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ALGORITHM FOR CALCULATION AND OPTIMIZATION OF SEDIMENTATION BASIN STRUCTURES FOR SMALL HYDROPOWER PLANTS

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Abstract

The paper addresses the optimization of geometric and cost parameters of sedimentation basins for small hydropower plants (SHPPs) operating on mountainous rivers. It is shown that widely used design solutions with variable geometry of sedimentation chambers are often due to the lack of a comprehensive methodology for the coordinated calculation of all elements of the structure and are not always economically optimal.

A systematic approach to the design of SHPP sedimentation basins is proposed, based on maintaining design flow velocities and using a constant chamber width. Based on a generalized analysis of calculation results for various values of discharge, chamber width, and captured particle sizes, a parametric model of the volume of monolithic reinforced concrete of the sedimentation basin is obtained in the form of a power-law function of the main governing factors.

The paper substantiates the selection of the maximum allowable particle size based on physical principles of abrasive erosion and the concept of hydraulic sedimentation velocity. A comparative analysis of different methods for calculating hydraulic sedimentation velocity (Stokes, Goncharov, Arkhangelsky, Rubey, Ferguson–Church) is performed for particle sizes typical of mountain rivers.

To assess capital costs, an aggregated cost model is developed that relates the construction cost of the sedimentation basin to the volume of reinforced concrete and a regional cost index for 1 m³ of monolithic reinforced concrete.

The results of the study can be used in the design and techno-economic justification of SHPP sedimentation basins, as well as in the development of unified methodologies for the optimal selection of their geometric parameters taking into account hydraulic and economic factors.

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Keywords: SHPP sedimentation basins, sediments, turbine types, hydraulic particle size, geometric optimization, suspended sediment sedimentation, construction cost, techno-economic optimization.

Methodological Reasons for the Use of Sedimentation Basins with Variable Geometry and Limitations of Existing SHPP Design Approaches

The design of sedimentation basins for small hydropower plants (SHPPs), especially in mountain river environments, is traditionally carried out using separate calculation methods for individual structural elements, integrated into a water intake structure. In practice, solutions with variable sedimentation basin widths along the length of the structure are quite common, despite their structural complexity and, as a rule, increased cost. Analysis shows that the main reason for the prevalence of such solutions is not their cost effectiveness, but the lack of an integrated methodology for the "package" calculation of a sedimentation basin as a single integrated hydraulic and technological system.

In a broad engineering sense, an SHPP sedimentation basin represents a sequence of interconnected elements, including a coarse trash screen, a supply channel, a sedimentation chamber with dead volume for sediment accumulation, a flushing unit, a fine trash screen, as well as a pressure chamber and a diversion inlet pipe. Each of these elements has its own calculation method based on local hydraulic criteria: permissible velocities, pressure losses, and sedimentation or flushing conditions.

At the same time, the parameters of these elements are interconnected through water flow, levels, and the characteristic flow cross-section. A particularly important connecting parameter is the width of the structure, which directly determines flow velocities in all zones of the sedimentation basin. A constant width ensures consistency of hydraulic conditions: velocities in front of the screens, in the sedimentation chamber, and in the diversion inlet zone are within the same scale range and can be matched within one-dimensional calculation models.

In the absence of an integrated methodology, the designer is forced to solve the problem sequentially, element by element. As a result, the requirements of various components often prove contradictory: the velocities acceptable for screen operation are too high for effective sedimentation; the minimum velocity requirements in the sedimentation chamber conflict with the washing requirements; and the requirements for a uniform velocity field in the pressure chamber are incompatible with the transient operation of the washing unit. In the absence of a formalized procedure for reconciling these requirements, the structure's geometry begins to perform a compensating function.

It is precisely in this situation that solutions with variable widths, diffuser and confusor sections, and additional buffer zones emerge in practice. Geometric "uncoupling" of the elements allows for the local satisfaction of the requirements of each node, but leads to the formation of extended transition sections, in which the flow is spatial, significantly non-unidimensional. For such zones, classical one-dimensional hydraulic models become inapplicable, and the sedimentation efficiency cannot be accurately estimated by calculation.

From an engineering perspective, transition sections typically cannot be fully included in the effective sedimentation length of a sedimentation basin. To ensure a given sediment collection rate, the designer is forced to increase the overall geometric length of the structure by the length of the inlet and outlet transitions. This inevitably leads to increased excavation and concrete work, more complex structural components, an increased number of joints and connections, and higher capital costs.

An additional consequence of using variable geometry is increased operational risks. Recirculation zones and localized flow accelerations often form in expansion and contraction zones, contributing to uneven sediment accumulation and deteriorating flushing conditions. As a result, the structure becomes more sensitive to hydraulic fluctuations and requires additional maintenance measures.

An important factor is the complication of construction of transition sections due to the complexity of their geometry.

Thus, the widespread use of variable-width sedimentation basins in small hydroelectric power station projects is primarily due to the methodological limitations of existing approaches focused on element-by-element calculations. The lack of a unified "package" methodology that takes into account the mutual influence of all sedimentation basin elements forces designers to resort to geometric complications as a means of compensating for inconsistent design requirements.

From a methodological perspective, a more rigorous and economically sound approach is one in which the entire sedimentation basin complex is considered as a single hydraulic-technological system with a minimum number of characteristic parameters. Using a constant width along the main sedimentation section allows for the design of the screens, sedimentation chamber, flushing unit, and pressure chamber to be integrated into a single system, reducing the length of transition zones and increasing the transparency of technical and economic optimization.

Implementing such an approach requires the development of an integrated calculation methodology in which the sedimentation basin's geometric parameters are selected not in isolation, but as part of a coordinated solution that ensures the required sediment collection efficiency at minimal net costs. The lack of such methods is currently one of the key reasons for suboptimal design solutions in small hydropower plant projects.

Literature Review and Analysis of Existing Approaches

Classical works on the theory of particle sedimentation in a flow [1,2] laid the foundation for calculation methods used to select the dimensions of sedimentation basins. Subsequently, these approaches were further developed in studies devoted to hydraulic structures and sediment-related problems (Morris [3]; Garde, Raju [4]).

Practical guidelines for the design of small hydropower plants [5,6] contain recommendations on structural layouts and permissible hydraulic parameters; however, the calculation of individual elements are performed separately.

Economic aspects of SHPP design and the assessment of construction costs are considered in the reports of NVE [7] and USBR [8], where the cost of sedimentation basins is determined through the volumes of construction works. At the same time, the mutual influence of sedimentation basin elements is not analyzed in these sources.

In the national engineering school, a significant contribution to the development of calculation methodologies for hydraulic structures was made by the works of G.I. Zhuravlev and V.I. Gubin. In Zhuravlev's textbook "Hydraulic Structures" [9], approaches to the calculation of intake and sedimentation structures are systematized, including requirements for velocity regimes, layout, and structural elements. At the same time, the calculation of sedimentation basins is considered predominantly on an element-by-element basis, without a formalized procedure for coordinating the parameters of all units within a single system.

The works of V.I. Gubin devoted to the design and operation of hydraulic structures on rivers with high sediment loads [10] emphasize the importance of considering actual hydraulic conditions and operational factors. They note that transition zones and sections with unsteady flows often fail to achieve the design efficiency and require additional sizing margins, which indirectly confirms the advisability of minimizing variable geometry when designing SHPP sedimentation basins.

Thus, the existing literature confirms that the absence of an integral calculation methodology leads to fragmented design solutions and the widespread use of sedimentation basins with variable geometry.

Description of the Calculation Model

To solve the stated problem, a program was developed in the VBA environment. The program makes it possible to perform the following tasks:

1. Based on the initial hydrological and morphometric data, to model the type of the river longitudinal profile and its thermal regime. On this basis, to assess the probable water temperature at the cross-section of the designed water intake.
2. Modeling the location of the designed sedimentation basin based on a given longitudinal profile and two transverse cross-sections, in order to assess excavation volumes and bank protection works.
3. Determine, based on the given pressure and type of installed turbine, the recommended clearances of the fine trash rack and the maximum diameter of particles passed through the turbine and determine the hydraulic size.
4. Determining the main dimensions of the pressure chamber to prevent vortex formation, rationally positioning the pressure pipe confusor, and ensuring sufficient volume to prevent the turbine from operating in an unstable condition. Determining the minimum possible width of the sedimentation basin based on the placement of the pressure diversion confusor.
5. Calculation of the plan area of the sedimentation basin. Determination of the optimal value of Bsedm, at which the minimum total construction cost of the sedimentation basin is achieved. Determination of the optimal length of the sedimentation basin.
6. Based on the obtained width, calculation of the fine trash rack for operation at maximum discharge and under winter conditions, taking into account the normatively permissible clogging.

7. The design depth of the filled sedimentation basin is coordinated with the height of the dividing wall, and, based on flushing conditions, the slope and water depths at the beginning and at the end of the sediment-filled sedimentation basin are determined.
8. An acceptable flushing frequency of the sedimentation basin during the flood period is specified for the given project, on the basis of which the depth of the dead storage chamber of the sedimentation basin is determined.
9. The bottom elevation of the inlet channel is tied to the elevation of the maximum filling of the sedimentation basin dead storage volume. To ensure independence of the calculation of the coarse trash rack from the parameters of the sedimentation chamber, a supporting wall is installed under the rack. The coarse trash rack, like the fine one, is calculated for operation at maximum discharge and under winter conditions, taking into account the normatively permissible clogging. The height of the supporting wall for the coarse trash rack is determined by comparison.

The block diagram of the program for calculating the sedimentation basin is shown in Fig. 1.

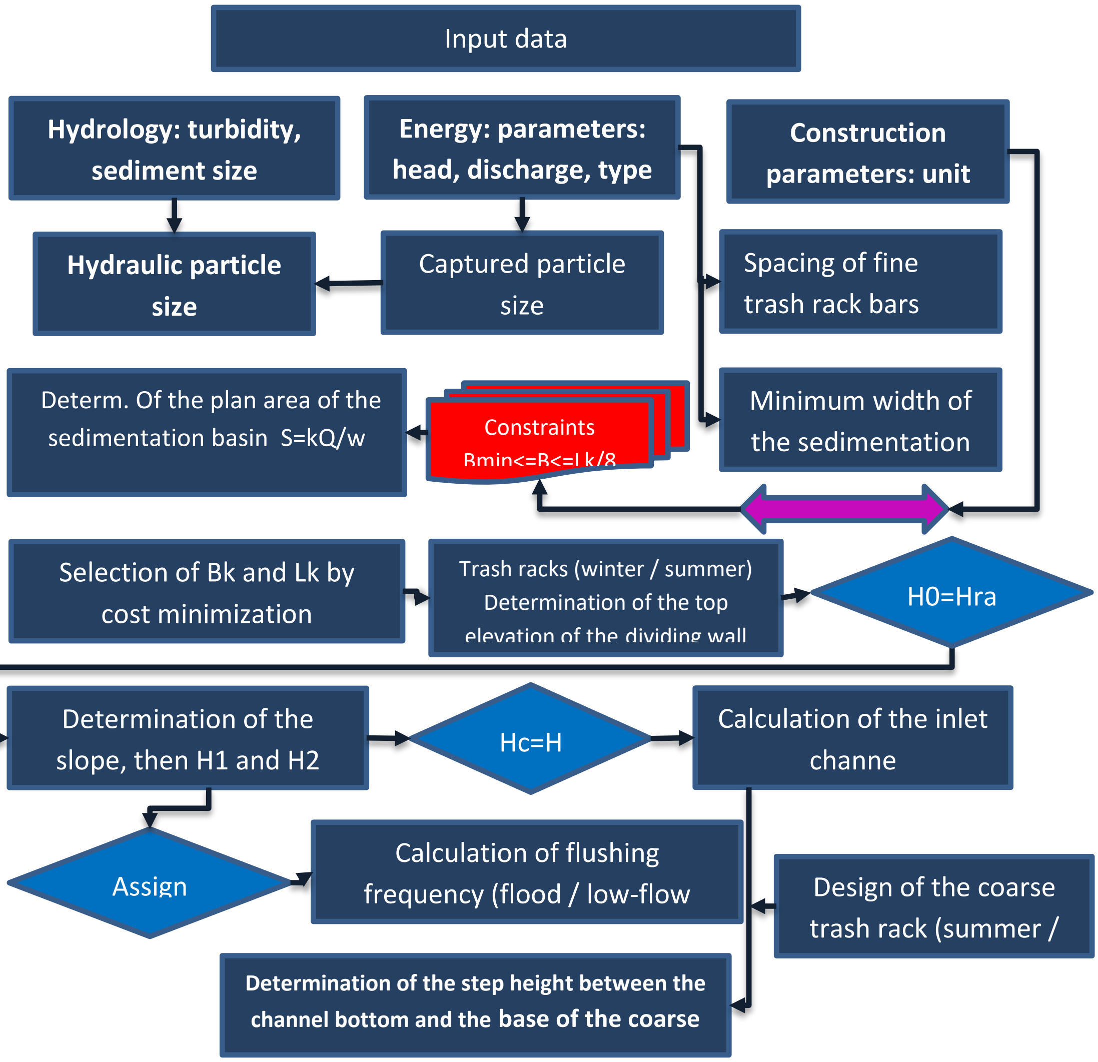

Fig. 1 The block diagram of the program for calculating the sedimentation basin is shown in

On the Methodology for Determining the Hydraulic Particle Size

During the program's development, questions arose about the methodology for selecting the maximum diameter of sediment particles passing through the turbine and determining the hydraulic particle size. Questions also arose regarding the hydraulic particle size determination, due to significant discrepancies in different literature sources. Meanwhile, these factors are key to ensuring the correct operation of the sedimentation basin and protecting the unit from the abrasive impact of sediments (Fig. 2).

Fig. 2 Wear of the Crossflow turbine runner as a result of the ingress of large sediment particles

The maximum permissible particle size allowed to pass through small hydroelectric power plant (SHPP) turbines is determined to prevent abrasive and cavitation-abrasive wear of flow path components, ensure the equipment's estimated service life, and comply with turbine manufacturer warranty conditions.

The intensity of abrasive wear of turbine components can be represented in a generalized form by the following relationship:

$$E \sim C_s \cdot d^n \cdot v^m, \quad (1)$$

where: Cs- is the concentration of solid particles, d is the characteristic particle size, v is the relative velocity of interaction of particles with the surface, n≈1–2 and m≈2–3 are empirical exponents. From this relationship it follows that an increase in particle size has a more significant effect on wear than an increase in their concentration, which necessitates strict limitation of the maximum permissible particle size.

The main factors in selecting the maximum permissible particle size are the turbine type, the design head of the plant, as well as the granulometric composition and mineralogy of the sediments [15–17]. The sensitivity of turbines to the abrasive impact of sediments varies significantly depending on their type.

High-head Pelton turbines are characterized by high jet velocities and the greatest sensitivity to sandy particles. For these turbines d_{max} value in the range of 0.15–0.30 mm is recommended.

Francis turbines have a more complex flow passage at relatively low flow velocities. Permissible values of dmax are on the order of 0.30–0.60 mm. However, for high-head turbines this value may decrease to 0.15 mm.

Crossflow turbines are distinguished by the relative simplicity of the flow passage and the absence of narrow channels, which makes them less sensitive to sediments compared to Francis turbines. For Crossflow turbines, it is recommended to take d_{max} within the range of 0.30–0.80 mm.

Kaplan turbines are low-head turbines and are practically not used in the construction of small hydropower plants in mountainous regions.

However, in practice, the permissible particle diameter is specified by the manufacturer and stipulated in the warranty obligations for the supply of SHPP equipment, and therefore is decisive in the selection of the diameter of particles to be settled. Based on this, drawing on experience in SHPP design in Armenia, Georgia, and Kyrgyzstan, as well as on discussions with leading European manufacturers of units for small hydropower plants, we have compiled an indicative table of permissible particle diameter values for different turbine types at various head ranges (tab. 1).

As can be seen from Table 1, for SHPPs constructed on mountainous rivers, the range of permissible particle sizes is 0.1–0.8 mm, which corresponds to fine and medium sand, for which the process of free sedimentation occurs in the transitional region between laminar and turbulent flow regimes.

In the calculation of sedimentation basins for SHPPs, the main parameter considering for the size of the captured particles is their hydraulic size.

Various methodologies based on different physical assumptions are used to assess the hydraulic particle size of sandy particles. These methodologies can generally be divided into three groups: analytical, semi-empirical, and experimental methods.

The particle size itself is not directly used in hydraulic calculations. The key design parameter is the hydraulic particle size ω(d), which represents the velocity of free sedimentation of a particle in still water. The design value of the maximum permissible particle size dmax is adopted in such a way that the following condition is satisfied:

$$\omega(d_{max}) \geq Vsedm, \qquad (2)$$

where: Vsedm- the characteristic flow velocity in the sedimentation basin. Fulfillment of this condition ensures reliable sedimentation of the hazardous sediment fraction before the water enters the turbine.

Table 1

Maximum permissible particle sizes allowed to pass through turbines

Head, m	Maximum particle size, mm			Name/Country
	Francis	Crossflow	Pelton	
25	0.5	0.8		Bila Tserkva / Ukraine
50	0.4	0.6		Chirukhi, Sanalia / Georgia
100	0.3	0.5		Ishkhanasar / Armenia
150	0.25	0.4		Jyrgalan / Kyrgyzstan
200	0.2	0.3	0.25	Turgen / Kyrgyzstan
300	0.2		0.2	Amberd / Armenia
500	0.2		0.2	Tush Ashu 1,2 / Kyrgyzstan
750	0.1		0.2	Bozuchuk, Dzhergez / Kyrgyzstan
1000			0.2	Informative

Table 2

Hydraulic particle size determined by various calculation methods

d, mm	Hydraulic particle size ω\omegaω, mm/s				
	Stokes	Goncharov	Arkhangelsky	Rubey	Ferguson–Church
0.05	2.2		1.6	2.2	2.1
0.1	9.0	6.63	6.10	8.4	7.5
0.15	20.2	14.90	11.69	16.7	14.9
0.2	35.9	20.42	17.80	25.3	23.2
0.25	56.0	26.02	24.60	33.2	31.8
0.3	80.7	31.62	32.15	40.3	40.4
0.35	109.9		40.4	46.7	48.6
0.4	143.5	42.92	48.40	52.4	56.5
0.45	181.6			57.7	64.0
0.5	224.2	54.02	63.32	62.5	71.1
0.55	271.3			67.0	77.9
0.6	322.8	65.22	79.05	71.2	84.3
0.65	378.9			75.1	90.4
0.7	439.4		93.9	78.9	96.2
0.75	504.4		100.7	82.4	101.8
0.8	573.9		106.9	85.8	107.1

To assess the applicability of the studied methods and to select the most optimal one for the investigated particle size range, calculations were performed using various methodologies and their comparative analysis was carried out. The calculation results are presented in tab. 2 and fig. 3.

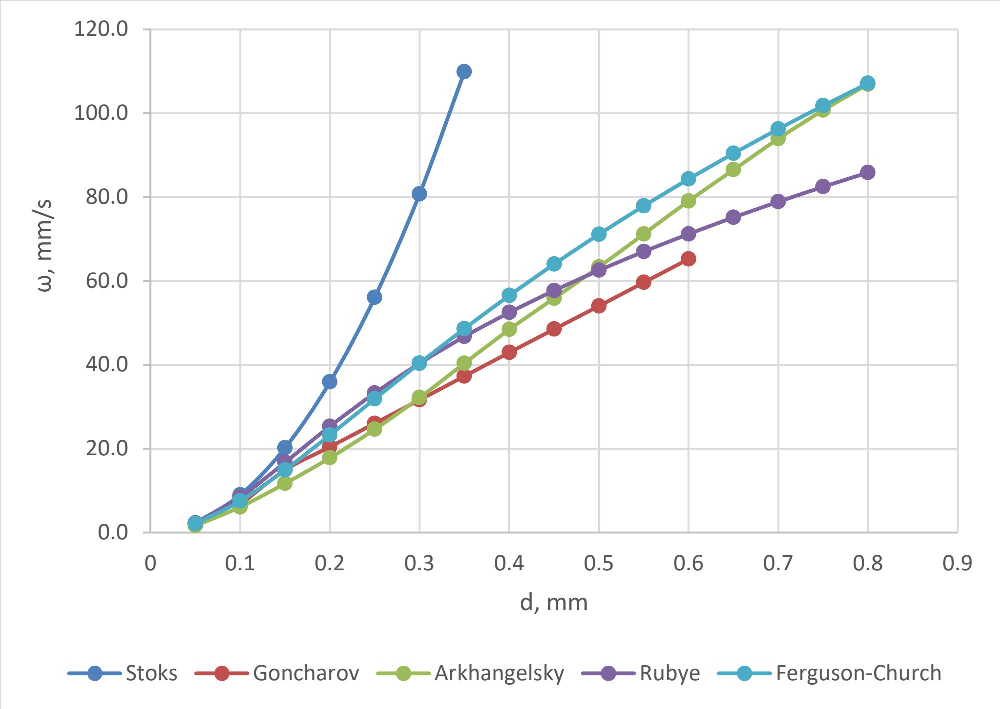

Fig. 3 Graphs of changes in hydraulic size from particle size, calculated using various methods

Stoks's formula [19] is based on a purely analytical solution for laminar flow. The classical Stoks's formula for determining the hydraulic particle size is valid only under laminar sedimentation conditions:

$$Re\_p = \omega \cdot d / \nu < 1, \tag{3}$$

For sandy particles in the size range characteristic of mountainous rivers (Re = 5–200), this condition is not satisfied, which makes the Stoks's formula inapplicable for substantiating dmax and necessitates the use of transitional and universal relationships.

In the works of B.V. Arkhangelsky and V.N. Goncharov [9,11], the hydraulic size is considered as a function determined by particle size, relative density, and water viscosity at different temperatures. As can be seen from Figure 1, calculations using Goncharov's method yield somewhat lower results compared to other calculation methods.

Rubey's formula [12] is widely used in engineering practice due to its simplicity and satisfactory accuracy for sandy particles. As can be seen from the performed calculations, it yields underestimated results for particle sizes above 0.5 mm. The calculation concepts of these methods assume a spherical shape of particles.

The Ferguson–Cherch formula [13] essentially develops the approaches incorporated in the above-mentioned methods and additionally introduces a correction accounting for particle shape and roughness. This formula provides the most physically substantiated description of sedimentation and shows good agreement with experimental data. A number of sources note that calculations using this methodology exhibit the highest agreement with experimental results (<5%).

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Based on the conducted studies, for the calculation of sedimentation basins of small hydropower plants constructed on mountainous rivers, it is recommended to determine the hydraulic particle size using the Ferguson–Cherch method, as the most accurate within the given range of sedimentation particle sizes.

Development of a Methodology for Rapid Assessment of the Construction Cost of Sedimentation Basins in Different Countries

To determine the impact of selecting the main dimensions on the construction cost of sedimentation basins, a series of calculations was carried out for various values of these parameters. The calculations were performed for real facilities designed in Armenia, Kyrgyzstan, Georgia, and Kazakhstan.

To reduce the influence of regional unit costs of materials and works, the following assumptions were adopted:

The construction cost was determined excluding VAT;

In addition to prices, it was decided to compare the volumes of the main types of works involved in the construction of sedimentation basins;

To exclude the influence of terrain configuration on cost, in all projects the terrain relief was conditionally assumed to be 1 m below the top of the sedimentation basin walls.

An analysis of the pricing structure for sedimentation basin construction shows that approximately 75% of the cost of a sedimentation basin is formed by the cost of placed concrete, and 17% by the cost of reinforcement. Consequently, the volume of placed reinforced concrete can be considered representative for assessing the construction cost of a sedimentation basin. To determine this relationship, calculations were performed using the developed program, with unit rates adopted for different countries.

To assess the construction cost of sedimentation basins for small hydropower plants, a linear relationship between the construction cost of the structure and the volume of monolithic reinforced concrete was identified:

$$P = A \cdot Vb + B, \quad (4)$$

where: P is the construction cost, thousand USD; Vb is the volume of monolithic reinforced concrete, m^3;

A is the unit cost proportional to the volume of reinforced concrete; B is a conditionally constant value reflecting costs for auxiliary elements (trash racks, flushing units, local reinforcements, construction organization).

The coefficients A and B depend on the regional price level for monolithic reinforced concrete and construction works.

The coefficients A and B, obtained through calculations performed using unit rates for different countries, are presented in tab. 3.

Further, the concept is based on the hypothesis of proportionality between the construction cost of a sedimentation basin and the unit cost of placed reinforced concrete, where concrete + reinforcement + works + transportation and machinery are integrally taken into account.

Analysis of information obtained from various sources made it possible to index the cost of 1 m³ of placed reinforced concrete for the countries under study (tab. 3).

Table 3

Some parameters for the systematization of sedimentation basin costs by country

Country	A	B	Price of 1m3 reinforsconcrete $	
Kazakhstan	0.35	14.6	150	
Uzbekistan	0.36	14.8	153	.02
Kyrgyzstan	0.39	15.8	165	.1
Georgia	0.48	19.6	202.5	.35
Armenia	0.53	21.5	223.5	.49

To account for regional differences, a relative cost index K is introduced, equal to the ratio of the cost of 1 m³ of monolithic reinforced concrete in the country under consideration to the baseline value (K=1.0) for the country with the lowest unit cost (Kazakhstan).

To obtain a universal cost model, a linear approximation of the coefficients A and B as functions of the index K was performed using the least squares method.

As a result, the following relationships were obtained:

$$A(K) = 0.3645 \cdot K - 0.0125,$$

$$B(K) = 14.32 \cdot K + 0.19, \quad (5)$$

The quality of the approximation was assessed using the coefficient of determination R^2. For the coefficient A(K), a value of R^2 = 0.9997 was obtained, and for the coefficient B(K), R^2 = 0.9991.

Substituting the obtained expressions, A(K) and B(K) into equation (4) and taking into account that the base value is K=150, a universal model for estimating the construction cost of an SHPP sedimentation basin is obtained:

$$P = (2.43C_x - 12.52)V_{bx} + (95{,}45C_x + 193.7), \quad (6)$$

where: C_x и V_{bx} accordingly, the cost of 1 m³ of placed monolithic concrete and the total volume of concrete works for the construction of the sedimentation basin in the country under consideration.

This formula makes it possible to:

estimate the construction cost of a sedimentation basin for a known volume of reinforced concrete;

perform a comparative techno-economic analysis of construction costs in different countries without reference to regional parameters.

Scope of applicability and limitations of the model

The proposed model is valid under the following conditions:

the structural scheme of the sedimentation basin corresponds to typical monolithic solutions and is designed with a constant width along its entire length;

the construction technology is comparable (monolithic reinforced concrete, standard reinforcement and formwork);

the cost of 1 m³ of monolithic reinforced concrete is determined uniformly (including materials, works, and overhead costs);

the technological levels of the countries under study in the field of construction are comparable.

Development of recommendations for optimizing the dimensions of sedimentation basins

In calculation methodologies of sedimentation basins, it is proposed to assign certain parameters of the sedimentation basin based on design experience (for example, Havg [10] or B [11]) and then to determine the remaining parameters of the sedimentation basin. The specified literature does not provide any recommendations for selecting economically optimal dimensions of sedimentation basins; instead, it is only recommended to perform several calculations with different initial parameters in order to select an optimal option.

An attempt was made to systematize the selection of the main parameters of the sedimentation basin in order to minimize its construction cost by generalizing the results of numerous calculations and comparing their outcomes. The calculations were performed using the developed program for comprehensive analysis of sedimentation basin parameters with a constant width.

It has been theoretically substantiated that, for a given discharge and hydraulic size (and, consequently, the size of the captured particles), the plan area of the sedimentation chamber is constant.

A series of calculations performed for various combinations of design discharge, diameter of captured particles, and sedimentation basin width, under identical structural assumptions and with preserved flow velocities (Fig. 4), made it possible to develop recommendations for the optimized selection of the main dimensions of the sedimentation basin.

The volume of concrete placed in the structures of the sedimentation basin as a whole (Vb) can be expressed by a power-law model of the following form:

$$V_b = C \cdot Q^{\alpha} \cdot B^{-n} \cdot d^{-m}, \qquad (7)$$

where: Vb -is the volume of concrete of the sedimentation basin, m³; Q is the design discharge, m³/s; B- is the basin width, m; d- is the size of the captured particles, mm.

By means of regression analysis, the coefficients of the equation were obtained. Thus, under the adopted approach to the structural design of the sedimentation basin, equation (7) can be written in the following form:

$$V_b = C \cdot Q^{1.01} \cdot B^{-0.74} \cdot d^{-1.06}\ , \qquad (7a)$$

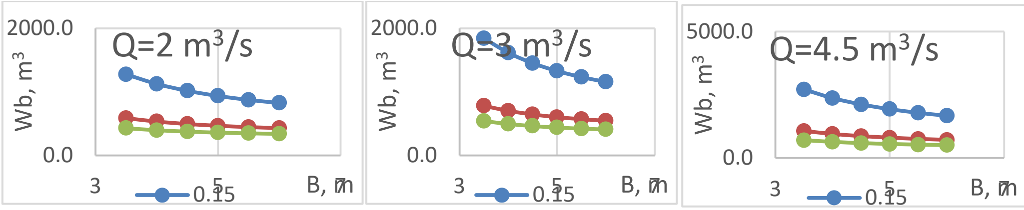

Fig. 4 Dependence of the volume of sedimentation basin concrete on the sedimentation basin width, the diameter of retained particles, at various design discharges

Analysis and physical interpretation of the obtained coefficients make it possible to draw the following **conclusions:**

The proximity of the α coefficient to 1 indicates that the volume of concrete placed in the sedimentation basin is practically linearly proportional to the design discharge of the SHPP. This is also theoretically confirmed by the linear dependence of the plan area of the sedimentation basin on the design discharge.

An increase in the width of the sedimentation basin has an effective influence on reducing the volume of placed concrete. However, it should be taken into account that excessive widening of the sedimentation basin may lead to a violation of flow linearity and a violation of the hydraulic laws adopted as the basis for the calculations. Based on this, it is considered necessary to adhere to the ratio L/B≈8, as recommended in a number of fundamental sources [1,6,10].

The influence of particle size increases sharply as the size of the captured particles decreases.

The obtained relationship is characterized by a coefficient of determination R2=0.98.

Limitations. The calculations were performed for a conditional object, and the task was set to minimize the influence of secondary factors on the comparability of the calculated options. Therefore, the construction site for the sedimentation basin was assumed to be horizontal, at the level of the full depth of the sedimentation basin. Within the considered range of parameters, the optimum is achieved at the upper boundary of the permissible width values.

In real calculations, the transverse slope of the bank where the sedimentation basin is planned to be constructed should be taken into account. This factor can lead to a significant increase in cost due to an increase in earthwork volumes. In the presence of additional constraints (relief, bank protection, site conditions), the optimum may shift inward within the range. Optimization of the L/BL/BL/B ratio in such cases is possible through direct calculation using the “Optimum Sedimentation Basin” program, with the input of the terrain relief into the program in the form of longitudinal and transverse terrain cross-sections.

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ՓՈՔՐ ՀԻԴՐՈԷԼԵԿՏՐԱԿԱՅԱՆՆԵՐՈՒՄ ՊԱՐԶԱՐԱՆՆԵՐԻ ՀԱՇՎԱՐԿԻ ԵՎ ՕՊՏԻՄԱԼԱՑՄԱՆ ԱԼԳՈՐԻԹՄԸ

Ս.Գ.Գաբայան
Ակադեմիկոս Ի.Վ. Եղիազարովի անվան ջրային հիմնահարցերի և հիդրոտեխնիկայի ինստիտուտ

Հոդվածում ուսումնասիրվում են լեռնային հոսանքների վրա գործող փոքր հիդրոէլեկտրակայանների (ՓՀԷԿ) պարզարանների երկրաչափական և ծախսային պարամետրերի օպտիմալացման խնդիրները: Ցույց է տրվում, որ փոփոխական նստվածքային խցիկի երկրաչափությամբ լայնորեն կիրառվող նախագծային լուծումները հաճախ պայմանավորված են բոլոր կառուցվածքային տարրերի համակարգված հաշվարկման համար համապարփակ մեթոդաբանության բացակայությամբ և միշտ չէ, որ տնտեսապես օպտիմալ են:

S.G.Gabayan

ALGORITHM FOR CALCULATION AND OPTIMIZATION OF SEDIMENTATION BASIN STRUCTURES FOR SMALL HYDROPOWER PLANTS

Առաջարկվում է ՓՀԷԿ-երի պարզարանների նախագծման համակարգային մոտեցում, որը հիմնված է հոսքի արագության պահպանման և խցիկի լայնության հաստատուն մնալու վրա:

Հոդվածում հիմնավորվում է առավելագույն թույլատրելի մասնիկի չափի ընտրությունը: Ներկայացվում է լեռնային գետերին բնորոշ մասնիկների չափերի համար նստվածքային արագության հաշվարկման տարբեր մեթոդների (Սթոքս, Գոնչարով, Արխանգելսկի, Ռուբի, Ֆերգյուսոն-Չըրչ) համեմատական վերլուծություն:

Ուսումնասիրության արդյունքները կարող են օգտագործվել փոքր հիդրոէլեկտրակայանների նախագծման գործընթացում:

Բանալի բառեր. պարզարան, ջրաբերուկ, տուրբինի տեսակ, հիդրավլիկական խոշորություն, երկրաչափական օպտիմալացում, կախված պինդ մասնիկների նստեցում, շինարարության արժեք, տեխնիկական և տնտեսական օպտիմալացում.

АЛГОРИТМ РАСЧЕТА И ОПТИМИЗАЦИЯ КОНСТРУКЦИЙ ОТСТОЙНИКОВ МАЛЫХ ГЭС

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В статье рассмотрены вопросы оптимизации геометрических и стоимостных параметров отстойников малых гидроэлектростанций (МГЭС), эксплуатируемых на горных водотоках. Показано, что широко применяемые проектные решения с переменной геометрией отстойных камер зачастую обусловлены отсутствием комплексной методики согласованного расчёта всех элементов сооружения и не всегда являются экономически оптимальными.

Предложен системный подход к проектированию отстойников МГЭС, основанный на сохранении расчётных скоростей потока и использовании постоянной ширины камеры.

В статье обосновывается выбор максимально допустимого размера частиц на основе физических принципов абразивной эрозии и концепции гидравлической скорости осаждения. Проведен сравнительный анализ различных методов расчета гидравлической скорости осаждения (Стокса, Гончарова, Архангельского, Руби, Фергюсона-Черча) для размеров частиц, характерных для горных рек.

На основе обобщения результатов расчётов для различных значений расхода, ширины камеры и размеров улавливаемых частиц получена параметрическая модель объёма монолитного железобетона отстойника в виде степенной функции от основных определяющих факторов. Для оценки капитальных затрат разработана укрупнённая стоимостная модель, связывающая стоимость строительства отстойника с объёмом железобетона и региональным индексом стоимости 1 м^3 монолитного железобетона.

Результаты работы могут быть использованы при проектировании и технико-экономическом обосновании отстойников МГЭС, а также при разработке унифицированных методик оптимального выбора их геометрических параметров с учётом гидравлических и экономических факторов.

***Ключевые слова*: отстойники МГЭС, наносы, тип турбин, гидравлическая крупность, геометрическая оптимизация, осаждение взвешенных частиц, стоимость строительства, технико-экономическая оптимизация.

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