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Effect of flow velocity on downstream energy absorbers and velocity coefficient

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Abstract. As a result of designing an energy absorber in the zone of conjugation of water outlet structures of low-pressure and medium-pressure reservoirs, the stilling basin is not only under the influence of vertical hydrodynamic pressure with a variable value but also the disappearance of stagnation of the stilling basin can also be affected by the hydrodynamic stress arising from the force of horizontal pressure in the energy absorber. The hydraulic jump in the pool junction zone is one of the simplest energy absorbers. To increase the efficiency of this process, it is necessary to improve the hydraulic regime downstream of the water outlet, reshape the interface mode in the stilling basin and on the apron surface, and eliminate flow disturbance, through the construction of special energy absorbers in the stilling basin. These structures exert reactive (accelerating implementation), dislocation (accommodating), and distributed forces on the flow.

1 Introduction

Estimation of the strength of the downstream elements of water outlet structures of reservoirs, and waterworks, determination of the mode of pool conjugation, and creation of methods for decreasing kinetic energy in the areas of pool conjugation are important. In this regard, improving the technology for determining hydrodynamic stresses for calculating the thickness of the stilling basin and the apron zone is of particular importance.

Problems such as calculating hydrodynamic stresses on the slabs of stilling basins and aprons downstream of multipipe water outlet structures have not been sufficiently studied. Also, the stresses and hydrodynamic effects on the stilling basin and apron structures, along with the water flow energy absorbing structures with known schemes and shapes, have not been studied to the desired level. In this respect, the role of the theoretical development of mathematical models reflecting the conjugation of the pools of water outlet structures and finding solutions for energy dissipation in the downstream area of reservoirs is of great importance.

The main content of the research consists of observation at the initial stage of the process of operation of the downstream areas of the water outlet structures of low-medium pressure reservoirs to draw up different schemes of the outlet part of the distribution of the average flow velocity along the dynamic axis and in plan in the apron and stilling basin. The hydrodynamic characteristic in the considered zone of the water flow is one of the main factors affecting the strength, reliability, and stability of the downstream elements of the structure [1-6]

In the experimental studies, energy absorbers in the form of short walls were chosen to mitigate the energy of flow, as shown in the diagram in Fig. 1 [7-9].

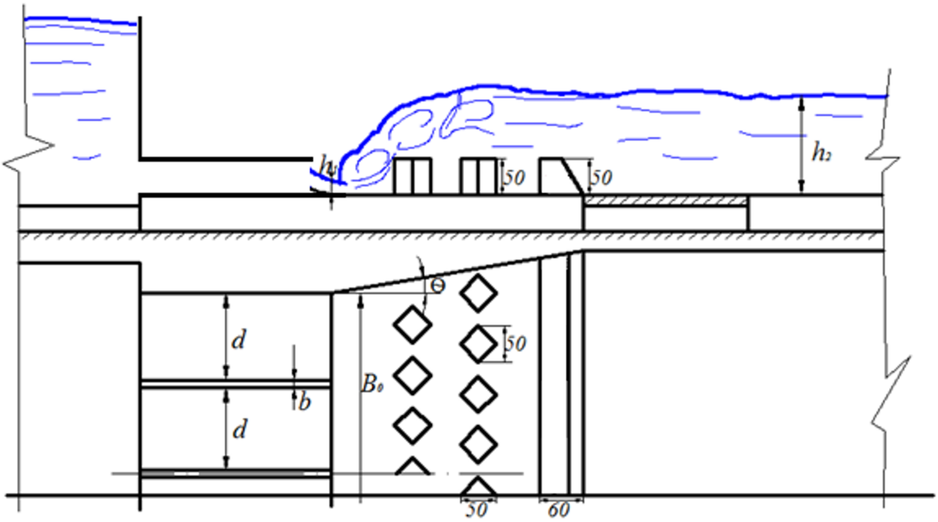

Fig.1. Schemes of location of energy absorbers in stilling basin downstream of water outlet of low- and medium-pressure reservoirs.

An analysis of the currently existing methods for hydraulic calculation of energy absorbers shows that their reactive effect on the flow is expressed as the main factor in calculating the energy of absorbers. The reaction of absorbers and expressions of their dependence on their shape, geometric dimensions, and location can only be obtained by conducting experimental studies. In this case, the most difficult task is determining the flow velocities impacting the absorbers and their resistance coefficients [10–16].

2 Results and discussion

The influence of the strength of the water flow is taken according to its shape, size, and kinematic characteristics. The coefficient of resistance to the movement of the opposite flow "C" is taken as a parameter characterizing the reaction of the absorber and the average hydrodynamic load. It is determined by the following formula.

$$C = \frac{\bar{R}_c}{\gamma\omega(\upsilon_{old}^2/2g)} \tag{1}$$

Here $\bar{R}_c$is absorber reaction, $\bar{R}_c = \gamma C\omega(\upsilon_{old}^2/2g)$;
γ is specific mass of water;
ω is the cross-sectional surface of the absorber relative to the water flow;
υ_{old} is the speed of the water flow near the absorber.

The resistance coefficient of the absorbers, the "C" value, is also calculated based on the flow velocity $\bar{\upsilon}_C$ in the compressed section.

It should be noted that in studies, the resistance coefficients of these absorbers are presented in the following general form [13]:

$$C = f\left(\frac{\upsilon_{old}}{\upsilon_1}, x\frac{Э_1 + p}{h_1}, x\frac{h_\partial}{h_2}\right) \tag{2}$$

Here, $\upsilon_{old} = \phi\sqrt{2gp + \upsilon_1^2}$, $\phi = 0{,}8$.

An increase in the level of deepening showed that three regimes replaced each other in the stilling basin. In this case, the value of "C" first decreases to a certain value and then increases to a certain value.

The minimum value of the coefficient "C" exists in the limit state of the hydraulic jump. This condition is explained by increased pressure in the front of the absorber and decreased in its rear part. As the absorber approaches the compressed section, the pressure in its frontal part increases. This will certainly lead to an increase in the "C" coefficient. This trend was observed in the first and second rows of absorbers. An increase in the ratio h_∂/h_2causes an increase in the value of "C" (Fig. 3); however, this situation continued until the absorber entered the jump turn zone.

As a result of studying the resistance coefficients in the stilling basin, it was observed that an increase in the relative height of the basin h_∂/h_1 led to an increase in the "C" coefficient.

As a result of the increase in kinetic energy due to the placement of absorbers far from the compressed zone, an increase in the depth of the flow and a decrease in its speed was observed. As can be seen from the curve graphs in Figs. 2 and 3, the speed ratio in front of the absorber l_1/h_1 can be expressed not in a proportional relationship but through a more complex relationship. It should be noted that the water flow velocities in the first row of absorbers are much higher than in the second row of absorbers. In addition, it was observed that the placement of absorbers in the center of the stilling basin led to a disruption in the movement of the vortex-like flow coming off the edge of the absorber.

This, in turn, leads to a decrease in the washing out of turbulent pulsation from the apron and from the rear fortified zone. An analysis of the pulsation in the stilling basin and the apron showed that the disruption of the movement of a large vortex-like flow begins with the first row of absorbers and ends in the second row. Behind checker-shaped absorbers, a rapid loss of energy was observed.

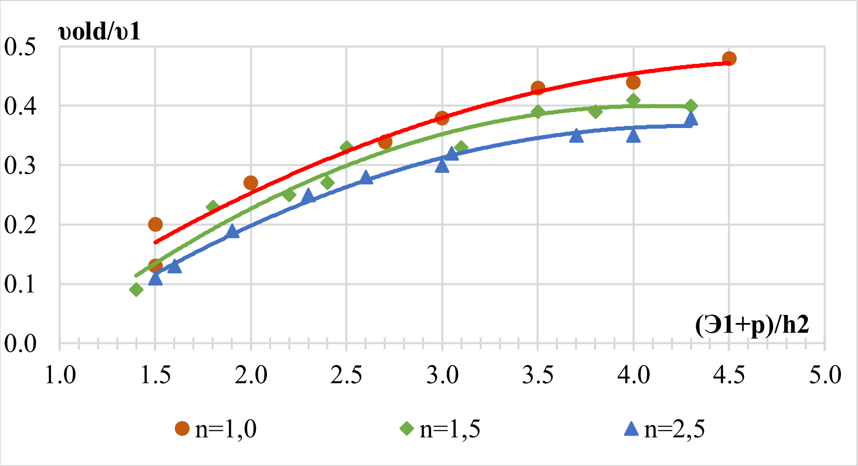

Fig. 2. Determination of horizontal stresses for study scheme

Graph is based on an expression $\frac{v_{old}}{v_1} = f\left(\frac{\text{Э}_1+p}{h_2}\right)$ for stilling basin wall.

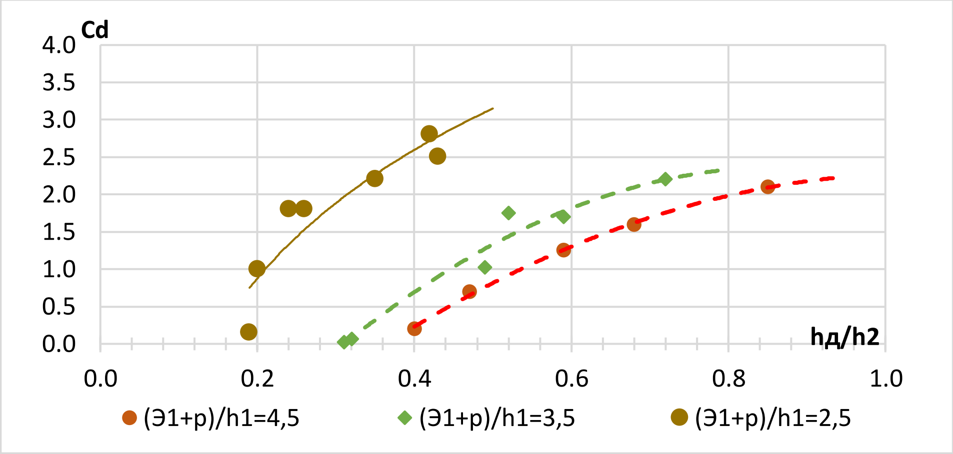

Fig.3. Determination of average horizontal stresses for study scheme

The graph is based on the expression $\mathrm{C}_d = f\left(\frac{\text{Э}_1+p}{h_1}; \frac{h_{д}}{h_2}\right)$ for stilling basin wall.

A parameter increase $\frac{\text{Э}_1+\text{p}}{h_1}$ leads to a decrease in *"C"* (fig.4).

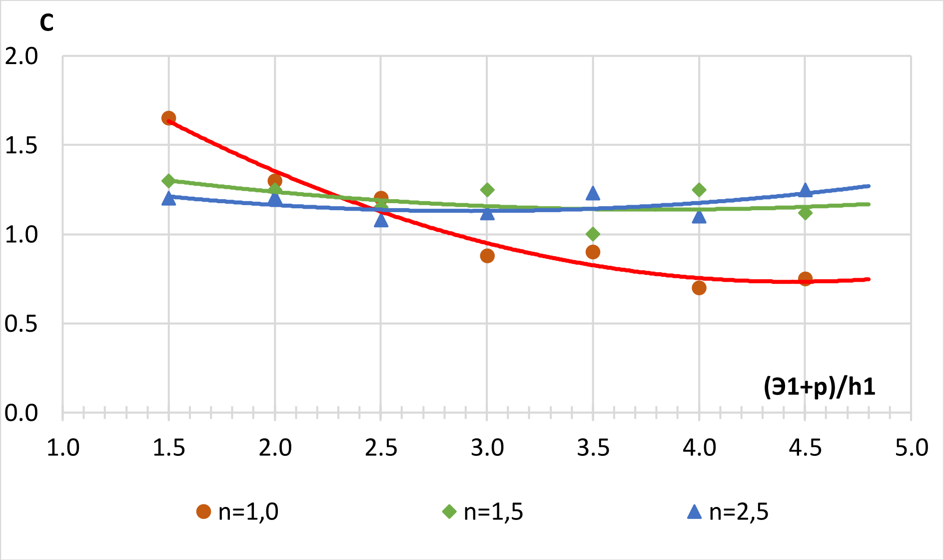

Fig.4. Determination of average horizontal stresses for research scheme.

Graph is based on equation $C = f\left(\frac{\text{Э}_1+p}{h_1}\right)$ for dissipating slab

As a result of observations of the pulsation components of the reactions of the checker-shaped absorbers and the stilling basin, expressions were obtained showing the relationship between the location of the standard relative values of the reaction pulsation and the kinematics of flows with the dimensions of the absorber.

3 Conclusion

It was noted that the maximum pulsation rate of the reaction of block-shaped absorbers could be detected when the absorbers are installed approximately in the center of the stilling basin (in the zone of maximum water flow rate).

This maximum, to a great extent, decreases in the second row, indicating that the energy of the jump flow in the second row is declining. It also shows that reaction pulsations and vortex flows increase with increasing $Э_1/h_1$ parameter. An increase in relative height h_c/h_1leads to an increase in the average pressure pulsation $p'_г$. An increase in the depth of penetration downstream showed the opposite picture.

A decrease in the frequency of reaction pulsations was observed in the second row of the block-shaped absorbers. This can be explained by transferring large-scale vortices from the edges of absorbers in the first row to the second row.

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