Advantages of solving the problem of turbine abrasion in the Burjar hydroelectric station by designing a sump

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Advantages of solving the problem of turbine abrasion in the Burjar hydroelectric station by designing a sump

A Badalov[1*], F Kattakulov[1], B Buvabekov [1[0000-0003-23895380]], U Kurbonova[1], A Abdukhalilov [1[0000-0001-5236-6168]] and M Rajabov[1]

[1]Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, Tashkent, Uzbekistan

vohidov.oybek@bk.ru

Abstract. Existing methods are considered for designing sedimentation tanks in the Burjar hydroelectric power station to solve the problem of abrasive wear of aggregates. Weighted sediments abrade the lining of derivational and station water conduits, as well as the working elements of hydraulic turbines. In the Burjar hydroelectric power station, there is a problem associated with the abrasive wear of the units. Abrasive wear of turbines leads to a significant drop in their efficiency, and therefore, a decrease in the power and energy generation of a hydroelectric power station, a reduction in the service life of hydroturbine equipment, and a fragment of wear. For the design of the sump, geological and hydrological information was collected about the Burjar hydroelectric power station. The sump is projected onto the derivation channel of the Burjar hydroelectric station. To determine the size of the sump, laboratory analysis of the water of the Burjar hydroelectric station was carried out. The hydraulic calculation of the sump includes determining the main dimensions of the chamber, sediment volume, flushing turbidity, and siltation time of the dead chamber volume with sediment. The calculation is described by the method of academician E.A. Zamarin. According to the method of E.A. Zamarin, the width of the chamber is 9.6 m and the length of the chamber is 73 m. These results are accurate and they were used during the design of the sump.

1. Introduction

The object of study is the Burjar hydroelectric power station. The subject of the study is the turbidity of the water flow. The purpose of the study is to reduce the damage caused by sediment during the design of hydropower plants, provide measures to protect structures and equipment from the penetration of dangerous fractions of sediment. The main objective of the study during the deposition of fine sediment in the sump is to ensure the permissible turbidity of the stream at the outlet of the sump, taking into account the required degree of clarification of the water.

When designing and operating hydraulic structures built on watercourses that carry a large number of small sediments, operating personnel have to solve many problems that depend on the purpose of using the water supplied by the hydropower facilities. For hydropower plants, especially the derivational type, this is a task associated with damage or destruction of the guide apparatus and the impeller of the turbines. If you do not perform a set of repair and restoration works, then the period of failure of hydraulic units becomes quite short. Experts confirming this fact, they believe that the interval between the overhaul periods of equipment due to abrasion by its sediments is: more than two years – with intensive abrasion; 3 – 4 years – with moderate abrasion; less than 4 years – with weak abrasion of aggregates with sediment. An engineering solution to this problem is the installation of

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sedimentation tanks for sedimentation - sedimentation plants for hydroelectric power plants, irrigation sedimentation tanks. Domestic and foreign experience in protecting irrigation systems against siltation by sediment indicates that, as a rule, sediments with an average fraction diameter larger than 0.01 mm (extremely rarely less than 0.01 mm) should be deposited in sedimentation tanks [1–4].

In the Burjar hydroelectric power station, the design of the sump has to solve the following issues: a) establish the location of the sump on the channel; b) choose the type of sump; s) determine the main dimensions of the sump [5–7].

2. Method

When performing work, hydraulic methods for studying the flow structure for the Burjar hydroelectric power station indicate values as the average water level to ensure normal operation based on known measurement methods. The research methodology in the process of modeling hydraulic transients corresponding to various modes of open channel operation has been clarified. The reliability of the data obtained in the course of theoretical studies is confirmed by mathematical methods to verify the adequacy of experimental results[8–13].

3. Results and Discussion

As a result of hydrogeological research, information about the object was collected. For example, in the area of the Burjar hydroelectric station (Republic of Uzbekistan), two aquifers have been established. The first one (upper) is confined to loess like deposits, the second (lower) to alluvial deposits represented by pebbles and underlying loess like clays (“stone loesses”). The first of them is a typical groundwater horizon and is used by the population of the city with numerous (over 600) dug wells. The deepest occurrence of these waters is observed in the middle of street Pushkin (Republic of Uzbekistan) lying hypsometrically above the adjacent territory. In the direction of the old city, the depth of groundwater decreases, and in some places waterlogging is observed in the Sheikhantaur (Republic of Uzbekistan) part of the city and along the street Jar-Kucha (Republic of Uzbekistan). The groundwater flow has a generally southwestern direction.

The water quality of these horizons is different; the first horizon has more mineralized waters up to brackish tastes. The waters of the second are quite suitable for water supply.

Groundwater wedges out on both sides in the form of springs and small springs. The flow rate of the springs does not exceed 0.4-0.7 hp springs are everywhere drowned out by gabions or concrete clothes. Their influence (during surveys) together with surface waters is manifested in the washing out of the smallest particles from under the gabions and their subsidence.

In the northern part of the site, in addition to the groundwater horizon, there is a zone with shallow bedding of waters - this is the top connected with the filtration from the Anchor channel (Republic of Uzbekistan). So pit 5, laid 20m north of the barracks office, the water was opened at 448.80 m, i.e. 15 m above the first standing horizon. The additionally laid pits 7, 8, and 9 (in the right exit dam) revealed a picture of the feeding of the high water from the channel. A decrease in water in the channel by 0.3 m (04/27/33 g) caused complete drainage of pit 9 and a sharp decrease in water in pits 7 and 8. The marked distribution of the upper water has a local character and is concentrated only above the drop. In the downstream, groundwater is drained by the Burjar irrigation canal (Republic of Uzbekistan) [14, 15].

The groundwater temperature in March – April 1933 did not exceed 10 *°C*. According to recent years of observations, the temperature in a constant aquifer in the annual cycle varied from 14.0 to 18.4 *°C*, and the water horizon is warmer from 15.4 to 21.3° *C* (wells 12 and 16). The maximum temperature was observed in August 1995.

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Table 1. In the average monthly and average annual water discharges in the sections of the HPPs of the Tashkent cascade (Republic of Uzbekistan) are given according to the data of JSC Hydroproject for the period 2002 – 2017.

Years	2001	2002	2003	2004	2005	2006	2007	2008	2009
Q, m^3/sec	22.41	20.53	26.47	30.20	31.87	28.47	30.20	28.67	30.73
Years	2010	2011	2012	2013	2014	2015	2016	2017	2018
Q, m^3 /sec	22.27	32.00	31.13	26.73	27.00	26.13	29.53	29.53	27.52

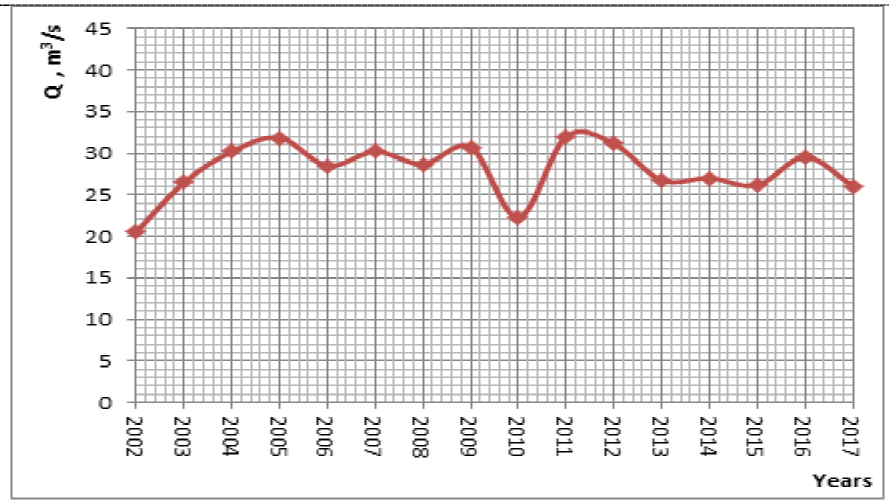

Figure 1. Average monthly and average annual water discharges in the sections

According to the table, in 2009 the maximum water flow rate of 52 m^3/s was discovered according to the data of the Burjar HPP:
— Head - maximum is 20.25 *m*;
— Estimated is 18.5 *m*;
— Minimum is 18.05 *m*;
— The average annual flow rate is 29.87 m^3/s;
— Estimated flow rate is 26.39 m^3/s;
— We take the number of units equal to 2, then Q_t = 13.195 m^3/s.

The average annual flow rate of 29.87 m^3/s is taken to calculate the size of the sump. Periodic sedimentation tanks for the Burjar HPP are selected.

Table 2. To determine the size of the sump, laboratory analysis of the water of the Burjar hydroelectric station is necessary

Estimated diameter of sediment, mm	Fractional composition of suspended sediment, P_i	Fractions weight ρ_i and volume μ_i		Hydraulic size u, cm/s
		$\rho_i, kg/m^3$	$\mu_i, l/m^2$	
0.25 – 0.35	$\sum P_i = 100\%$	$\rho_0 = 1.5 \mathrm{kg/m^3}$	$\mu_0 = 1.11 \mathrm{l/m^2}$	1.71

The hydraulic calculation of the sump includes determining the main dimensions of the chamber, sediment volume, flushing turbidity, and siltation time of the dead volume of the chamber with sediment. The calculation is described by the method of academician E.A. Zamarin. Definition of the main sizes.

The initial data for the calculation:

1. The flow rate of the channel is Q_k (m^3/s).
2. The weighted turbidity of the river is ρ_0 (kg/m^3).
3. Fractional composition of suspended sediment is P_1
4. The estimated diameter of sediment to be detained in the sump d_p (0.25 ÷ 0.35 mm).
5. The bulk weight of sediment is γ_n (1.3 ÷ 1.6 t/m^3).

Following a given percentage composition of sediment, for each fraction, both the weight (ρ_i) and volumetric (μ_i) turbidity are determined by the formulas:

$$\rho_i = \frac{P_i \rho_0}{100} \quad \mu_i = \frac{\rho_i}{\gamma_H} \quad (1)$$

The hydraulic fineness – W (*cm/s*) for each fraction is taken according to the schedule of 1.71 *cm/s*.

Then, the number of chambers $N = 3$, the water depth at the beginning of the chamber $H_1 = 5$, and the depth of the dead volume h_m is determined. They are set by the average speed during sedimentation:

$$\upsilon_0 = 0.3 \div 0.4 \ m/s$$

Flushing Speed:

$$\upsilon_{st} = 2.5 \div 3.5 \ m/s$$

Rinsing depth:

$$H_{st} = 0.5 \div 0.6 \ m$$

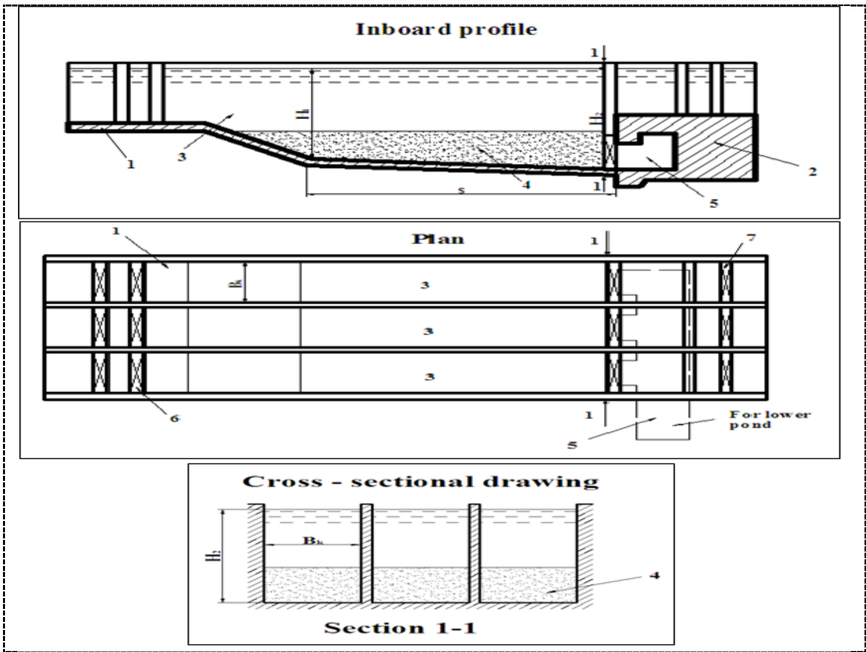

Figure 2. Scheme periodic action, multi-chamber, with periodic

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washing of settled pumps; 1 is input threshold; 2 is output threshold; 3 is camera; 4 is dead volume; 5 is washing gallery; 6, 7 are gates at the input and output thresholds

The width of the camera is determined by the formula:

$$B_{\kappa} = \frac{Q_{\kappa}}{N\vartheta_0 H_1} = \frac{29.87}{3 \cdot 0.2 \cdot 5} = 9.96m$$

The length of the chamber is determined by the formula:

$$S_{cham} = 1.25 H_1 \frac{\vartheta_0}{u} = 1.25 \cdot 5 \frac{0.2}{0.0171} = 73m$$

here: W_g is the hydraulic size of the estimated diameter of the sediment d_g = 0.0171m.
Live section area:

$$\omega_{st} = B_{\kappa} h_{st} = 9.96 \cdot 0.5 = 4.98m^2$$

Moistened perimeter:

$$\chi_{st} = B_{\kappa} + 2h_{st} = 9.96 + 2 \cdot 0.5 = 10.96m$$

Hydraulic radius:

$$R_{st} = \frac{\omega_{st}}{\chi_{st}} = \frac{4.8}{10.96} = 0.44m$$

Shezi coefficient:

$$C_{st} = \frac{1}{n} \cdot R^{(1/6)} = 51.3\ m^{0.5} / s$$

The necessary bias is determined by the formula:

$$i_0 = \frac{\vartheta_{st}^2}{C_{st}^2 R_{st}} = \frac{9}{2611.21 \cdot 0.44} = 0.008$$

here: the hydraulic elements of the wash flow are determined with a roughness coefficient *n=0.017*.
The found bias must satisfy the condition:

$$0.01 > i_0 > 0.005$$

The depth of the sump at the end of the chamber is determined by the formula:

$$H_2 = H_1 + i_0 S = 5 + 0.008 \cdot 70 = 5.56 \text{ m}$$

Pre-installed the ability to wash the sump according to the approximate formula:

$$Z - H_2 + h_{st} \geq 1.0 \text{ m}$$

In mining intakes, the head Z is determined from the water level mark in the sump.

If this condition is not met, it is necessary either to reduce the depth of the chamber or to move the sump down the channel path to a distance that provides the necessary head for washing the sump.

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4. Conclusion

- During the study, geological and hydrological information was collected about the Burjar hydroelectric power station. Based on this information, the average annual flow rate of a hydroelectric power station is equal to *29.87* m^3/s. Laboratory analysis of water of the Burjar hydroelectric power station was carried out. Dust is determined that the turbidity of the water is *1.5* kg/m^3.
- The estimated diameter of the sediment is *0.25 – 0.35 mm*. LA According to Set of Rules SP 164.1325800.2014, the destruction of a concrete structure by reinforced carbon cloth occurs when the breaking load reaches the calculated tensile of the composite material. As several experimental studies show, this statement is not valid sediments that fall into water facilities (irrigation canals, water receivers, diversion channels of hydroelectric power plants) significantly affect their effective operation. Weighted sediments abrade the lining of derivational and station water conduits, as well as the working elements of hydraulic turbines. With an engineering solution to this problem is the installation of sedimentation tanks for sedimentation – sedimentation plants of hydroelectric power stations.
- The author has identified a simpler and more reliable method for calculating sedimentation tanks based on the method of E.A. Zamarin, built on water bodies, carrying a large number of small sediments. According to the calculation, the number of chambers is $N=3$, the width of the chamber is 9.96 m, the length of the chamber is 73 *m*, the water depth at the beginning of the chamber is 5 *m*, the depth of the sump at the end of the chamber is 5.56 *m*.
- The optimal parameters of any of the considered settlers should be made on the basis of a technical and economic comparison of various options depending on the length, width, depth, design features, number of chambers, and washing intervals.

The sump option includes taking into account the minimum costs reduced to the same period of time for the construction, repair, and operation of structures and equipment.

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