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Parameters of flow in a section compressed by transverse floodplain dams

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Abstract. On floodplain rivers there are characteristic features of the construction of hydrotechnical structures, which in their design should be done taking into account this. These are the different types of floodplain and other floodplain, changes in the period of floodplain inflow, the interaction of flow and floodplain flows, the ability of floodplain rivers to water, the speed of flow and the features of turbidity, etc. The main purpose of this study is to develop a method of determining flow parameters in a two-way compressed cross-section with cross-dumbbells in the floodplain, taking into account the different bias of the Ozen and floodplain as well as the interaction of flows. Experimental studies were conducted for parallel case of two-sided poise Ozen and poise flow arrows. The width of the beams is 85 sm, the width of the beams is 30 sm, the length of the lath is 11 m, the slope is $i=0.0005$, the slope is $n=0.016$ and the parameter of the dumbbells is $n_n=0.023$. The flow parameters are long $F_{rp}=0.01-0.3$, $R_{ep}>10000$, floodplain $F_m=0.01-0.18$: $R_{ep}>4000$. On the surface, the change in the compression coefficient EPR in the cases of dumbbells installation angle $\alpha_d<900$ and $\alpha_d \geq 900$ was found to be heterogeneous and analytical expressions and graphs were developed to determine their values. The formulas for determining the speed of flow in a compressed cross-sectional area were proposed, taking into account the subordination of speed scanning to the expression Shlixting-Ayramovich in the zone of interaction by applying the equations of motion and consumption preservation

1. Introduction

The development of technologies for opening the flow patterns symmetrically swept by floodplain cross-blind dams, determining the hydraulic parameters of the flow in the confining range and the spreading zone, improving methods for calculating the velocity field, the length of the compression and spreading support areas are the most important task [1].

The very movement of the stream in floodplains attracts the attention of researchers from all over the world. In prose, the interaction of riverbed and floodplain flows is of paramount importance [2, 3, 4, 5, 6, 7, 8]. the capacity of rivers with floodplains [9, 10, 11].

The construction of cross structures in the hedgehog stream complicates the task more and requires solving the issue of their design taking into account numerous factors [12, 13, 14].

Areas of support, compression, spreading, and recovery appear [15, 16, 17, 18]. Of particular interest is the establishment of regularities of flow reshaping in the constriction range: maximum speeds at the head, uneven speeds in the core, speeds on the floodplain, and regularities of changes in the spatial compression coefficient.

Knowing the parameters of the flow in the alignment, we can predict the possible depth and boundaries of the washout, and correctly assign the depth of the bottom of the attachment.



2. Materials and methods

The purpose is to develop a method for determining the flow parameters in the bipolar cross-section of the rhombus, taking into account the variability of the river and the ridge, and the interaction of the flow in the river and the ridge. Research method and procedure. The study was conducted in the case of parallel axis dynamic dynamics in a rectangular-shaped river with a double rectangular foot. The width of the river is 30 sm, the width of the trunk is 85 sm, the length of the trunk is 11 m, the slope $i=0.00005$. Experiments were conducted in two series on river bed weights.

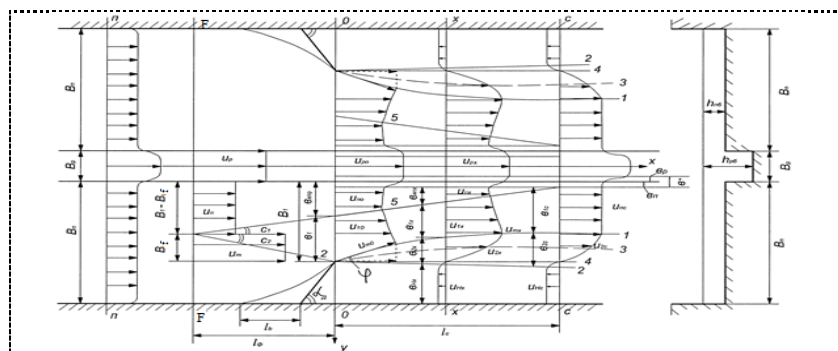
In the first series, the root and root gravity were equal $n = 0.016$, the second series was obtained by sand $d = 1.5 \div 2.0$ mm, with the coefficient $n_l = 0.023$ in the left thigh. To provide visual and instrumental research, the bottom of the tray is drawn 5x5 sm and 10x10 sm. On the walls, there is a telecentric running on the rails with a horizontal level.

Microcontroller SANIIRI electronic system TsISPV – 6 was used to measure speed. Besides, the measurements were used with cracks and spindles. The experimental studies were conducted at the following characteristics of the dump and the angle of installation $\alpha_d = 45 \div 1350$, with compression level $\theta_q=Q_{per}/Q = 0.14 \div 0.62$ (where Q_{per} , Q is the total damages in the dam). Thus, the number of Fruds corresponds to the natural regime in the river $Q = 5 \div 25$ l/h $F_{rp} = 0.01 \div 0.3$, $F_{rp} = 0.01 \div 0.18$. The turbulent mode was created in the hub $Re_p > 4000$, and $Re_p > 10000$. The condition of the planned issue was adopted on the recommendation of I.I. Levi $B/h > 6$. The velocities and flow directions were studied in the experiments.

Boundary and longitudinal differences of river and riparian flows, boundaries of upper and lower water circulation zones, depth, and transverse velocities were studied. The velocity was measured at depth 3 points, in the case of shallow depths measured at $0.6h$. The distance between the verticals is 2 to 10 sm, depending on the length of the zone. The water level was determined by spin-off and nivification. The upper and lower burrowing zones (zones) were calculated using water cuts and dyes, velocity divergence, and the water meter at the end of the ridge.

3. Results

Based on the results of experiments on the interaction of flow and ripple flow, the outline plan flow in compression and stagnation zones was developed, based on the results of experimental studies of the hydraulic parameters of the flow in the compressed section and the method for calculating the velocity field. The interaction of the river and the ripple flow is based on the results of experimental studies of the different velocities at the boundary of the two streams when the dams are deployed, accelerated mass transfer, slower flow, and acceleration in the ripple flow, the increased velocity at a certain width and similar characteristics. The compression of the two-rods with waterproof dams from the body, however, was based on the formation of zones of water shearing, compression, spreading, and potential energy recovery zones. Existing solutions have been studied based on the average velocity at the compressed cross-section, but the actual velocities are uneven at the O-O cross-section and compression zone (Figure 1).



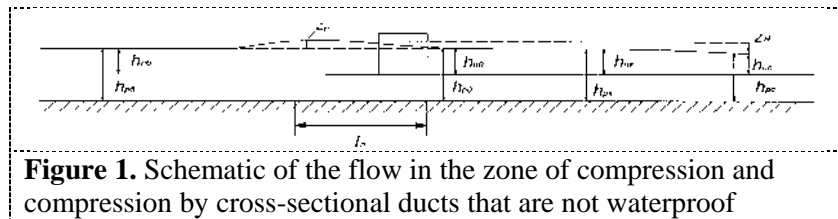


Figure 1. Schematic of the flow in the zone of compression and compression by cross-sectional ducts that are not waterproof

The following flow parameters are formed in the *O-O* compression cross-section: Low-impact core in the river, U_{po} velocity; less affected core in the race, speed U_{po} ; first intensive turbulent mixing zone, unevenly distributed flow rate U_{1o} ; the second intensive turbulent mixing zone, formed after compression cross-section, velocity U_{2x} .

We use the G.N.Abramovich [19] method to determine the flow parameters in the compressed stack and enter the hypothetical flow with the width B_p and velocity U_p , B_f and Speed U_m , Width $(B_1 - B_f)$, and U_p lf above the compressed stove.

The flow parameters in the *F-F* and *O-O* intersections are associated with the cost-saving and mobility equations.

$$\rho U_m^2 B_f h_n + \rho U_n^2 (B_1 - B_f) h_n + \rho U_p^2 B_p h_p = \rho h_n \int_0^{\epsilon_1} U_{1.o}^2 dy + \rho U_n^2 h_n (B_1 - \epsilon_1) + \rho U_p^2 B_p h_p$$

$$U_m B_f h_n + U_n (B_1 - B_f) h_n + U_p B_p h_p = h_n \int_0^{\epsilon_1} U_{1.o}^2 dy + U_n h_n (B_1 - \epsilon_1) + U_p B_p h_p \quad (1)$$

It has been established that the velocity distribution in the first zone ϵ_1 of intensive turbulent interference is subject to the theoretical dependencies of Shlixting-Abramovich.

$$\frac{U_{1.o} - U_{no}}{U_{m.o} - U_{po}} = (1 - \eta^{1.5})^2 \quad (2)$$

in this $\eta = \frac{Y_1 - Y}{Y_1 - Y_5 \epsilon} = \frac{Y_1 - Y}{\epsilon_1}$; $U_{1.o}$ is the relative ordinate of the point to be determined

Taking the formula (1) into the expression (2), we get the following equations:

$$U_{mo}^2 B_f h_{no} + U_{no}^2 h_{no} B_1 - U_{no}^2 B_f h_{no} + U_{po}^2 B_{po} h_{po} = U_{mo}^2 h_{no} \epsilon_1 (0.316 + 0.268 m_o + 0.416 m_o^2) + U_{no}^2 h_{no} (B_1 - \epsilon_1) + U_{po}^2 B_{po} h_{po} \quad (3)$$

$$U_{mo} B_f h_{no} + U_{no} (B_1 - B_f) h_{no} + U_{po} B_{po} h_{po} = U_{mo} h_{no} \epsilon_1 (0.45 + 0.55 m_o) + U_{no} h_{no} (B_1 - \epsilon_1) + U_{po} B_{po} h_{po} \quad (4)$$

In this equation: U_{mo} is the maximum velocity formed at the head of the dam; U_{po} is the speed of the core in the race; U_{po} is the flow rate in the river; h_{po} , h_{po} are ridge and stream depths in the river; B_f is the width of the flow at which the maximum velocity is formed at the hypothetical cross-section.

Apparently, in the 2 equations obtained, 4 are unknown, U_{po} , B_f , U_{po} and U_{mo}

A.M.Latyshenkov [18] proposed the coefficient of velocity increase along the river in the formulation of the system solution:

$$\beta_p = 1 + \frac{\theta_q}{\tau} \cdot \frac{\omega_p}{\omega_p + \epsilon_{np} \cdot \omega_n}$$

Where $\tau = Q_p / Q$ is the relative consumption of the river; ω_p, ω_n are the surface of the river and river sections between the transverse dams; $\epsilon_{np} = (\omega_p + \omega'_n) / (\omega_p + \omega_n)$, where ω'_n is live stream surface crosses the river and its compressed section

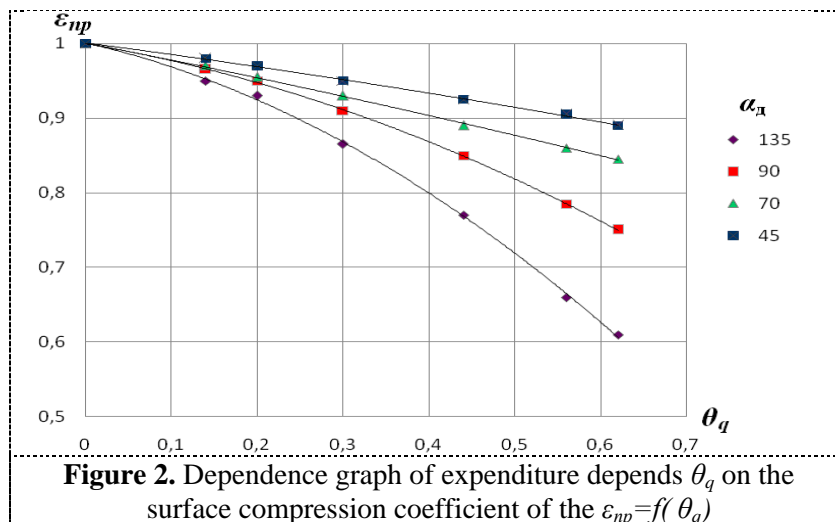
Experimental studies were performed ε_{np} to determine the surface compression coefficients, the results are presented in Table 1, and the graphical correlations $\varepsilon_{pp}=f(\theta_q)$ and $\varepsilon_{pp} = f(1 + \frac{\alpha_d}{180^0})$ were obtained based on the table results (Figure 2, 3). Based on the results, it was found that the angles of the dam installation variations in the case of $\alpha_d < 90^0$ and $\alpha_d \geq 90^0$ ε_{np} the following analytical expressions are suggested

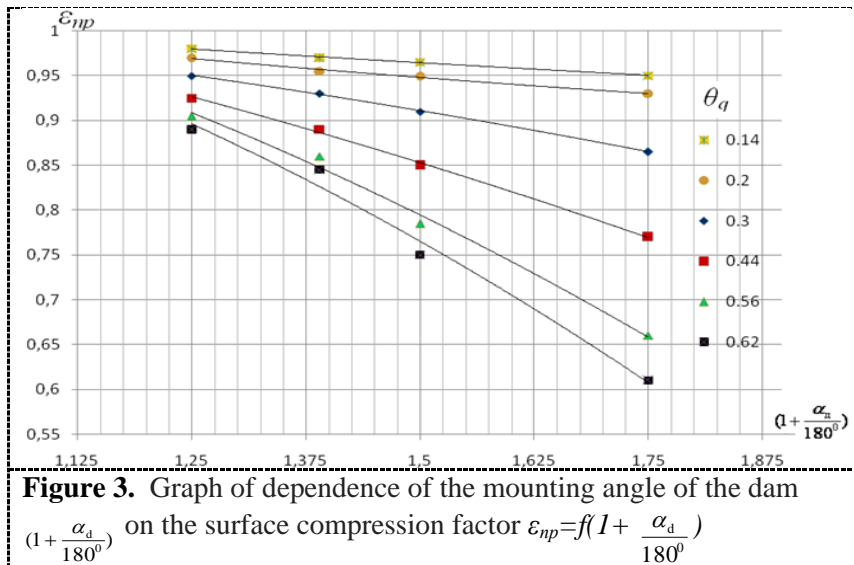
$$\varepsilon_{np} = 1 - 0.1 \cdot \theta_q^{1.15} \cdot \left(1 + \frac{\alpha_d}{180^0}\right)^{2.84} \quad \alpha_d < 90^0 \quad r^2 = 0.998$$

$$\varepsilon_{np} = 1 - 0.2 \cdot \theta_q^{1.62} \cdot \left(1 + \frac{\alpha_d}{180^0}\right)^{2.59} \quad \alpha_d \geq 90^0 \quad r^2 = 0.983$$

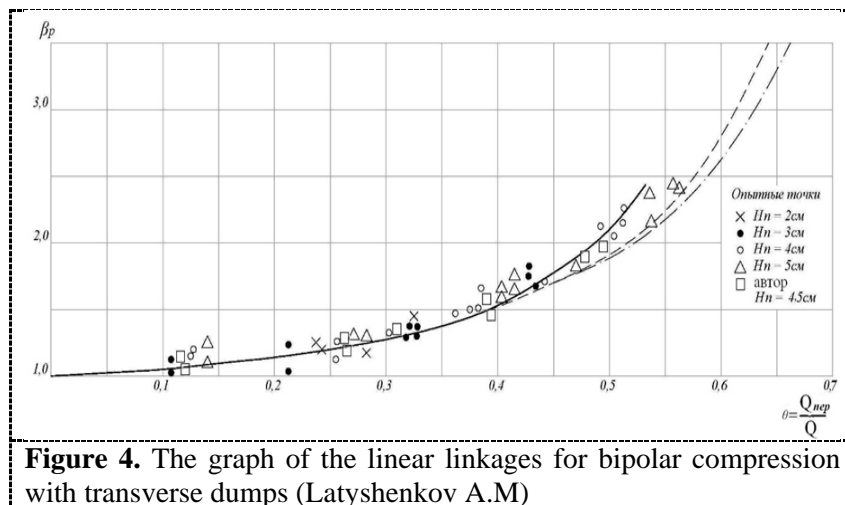
Table 1. The values ε_{np} of the surface compression coefficient calculated for the case of compression of the flow in the hinge by two-sided dumps are given in the table below.

α_d θ_q	135^0	90^0	70^0	45^0
0.14	0.95	0.965	0.97	0.98
0.20	0.93	0.95	0.955	0.97
0.30	0.865	0.91	0.93	0.95
0.44	0.77	0.85	0.89	0.925
0.56	0.66	0.785	0.86	0.905
0.62	0.61	0.75	0.845	0.89





The calculated values θ_q for each angular size are shown β_p in the graphs proposed by A.M.Latyshenkov [18] and the conformity of the graphs is appropriate for their compression states (Figure 4).



To determine the B_f , we compose the cost-saving equation in the $F - F$ (hypothesis cross-section) and $II - II$ (byte mode) states:

$$U_{p\sigma} B_p h_{p\sigma} + B_n U_{n\sigma} h_{n\sigma} = U_m B_f h_{n\phi} + U_n (B_1 - B_f) h_{n\phi} + B_p U_{p\phi} h_{p\phi} \tag{5}$$

here $h_{n\phi} = h_{no}$; $U_{p\phi} = U_{po}$; $U_{n\phi} = U_{no}$; $h_{p\phi} = h_{po}$

(5) The equation: $h_{no} = h_{pf}$ we get the following equation:

$$U_{p\sigma} B_p \bar{h}_{p\sigma} + B_n U_{n\sigma} \bar{h}_{n\sigma} = U_m B_f + U_n B_1 - U_n B_f + B_p U_{p\phi} \bar{h}_{p\phi} \tag{6}$$

(6) From the equation, we define the width of the hypothesis that the maximum velocity is formed:

$$B_f = \frac{U_{p\sigma} B_p \bar{h}_{p\sigma} + U_{n\sigma} B_n \bar{h}_{n\sigma} - U_{po} B_p \bar{h}_{po} - U_{no} B_1}{U_{mo} - U_{no}} \tag{7}$$

here $\bar{h}_{p\bar{\sigma}} = h_{p\bar{\sigma}}/h_{no}$; $\bar{h}_{n\bar{\sigma}} = h_{n\bar{\sigma}}/h_{no}$; $\bar{h}_{p\sigma} = h_{p\sigma}/h_{no}$

B_l is the width of the trunk in the compressed section; B_p, B_n are the width of the river and the ridge in the endless mode

B_f is the formula for determining the maximum flow rate in a compressed section using the cost-saving equation is given by equation (4):

$$U_{mo} = \frac{U_{p\bar{\sigma}} B_p \bar{h}_{p\bar{\sigma}} + U_{n\bar{\sigma}} B_n \bar{h}_{n\bar{\sigma}} - U_{p\sigma} B_p \bar{h}_{p\sigma} - U_{no} (B_l - 0.45\epsilon_1)}{0.45\epsilon_1} \tag{8}$$

Here it is $\bar{h}_{p\bar{\sigma}} = h_{p\bar{\sigma}}/h_{no}$; $\bar{h}_{n\bar{\sigma}} = h_{n\bar{\sigma}}/h_{no}$; $\bar{h}_{p\sigma} = h_{p\sigma}/h_{no}$

Experimental studies show that the positions of rays 5 and 2 are stable and determined (Figure 1).

$$\epsilon_1 = (C_1 + C_2) \cdot X \tag{9}$$

where are the turbulence constants according to experiments $C_1=0.23, C_2=0.16$ (Figure 5).

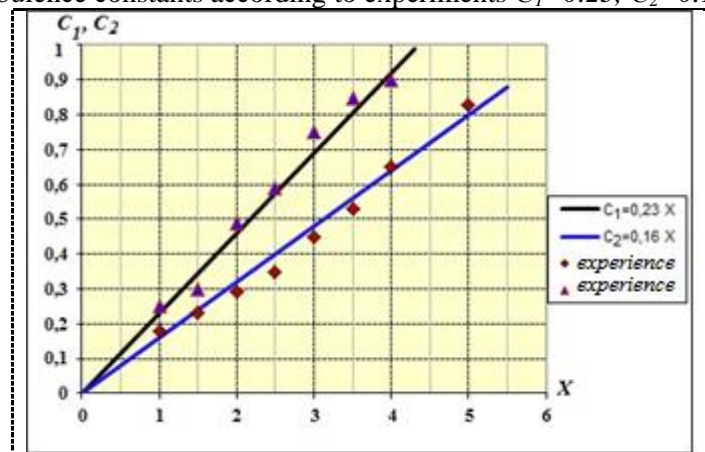


Figure 5. Values of the turbulence constants in the fictitious flow zone

Let's use this to determine the distance to the dummy section l_f and the width of the first zone of turbulent mixing ϵ_l

It is obvious from the ratio of the rectangle (Figure 1) on target $F - F$ and $O - O$ you can record

$$B_f + l_d \sin \alpha_d = l_d \sin \alpha_d + C_2 l_f \tag{10}$$

where from

$$l_f = 6.25 B_f$$

then (9) takes the form

$$\epsilon_1 = 0.39 l_f = 2.44 B_f \tag{11}$$

Substituting the obtained (11) into the equation of the amount of motion (3), after some transformations we get the square equation

$$0.425 m_0^2 + 0.654 m_0 + 0.229 = 0 \tag{12}$$

Analysis of equation (12) shows that it has two roots one is greater than or equal to one, it is discarded because it contradicts the physics of the phenomenon that would mean $U_{no} > U_{mo}$

A root less than one is accepted as valid and is equal to

$$m_{O2} = U_{no} / U_{mo} = 0.54 \tag{13}$$

Thus, the fact established experimentally by A. M. Latyshenkov [18] about a proportional increase in speeds on the floodplain and in the riverbed when the flow is constrained by transverse floodplain dams is confirmed theoretically using the equation of the amount of movement.

It should be noted that the proposed method for calculating the speed in the floodplain part of the constraint target is maintained for the flow as the average on the floodplain \mathcal{G}_n that is, without taking into account the actual distribution of speeds as we have done above.

It is interesting to compare the two methods. To do this we will use the equation of saving the flow rate recorded for the floodplain part of the constraint target $O-O$

$$\mathcal{G}_n h_{no} B_1 = U_{no} h_{no} (B_1 - \epsilon_1) + U_{mo} h_{no} \epsilon_1 (0.45 + 0.55 m_o) \tag{14}$$

Where from
$$\mathcal{G}_n / U_{no} = 1 + 0.45 \bar{\epsilon}_1 (m_o' - 1) \tag{15}$$

where $m_o' = U_{mo} / U_{no} = 1 / m_o$

Since in equation (15), the relative velocity is always $m_o' > 1$ that $\mathcal{G}_n > U_{no}$

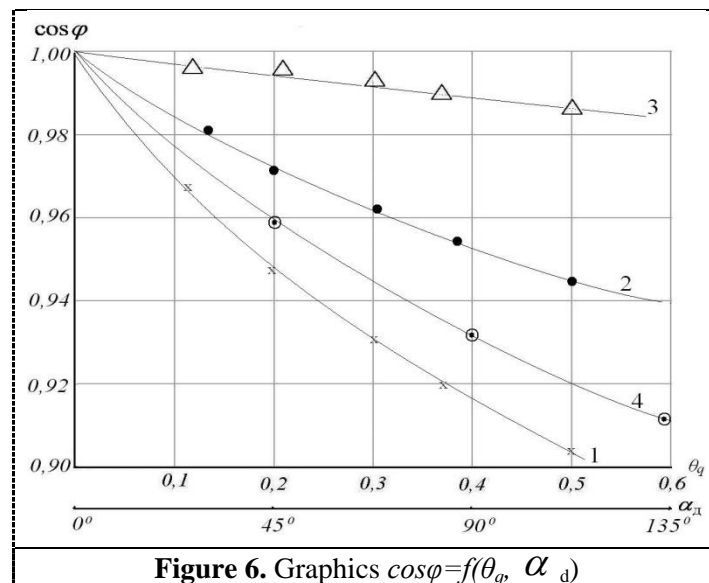
In other words, the calculation of the average speed on the floodplain by the method [18] gives some underestimated values

The obtained dependencies give the longitudinal component of the velocity vector. Meanwhile, to correctly determine the depth of local erosion at the head of the structure, it is necessary to know the actual values of the maximum speed and specific costs.

It is obvious (Figure 1)
$$U'_{mo} = U_{mo} / \cos \varphi = \kappa' U_{mo} \tag{16}$$

where φ is the angle between the channel axis and the velocity vector $\kappa' = 1 / \cos \varphi$

Experimental research shows the main impact on φ determines the degree of flow restriction and the angle of the dam installation (Figure 6).



1, 2, 3 - $\cos \varphi = f(\theta_q)$; 1 - (x) $x / l_{cc} = 0$; 2 - (●) $x / l_{cc} = 0,2$;
 3 - (Δ) $x / l_{cc} = 0,6$; 4 - $\cos \varphi = f(\alpha_d)$

As seen in Figure 6 $\cos \varphi$ decreases with increasing degree of constraint θ_q and the angle of the dam installation α_d . There is an increase $\cos \varphi$ by the length of the compression area and by the

width of the stream on the floodplain. In this case, the absolute values φ are reduced both in the length and width of the compression area.

According to [18] K' changes from $(1.55 - 2.0)g_n$. By formula $U_{mo} = 1.85U_{no}$ also, you must take into account K' according to the schedule (Figure.6) when calculating the maximum speeds in the range of constraint U'_{mo} .

4. Discussion

The construction of floodplain dams that symmetrically constrain the flow requires the establishment of a redefinition of flow parameters in the junction range.

Model studies were performed in the laboratory of the Department "Hydraulic structures and engineering structures" with the following flow parameters and structures: flow rate from 5 to 25 l/s, Froude numbers $F_{rp} = 0.01 \div 0.3$, $F_m = 0.01 \div 0.18$; Reynolds numbers $R_{en} > 4000$, $R_{ep} > 10000$, the degree of constraint on the flow $Q_q = 0.14 \div 0.62$ angles of the dam installation $\alpha_d = 45 \div 135^\circ$.

The previously proposed dependencies for determining the depth and size of the local washout are based on average speeds.

The solution to the problem is given taking into account the uneven distribution of speeds in the range of constraint. Different patterns of changes in the spatial compression coefficient were found at $\alpha_d < 90^\circ$ and $\alpha_d \geq 90^\circ$. The dependences for determining the U_{mo} , are obtained theoretically, and it is also established that the velocity distribution in the zone of a weakly disturbed core is universal.

A.M. The situation experimentally proved by Latishenkov, that is, when the flow is compressed with cross-dumbbells in the pedestal, the growth of the flow rate in the Ozen and POIS is based on the theoretical way of proportional change. At us $U_{no}/U_{mo} = 0.54$.

The resulting fasteners allow you to determine the longitudinal vector of the speed. Whereas, to correctly determine the washing depth next to the dumbbells (head), it is necessary to know the maximum speed and the actual values of the comparable costs:

Experimental studies speed vector and the angle between the Ozen axis φ to θ_q and α_d it was shown that the size affects, this is an increase in the size leads to a reduction in cost. Along the length of the compression zone and the width of the poppet flow there was an increase in size.

Together with this φ absolute value of decreases. Obtained graphics maximum U'_{mo} in the calculation of speed K' provides the possibility of determining the size

Direct calculations show that the depth of local washing is about 10 – 30% greater than the average speed of detection. Besides, there was an opportunity to visually determine the boundaries of reinforcement on the head of the structure on a fairly basic basis.

5. Conclusion

1. In contrast to solutions based on the average speed in the compressed section, there were parameters of the flow velocity, the speed in the loop, the maximum speed in the U_{mo} , the maximum speed next to the dumbbell bench U'_{mo} the determination formulas were developed taking into account the uneven scanning of the speed.

2. Degree of compaction by spending from experiments θ_q , installation angle of the dumbbell α_d it has been proved that the increase leads to a decrease in the coefficient of compression on the surface. Reduction intensity when built on dam current 0.09, when built against the current, the equality of 0,34 was determined, as well as ε_{np} to determine, some-analytical expressions were proposed.

3. With the proposed method, that is, taking into account the uneven breakdown of the speed in the compression section, the calculation was made 10 ÷ 30 magnitudes from the displacement depth determined by the average speed.

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