HYDRAULIC CALCULATION OF ENERGY DISSIPATORS

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Lower pool devices and energy dissipators are some of the essential elements of a hydraulic structure. The type of dissipator in the case of a bottom transition scheme in essence determines the elevation of the downstream floor. The selection of the type of dissipator depends on its hydraulic effectiveness, reliability of the calculation methods, reliable evaluation of the hydrodynamic loads, conditions of cavitation safety of the structural members, as well as the conditions of flow in the lower pool and their difference from natural flows. At the same time, consideration of all aforementioned factors is difficult due to the fact that they have been studied to different degrees for different dissipators. We will single out two main classes of dissipators. The first includes the simplest, effective, and long-known dissipators — baffle walls and stilling basins and their combinations (Fig. 1a, b, c, d). The greatest number of theoretical and experimental works have been devoted to these dissipators. The second class of dissipators includes slotted walls, baffle blocks, baffle piers, teeth, and their combination (Fig. 1e, f, g, h, i), which have been investigated to a far less degree than walls and basins due to the diversity of the schemes and labor intensity of their study.

For baffle walls and stilling basins extensive experimental data have been accumulated, especially on the relation between the lower pool depths and wall heights c and basin depths d for different lengths of the dissipators, and the data agree well [1]. This made it possible to recommend reliable experimental dependences for calculation [2, 3]. Approximate theoretical methods of calculating the height c and depth d suggest schematization of the phenomena, which does not correspond to real flow conditions, and therefore the results of calculation by the said methods do not agree with experiments. The hydraulic jump regimes and erosional ability of the flow beyond the dissipators have been studied in sufficient detail and data have been obtained on estimating the hydrodynamic loads on elements of the dissipator and conditions of their cavitation safety. It must be emphasized that the bulk of the experimental data was obtained for conditions of the two-dimensional problem. Unfortunately, there are insufficient data on the three-dimensional problem. For a number of reasons this direction is presently attracting almost no attention of investigators, although works whose results are of limited interest even for conditions of the two-dimensional problem continue to be published [4, 5]. Data on hydraulic calculation of walls, basins, and baffle wall with a basin located behind it are given in a concise form in [2, 3]. Suggestions on calculating scheme (Fig. 1d) are published in [6]. Recommendations on calculating all schemes (Fig. 1a, b, c, d) are being prepared for publication.

Baffle walls, stilling basins, and their combinations are quite effective energy dissipators making it possible, when necessary, to substantially increase the elevation of the floor and apron (Fig. 2) [1, 2, 3, 4]. In Fig. 2 h20 denotes the depth of the unsubmerged bottom hydraulic jump on a horizontal floor without dissipators for αc,d = 1, F1 = V12/gh1 is the Froude number referred to the contracted section 1–1 (Fig. 1), Zp0 = h20 — h1, the other notations are given in Fig. 1. Walls and basins are especially effective for a kinetic height c_k or depth d_k corresponding to the maximum reaction of the dissipators (the ends of the curves for the walls and basins in Fig. 2). In this case the presence of a surface whirlpool is provided before the dissipator in a critical or almost critical stable state even in the case of a rapid flow regime below the dissipator. The indicated circumstance must be taken into account for streams where one can expect a decrease of the levels of the lower pool as a consequence of transformation of the channel due to general and local scouring.

As already mentioned above, dissipators of the second class have not been studied in detail, there are suggestions on calculating blocks (square dissipators), piers, and other dissipators only for particular cases. Thus, in the guidelines [1] there are instructions about calculating a slotted wall for sp = 3h20 and ratio of pier width to slot width bp/bs = 3.4. Widely known in foreign practice are standard SAF and USBR dissipators [7, 8], representing a combination of diffusion blocks of piers and slotted sill (SAF and USBR-III) or without piers (USBR-II). It is characteristic that a decrease of the depth of the lower pool h2 compared to h20 provided by SAF and USBR dissipators is not more than 15-20%.

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Turning to the existing data, we note that the same dissipator in the form of one row of piers of the simplest rectangular or trapezoidal form is called a slotted wall by a number of authors [1, 2, 9, 10, etc.] and baffle blocks or piers by others [11, 12, 13, 14, etc.]. Strictly speaking, a dissipator with slotting it to the incomplete height (Fig. 1h) should evidently be called a slotted wall as well as in the case when the wall is placed in the central part of a channel or canal but has slots on the sides [15, 16, etc.].

The data on baffle blocks, piers, and other dissipators can be divided into two groups. The first group includes experimental investigations in which the depths of the lower pool $h_2$ and flow regimes were studied for various $F_1$, $s_p$, $s_1$, $c_p$, and $b_p/b_s$ [9, 10, 24, 25, etc.]. The second group includes experimental or theoretical works on determining the drag coefficients of the dissipator $C_x$ or total horizontal force of the flow on the block or pier $P$ [11, 12, 13, 14, etc.].

Let us examine first the case of one row of piers. Of greatest interest here from works of the first group is the fundamental research [10] devoted to a study of rectangular piers with $b_p/b_s = 1$ for a wide range of $\sqrt{F_1}$, $s_p/z_{p_1}$, $c_p/h_1$. For convenience of comparison with data on walls and basins, the results of W. Rand’s experiments are recalculated and given in Fig. 2. As could be expected, the hydraulic effectiveness of the piers is substantially less than that of a solid wall, the difference being especially noticeable for large $\sqrt{F_1}$. From works of the first group we must note also the V. E. Lyapin’s investigations [9] on the basis of which the recommendations given in [1] for $s_p = 3h_20$ and $b_p/b_s = 3.4$ were obtained.

In studies of the second group main attention was devoted to a determination of the force $P$ or coefficients $C_x$ on the basis of studying the distribution of the average pressures on the surface of the blocks or piers [14, 16, 17, etc.], or with the use of data of a direct measurement of the forces [13, 17, 18, etc.], or both methods [17, etc.]. The investigations were carried out for $b_p/b_s = 1$, which many authors consider optimal, and also in the case $b_p/b_s \neq 1$.

To compare investigations of the said groups it is necessary to compare the values of $P$. For a known depth of the lower pool $h_2$ the force $P$ can be determined from the momentum equation for an unsubmerged bottom hydraulic jump in the presence of piers. Under the assumption that the pressures at boundary sites are distributed according to the hydrostatic law and $\alpha_{c,d} = 1$, the equation is written in the form

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Fig. 1. Diagram of joining pools in the presence of energy dissipators: a) baffle wall; b) stilling basin; c) baffle wall with a shallow stilling basin located below it; d, e) stilling basin with baffle wall; f) two rows of piers; g, h) one row of piers; i) two rows of piers located at start of stilling basin.