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CALCULATION OF PARAMETERS OF THE CHANNEL EROSION IN TRANSITION SITES OF THE MOUNTAIN RIVER ZONE

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When erecting river structures, the planned outline of the channel changes in certain area. In these transition areas the correct estimation of channel erosion parameters is important. Existing methods for the calculation of these parameters have a number of serious shortcomings. On the basis of a universal mathematical method, a method for its particular application has been developed. It gives opportunity to obtain regularities in determining the parameters of channel erosion in transitional areas of sub mountai rivers. On their basis, it is possible to calculate the hydraulic flow characteristics and the coordinates of the new channel bed in the bridge crossing, formed after the stabilization of the erosion process. The developed method can be used by specialists in the design of river structures, as well as in making up recommendations for safe exploitations.

Key words: *river, channel, transition area, erosion, calculation of parameters.*

Introduction: When building channel structures, the planned outline of the river often changes: the width of the channel widens, but mostly it often narrows. Such transitional areas are mainly created by installing supports for bridges and for other communications, bank-protecting walls, etc. In bridge crossings, the change in the outline of the channel occurs both onshore and intermediate supports. In any case, the narrowing or widening of the channel width leads to a change in the characteristics of the flow, in particular, to a decrease or increase in its velocity field. Because of this, sedimentation begins in some cases in the transition area, in others –in the bed bottom erosion. It is very important to predict correctly possible deformations, since the trouble-free operation of channel structures, including bridge supports and bank-protecting dams, is determined by the reliability of establishing the depths of erosion. Thus, the determination of the position of the final, stabilized surface of channel erosion is relevant, especially in the areas of establishment of river structures, both scientifically and from a practical point of view. Existing methods, including numerical solutions for calculating the deformation of transitional sections of mountain streams, have a number of serious shortcomings. This is due both to the establishment of the initial characteristics of the drainage and the boundary conditions of the problems, and to the choice of the formula for calculating the sediment flow rate.

The aim of the work is to develop a method for predicting possible channel deformations in transitional sections of mountain streams and calculating flow and channel parameters on the example of bridge crossing.

Research results. In the works [1, 2] the existing methods and formulas are analyzed for determining the parameters of channel erosion in bridge crossing and in transition areas. The main shortcomings of the existing offers are estimated and mentioned here, the tasks of following researches are pointed out.

The author of the research has worked out the universal theory of channel formation, passing to a stabilized, balanced phase [3]. It characterizes also the hydro-dynamic processes rather well, which occur in the river areas, where the bridge crossings are. According to this theory, for the formation of coordinates of stabilized surface of deformations the following dimensionless equation is resulted:

$$\frac{d\bar{z}}{d\bar{x}} + \frac{d\bar{h}}{d\bar{x}} - \frac{Fr_0}{\beta_0 \bar{A}^3}\frac{d\bar{A}}{d\bar{x}} = i_0\ \bar{d}_{OT}^{1/3}\ \bar{A}^{(4a-10)/3}, \tag{1}$$

where the scale of boundlessness is to be the width of channel b_0, for example, $\bar{\bar{z}} = z/b_0$;

$\bar{\bar{z}}$ - is the required dimensionless coordinate of the stabilized surface of the bed bottom in the deformed transition region;

$\bar{h}$ - is the depth of the flow in the new channel with the surface of live section $\bar{A}$.

Besides the three mentioned unknown the remaining quantities of equation (1), including the relation $\beta_0 = b_0 / h_0$ and number of Freud - Fr_0 in the channel area with curve i_0 are either given or are determined by familiar methods. (The scale of boundlessness is accepted the width of b_0. (Here and after the parameters with index “0” relate to the channel area where sediment ability of the flow gets ultimate meaning).

In the conditions of observing sediment balance in work [4] the following dimensionless regularity between the area of the live section and the wetted perimeter of the flow was obtained:

$$\bar{\chi} = \bar{A}^a \tag{2}$$

In this paper it is indicated that for mountain and mudflows the indicator *a* varies in the interval 3 ... 4. In further developments for mountain rivers *a* = 7/2 occurs. Then equation (1) can be written as:

$$\frac{d\bar{z}}{d\bar{x}} + \frac{d\bar{h}}{d\bar{x}} - \frac{Fr_0}{\beta_0 \bar{A}^3}\frac{d\bar{A}}{d\bar{x}} = i_0\ \bar{d}_{OT}^{1/3}\ \bar{A}^{4/3}, \tag{3}$$

Equation (3) is solved in the presence of regularities between the hydraulic parameters of the transition. For simplicity, the shape of the channel in the section of the bridge is assumed to be rectangular. Consequently:

$$\bar{A} = \bar{\bar{b}}\ \bar{h}\ \beta_0 \tag{4}$$

$$\bar{\chi} = (\bar{b} + 2\bar{h})\frac{\beta_0}{\beta_0 + 2} \tag{5}$$

From the expression (5) follows that

$$\bar{\chi} = \frac{\beta_0}{\beta_0 + 2}\bar{b}\left(1 + 2\frac{\bar{h}}{\bar{b}}\right) = \frac{\beta_0}{\beta_0 + 2}\ \frac{\beta + 2}{\beta}\ \bar{b}, \tag{6}$$

where the coefficient $\beta = \bar{b} / \bar{h} = b / h$.

Accordingly from *a* = 7/2 cooperative solution of dependences on (2), (4) и (6), we get:

$$\bar{h} = \left(\frac{\beta + 2}{\beta_0 + 2}\ \frac{\beta_0}{\beta}\right)^{2/7} \cdot \frac{1}{\beta_0}\ \frac{1}{\bar{b}^{5/7}}. \tag{7}$$

Viewing the possible meaning of coefficients β_0 and β in practice, the equation (7) can be presented in the following way without any notable omissions:

$$\bar{h} = \frac{1}{\beta_0 \, \bar{b}^{-5/7}} \, . \qquad (8)$$

The final solution of the task may be given more strictly, however, further equations may occur transcendental. Thus the difference between the results of both solutions in practical relation is slight.

From the dependents (4) and (8) for the area of live section we have as follows:

$$\bar{A} = \bar{b}^{2/7} \, . \qquad (9)$$

The obtained universal equation (3), regularities (8) and (9) can be applied for solving problems on the calculation of parameters characterizing channel erosion in transitional sections of mountain rivers. For this, alongside the indicated expressions, it is necessary to use the boundary conditions of the given problem.

Suppose that on a certain segment of a mountain river with a width B_p and bed curve of i_p bridge supports are installed with length of l_0 and width of bridge pass $b_м$ (fig. 1). Flow rate Q is obtained from hydrological calculations. For the river section, where the stream acquires the ultimate channel forming capacity, the channel characteristics i_0 and b_0 are established. On their basis, the classical method determines the hydraulic parameters of the cross section of the flow A_0, h_0, β_0. These values are the starting points for the prediction of deformation of a bridge crossing through mountain rivers.

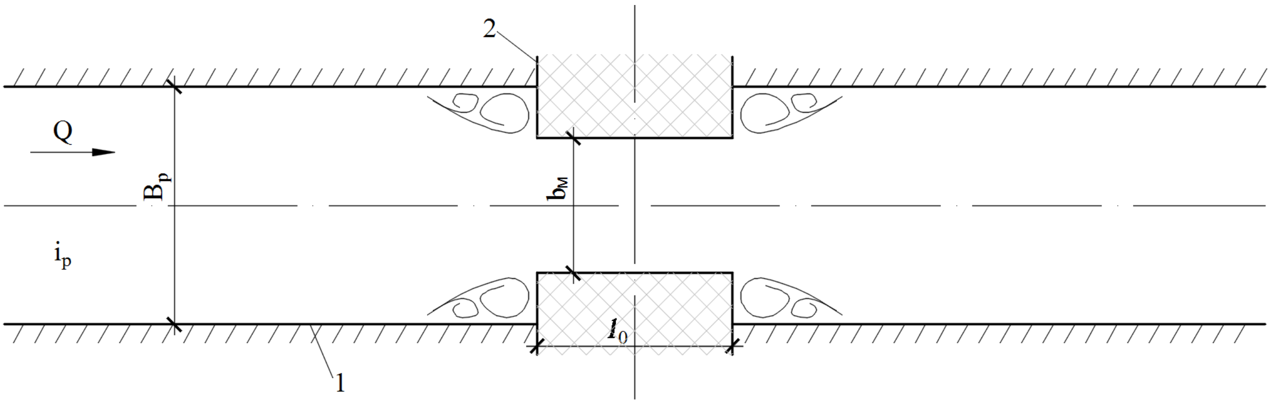

Figure 1. Planned drawing of bridge crossing
1 – natural channel, 2 – bridge supports.

After the establishment of bridge bases in the cross section area the regime of movement changes. The vortex zones forming in the support angles fall out of the general smoothly changing motion, and the planned outline of the lateral lines of the newly formed flow within the transition becomes narrower, and after the supports - the expanding form (fig. 1, 2). Therefore, for a channel width, a suitable approximating relationship (linear or curvilinear) can be chosen. For both cases the problem is solved. The paper presents the developments for the case with a linear change in width b within the transition (fig. 2): in the range $x = -(L_1 + l_0/2)$, channel width $b = B_p$. Further it begins to decrease and before the support ($x = -l_0/2$) is equal to the width of the bridge aperture $b_м$. Within the supports ($-l_0/2 \le x \le l_0/2$) we have $b = b_м$. After the supports, within the limits $l_0/2 \le x \le l_0/2 + L_2$, the flow expands and at the end of the section ($l_0/2 + L_2$) we again have $b = B_p$.. In this case, the reduction angles θ_1 and the expansion θ_2 for smoothly changing motion should be less than 12^0 [5]. For simplicity, we can take $\theta_1 = \theta_2 = \theta$, then we get $L_1=L_2=L$ (fig. 2). For the pointed forms of bridge section the method of calculating the deformations of channel is worked out (fig.3). This method is applicable for other forms of planned drawings of channel section areas as well.

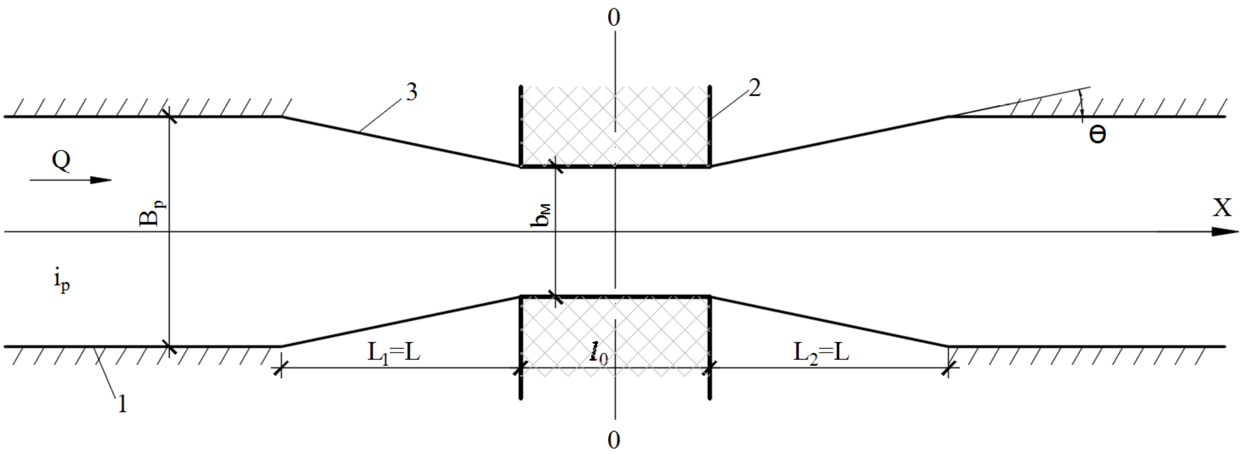

Figure 2. Calculating scheme of planned drawing of bridge crossing.
1 – natural channel, 2 – bridge supports, 3 – cross area of channel.

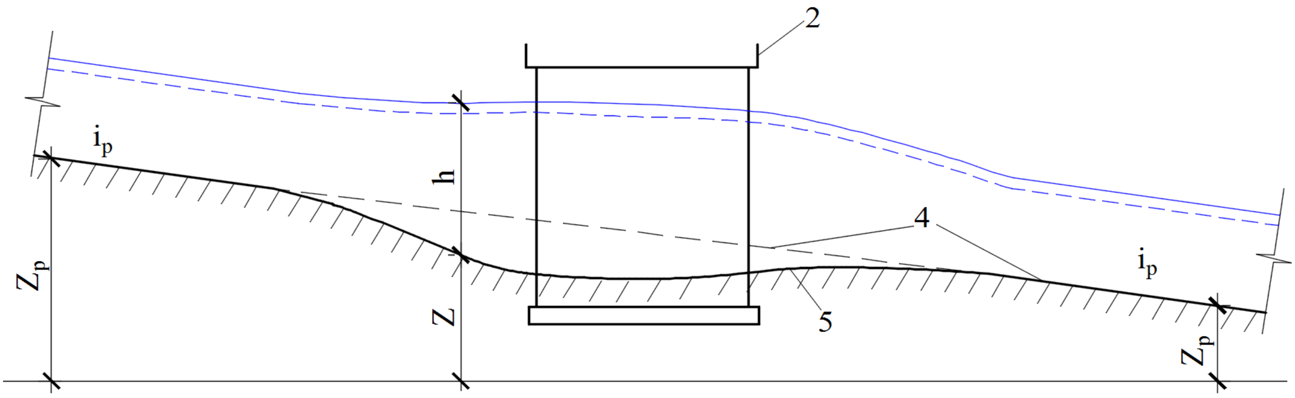

Figure 3. Prolonged profile of bridge crossing after erosion end.
2 – bridge support, 4 – channel bed before erosion, 5 – bed of channel after stabilization.

It is clear that, because of the decrease in the channel width, the flow velocity will increase and soil erosion will begin. During the erosion process, the bottom of the channel is deepened and the speeds will decrease. Simultaneously, the process of erosion gradually dies out, i.e. the balance of sediments along the length of the bed is restored, including in the bridge crossing. Therefore, for the analytical description of such a process, the above mentioned equations and regularities (3), (8), (9) can be used, together with the corresponding dependence by definition of the width of the transition area. Thus, in the channel section $-(L+l_0/2) \le x \le -l_0/2$, we have:

$$b = b_м + 2(x + l_0/2)\,tg(\pi - \theta) \;, \tag{10}$$

when $x = -(L + l_0/2)$, we have $b = b_м + 2L\,tg\,\theta = B_p$, when $x = -l_0/2$, we get $b = b_м$, in channel section $-l_0/2 \le x \le l_0/2$, we have:

$$b = b_м \;, \tag{11}$$

in the channel section $l_0/2 \le x \le l_0/2 + L$, we have:

$$b = b_м + 2(x - l_0/2)\,tg\,\theta \;, \qquad (12)$$

When $x = l_0/2$, we have $b = b_м$, when $x = L + l_0/2$, we get $b = b_м + 2L\,tg\,\theta = B_p$.

Expressions (10), (11) and (12) are shown in the way of boundlessness (scale of boundlessness is the width b_0). In this case for the given three sections of transition area we correspondingly get:

$$\bar{b} = \overline{b_м} + 2(\bar{x} + \bar{l}_0/2)\,tg(\pi - \theta)\,, \qquad (13)$$

$$\bar{b} = \overline{b_м}\,, \qquad (14)$$

$$\bar{b} = \overline{b_м} + 2(\bar{x} - \bar{l}_0/2)\,tg\,\theta\,. \qquad (15)$$

After differentiation of the expressions (13), (14) and (15) we will have:

$$\frac{d\bar{b}}{d\bar{x}} = -2\;tg\,\theta\,, \qquad (16)$$

$$\frac{d\bar{b}}{d\bar{x}} = 0\,, \qquad (17)$$

$$\frac{d\bar{b}}{d\bar{x}} = 2\;tg\,\theta\,. \qquad (18)$$

Simultaneously from the dependences (8) and (9) follows:

$$\frac{d\bar{h}}{d\bar{x}} = -\frac{5}{7\,\beta_0\,\bar{b}^{12/7}}\frac{d\bar{b}}{d\bar{x}}\,. \qquad (19)$$

$$\frac{d\bar{A}}{d\bar{x}} = \frac{2}{7\,\bar{b}^{5/7}}\frac{d\bar{b}}{d\bar{x}}\,. \qquad (20)$$

Accordingly with the dependents (9), (19) and (20) the universal equation (3) will get the following calculating way:

$$\frac{d\bar{z}}{d\bar{x}} - \frac{5}{7\,\beta_0\,\bar{b}^{12/7}}\frac{d\bar{b}}{d\bar{x}} - \frac{2\,Fr_0}{7\,\beta_0\,\bar{b}^{11/7}}\frac{d\bar{b}}{d\bar{x}} = i_0\;\bar{d}_{OT}^{1/3}\;\bar{b}^{8/21}\;. \qquad (21)$$

Joint solution of the resulting equation (21) and final conditions (13)…(18) lets us differentiate the coordinates of new depth on every transition area of bridge crossing dependent on *x* (fig.3), formed after the stabilization of erosion process.

Conclusion. The developed method for determining the coordinates of a stabilized deformation surface allows us to establish the depth of occurrence of the bases of bridge supports and other river structures in transitional sections of mountain streams. The method can be used by designers and operating personnel.

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ՀՈՒՆԱՅԻՆ ՈՂՈՂՈՒՄՆԵՐԻ ՊԱՐԱՄԵՏՐԵՐԻ ՈՐՈՇՈՒՄԸ ՆԱԽԱԼԵՌՆԱՅԻՆ ԳԵՏԵՐԻ ԱՆՑՈՒՄԱՅԻՆ ՏԵՂԱՄԱՍԵՐՈՒՄ

Պ.Հ. Բալջյան, Գ.Գ. Մադաթյան, Հ.Գ. Քելեջյան

Հայաստանի ազգային պոլիտեխնիկական համալսարան

Գետային կառուցվածքի տեղակայման դեպքում որոշակի տեղամասում փոխվում է հունի հատակագծային տեսքը: Այդ անցումային տեղամասերում կարևոր է ունենալ հունային ողողումների պարամետրերի ճիշտ գնահատումը: Համակիրառելի մաթեմատիկական մոդելի հիման վրա մշակվել է դրա մասնավոր կիրառման մեթոդ: Այն հնարավորություն է տալիս նախալեռնային գետերի անցումային տեղամասերում ստանալ հունային ողողումների պարամետրերի որոշման օրինաչափություններ: Դրանց օգնությամբ կարելի է հաշվարկել կամրջային անցման հիդրավլիկական պարամետրերը և այն հունի հատակի կորդինատները, որը ձևավորվել է ողողումների երևույթի կայունացման արդյունքում: Մշակված մեթոդը կարող է օգտագործվել գետային կառուցվածքների նախագծման ժամանակ, ինչպես նաև մասնագետների կողմից՝ կառուցվածքի անվտանգ շահագործման հայտարագրեր կազմելիս:

Բանալի բառեր. գետ, հուն, անցումային տեղամաս, ողողում, պարամետրերի հաշվարկ

РАСЧЕТ ПАРАМЕТРОВ РУСЛОВОГО РАЗМЫВА В ПЕРЕХОДНЫХ УЧАСТКАХ РЕК ПРЕДГОРНОЙ ЗОНЫ

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При возведении речных сооружений плановое очертание русла на определенном участке меняется. В этих переходных участках важна правильная оценка параметров руслового размыва. Существующие методы по расчету этих параметров имеют ряд серьезных недостатков. На основе универсальной математической модели разработан метод ее частного применения. Он дает возможность получить закономерности по определению параметров руслового размыва в переходных участках предгорных рек. На их основе можно рассчитать гидравлические характеристики потока и координаты нового дна русла в мостовом переходе, образованного после стабилизации размывного процесса. Разработанный метод может быть использован специалистами при проектировании речных сооружений, а также при составлении рекомендаций по безопасной эксплуатации.

Ключевые слова: река, русло, переходный участок, размыв, расчет параметров