DETERMINATION OF THE KINETIC ENERGY COEFFICIENT IN THE ZONE OF LOCAL EROSION OF THE EARTHEN CHANNEL CONNECTED TO THE LOWER REACH

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ОПРЕДЕЛЕНИЕ КОЭФФИЦИЕНТА КИНЕТИЧЕСКОЙ ЭНЕРГИИ В ЗОНЕ ЛОКАЛЬНОЙ ЭРОЗИИ ЗЕМЛЯНОГО КАНАЛА, СОЕДИНЕННОГО С НИЖНИМ ТЕЧЕНИЕМ

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ABSTRACT

The study focuses on analyzing the kinetic energy of the water stream flowing from spillway structures and its potential to cause erosion in the downstream channel. When water is discharged through a spillway, a large amount of kinetic energy is generated, which can directly erode the channel bed and banks located behind the structure. This process poses a serious threat to the stability and durability of hydraulic structures. The research emphasizes the importance of protecting the downstream channel from erosion through appropriate engineering solutions. Special hydraulic calculation methods were applied to determine the flow velocity and energy distribution behind the spillway. Based on the obtained results, recommendations for effective energy dissipation and channel reinforcement are proposed. The study aims to enhance the safety, reliability, and efficiency of spillway structures by preventing erosion and maintaining the stability of the downstream channel.

АННОТАЦИЯ

В данной статье рассматривается анализ кинетической энергии потока воды, вытекающего из водосливных сооружений, и её влияние на размыв русла в нижнем бьефе. При пропуске воды через водослив формируется значительное количество кинетической энергии, которая может вызывать прямой размыв дна и берегов канала за сооружением. Этот процесс представляет серьёзную угрозу устойчивости и долговечности гидротехнических сооружений. В работе подчёркивается необходимость защиты канала нижнего бьефа от эрозии с применением соответствующих инженерных решений. Для определения скорости потока и распределения энергии за водосливом использованы специальные методы гидравлических расчётов. На основе полученных результатов предложены рекомендации по эффективному гашению избыточной энергии и укреплению канала. Исследование направлено на повышение надёжности, безопасности и эффективности работы водосливных сооружений путём предотвращения размыва и обеспечения устойчивости русла нижнего бьефа.

Keywords: erosion, cohesive soil, lower reach, turbulent flow, experiment, flow velocity, aggregate, durability, model.

Ключевые слова. эрозия, сцепленный грунт, нижнее течение, турбулентное течение, эксперимент, скорость течения, агрегат, долговечность, модель.

Introduction. Under certain conditions, the contact of the downstream flow with the flowing streams occurs through a direct hydraulic jump. Various energy-reducing structures are built to suppress this hydraulic jump. In some cases, hydraulic jumps also occur after these structures, i.e., in the risberm. In this paragraph, we will consider the influence of secondary hydraulic jumps on the erosion funnel at the beginning of the channel. For this purpose, research was conducted in the "Modeling of Hydraulic Processes" laboratory of Karshi State Technical University and in the M-3 channel.

We know that the uneven distribution of flow velocity affects the estimation of the amount of motion and kinetic energy in the open channel. As a result of the uneven distribution of velocities along the channel cross-section, the velocity in the channel is greater than the calculated value relative to the pressure expression $\upsilon^2/2g$. Using the energy change theorem in problem solutions, the velocity can indeed be expressed as the pressure $\alpha\upsilon^2/2g$. Here α is the kinetic energy coefficient or Coriolis coefficient.

The uneven distribution of velocities also affects the amount of motion. According to the laws of mechanics, the amount of liquid flowing through the cross-section of the channel over time is expressed as $\alpha_0 \rho g Q$. Here, α_0 is the amount of motion or the Bussinescus coefficient.

Now we can calculate the average specific kinetic energy for a given cross section under consideration using the formula

$$(КЭ) = \alpha_c \frac{\upsilon^2}{2g} \qquad (1)$$

we express in the form. Where - average velocity in the considered cross-section; α_c - generalizing kinetic energy coefficient, i.e.

$$\alpha_c = \alpha + \alpha_n ; \qquad (2)$$

α - expresses the unevenness of the velocity distribution across the section; α_n- coefficient of the intensity of the actual velocity at certain u_a points of the section.

According to the research data, it was established that the change in the kinematic characteristics of the flow in the washing funnel depends to a certain extent on the initial turbulence of the flow exiting the fixed section, the type of hydraulic jump occurring, and their parameters.

Due to the decrease in the intensity of turbulence, the jump length and value change along the post-jump section, therefore, at the same average speeds for different sections of the post-jump section, we obtain different values of K.E., and consequently, different values of local erosion.

Materials and Methods. We conducted experimental experiments to determine the generalizing coefficient α_c in the channel bed after the wave hydraulic jump in the rocky risberm. For this, the Coriolis coefficient α was first determined, and the obtained experimental data were entered into Table 1.

Table 1.

Laboratory experimental data

№	1-stvor			2-stvor			3-stvor			4-stvor			5-stvor			6-stvor			α таж
	V_0 m/s	h_0	α	V_0 m/s	h_0	α	V_0 m/s	h_0	α	V_0 m/s	h_0	α	V_0 m/s	h_0	α	V_0 m/s	h_0	α	
1	0,31	0,045	1,018	0,28	0,05	1,016	0,29	0,065	1,012	0,45	0,06	1,013	0,43	0,04	1,014	0,32	0,035	1,016	1,015
2	0,60	0,052	1,020	0,60	0,06	1,019	0,81	0,068	1,014	0,68	0,065	1,016	0,45	0,045	1,016	0,35	0,04	1,017	1,017
3	0,73	0,055	1,022	0,4	0,065	1,018	0,42	0,07	1,015	0,6	0,068	1,017	0,43	0,050	1,018	0,40	0,045	1,018	1,018
4	0,82	0,062	1,024	0,88	0,07	1,021	0,85	0,076	1,017	0,90	0,073	1,018	0,77	0,055	1,019	0,67	0,05	1,021	1,020
5	0,78	0,065	1,024	0,86	0,075	1,020	0,87	0,08	1,018	0,81	0,076	1,020	0,74	0,065	1,020	0,69	0,055	1,021	1,017
6	0,89	0,068	1,026	0,87	0,080	1,023	0,88	0,09	1,019	0,90	0,085	1,021	0,87	0,075	1,021	0,85	0,06	1,023	1,022

Table 2.

Field experimental data

№	1-stvor			2-stvor			3-stvor			4-stvor			5-stvor			6-stvor			α таж
	V_0 m/s	h_0	α	V_0 m/s	h_0	α	V_0 m/s	h_0	α	V_0 m/s	h_0	α	V_0 m/s	h_0	α	V_0 m/s	h_0	α	
1	0,53	0,588	1,025	0,71	0,60	1,024	0,77	0,66	1,018	0,89	0,63	1,019	0,55	0,62	1,019	0,39	0,56	1,021	1,021
2	0,57	0,618	1,026	0,85	0,97	1,022	0,91	1,02	1,018	0,94	0,90	1,017	0,78	0,63	1,018	0,40	0,62	1,023	1,021
3	0,56	0,580	1,025	0,77	0,68	1,021	0,91	0,97	1,016	0,94	0,93	1,017	0,83	0,64	1,018	0,60	0,58	1,021	1,020
4	0,52	0,613	1,024	0,74	0,64	1,021	0,73	0,76	1,017	0,71	0,67	1,018	0,55	0,62	1,019	0,57	0,51	1,021	1,023
5	0,53	0,557	1,024	0,57	0,65	1,020	0,69	0,72	1,018	0,70	0,63	1,020	0,52	0,60	1,020	0,41	0,57	1,021	1,021
6	0,60	0,67	1,026	0,65	0,82	1,023	0,79	0,95	1,019	0,53	0,66	1,021	0,43	0,65	1,021	0,40	0,62	1,023	1,022

Results and Discussion. Analysis of the experimental data obtained to determine α Coriolis coefficient showed that this coefficient is in the range $\alpha = 1{,}015\ldots1{,}022$ under laboratory conditions and $\alpha = 1{,}021\ldots1{,}023$ under field conditions.

Also, the Coriolis coefficient was calculated using the experimental and experimental methods based on the obtained experimental data.

We summarize the experimental data obtained on the determination of the Coriolis coefficient and the calculated values of other authors and enter them into Table 3.

We summarize the calculated values of the authors and enter them into table 3.

Table 3.

Experiment on determining the Coriolis coefficient

№	α expriment	α	α [Chou]
	laboratory		
1	1,016	1,024	1,15
2	1,019	1,022	1,06
3	1,022	1,026	1,32
4	1,022	1,025	1,03
5	1,022	1,040	1,00
6	1,026	1,047	1,01
	дала		
1	1,02	1,08	1,09
2	1,02	1,05	1,12
3	1,025	1,10	1,08
4	1,02	1,098	1,15
5	1,025	1,13	1,18
6	1,03	1,16	1,25

For convenience in calculations, we enter the data into tables.

Table 4.

Laboratory experimental data

experiments	1	2	3	4	5	6
α	1,016	1,019	1,022	1,022	1,022	1,026
α_n	1,015	1,033	1,062	1,07	1,013	1,018
α_c	1,7	1,8	2,06	1,75	2,3	2,4
υ, m/s	0,5	0,65	0,72	0,80	0,85	0,90
ℓ_n/ℓ_{kr}	0,26	0,42	0,53	0,43	0,56	0,65
h_2, m	0,05	0,06	0,065	0,07	0,075	0,080
h_p, m (taj)	0,12	0,14	0,155	0,165	0,18	0,20
h_p, m (his)	0,28	0,22	0,17	0,4	0,16	0,24

.

Table 5.

Field research data

experiments	1	2	3	4	5	6
α	1,02	1,02	1,025	1,02	1,025	1,03
α_n	1,039	1,019	1,04	1,077	1,039	1,018
α_c	1,7	1,95	2,06	2,02	2,06	2,04
υ, m/s	1,01	1,050	1,0	0,939	0,865	0,844
ℓ_n/ℓ_{kr}	0,26	0,42	0,53	0,43	0,56	0,65
h_2, m	0,60	0,97	0,68	0,64	0,65	0,82
h_p, m (exp)	2,062	1,989	1,898	1,843	1,868	1,879
h_p, m	1,99	1,89	1,79	1,74	1,77	1,81

We construct a graph of the relationship $\alpha = f(\ell_n/\ell_{kp})$ based on the Coriolis coefficient $\alpha$and the ratio ℓ_n/ℓ_{kr} data entered in the tables.

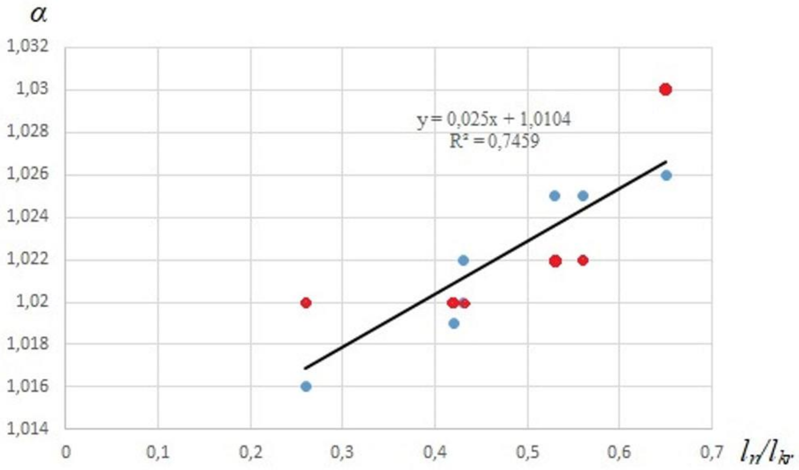

Figure 1. Graph of dependence $\alpha = f(\ell_n/\ell_{kp})$

Based on the processing of the experimental results (Fig. 1), to determine the Coriolis coefficient at the beginning of the local leaching process, the following

$$\alpha = 0{,}025\frac{\ell_n}{\ell_{kr}} + 1{,}01 \tag{3}$$

contact is suggested.

The unevenness of velocity distribution and the magnitude of the coefficient accounting for pulsation intensity in the propagation of the jump in the damper arise from the sharp and sudden expansion of the transit stream under the influence of the pulsation increment under the jump.

Based on the data of the summarizing coefficient and the ratio ℓ_n / ℓ_{kr}, introduced into the tables in the above-mentioned order, we construct a graph of the relationship $\alpha_c = f(\ell_n/\ell_{kp})$.

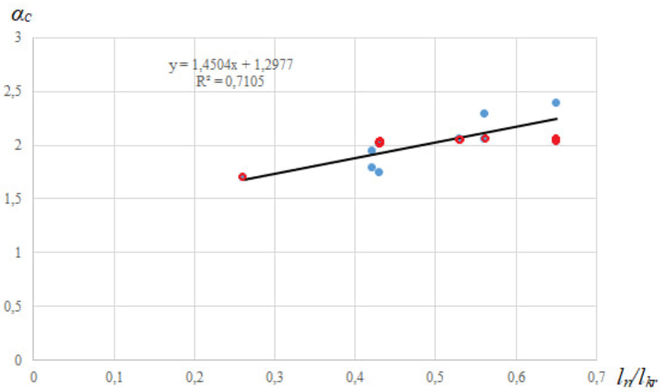

Figure 2. Graph of dependence $\boldsymbol{\alpha = f(\ell_n/\ell_{kp})}$

Based on the processing of the experimental results (Fig.2), this relationship is proposed for determining α_c generalizing Coriolis coefficient in the washing funnel.

With the help of the following formula, the maximum washing over time can be determined by the following formula:

$$h_{p(t)} = \frac{(\alpha_c \upsilon - \upsilon_0)^{1,7} h_0^{0,2}}{K(\rho^*)^{0,7}} - t_i^{0,4}, \qquad (4)$$

here $\rho^* = \frac{\rho_H - \rho}{\rho}$ - time corresponding to the washing moment; h_0 - flow depth at the end of the fixed section; α_c - unevenness of velocity distribution and coefficient of intensive pulsation.

In this case, the jump length can be calculated using formula $\ell_{sak} = 5,7(h_2 - h_1)$.

With its help, taking into account the dependence (3), it is possible to determine the depth of the funnel washing as follows:

The proposed method for fixed sections in the lower reach needs further development.

Local maximum washing occurs immediately after the risberm. This can be used as an evaluation criterion in the overall forecast of downstream erosion.

When calculating turbulent flow, it is usually possible to work with average velocities over longitudinal time at individual points of the flow. Diagrams of such longitudinal velocities in various vertical sections of the flow are presented.

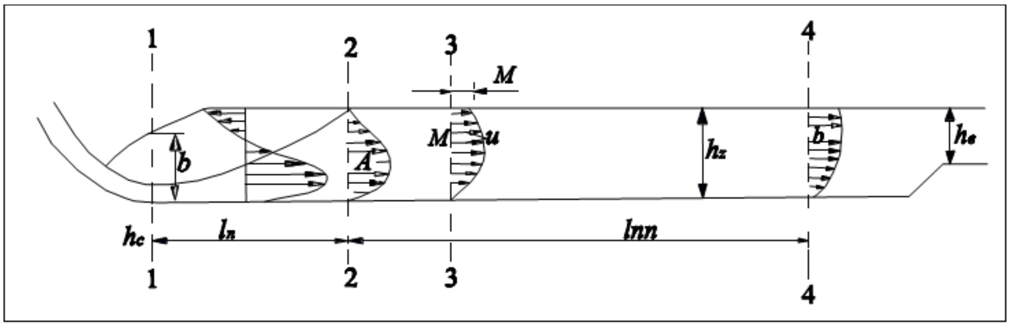

Figure 3. Diagram of average velocity deformations in the direction after the hydraulic jump section

As mentioned above, this equation is used to calculate local erosion occurring in the lower reach of the structure under the influence of a wave-like hydraulic jump. Consequently, when assessing local erosion occurring in the deformable section of the lower reach of the structure, it is important to determine the coefficient α_c characterizing the kinetic energy of the flow in this section. undefined

First of all, we will consider the problem of determining the time-dependent parameters of the washing funnel, which occurs in the section after the reinforced part of the lower reach under the influence of a hydraulic jump. After the energy of the water flow is not completely dissipated in the lower reach damper, it moves in the risberm, causing a small hydraulic jump, as a result of which a washing funnel occurs in the deformable section.

Using the table above, we will construct graphs of the dependence $(h_1/h_m) = f(x_i/x_m)$.

The process of processing the data on determining the relative profile of the washing funnel, shown in the figures, showed that it is impossible to have a universal profile of the washing funnel, taking into account the length of the fixed part of the lower reach, the distribution of specific discharges, the presence of specific discharges and the onset of turbulent intensity, and other factors.

Using the data presented in the table above, we will fill in Table 6.

Table 6.

Ratio of washing funnel parameters

1D	h_1/h_m	0,89	0,90	1	0,95	0,93	0,84
	x_i/x_m	0,27	0,45	1	1,28	1,42	1,57
2D	h_1/h_m	0,60	0,95	1	0,88	0,61	0,60
	x_i/x_m	0,27	0,45	1	1,28	1,42	1,57
3D	h_1/h_m	0,59	0,70	1	0,92	0,66	0,60
	x_i/x_m	0,27	0,45	1	1,28	1,42	1,57
4D	h_1/h_m	0,80	0,84	1	0,88	0,81	0,67
	x_i/x_m	0,27	0,45	1	1,28	1,42	1,57
5D	h_1/h_m	0,77	0,90	1	0,87	0,83	0,79
	x_i/x_m	0,27	0,45	1	1,28	1,42	1,57
6D	h_1/h_m	0,70	0,86	1	0,69	0,68	0,65
	x_i/x_m	0,27	0,45	1	1,28	1,42	1,57

Using this table, we construct graphs of the dependence $(h_1/h_m) = f(x_i/x_m)$.

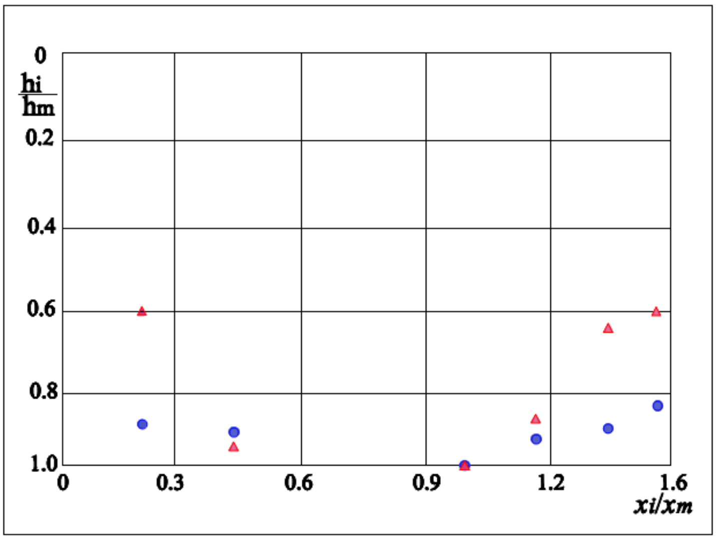

Figure 4. Relative profile of the flushing funnel

Conclusion. Both field and laboratory experiments have shown that the process of processing data on determining the relative profile of the washing funnel under conditions of a wave hydraulic jump, taking into account the length of the fixed part of the lower reach, the distribution of specific discharges, the presence of specific discharges and the onset of turbulent intensity, and other similar factors, does not allow obtaining a universal profile of the washing funnel.

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