas when determining the Shezy coefficient $C = \frac{1}{n} R^y$, the following expression can be obtained for the roughness coefficient using (Altshul et al, 1973):

$$C_{np} = R^y \sqrt{\frac{1+a}{n_1^2 + an_2^2}} \tag{23}$$

By introducing the mentioned coefficient of stiffness, N.N. Pavlovsky brings equation (23) to the following form: $C = \frac{1}{n_{\text{пр}}} R^y$

where: $n = \sqrt{\frac{n_1^2 + a \cdot n_2^2}{1+a}}$ (24)

If the walls of the channel consist of three different parts and the wetted perimeters of the three parts, respectively, are different, then the resulting roughness coefficient expression can be written as:

$$n_{np} = \sqrt{\frac{n_1^2 + a \cdot n_2^2 + a \cdot n_3^2}{1+a}}, \tag{25}$$

here it is: $a^1 = \frac{\chi_3}{\chi_1}$.

In conclusion, N.N. Pavlovsky writes that his proposed method for determining the coefficient of stiffness is likely to change in the future after additional research (Sarsekeev et al, 1990).

Results and discussion. As the available experimental studies show, in the case of different types of roughness in the channel cross-section, the hydraulic conditions of the flow movement are complicated by the formation of new sections with various obstacles, and as a result of this, the planar and vertical distribution of velocities on the cross-section undergoes drastic changes (Mai and et all, 2019). In it, in the surface layer of the flow, the center of gravity of the velocity graph moves to the lower side of the roughness value, so the area of influence of the high roughness region spreads over the majority of the flow section (Mikhalev, 1981).

The line of zero, indirect voltages correspond to the maximum values of the speeds. Along this line, the flow divided into two parts, each of which begins to act under the influence of one roughness (Musin, 2012). Based on this rule, we can consider each part of the flow lying on the line of zero lateral voltages as a separate channel and apply to them the derived formula for uniform motion, the Chezy formula (Musin et al, 2002). In order to summarize the main calculation relationship, we make the following point, regardless of the different roughness of the channel bottom, the state of steady movement of the flow maintained, and that is, the roughness of the channel walls remains the same for the entire area under consideration (Altshul et al, 1984).

At the same time, we accept tolerance values accepted in general hydraulics. The magnitude of slope contributing to movement in individual parts of the flow is the same everywhere; the velocities on the individual surface of any straight section of the cross section are the same for the first and second parts of the flow and are equal to the highest (maximum) speed (Altshul et al, 1973).

In general, in order to determine the average roughness of the channel base and frames we assume that the cross-sectional area of the channel roughly divided the moisture content of the channel χ_1, χ_2, χ_3 and the roughness coefficients $n_1, n_2 ... n_N$.

When calculating the, well-known scientists Horton and Einstein made the following recommendations (Wang and et all, 2018), the velocities in the sections under consideration are the same and the average speed at any point is equal, while the stiffness coefficient we determine can be defined as:

$$n = \left[\frac{\sum_{1}^{N} (\chi_N n_N^{1,5})}{\chi} \right]^{2/3} = \frac{(\chi_1 n_1^{1,5} + \chi_2 n_2^{1,5} + ... + \chi_N n_N^{1,5})^{2/3}}{\chi^{2/3}} \tag{26}$$

Pavlovsky, and Mühlhofer, Einstein, and Bank (Sun and et all, 2020) suggest the way to find the channel stiffness coefficient as follows:

$$n = \left[\frac{\sum_{1}^{N} (\chi_N n_N^{2})}{\chi^{1/2}} \right]^{1/2} = \frac{(\chi_1 n_1^{2} + \chi_2 n_2^{2} + ... + \chi_N n_N^{2})^{1/2}}{\chi^{1/2}} \tag{27}$$

In addition, one scientist Lotter suggests to define it as follows (Altshul et al, 1973).

$$n = \frac{\chi R^{5-3}}{\sum_{1}^{N} \left(\frac{\chi_N R_N^{5/3}}{n_N} \right)} = \frac{\chi R^{5/3}}{\frac{\chi_1 R_1^{5/3}}{n_1} + \frac{\chi_2 R_2^{5/3}}{n_2} + ... + \frac{\chi_N R_N^{5/3}}{n_N}} \tag{28}$$

where, $R_1, R_2, ... R_N$- hydraulic radii of the obtained plots. For any section $R_1 = R_2 = ... = R_N = R$ will be.

The roughness of the bottom of the channel may change due to ice freezing on the water surface in the channel. In order to explain this phenomenon, Lotter (Altshul et al, 1973) concluded that the roughness values of channels with a deep channel and frozen surface can be found as follows (Yerzhanova et al, 2017).

Table 1 - Approximate values of the roughness coefficients of the bottom of channels with ice on the surface

Ice formation	Flow rate in the channel, cm/s	Coefficient of roughness
Glossy finish:		
ice floes	0,39 – 0,6	0,01-0,012
	0,6-high	0,014-0,017
	0,39-0,6	0,016-0,018
	0,6-high	0,017-0,02
There is floating ice, the surface is rough and rough	-	0,023-0,025

For example, n_1 and n_2 – stiffness coefficients of the channel with a layer of ice and the channel free of ice. Using equations (1) and (3) above, you can find the stiffness coefficient of the ice layer. However, the coefficient calculated in this way may sometimes have a negative sign, but this does not have any effect (Altshul et al, 1973).

To get closer to the true solution of this problem, according to Pavlovsky (Altshul et al, 1984), it is necessary to assume that the total resistance to fluid movement is equal to the sum of the resistance forces formed by the bottom of the channel and the ice layer, then it turns out that

$$k\upsilon^2\ell\chi = k_1\upsilon^2 l\chi_1 + k_2\upsilon^2 l\chi_2 \tag{29}$$

Where subscripts 1 and 2 refer to channel bottom and ice sheet, respectively (Chow, 1969). If the flow and roughness of the channel are known, then the Manning formula can be used to determine the slope of the flow during uniform movement in the prismatic channel with the given average equilibrium value (Musin and et all, 2005).

A slope determined in this way called a normal slope. A uniform surface flow at a normal slope can be either turbulent or laminar depending on factors such as flow, slope, viscosity, and surface roughness. If the flow velocity and depth are relatively small, viscosity becomes the dominant factor and the flow moves in laminar mode. A brief look at the details of water movement in canals shows that it is a very complex process (Altshul et al, 1984).

In general, the solution of the main design relationship consists in determining the wetted perimeters and areas that fall into individual roughness-valued cross-sections. Determining the wetted perimeters of individual parts does not cause too many difficulties, and they defined as the corresponding facet of the geometric figure. It should note that the edge of the wall should lie on the considered base of the channel.

However, it is a very difficult problem to determine the area of figures that meet walls of individual thickness. The methods of P.N. Belokon, G.K. Lotter, N.N. Pavlovsky and E.E. Shiperko known in the scientific literature (Altshul and et all, 1973). Based on large assumptions (assumptions) about equality, but they have not confirmed in practice. Current measurements in laboratory conditions, performed by us and other authors, show that they differ significantly, and they allow significant errors in calculations. So, we come to the following conclusion, trying to solve the problem of the stiffness coefficient using generally accepted methods did not allow us to get the results we needed: it is not enough to use only the equation of steady motion, and therefore, it is necessary to consider other ways of solving the problem. In our opinion, it is the simplest method to which all authors dealing with the problems of channel calculation of various complexity should apply.

Conclusions. In natural conditions, many factors affect the roughness coefficient of the channel bed, taking them into account, the well-known scientist Kovan proposed to find the given roughness coefficient with the following relationship [2]:

$$n = \left(n_0 + n_1 + n_2 + n_3 + n_4\right)m_5 \tag{30}$$

they are, n_0 – the value of the roughness coefficient for canals where the bottom soil is natural and shiny; n_1 – a coefficient that takes into account the fact that the bottom of the canal is made of different soils; n_2 – coefficient that takes into account and calculates the parameters of the channel section; n_3 – coefficient that estimates the probability of an obstruction downstream; n_4 – coefficient that takes into account the nature of the mode of movement of water in the channel and the barrier effect of vegetation on the bottom; m_5 – coefficient that evaluates the consequences of the meandering of the considered water channel (Altshul et al, 1973).

The components of the roughness coefficient representing the resistance state of the channel base, depending on the characteristics and conditions of formation of channels and open channels, likely accepted based on the table below (Altshul et al, 1984).

Table 2 – Finding the coefficient of friction for a given duct channel

Factors that influence the value of the coefficient of stiffness of the channel base	Characteristics of sequences influencing channel bed roughness	Determining the stiffness coefficient	The value of the coefficient to be taken for calculations
Soil at the bottom of the canal channel	Soil Broken stone Crushed gravel Raw gravel	n_0	0,02 0,025 0,024 0,028
The level of inhomogeneity of the canal bed surface	Unremarkable (glossy surface) It was barely noticeable Average It was noticeable	n_1	0 0,005 0,01 0,02
Change of channel cross-section	Slowly By accident Repeated many times	n_2	0 0,005 0,01-0,015
Effect of obstacles in the channel	Unremarkable Only a little As you know Considerably	n_3	0 0,01-0,015 0,02-0,03 0,04-0,06
Effect of vegetation on the channel bed	Down Average Top So much	n_4	0,05-0,01 0,01-0,025 0,025-0,05 0,05-0,1

The degree to which a channel or channel course is bent	Unnoticeable Observable Very high	m_5	1 1,15 1,3

It is necessary to calculate n_1 when determining the value of the coefficient, the degree of inhomogeneity of the surface of the channel base to found can calculated. The value is estimated with a homogeneous surface; but only a small fraction of these amounts is obtained for deeply dug, slightly flushed canal frames or water mules (Sun et al, 2020).

When selecting the value of the coefficient n_2, which describes the change in the parameters of the channel or channel cross-section, the elements of the channel cross-section are determined (Koibakov et al, 2020).

The coefficient n_3, which takes into account the presence of obstacles in the canal channel, is described when there are obstacles such as sediment accumulation, tree roots, roots protruding from the surface, various large stones, fallen and horizontal standing. When determining the factor n4, which takes into account the influence of vegetation growing in the canal channel and foot, the level of herbivory controlled (Wang et al, 2018).

To perform calculations, we set the speed of the water depth in the channel at 0.2h as i0.2, that is, the bottom is taken at a distance of 0.8 h from the bottom of the channel, where h is the average water depth (Altshul et al, 1984). The velocity at a depth of 0.2 h given by the following relationship

$$u_{0,2} = 5{,}75\upsilon_{mp} \lg \frac{24h}{k} \tag{31}$$

The required water velocity at a depth of 0.8h at different (Yerzhanova et al, 2017) velocities can found as follows

$$u_{0,8} = 5{,}75\upsilon_{mp} \lg \frac{6h}{k} \tag{32}$$

We pass from the circular channel to the trapezoidal channel

$$\lg \frac{h}{k} = \frac{0{,}778x - 1{,}382}{1 - x} \tag{33}$$

They are $x=u_{0,2}/u_{0,8}$.

Substituting the value R=h into the given equation (33), we obtain (Chow, 1969):

$$\frac{\upsilon}{\upsilon_{mp}} = \frac{1{,}78(x + 0{,}95)}{x - 1} \tag{34}$$

The comparison results

$$\frac{\upsilon}{\upsilon_{mp}} = \frac{h^{1/6}}{3{,}81n} \tag{35}$$

Equating the first parts of equations (34) and (35) found according to the calculation results, we get the formula value of n (Altshul et al, 1984):

$$n = \frac{(x-1)h^{1/6}}{6{,}78(x+0{,}95)} \qquad (36)$$

Because of summarizing the equation for finding the roughness coefficient at the base of the open channel, we obtained equation (Altshul et al, 1984). As we can see from the equation, it mainly depends on the ratio of the velocities at the depths of 0.2x and 0.8x in the channel and the value of the average depth in the channel. In order to check the accuracy of this equation, the results of physical control on the relationship between channel stiffness and average depth used as a basis.

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