METHOD FOR CALCULATING THE METAL RACK STRUCTURES OF DEBRIS-TRAPPING HYDRAULIC STRUCTURES

Shoniyozov Shahzod Abdusamat o‘g‘li, Independent Researcher
shoniyozovsh1995@gmail.com
https://orcid.org/0009-0001-1741-1119
Institute of Irrigation and Water Problems

Аннотация. Мақолада чиқиндиларни тутиб қолувчи панжарали металл конструкцияли гидротехника иншоотини чегаравий ҳолатларнинг I ва II гуруҳлари бўйича ҳисоблаш услуби кўриб чиқилган. Конструкцияга таъсир этувчи доимий юкламалар аниқланиб, балка элементларининг мустаҳкамлик ва эгилиш шартлари асосланган.

Калит сўзлар: чиқиндиларни тутиб қолувчи иншоот, панжарали металл конструкция, чегаравий ҳолатлар усули, меъёрий қаршилик, ҳисобий қаршилик, доимий юклама, эгувчи момент, балка мустаҳкамлиги, эгилиш.

Аннотация. В статье рассмотрена методика расчёта решётчатого металлического сороудерживающего гидротехнического сооружения по I и II группам предельных состояний. Определены постоянные нагрузки, действующие на конструкцию, и обоснованы условия прочности и прогиба балочных элементов.

Ключевые слова: сороудерживающее сооружение, решётчатая металлическая конструкция, метод предельных состояний, нормативное сопротивление, расчётное сопротивление, постоянная нагрузка, изгибающий момент, прочность балки, прогиб.

Abstract. The article considers a method for calculating a debris-retaining hydraulic structure made of a steel trash rack according to the first and second groups of limit states. The permanent loads acting on the structure are determined, and the

strength and deflection conditions of the beam elements are substantiated.

Keywords: debris-retaining structure, steel trash rack, limit state method, characteristic resistance, design resistance, permanent load, bending moment, beam strength, deflection.

Introduction. In the water management system of the Republic, structures of various configurations are used to trap debris carried by water flow in main and inter-farm irrigation canals, thereby ensuring the safe and reliable operation of hydraulic structures. In particular, assessing the resistance of rack-type hydraulic structures to dynamic loads and improving the methods for calculating hydrodynamic and deformation processes arising from their interaction with water flow are important scientific and practical tasks.

Main Part. Stages of Calculating Metal Structures. The method for calculating the deformation parameters of metal structures involves determining the shape, overall dimensions, cross-sections, and dimensions of connecting elements of the metal structure to ensure its reliability, safety, service life, and efficiency.

The calculation of metal structures consists of the following stages:

Developing the calculation scheme;

Calculating the loads;

Calculating the stress values in the metal structural elements;

Selecting the cross-sections of structural elements according to the applied loads;

Testing the selected cross-sections.

The first three stages mentioned above constitute the static analysis of the metal structure, while the remaining two stages constitute the structural design process.

Currently, the structural design of metal hydraulic structures is carried out using the scientifically well-established Limit State Method.

Limit State Method. The limit state of a metal structure is defined as a condition in which the structure fails to meet the design requirements and criteria

imposed on it during operation. The limit states of metal structures are conventionally divided into two groups:

First Group (Group I): During operation, the metal structure reaches a certain limit state in which it becomes completely unfit for use. In other words, both functional and structural failures occur in the metal structure, rendering it entirely unserviceable.

Therefore, when calculating the deformation parameters of any metal hydraulic structure, the load-bearing capacity of the structure corresponding to the first limit state group must be assessed first.

In the calculations, the probable stresses acting on the structural elements must not exceed the minimum load-bearing capacity of those elements:

where: N – is the maximum stress, depending on the design scheme and applied load; Φ – is the minimum load-bearing capacity, depending on the material type and the geometric parameters of the cross-section.

Second Group (Group II): The limit state in which a metal structure becomes unfit for use during operation due to wear and other factors. When calculating the limit state of a metal structure according to Group II, only the deformation parameters of the structural elements under bending are considered.

When calculations are performed using the methods of this group, deformation is calculated based on standard loads. That is, in these calculations, the actual deformation values must not exceed the permissible values:

Where: f – is the actual deformation parameter; f_u – is the standard value specified in regulatory documents.

Strength Characteristics. The main strength characteristic of a metal structure is its design resistance. When calculating the deformation parameters of metal structural elements under compression, tension, and bending, two values of the design resistance are taken into account:

Design resistance based on the yield strength R_y,

Design resistance based on the ultimate strength over time, or R_u.

The values of the above-mentioned quantities are determined through statistical analysis of laboratory test results obtained from material specimens.

However, in practice, the test results for laboratory specimens of many metal structural elements used in engineering may sometimes differ from the properties of actual structural elements. Therefore, in such cases, deformation parameters are calculated using the design resistance method. The design resistance method can also be applied in two forms:

Design resistance based on the yield strength R_yd;

Design resistance based on the ultimate strength R_ud.

Design resistances are determined by dividing the characteristic resistance value by the material reliability factor:

$$R_y = \frac{R_{yn}}{\gamma_m} \text{Ba} R_u = \frac{R_{un}}{\gamma_m}$$

Where: γ_m – is the material reliability factor.

Calculation of Permanent Loads Acting on a Hydraulic Structure with a Metal Structure. The permanent loads acting on hydraulic structures with metal structures in canals (debris-trapping structures) are mainly the self-weight of the structure and the hydrostatic pressure forces of the water flow.

Since the elements of the debris-trapping structure in canals that are exposed to the water flow mainly consist of a mesh-like reinforcement frame (with a spacing of 50 cm), the hydrostatic pressure forces exerted by the water flow are neglected.

In this case, only the weight of the metal structure is taken into account in the calculations and is determined using the following expression:

Where: δ_i – is the layer thickness.

The design value of the structure's weight is determined using the following

expression:

Where: γ_f – is the load reliability factor.

Next, we perform the deformation calculation for the load acting on the beam of the metal structure. Two internal forces mainly arise in the beam: the shear force and the bending moment. Therefore, selecting the cross-sectional parameters of beams is of great importance. The strength of the beam is determined by the following condition:

In some cases, it is expressed by the following deflection limit condition:

$$f = \frac{kM^n l^2}{EI_x} \leq f_u$$

Conclusion. When calculating the rack-type metal structures of debris-trapping hydraulic structures, the calculation method based on the limit state method makes it possible to substantiate the reliability and safety of the structure. This method consists of static analysis and structural design stages. Under Group I, the load-bearing capacity of the structure is assessed, while under Group II, the deflection of the beam elements is checked. Since the part of the structure exposed to the water flow consists of a mesh-like frame, the self-weight of the structure is taken as the main permanent load in the calculations. The presented strength and deflection conditions serve as the basis for selecting the cross-sections of the beam elements of the structure.

References:

1. Abramowitz, M., and Stegun, I. *Handbook of Special Functions*. Moscow: Nauka, 1999.
2. Altshul, A. D., and Kiselev, P. G. *Hydraulics and Aerodynamics: A Textbook for Higher Education Institutions*. Moscow: Stroyizdat, 1975. 323 p.
3. Gurevich, M. I. *Theory of Ideal Fluid Jets*. Moscow, 2009. 536 p.
4. Idelchik, I. E. *Handbook of Hydraulic Resistance*. Edited by K. T. M. Steinberg. Moscow: Mashinostroenie, 1992. 672 p.

5. Koff, N. E., Klebel, I. A., and Roze, I. V. *Theoretical Hydromechanics*. Moscow, 2003. 727 p.
6. Lavrentiev, M. A., and Shabat, B. V. *Problems of Hydrodynamics and Their Mathematical Models*. Moscow–Izhevsk: Research Center "Regular and Chaotic Dynamics," 2003. 416 p.
7. Ovsyannikov, L. V. "Lagrangian Approximations in Wave Theory." In *Nonlinear Problems in the Theory of Surface and Internal Waves*. Novosibirsk: Nauka, 2015, pp. 10–77.
8. Shoniyozov, Sh. A., Kazakov, E. A., Ro'ziev, M. O., and Ulugbekov, B. B. "Methods for Calculating the Resistance Coefficient of Grilles and Mesh Structures in Hydraulic Engineering Structures and Their Analysis." *European Journal of Interdisciplinary Research and Development*, vol. 39, May 2025. ISSN (E): 2720-5746.
9. Shoniyozov, Sh. A., and Alisherov, I. B. "Main Hydraulic Parameters of the Canal and Their Analysis." *European Journal of Interdisciplinary Research and Development*, vol. 45, November 2025. ISSN (E): 2720-5746.