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Fixing the slopes of the channel with combined expansion and filter seams

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Abstract

To combat filtration losses on irrigation canals, various types of protective coatings are used. Monolithic and prefabricated reinforced concrete cladding, asphalt concrete coatings, cladding with the use of polymer films are widespread. Initially, the groundwater level in these areas is below the mark of the canals. Therefore, the task at the first stage of operation of structures is to eliminate filtration losses from the channel. In the future, due to infiltration from the above canals, reservoirs and irrigation of adjacent territories, groundwater is supplied and groundwater levels rise above the canal mark. It is obvious that this situation can lead to adverse consequences, especially when the water level in the canal drops rapidly. At the same time, significant hydrodynamic pressures of water, which can cause the destruction of slopes, will have to act on the cladding. Therefore, the study of the protection of the canal lining from the effects of these filtration waters is of great practical importance.

The most reliable fastenings of canal slopes in similar conditions are those that under normal conditions of the canal operation, when there is no backwater from the groundwater side, the lining should exclude filtration from the canal, i.e. filtration losses of irrigated water, and in the presence of backwater and with a rapid decrease in the water level in the canal, it should provide free exit of the soil flow into the channel of the canal or its discharge in the other direction. This eliminates the occurrence of significant hydrodynamic pressures, and the destruction of the fastenings of the slopes of the channel.

This article provides an analysis of the design of the fastening of the slopes of the channel working in various geological and hydrogeological conditions. A new design for fixing the channel is considered. The principle of their work is given. The technique of filtration calculation of channels with such fasteners is given. The proposed mounting design meets the above requirements and thereby provide strength and stability of the lining during the operation of the channel.

Keywords: *channel, slope fastenings, channel lining, filtration, reliability, durability, drainage device, slope stability, false seams, rapid reduction of water level in the channel.*

I INTRODUCTION

To prevent water filtration from canals and an unacceptable rise in groundwater level in the near-channel zone, antifiltration linings and screens of various designs are widely used. The most widely used are antifiltration linings from a polymer film with a protective coating of concrete, the so-called concrete-film linings, which are currently recognized as the most effective in terms of antifiltration qualities. However, such fastening proved to be unsuitable in conditions when groundwater is expected to be backfilled, the cladding design cannot simultaneously ensure the exclusion of filtration from the channels and if groundwater backwater occurs, they can freely exit into the channel.

To relieve the emerging hydrodynamic pressures, various design solutions of the linings and drains themselves have been widely used recently.

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A.F. Pechkurov and E.I. Mikhnevich proposed and applied on a number of objects slabs of porous concrete on a cement and polymer binder [1].

V.A. Feitelson proposed two-layer concrete and reinforced concrete slabs, where the upper layer of dense concrete is facing, and the lower one of large-porous concrete is filtering [2]. This mounting design allows some surface silting of the pores, as well as the possibility of destruction of the filter layer during alternate freezing and thawing, which ends with the formation of the inverse filter. Double-layer boards were used in Latvia. They were laid on fiberglass, which should also be included in the design of the inverse filter.

Abroad, instead of fiberglass when laying concrete and reinforced concrete slabs, filter mats made of polymer materials are used.

N.V. Baranov and Yu.A. Sobolevsky proposed and implemented the design of fastenings for drainage channels in sandy soils in the form of slabs of dense concrete with their emphasis on beams made of large-porous concrete [3].

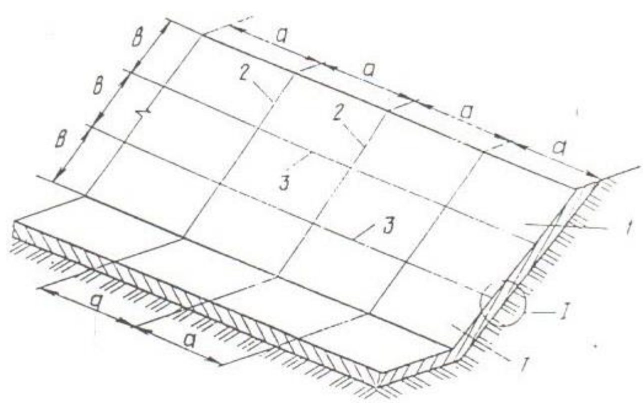
The disadvantage of all these fixtures is the inability to exclude water losses from the channel during the period when the groundwater level is even lower than the bottom of the channel.

The closest destination to the conditions under consideration is fastening with drainage holes with non-return valves, which provides both unloading of the filtering pressure due to the release of water into the channel during rapid emptying and prevention of loss of irrigation water under normal conditions of the channel [4].

The disadvantages of this mount are the low reliability of its operation due to the rapid failure of the valves, the possibility of siltation, the complexity and high cost of manufacturing them in sufficiently large quantities.

Methodology

We have developed a new design for securing slopes; it constructively represents monolithic or prefabricated reinforced concrete slabs, separated by transverse and longitudinal joints at a certain distance, determined by calculations [11]. Seams are made in the form of a weakened construction of the transverse profile of the cladding. TheschemeofwhichisshowninFig. 1.



a)

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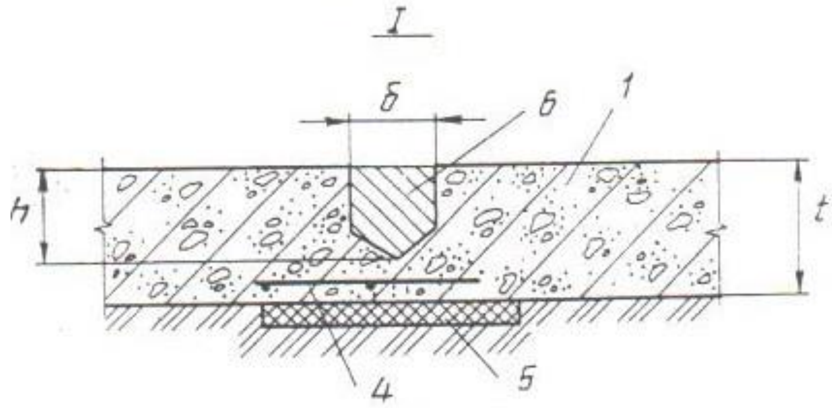

b)

Fig. 1 Combined deformation and filtration seam. a) general view; b) node I

1-cast concrete; 2-transverse seams; 3-longitudinal seams; 4- fittings; 5-filter made of artificial fiber materials; 6- board.

Mounting the slope as a whole works as follows. In normal operation of the channel, when there is no backwater from the groundwater side, the lining should exclude filtration from the channel, i.e. filtration losses of irrigated water. And when the groundwater level rises, which creates unfavorable pressures during the rapid discharge of water in the channel, specially made seams should crack with a certain opening (but without breaking the slope) and let water pass into the channel, thereby relieving the hydrodynamic pressure on the mounting plates.

The filtration calculation of channels with such slope fastening includes, firstly, determining water losses from the shielded channel in the absence of backwater and, secondly, determining the distance between the joints, providing a sufficient decrease in hydrodynamic pressure in the presence of backwater without compromising the stability of the fastening and normal channel operation.

The specific filtration flow rate from the shielded channel in the absence of backwater according to the scheme in Fig. 2 can be determined by the formula [5].

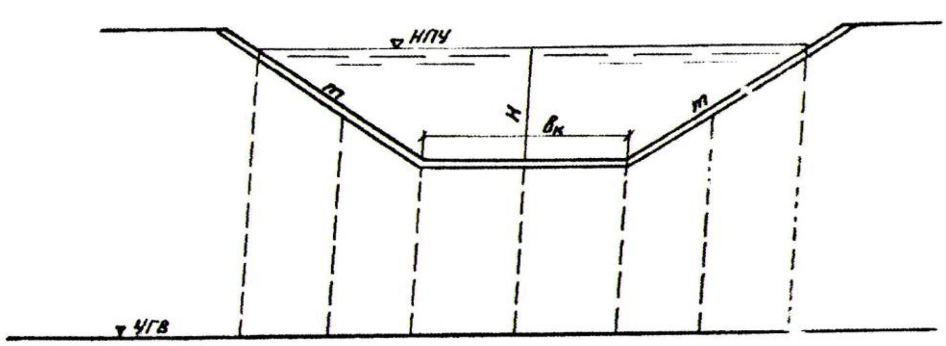

Fig. 2.scheme for calculating filtering from channels without backwater

$$q = k_6 \frac{H+t}{t} \left(\text{в}_k + H\sqrt{1+m^2}\right), \qquad (1)$$

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where: H is the depth of the water in the channel;

t is the thickness of the concrete lining;

в_k– bottom channel width;

k_б– concrete filtration coefficient;

m– slope laying.

The movement of water under the lining in this case occurs with incomplete filling of the pores of the soil.

As the studies of [6] show, in most cases the filtration losses from the lined channels are much higher than the calculated ones. This is due to the appearance of cracks in the lining and the destruction of technological seams.

False seams of the type considered here, structurally performed in advance in a weakened form, can generally open before the occurrence of groundwater backwater. Then, of course, there will be a loss of water from the channel into the ground. These water losses can be determined by the method of R.M. Gorbachev [6].

In general terms, water losses depend on the width of crack opening, the effective pressure, capillary and filtration properties of the soil, and can be calculated according to Table 1 [6], in which the following conventions are adopted:

q- filtration flow through an un-sawed crack, m2 / day;

Δ- opening width of the through crack, mm;

К- coefficient of filtration of the underlying soil, m / day;

Н- water pressure above the crack, m;

Нк- capillary pressure equal to 0.5, m;

hk-the height of the capillary rise of water in the ground, m

During the operation of the channels, cracks in the concrete cladding are silted and self-sealing. Silt cracking in concrete reduces the permeability of the cladding.

It is known that near various drainages there is a significant deviation of groundwater movement from plane-parallel, caused by the appearance of local zones of sharply changing filtration. In these cases, the influence of zones of sharp deformation of the flow,

Table 1

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$H+H_{к}$,м	Q / k valuefor				
	Δ=0,5 мм	Δ =1мм	Δ =3мм	Δ =5 мм	Δ =10мм
0,50	0,39	0,42	0,48	0,52	0,58
1,00	0,72	0,78	0,87	0,93	2,04
1,50	1,05	1,14	1,26	1,32	1,45
2,00	1,37	1,49	1,62	1,71	1,86
2,50	1,67	1,78	1,99	2,10	2,25
3,00	1,97	2,07	2,35	2,48	2,64
3,50	2,28	2,38	2,69	2,86	3,03
4,00	2,59	2,70	3,03	3,21	3,42
5,00	3,17	3,28	3,69	3,90	4,17
6,00	3,76	3,87	4,35	4,59	4,92
7,00	4,30	4,44	5,00	5,25	5,67
8,00	4,84	5,00	5,66	5,92	6,47
9,00	5,34	5,52	6,25	6,58	7Д1
10,00	5,84	6,08	6,84	7,25	7,82

characterized by a drop in pressure in them, can be taken into account using the method of filtration resistance.

When calculating false seams, we will consider them as vertical interacting wells, replaced for clarity by equivalent continuous trenches. With this approach, the zone of sharply changing filtration is excluded from consideration [7].

The maximum residual pressure between drainage wells is determined by the formula [8].

$$h_M = \frac{q_c}{k} \left(\frac{1}{\pi} \ell n \frac{2a}{\pi в_c} + 0{,}22 \right. \quad (2)$$

whereq_c- is the flow rate of 1 pm the length of the drainage well defined on the model;

a – seam pitch (wells);

вс – the width of the seam (wells).

The determination of the flow rate q_c is performed by the EGDA method.

In addition to vertical joints located at a certain distance along the channel, the considered scheme also provides for horizontal longitudinal joints on slopes (Fig. 1). the purpose of these seams is primarily associated with the creation of favorable conditions for the development of vertical seams. In general, these seams will help to reduce the pressure of groundwater on the slopes of the channel.

For an approximate assessment of the effect of a longitudinal seam on pressure reduction, we used

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the technique given in recommendations [9], according to which the horizontal drainage element is replaced by a vertical well equivalent in water inflow (Fig. 3). the equivalent radius of the wells is determined by the formula:

$$\ell n r^* = \ell n \frac{a}{4} - \frac{M}{a} \ell n \frac{M}{\pi r_г}, \qquad (3)$$

wherer^* – is the radius of the equivalent well;

r_г– radius of the horizontal seam;

м – distance between horizontal seams;

a– distance between vertical seams.

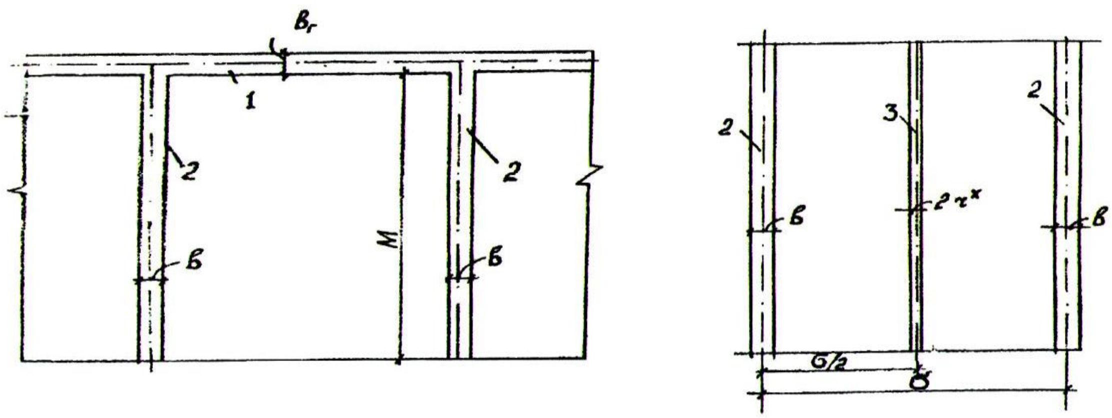

Fig. 3 design scheme of combined drainage.

1-horizontal drainage element; 2- vertical drainage element; 3- replaceable drainage element.

Thus, instead of combined drainage, consisting of vertical and horizontal seams, we get an equivalent system of three vertical wells. An equivalent well is placed in the gap between the main vertical wells (seams) at a distance of a / 2.

The distance between the seams is determined by experimental-theoretical methods. The optimal distance is that which provides a decrease in the hydrodynamic pressure to a value sufficient already for stability of the mount.

Results

To assess the effectiveness of the considered design of the channel lining, we give an example of calculations with the following initial data: N = 7m; t = 0.2m; m = 2.5; c = 16m; with concrete monolithic cladding according to [10] Kb = 3.46 x 10-3 m / day.

Substituting these values of the quantities in (1) we obtain:

$$q = 3{,}46\text{x}\ 10^{-3} \frac{7 + 0{,}2}{0{,}2} \left(16 + 7\sqrt{1 + 2{,}5^2}\right) = 4{,}34\text{м}^2/\text{сут}.$$

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Let us determine the filtration flow rate through a horizontal crack with a unit length (1 m) with an effective pressure H = 7.0 m. the underlying soil is sand, the filtration coefficient of which is K = 5 m / day, hk = 0.50 m, Hk = 0.5 x 0.5 = 0.25 m. in view of the smallness, we neglect the capillary rise of sand.

From Table 1, for H = 7m and crack width Δ = 3mm, Δ = 5mm and Δ = 10mm, we find q⁄k values of 5.00, 5.25 and 5.67, respectively. Then we will have:

при$\Delta = 3$ мм$q = 5{,}00 \text{x } 5 = 25$ $м^2/сут$

при$\Delta = 5$ мм$q = 5{,}25 \text{x } 5 = 26{,}25$ $м^2/сут$

при$\Delta = 10$ мм$q = 5{,}67 \text{x } 5 = 28{,}35$ $м^2/сут$.

As noted above, during the operation of the channels, cracks in the concrete cladding are silted and self-sealing. Silt cracking in concrete reduces the permeability of the cladding.

For practical calculations of filtering through silted cracks, it is recommended to use a special table [6]. According to this table, it is possible to determine the flow rate through a horizontal silted crack 1.0 m long with a concrete cladding thickness t = 0.20 m and a water head N = 7 m. In this case, the flow rate through a silted crack more than 2 mm wide with a pressure gradient equal to one, will be 0.006 m2 / day. In fact, the effective pressure gradient is I = (H + t) / t = 36, and therefore, the total filtration flow through the crack will be 0.006x36 = 0.216 m2 / day.

The determination of the flow q_c is performed on the instrument EGDA. When calculating our channel, we adopted the case of an instant decrease in the water level in the channel when the groundwater level rises to the top of the slope. The resulting hydrodynamic mesh of the filtration flow is shown in Fig. 4. the results of the calculation to determine the maximum pressure value when opening a gap (crack) of 5 and 10 mm are shown in table 2.

Table 2.

Currenttapenumbers	Consumption by current tapes per 1 meter	Pressure values at sun = 5mm and the distance between the seams a (m)						Pressure values at sun = 10mm and the distance between the seams a (m)					
		1,5	3,0	2,5	3,0	4,0	5,0	1,5	2,0	3,5	3,0	4,0	5,0
1	0,12	0,34	0,48	0,62	0,76	1,06	1,37	0,3	0,42	0,55	0,68	0,95	1,23
2	0,39	1,11	1,55	2,00	2,47	3,44	4,44	0,98	1,37	1,79	2,21	3,09	4,00
3	0,39	1,11	1,55	2,00	2,47	3,44	4,44	0,98	1,37	1,79	2,21	3,09	4,00
4	0,58	1,65	2,30	2,98	3,68	5,11	6,60	1,45	2,04	2,66	3,29	4,60	5,96
5	0,35	0,99	1,39	1,8	2,22	3,09	3,98	0,88	1,23	1,61	1,99	2,78	3,60
6	0,26	0,74	1,03	1,34	1,65	2,29	2,96	0,65	0,92	1Д9	1,48	2,06	2,67
7	0,17	0,48	0,67	105	1,29	1,50	1,93	0,43	0,60	0,78	0,96	1,35	1,75

We determine the radius of the equivalent well at M = 7 m according to the formula (3).

Thus, in place of combined drainage, consisting of vertical and horizontal seams, we get an equivalent system of three vertical wells: two, for example, with a radius of 5 mm and one with a radius 4,94x10-4 ,

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2,31x10-2, 2,44x10-1accordingly, at distances a = 3, 4, 5 m. An equivalent well is placed in the interval between the main vertical wells (seams) at a / 2 distance.

Due to the fact that the width of the horizontal joints at a ≤ 5 m turned out to be less than 0.5 mm, their influence on the total flow rate of water filtration in the channel was not taken into account and therefore went into the calculation margin.

To determine the necessary distance between the joints, the stability calculations of the mounting plates for tipping and floating up from hydrodynamic pressure acting on the facing of the slopes when raising the groundwater level were performed. Calculations are performed according to regulatory documents [15,]. The calculations are carried out with an instantaneous release of the water level in the channel, i.e. when H = 0. The values of the existing hydrodynamic pressures of groundwater are taken from table 2. The results of calculating the stability of slope slabs are shown in table 3 and the channel bottom in table 4.

As can be seen from table 3, when the thickness of the opening of the seam is 5 mm, the stability of the fastening of the slope to float is provided only if there is a seam through 1.5 m. and at sun = 10 mm, these seams can be completed in 2.0 m. Thus, in order to ensure that the distance between the seams is more than 2.0 m, the thickness of the opening of the seam should be at least 10 mm.

As can be seen from table 4, the channels of the bottom of the channel, having a thickness of 0.2 m, are not resistant to float even if there is a seam after 2.0 m. To ensure the stability of the plates of the bottom of the channel to float, it is necessary to increase the thickness of the fastening, while simultaneously increasing the dimensions of the opening of the seam.

Table 3.

"б" м	$в_c$ =5мм		$в_c$=10мм		$в_c$=20мм		$в_c$=30мм		$в_c$=40мм	
	$К_{опр}$	$К_{всп}$	$К_{опр}$	$К_{всп}$	$К_{опр}$	$К_{всп}$	$К_{опр}$	$К_{всп}$	$К_{опр}$	$К_{всп}$
5	-	-	1,16	0,39	-	-	-	-	-	-
4	-	-	1,50	0,50	1,68	0,56	1,82	61	1,92	0,64
3	1,88	0,63	2,10	0,70	2,36	0,79	2,56	86	2,73	0,91
2,5	2,30	0,77	2,47	0,86	2,95	0,99	3,16	06	3,40	1,14
2,0	2,98	1,00	3,38	1,13	3,85	1,29	4,21	41	4,49	1,50
1,5	4,18	1,39	4,73	1,58	-	-	-	-	-	-

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Table 4.

"б" м	$в_c$=10мм			$в_c$=20мм			$в_c$=30мм			$в_c$=40мм		
	0,2	0,25	0,30	0,20	0,25	0,30	0,20	0,25	0,30	0,20	0,25	0,30
2,0	0,61	0,75	0,89	0,70	0,87	1,03	0,76	0,93	1,12	0,81	1,00	1,20"
1,5	0,85	1,04	1,25	0,98	1,22	1,46	1,09	1,33	1,60	1,16	1,43	1,72

Discussion

Turning to a comparative assessment of the measures considered here to prevent the harmful effects of groundwater abstraction, it should be noted that it is mainly based on a generalization of the available experience and the performed analytical calculations. There are still experimental checks of the results both in the laboratory and in the field, on the basis of which appropriate refinements and some changes to the recommended design solutions can be made.

The use of the proposed design of the fastening of the slopes of the channels in comparison with the known allows to achieve the following advantages:

- save water by eliminating filtration losses from the canals during a period of low groundwater level position;

- simplicity of the design scheme and the possibility of combining a number of necessary joints for various purposes - shrink, temperature, seismic and subsidence;

- the relatively low complexity of the manufacture of seams and the practical absence of operating costs in the process of further functioning of the channel;

- lack of special devices for drainage and discharge of drained water in the process of reducing groundwater backwater;

- to increase the reliability of the operation of the cladding and the channel as a whole in conditions of variable hydraulic regime and rising groundwater level.

Conclusion

Thus, the proposed design of the fastening of the slopes of the channel eliminates plate overburden by excessive hydrodynamic pressure with high standing groundwater and a sharp discharge of water in the channel, to ensure the reliability and durability of the lining during operation. Eliminates filtration losses from the canal at low standing groundwater level.

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