ANALYTICAL DETERMINATION OF WASHING TIME OF HEAD WATER OF WATER RECEIVING STRUCTURE

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Head water of water receiving structures located in the mountain rivers is often sandy. Therefore, large amount of sand and gravel runs into the canals causing the emergency situation. Based on mathematical modeling of washing process, the determination of intermediate and full washing time of the head water of the water receiving is developed. With this, it is possible to effectively plan the operational conditions of the hydrosystem.
Common charts of the head water washing as well as profile and scheduled charts are given on figures.
Practical recommendations for applying the method suggested by the author are presented.
Key words: ***River, water intake, drifts, head water, washing.***

In the process of ensuring safety and effectiveness of the operation of dams and consequently their reservoirs, it is important that the head water is timely washed for the purposes of cleaning it from deposited sediments. In most cases this activity is quite successfully fulfilled in practice. However, it is conducted without preliminarily specified criteria or developed recommendations about the forecast of intermediate and final results of washing process. The reason for this is low level of its experimental and theoretical study. In this paper, an attempt to develop the method of time estimation for washing the head water of water receiving structures based on mathematic modeling of the washing process was made.

The majority of the reservoirs constructed on the mountain and submountain rivers are filled with sediments as the time of their operation expires and even earlier and their further exploitation is unreasonable. The mentioned circumstances more often occur in water receiving structures used for energy, irrigation and communal purposes. The reason for quick fill up of the head water is the small volume of the reservoirs.

Due to the careless exploitation and partially construction defects, the head water of many headgates fills up with gravel transported through the riverbed during flood. Consequently, sand and fine gravel start to enter into the settling or other sediment-clearing units. An emergency exploitation of the water receiving system which may result its failure occurs.

In order to avoid such consequences during exploitation process, it is necessary to plan and perform periodic washing/flushing of the head water. Naturally, this requires the presence of relevant construction decisions (bottom passages, bypass tunnels, etc.) in the structure. In case of their absence, relevant reconstruction of the water facility is required in order to be able to conduct the washing process.

As the experience of the reservoir and water receiving hydrosystem exploitation shows, ordinary operation of the structures in most cases is achieved when both the design is completed and the operation is skillfully organized. Such qualities are characteristic to medium and large dams. As for the water receiving structures installed mainly on the feeders, their operation condition is far from satisfactory.

The cleaning process of the head water from the sediments is a complex problem where the problem of determination of time of partial or full washing T is extremely important. On practice it is accepted to maintain one, two or three flushing passages equipped with gates depending on the width of the structure (these passages are furnished with gates) on the dam body.

Below is an analytic design for calculating T value for the case when the flushing outlet is installed in the middle of the water receiver.

Let's determine the inclination of the riverbed bottom i_r, height of sediment deposition in the head water H (for the dam the value H maximum – H_m), length of outlets (dam thickness at the passage) δ. At the initial stage of gate opening, the inclination of the surface of sediments to be washed i (i_o its initial value) is determined like (fig. 1)

$$i_o = tg\gamma_o = \frac{H_м}{\delta}; \qquad (1)$$

$$i_o = tg\gamma_o = \frac{H + z_p}{S\cos\alpha}, \qquad (2)$$

Where γ – angle of inclination of the surface of the sediments to be washed (γ_o- its initial value); z_p- coordinate of the riverbed bottom; α- angle of the riverbed inclination; S – distance from the damsite.

For the lowland and submountain rivers, due to trifle angle α $i_P = tg\alpha = \sin\alpha$ and $S \cdot \cos\alpha = S$ are obtained. However, for the mountain rivers it is necessary to apply communications (1) and (2). As a result of simple conversions, instead of (2) will get

$$i = i_P + \frac{H}{S \cdot \cos\alpha}. \qquad (3)$$

Identifying the angle of deposition of the sediment surface till washing through I, in preset values i_r and H_m it is possible to determine the thickness of deposition H subject to the distance S (fig. 1).

$$H = H_M - S(i_P - I) = H_M - S \cdot i_P(1 - \frac{I}{i_P}). \qquad (4)$$

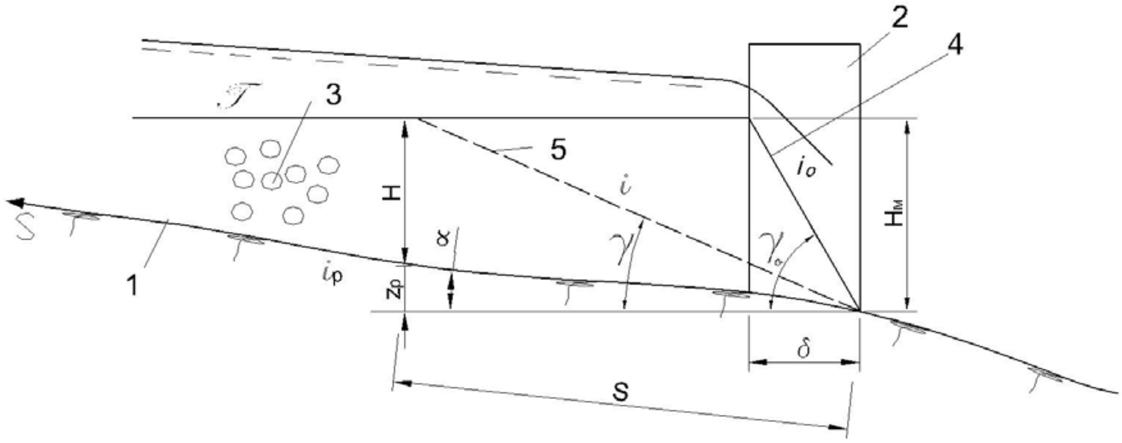

Figure 1. Diagram of Head Water Washing
1 - riverbed; 2 – dam; 3 – sediment deposition; 4 – condition of the surface of the sediment deposition at an early washing stage; 5 – the same at the following stages; 6 – washing water layer

Taking into the account the results of experimental and in-situ researches for correlation $\frac{I}{i_P} = K$ will obtain variation interval from 0,4 to 0,8 [1,2]. For the water receiving systems $K = 0{,}4,...,0{,}6$.

In dependence (3) replacing the height H by its value from (4), will have

$$i = i_P + \frac{H_M - S \cdot i_P (1 - K)}{S \cdot \cos\alpha}, \quad (5)$$

or

$$i = i_P + \frac{H_M}{S \cdot \cos\alpha} - \frac{i_P (1 - K)}{\cos\alpha}. \quad (6)$$

Since $\sin\alpha = i_P$, then using $\sin\alpha$ instead of $\cos\alpha$, from the last equation will obtain

$$i = i_P + \frac{1}{\sqrt{1 - i_P^2}} \left[\frac{H_M}{S} - i_P (1 - K) \right]. \quad (7)$$

Equation (7) determined the dependence between the current value of the inclination of the deposition surface to be washed and the distance of such surface front.

If before the derivation of the equation (7) there were no reasonable assumptions made, then there arises their need in further elaborations.

Sediment discharge of washing q_t, transported through the passage, changing depending on time (with decreasing angle i), decreases. Within the elementary period dt washing front from 1-1 site will move to 2-2 site covering the distance dS (fig. 2). Besides, the deposition thickness H is replaced by dH (thickness H, like the angle, decreased upstream). Elementary pump volume, washed during dt period, in the first approximations will be determined as (fig.2)

$$dW_C = \frac{H + z_P}{i_P} b \cdot dH, \quad (8)$$

Where b – variable width of the riverbed formed in front of the passage as a result of washing (fig.3)

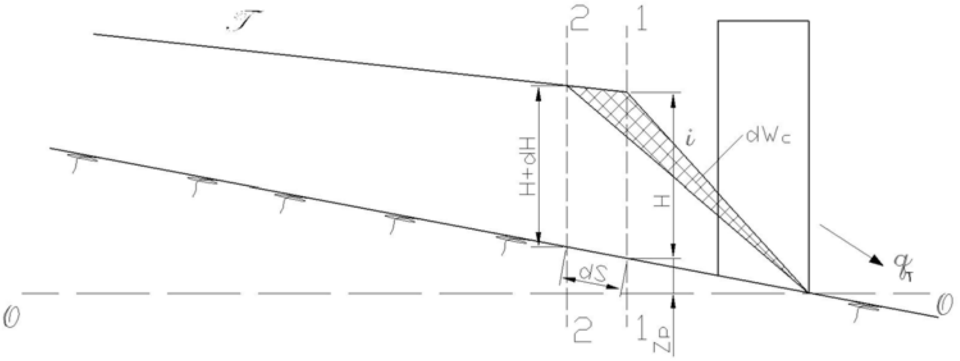

Fig. 2. Profile Diagram of Washing/Flushing Process

Of course, b value is formed by the stream moving in smoothly-changing form (the angle of the stream line expansion does not exceed $\beta = 8^o - 12^o$). Given this, for the determination of such width the following communication can be written (fig. 3):

$$b = b_{np} + 2S \cdot tg10^o, \tag{9}$$

Where b_{np} - width of the washing passage. In a damsite (S=0) we have $b = b_{np}$.

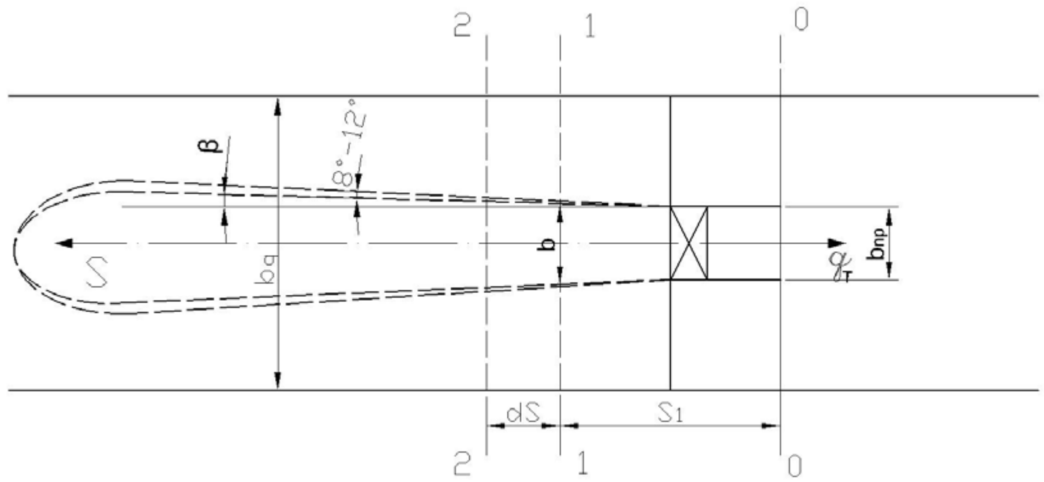

Fig. 3. Scheduled Diagram of Washing/Flushing Process

Taking into the account the communication (9), the dependence (8) will be written as:

$$dW_C = \frac{H + z_P}{i_P}(b_{np} + 2 \cdot S \cdot tg10^o)dH. \tag{10}$$

Considering that the volume discharge of the sediments coming out of the passage is indicated through q_t, for elementary washing period dt the equation of the sediment management can be written in form of:

$$dW_C = q_T \cdot dt. \tag{11}$$

Equaling right parts of the equations (10) and (11), will obtain

$$q_T \cdot dt = (b_{np} + 2 \cdot S \cdot tg10^o)dH, \tag{12}$$

or

$$dt = \frac{H + z_P}{i_P \cdot q_T}(b_{np} + 2 \cdot S \cdot tg10^o)dH. \tag{13}$$

From the obtained differential equation, the dependence between the washing front condition (coordinate S) and the period within which the sediment volume located between the water receiver and the mentioned site is washed/flushed is specified by means of integration.

Edge conditions for the integration are:

in t=0 S=0 or $H=H_m$;

in $t=T_{washing}$ $S=S_t$, H=0, где $T_{washing}$ – duration of full washing of the head water.

In the equation (13) the values z_p, i_p and b_{np} are initial values and are easily determined. As for the value q_t, some well-know methods can be applied for its determination and some

methods (M. A. Mostkov [3], Craf W. [4], P. O. Baldjan [2], etc.) can be applied for checking.

So, for estimating full or partial washing time of the head water of water receiving structures it is correct to use the suggested equation (13).

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