TRANSPORT AND MOBILITY

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Bik I., Degtyareva V. Assessment of the possibility of using the dam roadbed as a highway

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Abstract. *The possibilities of using the earthwork of the dam as a highway are considered. The permissible loads on the earthen structure have been determined. Restrictions have been introduced for the operation of a certain type of motor transport.*
Keywords: *mobile load, slop stability, margin coefficient*

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1. Introduction

When using dams as a road, it is necessary to ensure the required level of reliability in terms of strength, stability and deformability of the roadbed under the influence of established external and internal loads in accordance with [1].

According to [2], the impact of transport load on strength and stability is taken into account:

- in the form of an additional static load on the surface of the roadbed;
- additional dynamic impact arising, spreading and attenuating in the soils of the roadbed and its base, leading to a decrease in the calculated values of the strength and deformation properties of the soils.

Static normative and design characteristics of soils when assessing the reliability of the embankment are determined in accordance with the characteristics of the soils that make up the embankment body of the dam [3, 4].

When taking into account the dynamic impacts from vehicles in calculations of the strength, stability and deformability of the roadbed of a dam, on the crest of which a road is organized, standard loads and design loading schemes should be specified in accordance with [5, 6].

The article discusses the calculation method of the permissible load on the earthwork of the dam [7-9] using the example of the right-bank dam of the approach channel of the Novosibirsk lock. The technological passage of vehicles is located on the crest of the right-bank dam of the lower approach channel of the Novosibirsk lock. The schematic general plan of the lock is shown in Fig. 1.

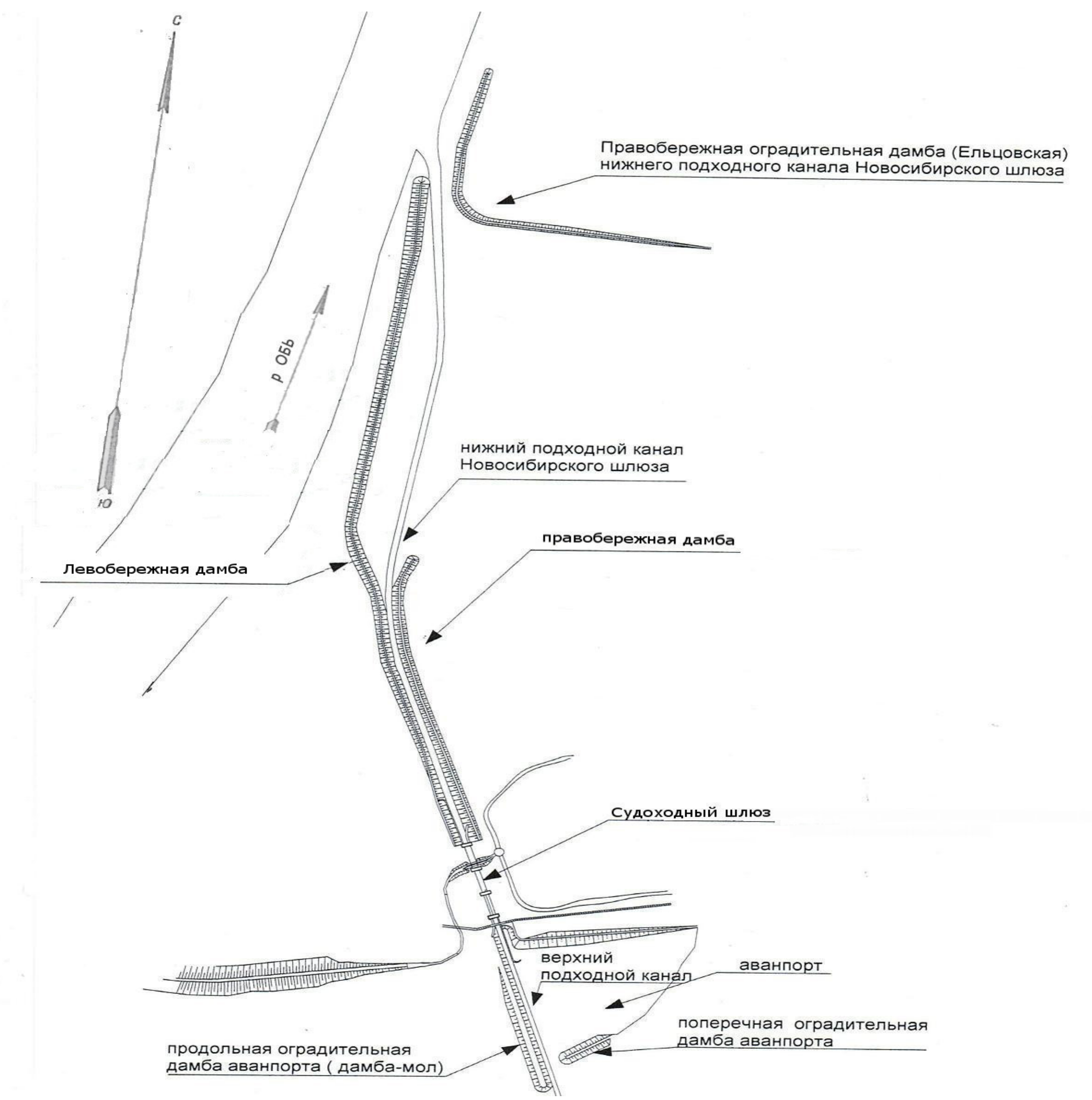

Figure 1. Schematic general plan of the hydroelectric power station

2. Materials and methods

One of the main factors influencing the stability of a soil structure is the hydrological conditions of the soil. The soil deposits of the dam in question are represented by sands of varying sizes, sandy loams, loams and clays. The thickness of the listed sediments is not maintained in depth and in plan, the soils often pinch out and replace each other. In the swampy area (the area of the oxbow lake), swamp deposits in the form of highly decomposed brown peat are widespread. The bulk soils of heterogeneous composition are a mixture of gravelly sand, pebbles, sandy loam, loam and construction waste.

The water-bearing rocks are silty sands, fine to medium-sized sands, and less often sandy loams; at the base of the deposits lie gravelly sands, gravel and pebble soils.

Depending on the surface elevations and the slope of the groundwater flow, the depth of groundwater varies from 2.9 to 9.0 meters.

The calculation of the stability of the slope of the embankment of the dam at the Novosibirsk lock, taking into account the dynamic impact of vehicles, was carried out taking into account the possible displacement of part of the slope as a result of a cut along the critical surface, which takes the form of a circular cylindrical with some rotation around the horizontal axis [2, 10] (Fig. 2).

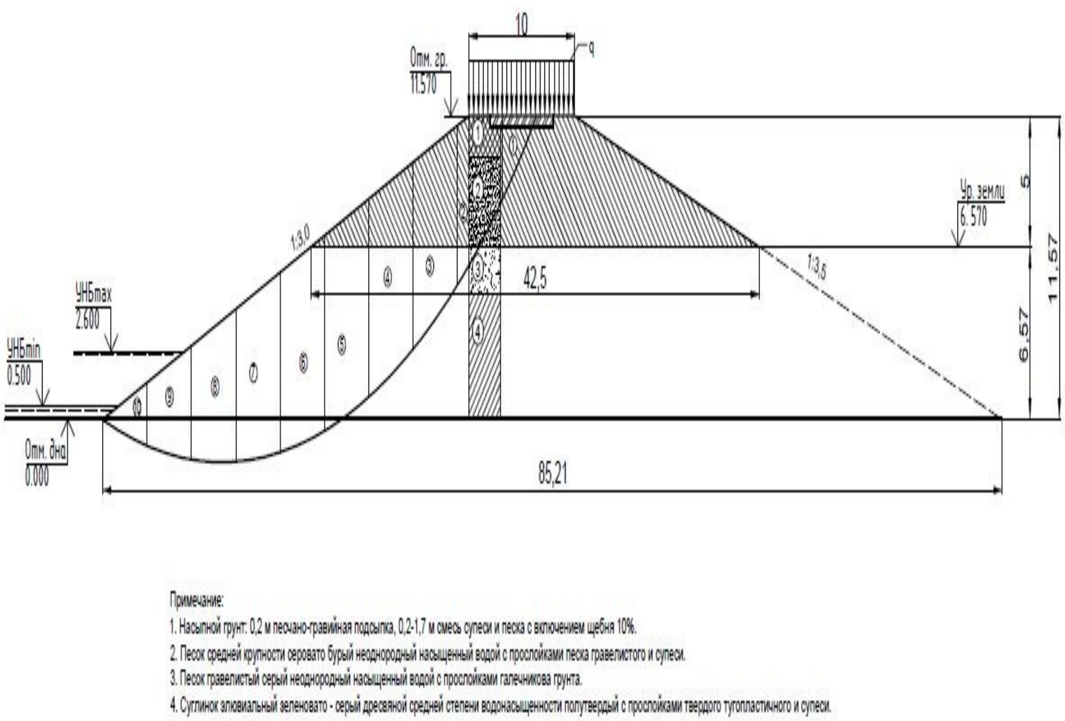

Figure 2. Calculation scheme of the dam embankment

The calculations were performed for the conditions of a flat problem, i.e. for a slope element with a length (along the route) of 1.0 m. The width of the dam is 10 meters, the height is 11.57 meters, the slope angle from the NPK side is 1:3. Medium-sized sand with a density of $\rho_г$ =2.03 t/ m^3 with an angle of internal friction of 35 ^{0} (blocks 1-2), with an angle of internal friction of 25 ^{0} (blocks 3-4); loam with a density of $\rho_г$ =1.9 t/ m^3 with an internal friction angle of 20 ^{0} (blocks 5-10) and specific adhesion c =0.1 t/ m^2 .

When calculating the stability of the dam's embankment slopes, the forces arising in it from the soil's own weight, taking into account the water level in the NPK and from the impact of a temporary moving load of intensity q (Fig. 2), were taken into account.

The calculation of the standard load with intensity q from motor vehicles on public roads was performed on the basis of GOST [6]. The schemes for determining the design loads are presented in Fig. 3, 4.

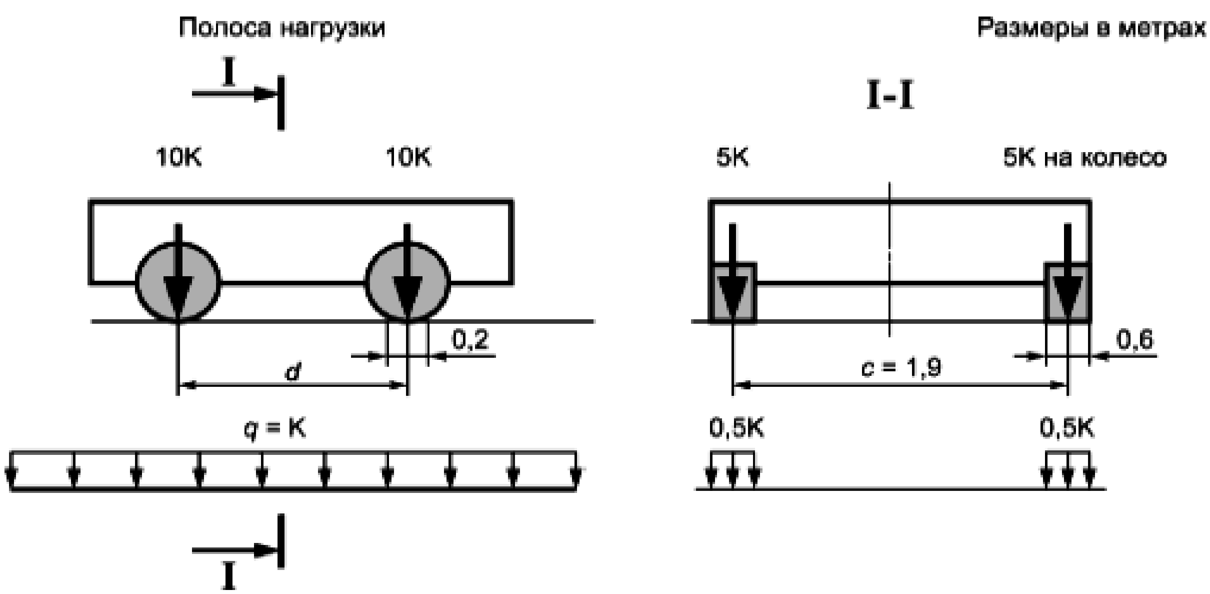

Figure 3. Scheme of standard load of the AC from motor transport

Load diagram (AK) corresponds to the load from passenger cars, diagram b) (NK) is recommended for vehicles carrying heavy loads (freight transport) [6].

The standard load AK (Fig. 3) includes one two-axle bogie with an axle load of 10K (kN), and a load q with an intensity of K (kN/m) uniformly distributed along the road. Load class K is taken in calculations to be equal to 10 (for highways with lightweight and transitional road surfaces [6]). The base of the load trolley AK (d) in calculations for highways is taken to be equal to 2.5 m.

We reduce the load from the AK trolley to an equivalent uniformly distributed load [6] with an intensity of q_{AK} (kPa):

$$q_{AK} = \frac{7{,}4n}{B_{зп}} K = \frac{7{,}4*2*10}{10} = 14{,}8кПа \cong 1{,}5т/м^2,$$

where $B_{зп}$ =10 – width of the roadbed at the top;

n =2 - number of traffic lanes;

K =10 - load class for roads with light and transitional type road surfaces.

The standard load of the NK (Fig. 4) is presented in the form of a single four-axle bogie with an axle load of 18K (kN). The load class is taken as $K = 8.3$ (for highways of all categories [5]).

The moving load of intensity q from freight transport on the surface of the roadbed is determined by the formula [5]:

$$q_{НК} = \frac{4*18K}{(D+0{,}2)(c+0{,}8)} = \frac{4*18*8{,}3}{3{,}8*3{,}5} = 45kH/м^2 = 4{,}5\,т/м^2,$$

where D=3.6 is the NK load base (m);

c=2.7 – track width of the load (m).

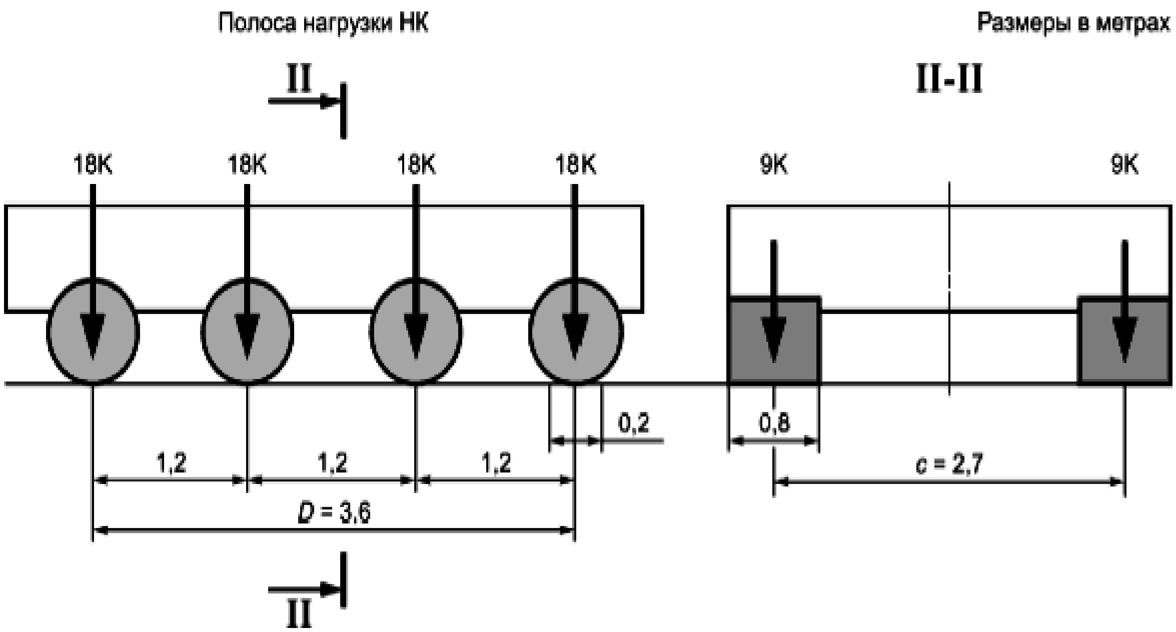

Figure 4. Scheme of standard load of the NK from motor transport

To assess the stability of the slopes of the roadbed, assuming that the violation of its stability can occur in the form of a collapse with shear and rotation, the method of circular cylindrical sliding surfaces in the modification of K. Terzaghi is used (Fig. 2).

The degree of stability of the slope of the roadbed is assessed by the value of the coefficient of safety of stability, determined by the ratio of the moment of the retaining forces $M_{уд}$ to the moment of the shear forces $M_{сдв}$, relative to the center of the most dangerous sliding arc

$$K = \frac{M_{уд}}{M_{сдв}}.$$

To determine the safety factor, the selected sliding soil massif, limited by the sliding curve, is divided by vertical sections into 10 blocks (Fig. 2). The width of the blocks is taken to be 4 meters.

The dynamic impact of vehicles is taken into account by introducing a distributed load on the dam crest with intensity q, determined by the first formula above for passenger cars and by the second formula for trucks [5].

Based on the obtained calculation scheme, the reaction of the soil on the sliding surface is determined for each selected block, consisting of the friction force $N_i * tg\phi_i$ directly proportional to the normal pressure, and the adhesion force $C_i l_i$, where ϕ_i is the calculated value of the angle of internal friction of the soil in the block under dynamic action; is the calculated value of the specific adhesion of the soil in the block; l_i is the length of the segment of the sliding arc within the block; $N_i = Q_i * \cos\alpha_i$ is the normal component of the weight of the block; α_i is the angle of inclination of the sliding surface of the block to the horizon.

The shear force was determined using the dependence $T_i = Q_i * \sin\alpha_i$.

3. Results and Discussion

The calculation results are presented in Tables 1, 2 and 3.

Table 1

Calculation of stability characteristics of soil blocks
in the absence of motor vehicles on the crest of the dam

Block ordinal number	Q_i	$T_i = Q_i * \sin\alpha_i$	$N_i = Q_i * \cos\alpha_i$	$N_i * tg\phi_i$	$C_i l_i$
1	10 ,4	6.7	8.1	5.6	0
2	35.7	20.4	29.3	20.5	0
3	47.5	23.7	41.3	19.2	0
4	53.2	20.8	48.9	22.8	0.4

Block ordinal number	Q i	$T_i = Q_i * \sin\alpha_i$	$N_i = Q_i * \cos\alpha_i$	$N_i * tg\phi_i$	$C_i l_i$
5	28.0	8.7	26.6	9.6	0.4
6	25.1	6.5	24.3	8.7	0.4
7	24.2	3.8	23.8	8.6	0.4
8	19.2	0.6	19.2	6.9	0.4
9	14.0	0.4	14.0	5.0	0.4
10	9.1	1.4	8.9	3.2	0.6
total		93, 0		110.1	3.0

Table 2

Calculation of stability characteristics of soil blocks at standard load of the AK on the dam crest (passenger vehicles)

Block ordinal number	Q i	$T_i = Q_i * \sin\alpha_i$	$N_i = Q_i * \cos\alpha_i$	$N_i * tg\phi_i$	$C_i l_i$
1	16.5	10.5	12.7	8.9	0
2	40.22	22.7	33.0	23.1	0
3	47.5	23.7	41.3	19.2	0
4	53.2	20.8	48.9	22.8	0.4
5	28.0	8.7	26.6	9.6	0.4
6	25.1	6.5	24.3	8.7	0.4
7	24.2	3.8	23.8	8.6	0.4
8	19.2	0.6	19.2	6.9	0.4
9	14.0	0.4	14.0	5.0	0.4
10	9.1	1.4	8.9	3.2	0.6
total		99.1		116.0	3.0

Table 3

Calculation of stability characteristics of soil blocks at standard load H K on the dam crest (trucks)

Block ordinal number	Q i	$T_i = Q_i * \sin\alpha_i$	$N_i = Q_i * \cos\alpha_i$	$N_i * tg\phi_i$	$C_i l_i$
1	28.4	18.3	27.9	15.3	0
2	49.2	28.1	40.3	28.2	0
3	47.5	23.7	41.3	19.2	0
4	53.2	20.8	48.9	22.8	0.4
5	28.0	8.7	26.6	9.6	0.4
6	25.1	6.5	24.3	8.7	0.4
7	24.2	3.8	23.8	8.6	0.4
8	19.2	0.6	19.2	6.9	0.4
9	14.0	0.4	14.0	5.0	0.4
10	9.1	1.4	8.9	3.2	0.6
total		112.3		127.5	3.0

Based on the calculations carried out, the coefficient of safety of the slope of the roadbed for the adopted sliding surface was determined:

$$K = \frac{\sum (N_i * tg\phi_i + C_i l_i)}{\sum T_i}.$$

According to the data in Tables 1-3, the stability coefficients of the embankment slope are found for the considered operating conditions of the dam:

- in the absence of motor vehicles on the crest of the dam

$$K = \frac{110{,}1 + 3{,}0}{93{,}0} = 1{,}22;$$

- in case of presence of passenger vehicles on the crest of the dam

$$K = \frac{116{,}0 + 3{,}0}{99{,}1} = 1{,}2;$$

- in case of presence of freight transport on the crest of the dam

$$K = \frac{127{,}5 + 3{,}0}{112{,}3} = 1{,}16.$$

Considering that for roads of the second category, according to GOST, the standard slope stability coefficient is K_H = 1.2 , we conclude that the movement of freight transport (K = 1.16 < 1.2 = K_H) along the dam crest is unacceptable. The movement of passenger vehicles complies with the standard loads.

Consequently, the movement of heavy-duty vehicles (with an axle load of more than 3 tons) along the right-bank dam of the lower approach channel of the Novosibirsk lock, in order to ensure the strength and stability of the slope of the hydraulic structure and prevent deformation of the roadbed , must be prohibited.

References

1. GOST 27751-2014 «Reliability of building structures and foundations. Basic Provision», Intro . 2015-07-01, M. , 2015, 14 p.
2. ODM 218.2.068-2016 «Recommendations for taking into account the dynamic impact of modern vehicles when calculating the strength, stability and deformability of the roadbed», Introduced on 27.04, 2016, M.,2016, 51p.
3. Declaration of Safety of the Novosibirsk Gateway NRGS., 2023, 115 p.
4. Research report «Survey of the Novosibirsk gateway», Novosibirsk: SЫГЦЕ, 2022, 68 p.

5. GOST R 52748-2007 «Public roads. Standard loads, design loading schemes and approach dimensions», Introduced, 2008-01-01, M., 2008, 17 p.

6. GOST 32960-2014 «Public roads. Standard loads, design loading schemes», Introduced, 2015-07-01, M., 2015, 7 p.

7. Bik, I., Degtyareva, V. (2020) «Assessment of the stability of coastal slopes during river meandering», Siberian Scientific Bulletin, XXIV , pp. 54-56.

8. Bik, I., Degtyareva, V. (2023) « Assessment of bank stability at the Novo - Loginovsky bend of the Irtysh River», Scientific problems of Siberia and the Far East, No.2, pp. 73-76.

9. Bik, I. (2018) «Experimental studies of the stress-strain state of hydraulic structures», Novosibirsk: SSUWT, 105 p.

10. ODN 218.046-01 «Design of flexible road surfaces», Introduced 2001 01-01. M, 2001, 143 p. Date of update: 2021-01-01.