International Journal of Religion
2024
Volume: 5| Number 11 | pp. 3951 – 3958
ISSN: 2633-352X (Print) | ISSN: 2633-3538 (Online)
ijor.co.uk
DOI: https://doi.org/10.61707/fg84c375

Forecast of Stabilized Channel Transformations in Prismatic River Channels

Pargev Baljyan[1], Arestak Sarukhanyan[2], Hrachya Karapetyan[3] and Hovhannes Kelejyan[4]

Abstract

The perfection of nature in its simplicity and harmony. It is revealed in the process of her cognition. A striking example of harmony is the relationship between a river flow and its bed. In one area the stream begins to wash away the river bed, in another the washed away soil is deposited. In both cases, over time, the processes practically die out and a long-term equilibrium is restored. The work considers the problem of predicting river bed transformations at the stage of their stabilization. The goal is to determine the slope of the transformed bed, which has a prismatic shape. It is noted that between the transit zone and the sediment deposition zone there is a "critical section" of the river, where the turbidity of the flow reaches its maximum value and there is no erosion of the river bed or sedimentation. The parameters of this section have an important influence on the process of stabilization occurring in the river. The slope of the new bed of the channel after stabilization of the process was determined by two analytical methods. In the first case, the sediment balance equation uses a number of formulas for sediment consumption. In the second case, this slope is established by analyzing the equation describing the period of stabilization river bed transformations. The research results show that after stabilization of river bed transformations in the prismatic section of the river, a new slope is established that is quite close to the slope of the "critical section".

Keywords: *River Bed Transformation, Flow, Turbidity Level, Sediment, Bed, Slope, Stabilization of The Bed-Formation Process.*

INTRODUCTION

The river system is in perfect harmony with the environment. The mutual influence of the river flow and the channel occurs in full compliance with the laws of nature. Forecasting the results of this process is of great scientific and especially practical importance. The transformation of natural and artificial water streams is accompanied by erosion of the river bed (Fig. 1) or deposition of sediment in it (Fig. 2). In some sections of the bed this process can develop actively, in others it can develop quite slowly. There are many factors that determine the speed of transformation. The main ones are the geology of the bed-forming soil, hydromorphological, hydrological, and hydraulic characteristics; and anthropogenic impacts (including the installation of various riverbed structures)

[1] National Polytechnical University of Armenia

[2] National University of Architecture and Construction of Armenia

[3] National Polytechnical University of Armenia

[4] National University of Architecture and Construction of Armenia

Fig. 1 Destruction of the bridge due to erosion of the riverbed under the bridge.

https://oir.mobi/630018-razrushennye-mosty-v-vode.html

Fig. 1 Stabilization of river bed transformations before a barrage

Over time, the started process of transformations fades out and the river bed acquires a new, virtually stabilized state (Fig. 2). This means that a sediment balance is ensured along the length of the stabilized section, i.e. there is no bed movement or sedimentation [3]. Forecasting the position of the stabilized bed surface makes it possible to:

determine the sediment volume that allows, for a target life, to establish the geometric parameters of sediment retention structures;

determine the maximum depth of bed movement, allowing to correctly select the toe level of abutment piers, bank protection walls, etc.;

assess the possible environmental and economic consequences of river bed changes.

The objective of this study is to establish the slope of the new bottom prismatic riverbed after stabilization of the transformation process.

The ability to anticipate the location of the stabilized surface of a riverbed following sedimentation or erosion processes enables the accurate determination of the parameters necessary for the design of future river structures. Specifically, an dependable prediction of the slope angle of sediment deposits facilitates the precise computation of the sediment volume ahead of the mudflow barrier structure (Fig. 2), and thus, the accurate selection of its requisite elevation.

Education

Protection of water resources and their efficient use has an important impact on the sustainable development of the economy of each country. The Government of Armenia is implementing a large-scale program for the construction of water systems and reservoirs. For the implementation of this program, an important place is given to the training of professional specialists. The National University of Architecture and Construction of Armenia runs undergraduate and graduate educational programs in water management and hydraulic engineering. In educational disciplines, an important place is given to the study of riverbed processes of natural and anthropogenic origin. This allows you to correctly predict possible non-standard operating situations.

Research Results

Each value of bed, hydraulic, and granulometric parameters corresponds to a certain value of the maximum sediment flux (Q_S) or the maximum turbidity level of the stream (S). This flow is not able to transport more than this amount. In the upper, steep sections of natural streams, the flow turbidity level is usually less than the maximum turbidity level. In the lower, flat areas, on the contrary, the hydraulic performance is less than the turbidity level of the incoming flow. Therefore, sedimentation occurs in this area [4].

It follows that between the areas of transit and sedimentation there should be a “critical section” where there is practically no bed movement or deposition. In this area, turbidity level reaches its maximum value. The parameters of the “critical section” have an important influence on the stabilization process of river bed transformations. Depending on the changes in the flow characteristics, the location of the "critical section" definitely varies.

However, field observations of many mountain and piedmont rivers show that significant river bed transformations occur with flood flows of average power [5]. More powerful flows are transient, while ordinary expenses are low-power. Therefore, in these two cases, significant changes do not occur in the river bed. For each water stream, the range of change in the “critical section” is small. Thus, for the “critical” and stabilized sections, balance equations can be written as:

$$S = S_0 \tag{1}$$

or

$$Q_S = Q_{S0} \tag{2}$$

The quantities with index “0” refer to the “critical section”.

To determine the slope of the stabilized bed in a rectangular prismatic bed (Fig. 3 and 4), equations (1) or (2) use formulas for calculating sediment flux or flow turbidity level. The accuracy of solving problems related to sediment is determined by the reliability of these formulas [6,7].

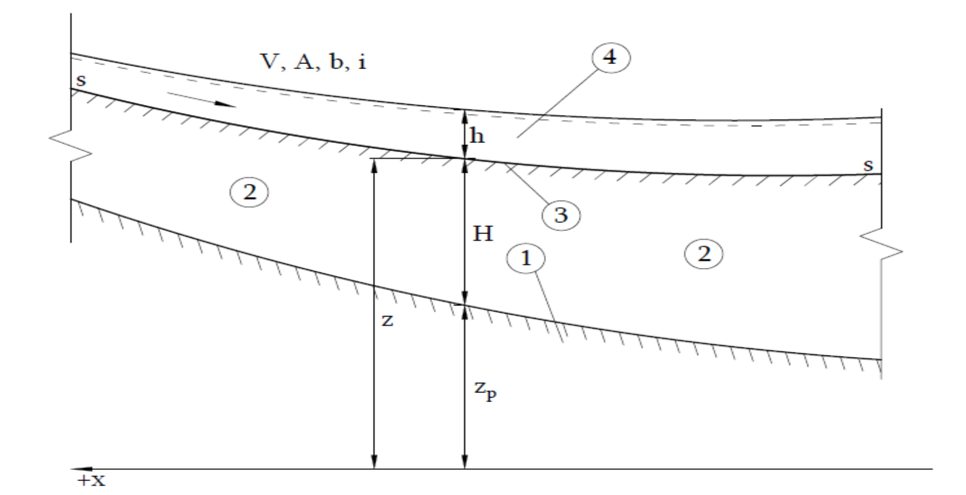

Figure 3. Longitudinal profile of the near-prismatic bed after stabilization

Bed before river bed transformations;

Bed after stabilization;

Flow movement on a stabilized surface.

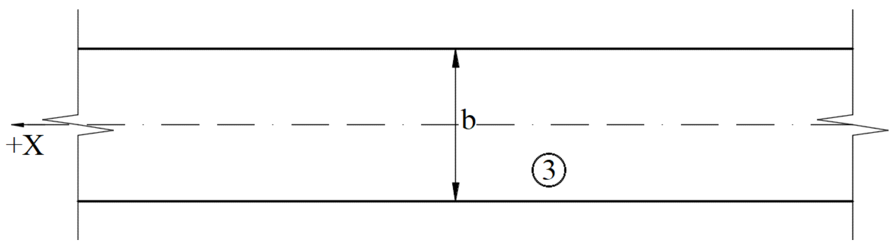

Figure 4. Prismatic channel plan

Flow movement on a stabilized surface.

In the case of stabilization of river bed evolution when the sediment balance equation takes place, the impact of possible inaccuracies of the indicated formulas on the development results carried out is sharply reduced. To confirm this hypothesis, a number of formulas [8,9,10,11] are used in Equations (1) and (2). Of these development results, only development results with consideration of the formulas of Kelejyan H. et Graf-Agaroglu are given below.

To determine the volumetric turbidity level of a stream, Kelejyan H. proposes Formula [9]:

$$S = 0.027\left(\frac{V}{V_*}\right)^2 i^2 \left(\frac{d}{\Delta j}\right)^{0,25}, \qquad (3)$$

where i -is the bed slope, d -is the average diameter of sediment in the flow, j -is the coefficient of non-uniformity of sediment particles, Δ -is the average size of the roughness peaks of the bed soil. Using the quantity of the dynamic velocity, as well as the Chézy formula and the Strickler-Zhang relation for the coefficient Δ [10], we obtain:

$$S = 0.042 C^2 i^2 \left(\frac{d}{d_{bed}}\right)^{0.25}. \qquad (4)$$

Taking into account the sediment balance equation (1), we can write:

$$C^2\, i^2 \left(\frac{1}{d_{bed}}\right)^{0.25} = C_0^2\, i_0^2 \left(\frac{1}{d_{bed\ 0}}\right)^{0.25} \quad . \tag{5}$$

According to the continuity equation, the flow rate along the length of the river bed does not change. Therefore, the Chézy coefficient can be taken as constant. In that case, Par (5) will take the following form:

$$i = i_0 \left(\frac{d_{bed}}{d_{bed\ 0}}\right)^{1/8} \quad . \tag{6}$$

It is obvious that the average diameters of the bed soil in the "critical area" and in the area of stabilization of river bed transformations are quite close. Therefore, the 1/8 of their ratio is practically equal to unity. So, we get:

$$i = i_0 \ . \tag{6}$$

Thus, after stabilization of the process of river bed transformations, a new slope is formed in the area which is equal to the bed slope of the "critical section". This result is expected, since the latter also lacks bed movement or sedimentation.

We carry out a similar development using the Graf-Agaroglu formula [11]:

$$q_T = 10.4 \left(\frac{V}{C}\right)^3 \left(\frac{V^* \rho}{\rho_T - \rho}\right)^2 \frac{1}{d\sqrt{g}} \quad . \tag{7}$$

According to Equation (2), we have:

$$\left(\frac{V}{C}\right)^3 \left(\frac{V^* \rho}{\rho_T - \rho}\right)^2 \frac{1}{d} = \left(\frac{V_0}{C_0}\right)^3 \left(\frac{V^* \rho}{\rho_T - \rho}\right)^2 \frac{1}{d_0} \quad . \tag{8}$$

Using the Chézy formula, while taking into account the rationale for the previous development, we get

$$i = i_0 \ . \tag{9}$$

The reliability of the results is also confirmed by the analysis of the differential equation obtained during the development of the theory of the stabilized stage of vertical channel transformations. When deriving this equation, the following equations were used: the movement of the flow and its continuity [12], the deformation of the channel [13], as well as the laws of the transverse shape of the channel, the equation for determining the resistance of a two-phase flow [14], etc.As a result, the following dimensionless equation was obtained [15],

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

where dimensionless quantities

$\bar{z}$ = the coordinate of the stabilized bed of the channel,

$\frac{d\bar{z}}{d\bar{x}} = i_S$ = longitudinal slope,

$\bar{h}$ = flow depth,

$\bar{A}$ = flow cross-sectional area,

$\bar{d}_b$ = diameter of soil particles at the bottom of the channel,

β_0 = ratio b_0/h_0,

Fr_0 = Froude number,

i_0 = the slope of the channel,

a = the exponent obtained from the sediment balance.

Parameters, with subscription "0", of the flow and channel at the limiting section [16].

The linear dimensionless scale is taken to be the channel width b_0.

For the rectangular channel we get

$$\bar{A} = \beta_0 \cdot \bar{b} \cdot \bar{h}\,, \tag{11}$$

$$\bar{\chi} = \frac{\beta_0}{\beta_0 + 2}\left(\bar{b} + 2\bar{h}\right): \tag{12}$$

From solution of Eqs. (11) and (12) and taking into consideration the dependence obtained between parameters $\bar{A}$ and $\bar{\chi}$ after fully stabilized channel transformations [16] follows

$$\bar{h} = \frac{1}{\beta_0}\,\frac{1}{\bar{b}^{a-1/a}}\,, \tag{13}$$

$$\bar{A} = \bar{b}^{1/a}\;: \tag{14}$$

Using dependencies (13) and (14), equation (10) will take the form

$$i_S + \frac{a-1}{a\,\beta_0\,\bar{b}^{(2a-1)/a}}\,\frac{d\,\bar{b}}{d\,\bar{x}} + \frac{Fr_0}{a\,\beta_0\,\bar{b}^{(a+2)/a}}\,\frac{d\,\bar{b}}{d\,\bar{x}} = i_0\,\bar{d}_{OT}^{1/3}\,\bar{b}^{(4a-10)/3a}\,. \tag{15}$$

For the problem posed, when a rectangular prismatic channel is considered, we have b=const. In this case $\bar{b}$ = 1 and $\frac{d\,\bar{b}}{d\,\bar{x}} = 0$. From equation (15) it follows that

$$i_S = i_0\,\bar{d}_{OT}^{1/3}\;. \tag{16}$$

Since the dimensionless diameter $\bar{d}_b$, and especially its 1/3 degree, are very close to unity, we obtain $i_S = i_0$. Thus, the analysis of the differential equation describing the stabilized stage of channel transformations confirms the above obtained result, where the sediment balance was used.

Comparison Of Analytical Results with Experimental Data

To evaluate the obtained prediction results, they were compared with experimental data [17]. These experiments were carried out to establish the coordinates of a stabilized sediment surface in front of a protective dam. The values of the initial parameters of the experiments are as follows: flow rate Q=10.2•10^{-3} m^3/sec; channel slope i_0 =0.12; dam height H_d =0.35 m; width of the upper part of the dam B_d =1.5 m; slope coefficient of the side walls of the channel m=1.0. The coordinates of sediment deposits upstream are given in the table.

TableCoordinates of the stabilized sediment surface

x, m	0	0.35	0.88	1.52	2.15	2.65	3.42	4.18
z, m	0.35	0.36	0.39	0.46	0.54	0.61	0.65	0.69

For clarity, in Fig. 5 tabular data is provided and the predicted surface of sediment deposits is drawn.

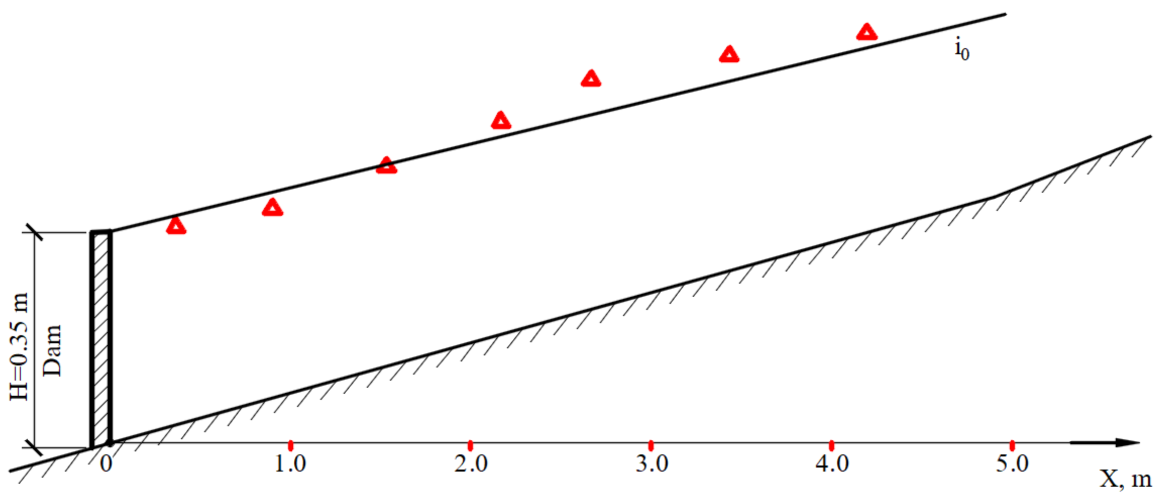

Fig. 5. Graphic comparison of the results of the forecast and experiment.

predicted sediment surface, experimental values of surface coordinates.

The observed fairly good correspondence shows that after the completion of channel transformations, a new bottom is formed in prismatic channels, the slope of which is determined by equality (9).

CONCLUSION

In river beds, there is a "critical section" when the flow becomes the most turbid between the sediment transport zone and the deposition zone. After stabilizing channel changes, the new bottom in a part of the river with a prismatic, almost rectangular channel obtains a slope that is nearly equivalent to the slope of the "critical section." In certain situations, estimating the volume of sediment deposition and determining the depth of channel deformations are made possible by predicting the location of a stabilized, new channel bottom.

REFERENCES

Zawiejska J., Krzemien K. Man-Induced changes in the Structure and dynamics of the upper Dunajec river channel. /Prace Geograficzne. Krakow, 2004, № 56(2). P. 111-124. https://www.sav.sk/journals/uploads/05191226Zawiejska,%20Krzemien.pdf

Vorosmarty, C. J., M. Meybeck, B. Fekete, K. Sharma, P. Green, and J. P. M. Syvitski, Anthropogenic sediment retention: Major global impact from registered river impundments, Global Planetary Change, 39, iss. 1-2, 2003. P.169–190.
https://www.sciencedirect.com/science/article/abs/pii/S0921818103000237

Dey, S. Fluvial Hydrodynamics: Hydrodynamic and Sediment Transport Phenomena; Springer: Berlin, 2014. 687 p.
https://link.springer.com/book/10.1007/978-3-642-19062-9

Rysin I., Petukhova L. Monitoring of channel processes on the interfluve between the Kama and the Vyatka rivers /Sediment Transfer through the Fluvial System (Proceedings of the International Symposium held at Moscow, 2004). IAHS Publication 288, 2004. P. 261-268.

Chalo hodynamic Types Of River Bed In The Kama Basin /Questions Of Physical Geography And Geoecology Of The Urals. Perm, 2000. P. 99–116. (rus.)

Pozdnyakov Sh.R., Shmakova M.V. Comparative Analysis Of Formulas For The Bed Flow Discharge On The Example Of The River Ala Archa (Kyrgyz Alatau)/ Material of 2nd All-Russian School-Conference <Ecosystems Of Small Rivers. Ecology, Protection, Volume II, Borok, 2014. P. 320-323. (rus.)

Muskatirovic J. Analysis of Bedload Transport Characteristics of Idaho Streams and Rivers /Earth Surface and Landforms, Vol. 33, No. 11, 2008, pp. 1757-1768.

https://eurekamag.com/research/022/157/022157056.php

Yufin A.P. Sediment Movement and Hydraulic Transport. - M.-L. Gosenergoizdat Publiser, 1963. 199p. (rus.)

v R.S., Shtankova N.N. Sediment Yield, Bed-Forming Water Flows And Morp

Talmaza V.F., Kroshkin A.N. Hydromorphometric Characteristics Of Mountain Rivers. – Frunze: Kyrgyzstan, 1969. 204 p. (rus.)

Kelejyan H.G., Baljyan P.H. Formula For Calculating The Transporting Capacity Of Mountain Drains // Collection of articles of the XXI International Scientific and Practical Conference “Ecology and Life”. - Penza: Privolzhsky House of Knowledge, 2011. P. 9-12. (rus.)

Graft W.H., Acaroglu E.R. Sediment Transport In Conveyance Systems. (Part. I) /Hydrol. Sci. J. 1968. - XIII , N2. P.29-39.

Hubert Chanson The Hydraulics of Open Channel Flow: An Introduction. (Basic principles, sediment motion, hydraulic modelling, design of hydraulic structures)- Second edition, Elsevier: 2004.- 585 p.

https://shop.elsevier.com/books/hydraulics-of-open-channel-flow/chanson/978-0-7506-5978-9

Velikanov M.A. Dynamics of channel flows. M.: GITTL, Vol. 1, Vol.2, 1954. 648 p. (rus.)

Serrano-Núñez V., Watson-Hernández F. et al. Correction of Empirical Equations Known as “Strickler-Type” for the Calculation of the Manning’s Roughness Coefficient for Costa Rica’s Northern Pacific Conditions /J.Hydrology 2022, 9 (5). P. 71-84.

https://doi.org/10.3390/hydrology9050071

Baljyan V.P. Development of theoretical foundations of the steady stage of channel transformation /Proceedings of National Academy of Sciences of Armenia and NPUA, Series TS. Vol. 72, N1, Yerevan, 2019. P. 131-140. (rus.)

https://arar.sci.am/dlibra/publication/36983

17. Baljyan P.H. Determination of the relationship between the hydraulic parameters of flows with the constancy of their sedimentrying ability /Proceedings of National Academy of Sciences of Armenia and NPUA, Series TS.. Vol. 58, N2. - Yerevan, 2005. P. 380 - 385. (rus.)

https://arar.sci.am/dlibra/publication/35951

18. Asatryan R.H. 17. Laboratory studies of through anti-mudflow dams. /Collection of scientific papers GruzNIIGiM: Issues of protection of reclaimed lands in mountain conditions. Tbilisi, 1984, P.10-14. (rus.)

Information about Authors

Pargev Baljyan (Corresponding author) - Base laboratory "Hydraulic engineering" National Polytechnical University of Armenia, 105 Teryan str., Yerevan, Armenia, 0009

baljyan-1951@list.ru

ORCID: https://orcid.org/0000-0002-8936-2547

Arestak Sarukhanyan - Department of Water Systems, National University of Architecture and Construction of Armenia, 105 Teryan str., Yerevan, Armenia, 0009

asarukhanyan51@mail.ru

ORCID: https://orcid.org/0000-0003-4928-9960

Hrachya Karapetyan - Base laboratory "Hydraulic engineering"National Polytechnical University of Armenia, 105 Teryan str., Yerevan, Armenia, 0009

aharoyal@insurer.am

Hovhannes Kelejyan - Department of Water Systems, National University of Architecture and Construction of Armenia, 105, Teryan str., Yerevan, Armenia, 0009

hovo98@mail.ru

ORCID: https://orcid.org/0000-0003-1578-0786