Protection filters of the pit in soft saturated soils

Filtres pour protection des excavations dans les sols mous saturés

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SYNOPSIS: The substantiation of seepage slope stability of the pit in soft saturated soils represent by Quaternary deposits and silty clay interlayers is under consideration in this paper. It is necessary to load in bulk the layer of the soil for ensuring slope stability. If the moisture is similar to the moisture of liquid limit the pore water pressure of the clayey silt will be equal to the height of overlying layer. On the contact with the overlying granular material the clayey silt will flow and will penetrate into pores of filter granular material. For the analysis of slope stability of the yield soil it was used the well known relation of soil equilibrium as Bingam's body. Initial stress for clayey soil was determined by graphic relation by V.Volsky by extrapolation. Experimental control of seepage stability of the soil on the contact with filters having various compositions have been made in consolidation - filtration apparatus.. High gradients of the head were noted under conditions of making load. On the basis of these tests the calculated filter compositions ensuring seepage stability of oversaturated soils of the slope of the pit were confirmed.

Soil filter tests are in process at Unii Vodgeo. Applying this type of filters we give the possibility to base safe and economical protective filters of earth dams and soils of foundations.

In this work we have the example of substantiation of the slope pit stability in soft saturated soils represent Quarternary deposits with interlayers and silty clay galls having thickness 10-12 mm.(Fig.1)

Analysis of stress-strain conditions of this pit and the test of model samples by centrifugal apparatus gives us the opportunity to calculate the steepness of the blanket; it was note that the consolidation of silty interlayers was insignificant and the soil was almost natural during the first half of the year after excavation (I).

This requires supplementary substantiation of silty slope interlayers stability and its protection by proper filter composition in the case of the groundwater level lowering.

Taking into account that the liquid limit of interlayers is similar to the moisture in the boundary of the yield and that the load of overlying interlayer is transfer to water completely, then the pore water pressure of these interlayers is the function of the weight of overlying layer. We consider the soil existing in yield-plastic conditions as Bingam's body.

The soil existing in yield-plastic conditions comes into contact with granular material of filter; it glows and penetrates into pores of coarse-grained material. For the discription of equlibrium of yield-plastic conditions in the pore of the filter it was used the well known relations of permissible gradient of head accepted by V.V.Volsky in the case of soil-filter state of contact (2).

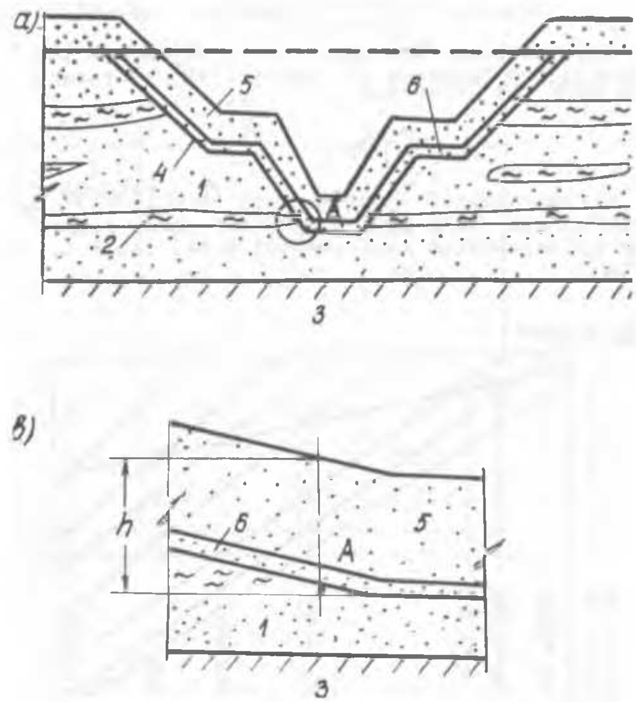

Fig.1. The diagram to the estimation of seepage stability of the pit slope.
a) the diagram of the pit;
b) the calculated diagram of silt interlayers;

1) - Quaternary deposits, sand;
2) - interlayers and silty clay galls;
3) - bed; 4) - the outline of the pit;
5) - filling; 6) - filter.

$$i^{perm} = \frac{2\tau_o}{\rho_w \cdot r}, \qquad (1)$$

where i^{perm} - permissible gradient of head in the soil;
τ_o - initial shear stress of the soil;
r - pore radius of granular soil; cm;
ρ_w - unit weight of water.

We consider the average pore filter size as calculated for this behavior of the soil (3).

$$D^o_{average} = D^*_{60} = \alpha_n D_{60}, \qquad (2)$$

where D_{60} - diameter of filter particle, particles having the lesser diameter amount 60% of total weight.

α_n - the coefficient is the function of the porosity;

The radius of filter pore is

$$r = \frac{\alpha_n \cdot D_{60}}{2} \qquad (3)$$

Taking into account formulas (1), (3), we have the permissible diameter of filter particles; it provides the seepage stability of the soil

$$D_{60} = \frac{4\tau_o}{\rho_w \cdot \alpha_n \cdot i^{perm}} \qquad (4)$$

Initial shear strenght for clayey soils is determined by means of viscotester, as result we have the relation

$$\tau_o = f(W)$$

We had plotted the nomograph $\tau_o = f(W, W_L^I)$, containing silty soil properties under reviev by extrapolation experimental data, table I, fig.2.

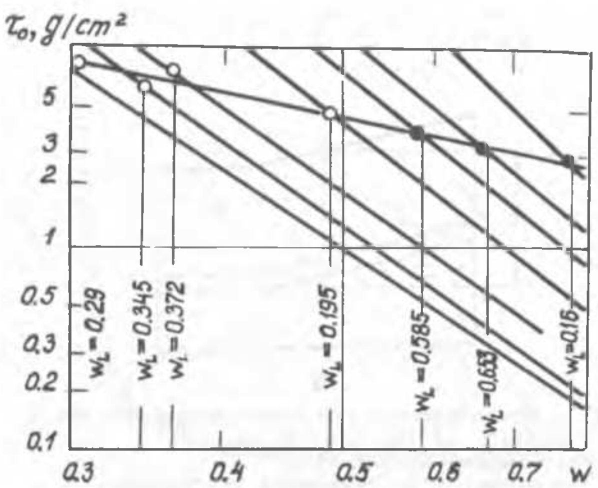

Fig.2. The nomogram of strength dependence on the moisture and
o - according to data by V.Volsky;
o - according the extrapolation.

Considering the one-dimension flow moving in the direction to the slope of the pit in natural conditions and testing immediate applications of sand weight load we have the maximum value of pore pressure in the lowest part of the slope near by the point A (fig.1); this value is $P = \rho_1 \cdot h$, where h - the thickness of sand layer; ρ_1 is the density of dry soil.

ρ_1 = 1800 kg/m^3 is equal to 18 metres of water head.

The value of the calculated gradient head in the exit place of 5 centimetres is equal to i = 360. We consider this place for the comparison with consolidation-percolation tests.

We have the value τ_o = 320 = 250 Pa by graphes in fig.2 for clayey silt interlayers of the foundation in the boundary of the yield having moisture W_L = 0,67...0,78.

According to formula (4) with i = 360 we have obtained the permissible diameter of the filter within limits

D_{60} = 0,92 ... 1,18 mm

Taking into account a number of assumptions established at the estimations and importance of decided task it was carried out the experimental check of seepage stability of the clayey silt with differential filter composition - Percolation apparatus by immediate leading of the sample.

The soil sample of undisturbed structure was placed in the operating chamber without disturbance of the structure, the thickness of the soil was 5 cm; the layer of the filter was made of differential fractions and natural sand soil, table II, fig. 3.

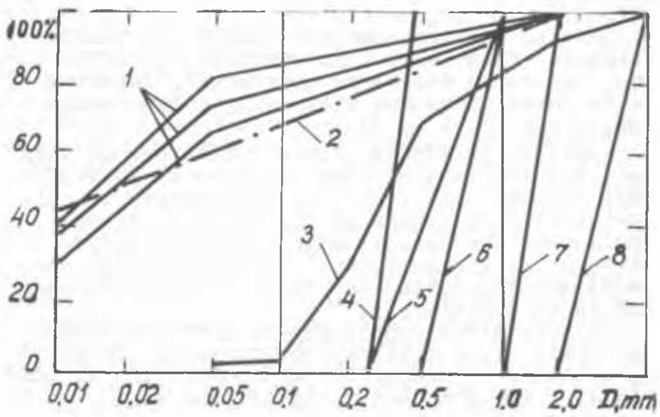

Fig.3. - Granular contents of soils.
1 - soils tested by V.Volsky;
2 - clayey silt;
3 - natural sand soil;
4-8 - filters using in tests.

After placing in the chamber the sample was under load in one step to 270 Pa (safety coefficient).

During tests 1-4 the outflow of the water flew to the upper chamber, then to the filter and to the lower part of the unit; with that the water height in the piezometer connected to the lower part of the chamber was 2,0 m and higher.

In tests 5 and 7 the outflow of the water from the lower chamber was overlapped and was directed to the upper part of the chamber.

Table I. Properties of the clayey soils.

Clayey soils	Consistency W ; W_L ; W_P			density index
	natural	liquid limit	plastic limit	
Clayey foundation	$\sim W_L$	0,67 - 0,78	0,25 - 0,38	25-32
Under test				
The sample of undisturbed structure I	0,585	0,653	0,368	28,5
The sample of undisturbed structure II	0,623	0,585	0,273	31,2
* Kejsovka dam				

* The soil is testing by V.Volsky

Table II. Some data of consolidation-percolation tests of clay silt.

Numbers of test	Numbers of samples of undisturbed structure	The size of filter particle, D, mm	Before test		After test		Time T, hour
			moisture W	density ρ_s	moisture W	dansity ρ_s	
1.	The sample of undisturbed structure I	0,01-1,0*	0,585	1400***	-	-	9,0
2.	-"-	0,25-0,5	-"-	840	0,271	1870	42,0
3.	-"-	0,5 -1,0	-"-	900	0,257	1800	47,5
4.	The sample of undisturbed structure,II	2 - 5**	0,623	900	0,259	1340	0,5
5.	-"-	0,5-1,0	0,690	890	0,538	1300	47,0
6.	-"-	0,25-1,0	0,690	350	0,316	1330	48,5
7.	-"-	1,0-2,0	-"-	900	0,288	1330	2,0

* natural sand; ** the soil bulging through the filter;
*** the soil was compacted in addition.

The settlement of the sample was controled by gages fasten to pillars of the apparatus. It was the settlement of the soil sample over all experiment; if particles of filter had D = 2,0 - 5 mm and D = 1,0 - 2 mm, the soil settlement wass accompanied by the soil bulging through the filter and by the soil expanded from under extruding die during experimants 4 and 7.

Generalising various findings we can note that the condition for the seepage stability of plastic clayey silt contacting with testing fillings of filters having diameter lesser than D = 0.5 - 1 mm have been provided; if filters have D = 2,0 - 5,0 and D = 1,0 - 2,0 this condition have not been provided.

The values of permissible gradients with the soil moisture approaching to the value of the boundary moisture of the yield or exceeding this value in tests and with the known filter composition have been determined according to relation (4), table III.

We saw in this table that within limits of tests 4 and 7, where it was the soil bulging through the filter, the calculated permissible gradient was lesser than the gradient have resulted by the tests; that is the calculated data have been confirmed by experimental data.

So, the formula (4) is recommended for the estimation of the seepage stability of plastic soil in the contact with the filter laying on the surface of the pit slope.

It is our opinion that the filtration seepage stability of plastic clay soil under considerable scheme of contact would be provided if

$$i^{calc} < i^{perm} \qquad (5)$$

The calculated gradient of the lower part of the pit alope is equal to $i^{calc.} = 360$, that is lesser than the permissible gradient i^{perm} and the test gradient i^{test} under the condition that the seepage stability have been peovided (3). Consequently, the contact bulging strength of the soil will be provided if the diameter of filling filter will not be larger than D = 0,5 - 1,0 mm.

Under existing silt interlayers of the pit the outflow of the water will have the direction approaching to horizontal and will flow down the slope.

According to Pravednay's relation (4) we have controlled the scouring of clay silt interlayers of the slope contacting with filter filler having D = 0,5 - 1,0. Permissible gradient of the scouring on the contact is

$$i_c^{perm} = \sqrt{\frac{1}{D^{\circ}_{max}}} - 0{,}75\,, \qquad (6)$$

where D°_{max} - the maximum diameter of pore filter (cm).

On recommendation (2) D°_{max} is equal to

$$D^{\circ}_{max} = \alpha_n \cdot \lambda_{90} \cdot D_{90}\,,$$

where λ_{90} - the coefficient allowing for filter stratification in filling.

D_{90} - diameter of filter particle, particles having the lesser diameters amount 90% of total weight.

For the filter 6 having the coefficient of differential particle size Coef. 60/10 =1,41; α_n =0,32; λ_{90} = 1.

According to formula 6 under D = 0,9 mm it was determined i = 5,25 that is considerable greater than the calculated gradient of contacting scouring $i^{calc.}$ = sin a = 0,165 (a - the angle of pit slope deflection).

Consequently the filter 6 ensures the seepage stability of silty clay interlayers under seepage flow percolating along the line of contact. According to graphical relation by

Table III. The comparison of calculated permissible values of gradients with experimental values.

Numbers of tests	Soil properties: liquid limit W_L	Soil properties: moisture in the test W	T_o, Pa	Calculated size of pore filter diameter D^o, cm	Gradients permissible i^{perm}	In test i^{test}	The ensuring of seepage stability
1.	0,585	0,585	520	0,0062	3350	1080	It is providing
2.	0,585	-"-	-"-	0,0108	1920	-"-	-"-
3.	0,585	-"-	-"-	0,0224	910	-"-	-"-
4.	0,653	0,653	400	0,102	156	540	It does not providing
5.	0,653	0,690	280	0,0224	500	-"-	It is providing
6.	0,653	-"-	-"-	0.0144	780	-"-	It does not providing
7.	0,653	0,690	-"-	°,0345	320	-"-	-"-

V.S.Istomina (5) it was made the control of soil sand seepage stability of the pit slope on contact scouring.

$$i^{perm} = f\left(\frac{D_{10}}{d_{10} \cdot tg\varphi}\right), \qquad (8)$$

where d_{10} and D_{10} - active diameter of sand soil particle and filter particles;

φ - the angle of internal friction of sand.

If the soil properties are following: d_{10} = 0.12 mm; tg φ = 0,5 (φ = 27°) and diameter of the filter is D_{10} = 0,53 mm then formula is

$$\frac{D_{10}}{d_{10} \cdot tg\varphi} = 8,8$$

The point with this coordinate and i^{calc} = 0,165 are in the zone of permissible properties of contacting soils that the seepage stebility of sand places of pit slope is provided.

CONCLUSIONS

Oversaturated silt interlayers on the contact with coarse grained filters can be ustable it can penetrate into pores of protection filter and as a result of this is the slope sliding.

These explorations allow us to estimate the permissible content of granular filter having the diameter of particle D = 0,5 - 1,0 mm, it provides the seepage stability of the pit slope.

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