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ANTI-ICING DRAINAGE PROTECTION FACILITY

Background. In design and construction practice, we often have to deal with complete and incomplete drainage. Complete horizontal drainages are arranged in single-layer beds or water-bearing beds of small thickness if confining bed is buried at a depth of no more than 8-10 m. In single-layer beds of large thickness, as well as in two-layer beds drainage is incomplete. In the latter case drain cuts across the upper layer (usually low-permeable) and uncover the lower layer.
Results and conclusions. The technique of selection of design parameters of a drainage facility in the context of the general problem of icing control at the stage of its formation is considered. The design of anti-icing drainage protection facility is presented, the principle of its operation is described.

Keywords: drainage, protection against icing**,** water drainage.

Introduction

Impounded areas are characterized by two-layer structure of water-bearing bed, whose lower layer is more permeable than upper layer. Free surface of ground waters is usually located within the upper layer, whose thickness is rather small.

In deciding on a drainage type, the horizontal drainage should be preferred as it is the most suitable and economic method.

In design and construction practice, we often have to deal with complete and incomplete drainage. Complete horizontal drainages are arranged in single-layer beds or water-bearing beds of small thickness if confining bed is buried at a depth of no more than 8—10 m. In single-layer beds of large thickness, as well as in two-layer beds drainage is incomplete. In the latter case drain cuts across the upper layer (usually low-permeable) and uncover the lower layer.

Hydrogeology calculation of drainage systems considers the structure of water-bearing horizons and characteristics of their boundaries, conditions of the natural and anthropogenic (additional) feeding and drainage of ground waters, as well as degree of hydrodynamic incompleteness of drainage facilities. A special attention is paid to the additional infiltration feeding of ground waters. Rate of such feeding ω is rather high and reaches 10^{-2} m/day in the particular sites. On average, it ranges within $5{\cdot}10^{-3}$—$5{\cdot}10^{-4}$ m/day, significantly increasing during the period of spring snowmelt.

In the majority of cases the horizontal drainage is free-flow; constant water level is maintained in drains during operation, therefore, design dependencies must satisfy these conditions.

As infiltration feeding enters from above, filtration becomes stationary, and draining effect spreads to some distance l_ω, which is referred to as a drainage distance. The drainage distance depends on feeding intensity ω, filtration properties of rocks and decreasing water level in drains. A nonstationary filtration phase lasts no longer than

$$t = u \cdot l_\omega^2 / (2 \cdot k \cdot h_c)\,. \tag{1}$$

The hydrodynamic scheme of the complete single-line drainage in the single-layer water-bearing bed is shown in Fig. 1a; the hydrodynamic scheme of the incomplete drainage in the two-layer bed is shown in Fig. 1b.

In the general case of water-bearing bed with anisotropy of filtration properties, in conditions of established filtration and additional infiltration feeding arrival from above, the construction of depression surface and complete water inflow to the unit of length was performed using following dependencies:

$$h = h_e - (h_e - h_{\text{др}}) \cdot (1 - \bar{x}) + \frac{4 \cdot \omega \cdot l_\omega}{\pi^2 \cdot k_{\text{пр}}} \Theta_{10}\left(\frac{\bar{x}}{\gamma}, \frac{\bar{h}_0}{\gamma}\right); \tag{2}$$

$$q = 2 \cdot \omega \cdot l_\omega; \tag{3}$$

$$\Theta_{10}\left(\frac{\bar{x}}{\gamma}, \frac{\bar{h}_c}{\gamma}\right) = \sum_{n=1}^{n=oo} \frac{\sin \frac{2 \cdot n - 1}{\gamma} \pi \cdot \bar{x}}{(2n-1)^2 \cdot th \frac{2n-1}{\gamma} \cdot \pi \cdot \bar{h}_c}; \tag{4}$$

$$\bar{h}_c = \frac{h_c}{l_\omega}; \tag{5}$$

$$\bar{x} = \frac{x}{l_\omega}, \qquad (6)$$

l_ω is the drainage distance calculated by the formula

$$l_\omega = \sqrt{k_{пр} \cdot (h_e^2 - h_{др}^2) / \omega}\,. \qquad (7)$$

When designing horizontal drainages, following hydraulic calculations should be performed:

- determination of drainage water intake capacity;
- selection of drainage surfacing;
- selection of filter casings for drains;
- determination of water discharge capacity of the drainage;
- determination of water discharge capacity of the filter beds.

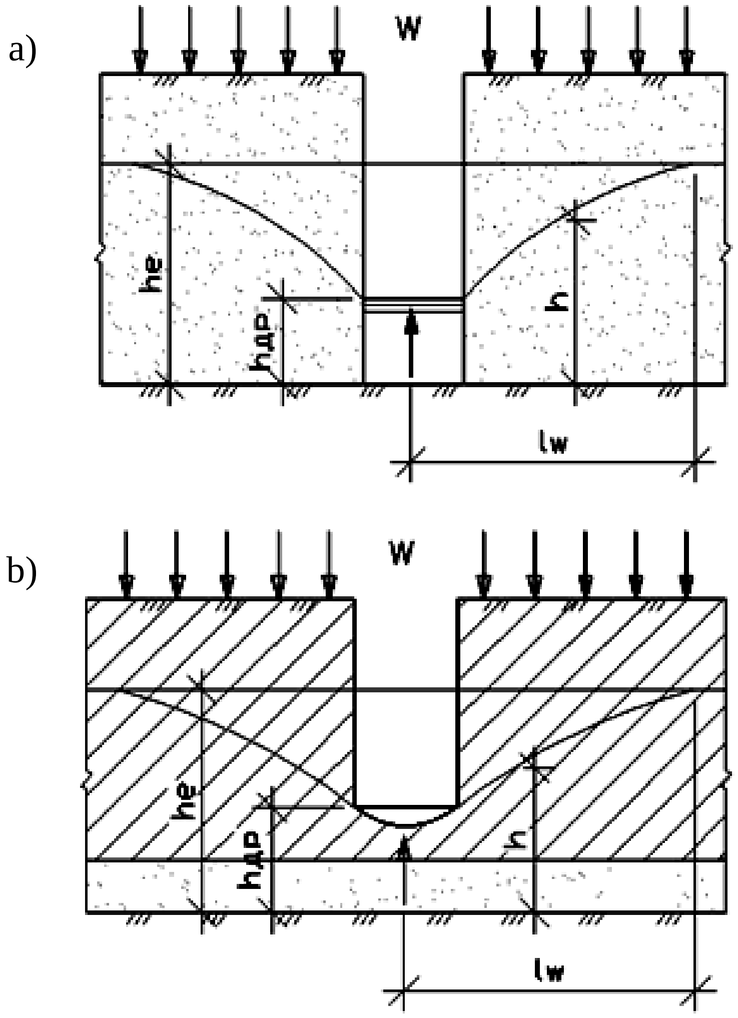

Fig. 1. Design schemes of a single-line drainage

1. Determination of drainage water intake capacity

Water-intake part of the horizontal drainage is arranged in the form of a round water-intake hole.

The diameter of the round holes is taken to be 2—2.5 cm.

The holes are staggered over the entire boot area.

The number of water-intake holes is determined using hydraulic calculation based on the fact that water outflow from the filter surfacing through the hole into the tube internal cavity results in head loss h_0 (Fig. 2).

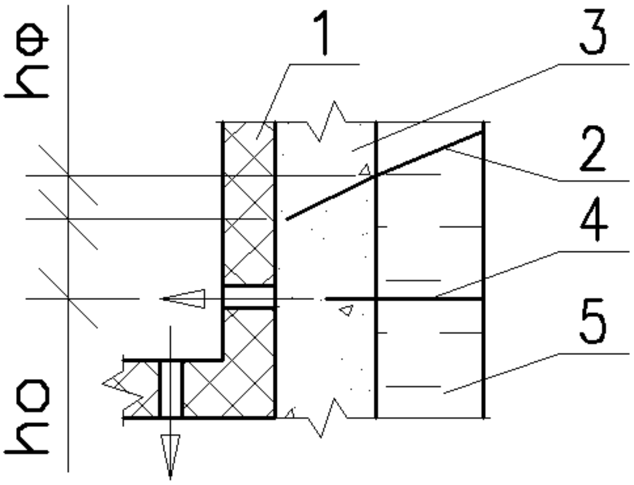

Fig. 2. Scheme of filtration stream outflow through a round hole in a drain wall:
1 — drain wall; 2 — ground water level; 3 — surfacing; 4 — current lines; 5 — drained ground;
h_0 — head losses in a covering; $h_ф$ — head losses during the outflow through a water-intake hole

The number of the holes in a unit of length is determined by the formula

$$n = q / \mu_0 \cdot F_0 \sqrt{2 \cdot g \cdot h_0}\,, \tag{8}$$

where q is the water inflow in a unit of drain length; μ_0 is the coefficient of the hole discharge; F_0 is the area of the hole; h_0 is the head losses during outflow through the hole; g is the gravity force acceleration [1].

2. Selection of drainage surfacing

Drainage powders are selected depending on drained soil composition. To select powder for cohesive soil drainage, it is appropriate to apply design charts developed by V. S. Istomina [1].

The order of selection is as follows. The coefficient of different grain sizes of surfacing is given in the range up to 10. At the given coefficient, in accordance with charts [1], limiting values of the average diameter of surfacing particles D_{50}^{I} are selected depending on the soil characteristics (within the limits of the tolerance range). Thereupon the first boundary curve of grain-size distribution of the drainage surfacing is constructed for minimum value D_{50}^{I}; value of D_{60}^{I} is taken approximately:

$$D_{10}^{I} = D_{60}^{I} / \eta_{ф}, \tag{9}$$

as well as value of $D_{\max}^{I}$.

The second curve of grain-size distribution is constructed in a similar way. Soils enclosed between the curves can be applied for the first layer of drainage surfacing provided that $\eta_{ф}$ is equal to the value prescribed at the beginning of calculation. If the point of intersection of coefficient of heterogeneity of the examined soil and the average diameter is in the tolerance range, then the soil is suitable for surfacing, otherwise, it is not.

The selection of the second and subsequent layers of drainage surfacing is performed similarly to the selection of the first layer, the first being taken as a drained soil. The order of selection of horizontal drainage surfacings in non-cohesive soils is also based on work with the charts and begins with determination of suffusion properties of soils [2].

3. Selection of the filter casings

The thickness of the filter casing is determined with consideration for the depth of drainage. The thickness should be not less than 10 mm in the compact condition the filters made of felt; not less than 3 mm when producing the filters made of glass laps ВВ-Г, ВВ-К or ВВ-Т.

The filtration coefficient $k_{ф}$ is determined by the graph $k_{ф} = f \cdot (p, d_{э.в.})$, where p is the pressure on a filter, kg/cm^2; $d_{э.в.}$ is diameter of elementary fiber of applied fibrous material, micron.

Head losses on the filter made of fibrous materials are determined by the graph $V_{ф} = f(\Delta H)$, where $V_{ф}$ is the rate of filtration on the filter contour, cm/sec; ΔH — head losses on the filter [3, 4].

4. Determination of water discharge capacity of the drainage. The calculation of water discharge capacity of the drainage is performed from the condition of necessity of passage of the whole discharge entering the drain at maximum depth of drain filling, which is not less than: in drain-dehumidifiers — $0.1d$, in drain-collectors — $0.3d$, in main drains — $0.5d$. Total cross-section work of drains is not permitted [1].

Rate of water movement in horizontal drains is assumed in the range 0.15—1 m/sec. For tubular drains laid in clay soils, minimum water rate is assumed in the range 0.15—0.2 m/sec, for tubular drains laid in sandy soils, 0.3—0.35 m/sec. The diameter of drain pipes is determined depending on the water filling degree and the rate of water movement in pipes. Given pipe filling degree h/d (where h is the depth of pipe filling, d is the diameter of the pipe) and rate of water movement in pipes, pipe diameter is calculated by the formula

$$d=\sqrt{4Q/\beta\cdot\pi\cdot V}, \tag{10}$$

where β is the coefficient depending on the degree of filling h/d and determined by the graph $V_{ф}=f(\Delta H)$; Q is the drain discharge equal to the water inflow to the drain. This inflow is determined in the course of filtration calculation.

The gradient on perforated sites of horizontal tubular drains is determined with consideration for the discharge which is variable over the length of the drain. Considering that water inflow to the drain is uniform, the gradient in arbitrary cross-section at the distance x from the beginning of the drain at the whole length L is determined by the formula

$$i=V^2\cdot x^2/L^2\cdot C^2\cdot R^2, \tag{11}$$

an average gradient of the whole pipeline is defined by the formula

$$i_{cp}=V/3C^2\cdot R. \tag{12}$$

The value of hydraulic radius is determined by the formula

$$R=\alpha\cdot d/4, \tag{13}$$

where coefficient α is obtained from the graphs of dependence of coefficients α and β on the depth of filling (h/d).

Coefficient of resistance C, m^2/sec, is calculated by the N. N. Pavlovsky formula:

$$C=R^y/n; \tag{14}$$

$$y=2\sqrt{n}-0.13-0.75\sqrt{R}(\sqrt{n}-0.1), \tag{15}$$

where R is the hydraulic radius, m; n is the coefficient of roughness.

The coefficient of roughness is not constant. It varies from 0.015 to 0.27 depending on the value of the drain gradient and degree of drain filling.

5. Determination of water discharge capacity of the filter beds

Hydraulic calculation of the filter beds made of non-cohesive material, is performed in the following order [5]. Using the results of filtration calculation, inflow to the filter bed is estimated, whence, knowing bed cross-section F, we calculate the rate of water filtration in a bed by the formula

$$V_{ф} = Q / F. \tag{16}$$

Thereupon filtration mode (laminar or turbulent) is determined by Reynolds number R_e, which is calculated by the following formulae:

1) for homogeneous material with grain size less than 1 cm (Lomize equation)

$$R_e = V_{ф} \cdot d_{cp} / 6(1-n) \cdot v, \tag{17}$$

where d_{cp} is the average diameter of the particles of the filtration layer, n is the porosity; v is the kinematic coefficient of viscosity of the water being filtered;

2) for inhomogeneous material with grain size less than 1 cm (F. I. Kotykhov equation)

$$R_e = 4 \cdot V_{ф} \sqrt{2k_{np}} / (v \cdot n^{1,5}), \tag{18}$$

where $k_{np} = k_{ф} \cdot v / g$ is the coefficient of porous medium permeability, m^2, determined by the formula

$$k_{np} = k_{ф} \cdot v / g. \tag{19}$$

Deterioration in linear mode of water movement occurs at $\mathrm{Re} > 1.7$ in homogeneous material, and at $\mathrm{Re} > 0.3$ in homogeneous material provided that Re was calculated by the formulae above.

At laminar movement of filtration flow, head losses in the filtration layer are calculated by the formula

$$\Delta h = V_{ф} \cdot l / k_{ф}, \tag{20}$$

where l is the path length of filtration in a layer.

At turbulent flow mode, head losses are calculated by the formula

$$\Delta h = l \sqrt{V_{ф} / k_{ф}}. \tag{21}$$

Based on the technique described above, anti-icing drainage protection facility was designed.

6. Design of a drainage

Design includes a frame consisted of the blocks of drainage gutters positioned vertically one above the other, and a cover with holes (Fig. 3). With the use of these elements, a drainage facility is constructed around the circumference of water drainage area. The water is drained in such a way as to be a safe distance from the protected structures.

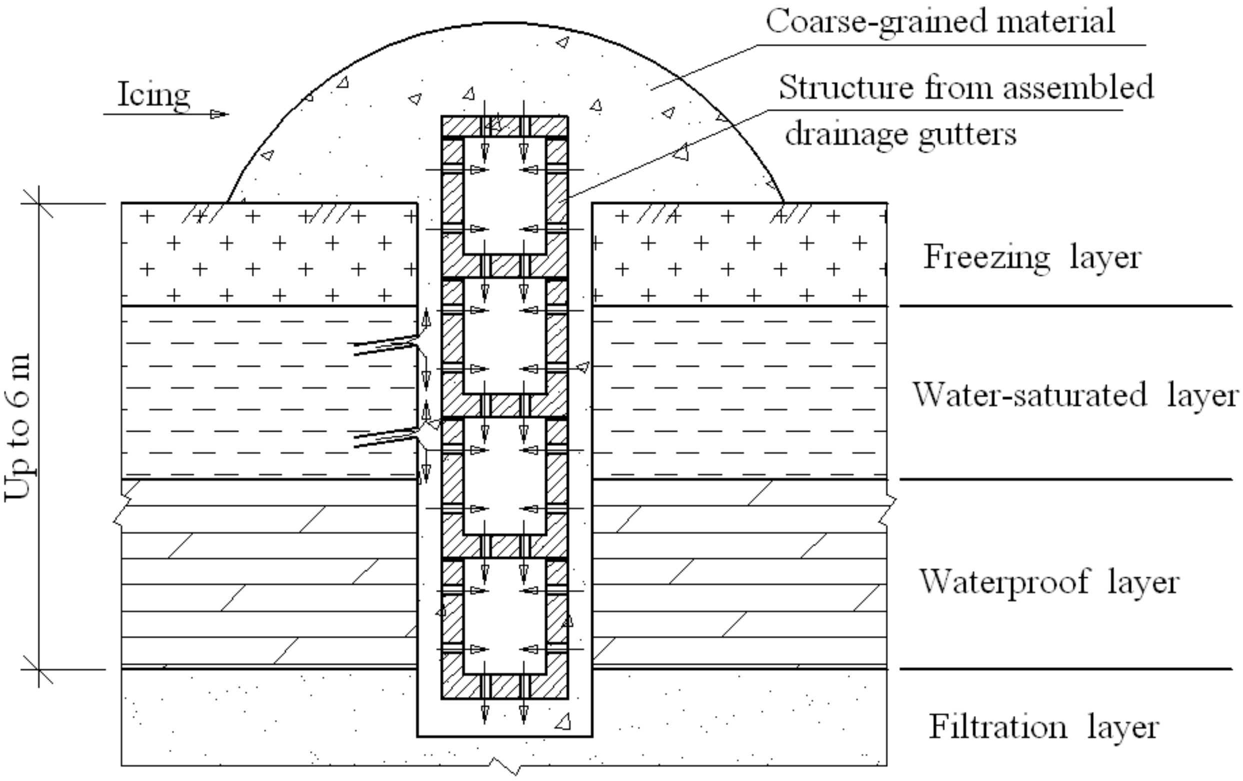

Fig. 3. Drainage facility in section

This facility cuts ground layers to redirect, which helps to struggle with icing at the stage of its formation.

Consider the design of the element of the drainage system. The element of the drainage system (water drainage gutter) is designed on the basis of the standard design [6] (Fig. 4). We improved the design by inserting oiled wood plugs in the places where holes are located. These plugs are removed after stiffening of concrete.

When designing the drain age facility, it is necessary to take into account the facility operation area (using area environmental data, it is necessary to choose appropriate grade of concrete by frost resistance and strength quality of concrete).

7. The principle of protection against icing

This design surrounds the hazard area — area of ice formation, and thereby prevent icing water from pouring outside.

Surface drainage covering with coarse-grained material serves to increase in freezing depth (fulfilling the heat insulation function), thereby preventing water from freezing and promoting filtration of surface icing waters in underlying layers. During flood period, this structure prevents protected facility from underflooding.

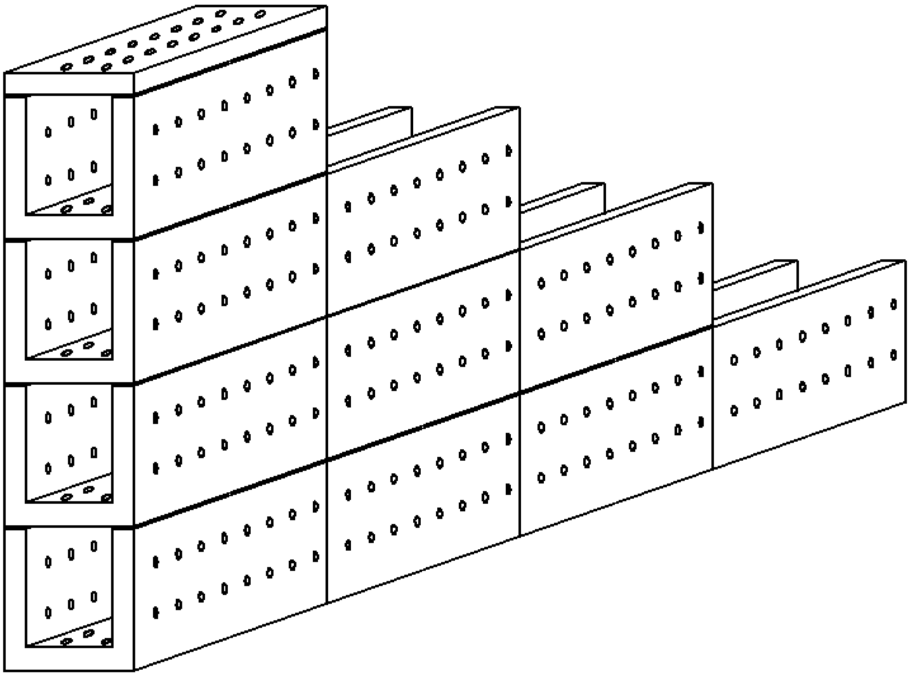

Fig. 4. Drainage structure in perspective

Conclusion

The drain age facility was developed with consideration for the basic hydraulic phenomena occurring in drainage system used for protection against icing.

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