METHODOLOGY FOR CALCULATING THE SIDE WALLS PERFORATION IN DISTRIBUTION DRAINAGE PIPELINES

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Distribution drainage pipelines play a critical role in water management systems, particularly in agricultural irrigation and land reclamation projects, horizontal and radial water intakes [1, 2]. The efficiency and reliability of these pipelines significantly depend on their structural and hydraulic parameters. Among these, the perforation of the side walls is a key design element, directly influencing water flow dynamics, filtration efficiency, and overall performance of the drainage system.

Despite advancements in pipeline engineering, the development of accurate and practical methodologies for calculating side wall perforation remains an ongoing challenge. Traditional approaches often rely on simplified assumptions that may lead to suboptimal designs that either fail to meet operational requirements or incur unnecessary construction and exploitation costs [3].

Holes are made in the walls of a distribution drainage pipeline to distribute water along its length. Typically, to protect these openings from the ingress of soil particles, the pipeline walls are covered with a layer of filtering material. Each filtering material has its own resistance. Knowing the value of this resistance, the size and number of perforation holes in the pipeline can be determined using the proposed methodology.

Studies [4, 5] demonstrate that the flow rate of liquid entering the surrounding soil from a unit length of a pressure distribution drainage pipeline in reclamation systems is calculated using the formula:

$$q = \frac{dQ}{dx} = -k_f \frac{h}{\overline{\overline{F}}}, \tag{1}$$

where Q is the flow rate at a distance x from the beginning of the pipe; k_f is the filtration coefficient of soil around the pipe; h is a variable piezometric head along the length of the pipe, which causes the outflow of liquid from the pipeline into the surrounding environment; $\overline{F}$ is dimensionless filtration resistance (its determination represents a separate filtration problem [6]).

It is assumed that the filtration coefficient of the side surface of the drainage pipeline is an order of magnitude greater than the filtration coefficient of the surrounding soil, so its effect is neglected.

At the same time, many works [7, 8] show that the flow rate of liquid escaping from the distribution pipeline through evenly spaced perforation holes along its length is determined by the following relation:

$$q = \frac{dQ}{dx} = -\mu_{dis} \alpha_p \sqrt{2gh}\,, \tag{2}$$

where μ_{dis} is the perforation hole discharge coefficient; $\alpha_p = \sum \omega_h / l$ is the area of the perforation holes (slits) per unit length of the pipe; g is the acceleration due to gravity.

In the case where the intensity of liquid distribution is the same in both cases, it can be written as:

$$\mu_{dis} \alpha_p \sqrt{2gh} = k_f \frac{h}{\overline{F}}\,. \tag{3}$$

From formula (3), the dimensionless filtration resistance of the drainage pipeline can be determined by the following relation:

$$\overline{F} = \frac{k_f \sqrt{h}}{\mu_{dis} \alpha_p \sqrt{2g}}\,. \tag{4}$$

From (4), after simple transformations, it is easy to obtain:

$$\overline{F} = \frac{k_f \sqrt{h}}{\mu_{dis} \pi D S \sqrt{2g}}\,, \tag{5}$$

where l, D is, respectively, the length and diameter of the pipeline; $S = \frac{\sum \omega_h}{\pi D l}$ is the ratio of the total perforation area in the drainage pipeline to the total side surface area of the drain (in the case of uniform perforation of the pipeline walls – the same per unit length of the pipe).

By assuming an average value for the discharge coefficient through a small hole $\mu_{dis} = 0.62$ and $h = h_{av}$, the value of the relative perforation of the drainage pipeline walls, which will ensure the distribution of the required flow from the drainage pipeline, can be easily determined from formula (5):

$$S = 0{,}36 \frac{k_f}{D\overline{F}} \sqrt{\frac{h_{av}}{g}}\,. \tag{6}$$

In general, when designing drainage pipelines for engineering systems, various tasks are addressed depending on the specific requirements. Typically, the following parameters are known: the required velocity V_{in} (flow rate Q_{in}) at the beginning of the pipeline; the length of the pipeline l; its diameter D; and the generalized parameter A_{dis}.

Then, for pipelines with effective structural characteristics, the relative degree of the side walls perforation of the pipeline is recommended to be determined by the formula:

$$S = 0{,}14 \frac{D}{A_{dis} l}\,. \tag{6}$$

The total area of the holes (slits) in the side walls of the distribution drainage pipeline will be (m²):

$$\sum \omega_h = S \cdot \pi \cdot D \cdot l = 0{,}14 \frac{\pi D^2}{A_{dis}}. \qquad (7)$$

By specifying the diameter of one hole d_h, the total number of holes along the entire length of the drainage pipeline can be determined:

$$N = 0{,}56 \frac{D^2}{d_h^2 A_{dis}}. \qquad (8)$$

Then, assuming uniform perforation along the length, the number of holes per meter of pipe will be:

$$n = \frac{N}{l}. \qquad (9)$$

Therefore, based on the use of the presented relationships, a reliable methodology for determining the degree of perforation of the side walls of the distribution drainage pipeline has been developed, and quite simple calculation dependencies have been obtained.

References

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