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SOBOLEVSKY Yu. and BARANOV N.
Byelorussian Polytechnical Institute, USSR
MIKHNEVICH E.
Byelorussian Research Institute, USSR

Stabilization of filtering slopes by means of glass-fibre and synthetic fabrics

Fixation de talus filtrants à l'aide de tissus en fibres de verre et synthétiques

Lors de l'exécution des fouilles et de la construction des ouvrages en terre dans les conditions des sols saturés en eau c'est la fixation des talus qui est le processus le plus difficile et le plus coûteux. Dans ces buts on utilise le plus souvent des structures en béton armé et en béton bitumineux aussi bien que des recharges en matériaux à gros grains. Les recherches ont fait voir que l'emploi des tissus filtrants en fibres de verre et des tissus synthétiques pour la fixation des talus simplifiait considérablement le travail et élevait le rendement de travail de 5 à IO fois.
Deux méthodes de l'utilisation efficace des tissus pour la fixation de superficie et de profondeur des talus ont été élaborées. Les experiences sur la fixation des talus à l'aide des tissus ont été effectuees dans une auge de sol et sur les chantiers hydrauliques et d'amélioration de la R.S.S.B. et de la France ou l'on avait utilise des tissus en fibres de verre soviétiques (ССТЭ, ССФ, АССТ, ТСФ) et le tissu synthétique français "Bidim". Quant aux talus soumis à l'action conjointe des torrents superficiel et de fond la construction la plus efficace est la fixation en tissus filtrants ayant la forme des poches de recharge remplies de matériaux à gros grains. Là où il n'y a pas de torrent superficiel il suffit d'utiliser la recharge à gros grains sur une couche du tissu avec l'enterrage des bords de ce dernier. Les éléments de construction de ces types de fixation sont calculés d'après la méthode élaborée. Si la déformation pénètre dans la profondeur du talus (parties à la filtration sous pression, gisement des sols par couches) il est raisonnable d'appliquer la méthode de profondeur, où les tissus jouent le rôle d'un élement de drainage et de renforcement. L'effect de drainage est obtenu grâce à une bonne permeabilité du tissu et celui de renforcement à cause de sa haute résistance.

At present synthetic filter fabrics are being increasingly used in Geomechanics. At first they were used as wraps for ceramic pipe joints and as braids for plastic perforated drain pipes in agricultural reclamation. They were also used as filters for water drawdown. Later the fabrics were used as drainage elements in order to make them more reliable and durable.

Synthetic cloths were applied to perform these functions beneath fills in clayey, muddy and peaty soils as well as in peat instead of fascines.

The application of synthetic filter cloths considerably reduces the quantity of natural drain materials in store such as:rubble gravel and torpedo sand. It also decreases transport operations of these natural materials, lowering construction costs in building graded filters in drainages and simplifying their design.

The fabric fibrous texture allows the passage of water, while, at the same time, filtering out most fine soil particles on the way of underflows. In contrast with natural drain materials they are capable of standing tensile forces on the filter slope surfaces and in the massif, as well as at the fill toes on the weak base under dynamic actions while freezing the soils heaved.

The combination of filtering and mechanical effects of the synthetic cloths is favourable for stabilizing filter slopes and saturated bases.

During last years the filtering fabrics have already been used both for surface drainage and uniform load distribution in loose deformed and swampy soils in such countries as: France, Belgium, Finland, the FRG, the USSR and USA. These may also be used for stabilizing earth fill slopes and artificial channels.

Our investigations have shown that the application of filtering fabrics in the slopes of drainage channels considerably simplifies work and raises labour productivity 5-IO times (while performing stabilization).

The aim of the investigations carried out by the authors of the report was to stabilize filtering slopes. The report presents some methods of the application of synthetic fabrics for this purpose.

The methods of stabilizing slopes proposed are used to protect the slope body and its surfaces from the action of various failure factors, such as: washouts by overflows and underflows, wave abrasion, weathering and the like. If the soil slope surfaces are not properly stabilized, this may become a cause of potential instability. In many cases the stabilizing cloths with their own weights eliminate the zones of the ultimate stress state both on the slope surface and inside.

Placed in sandstone and sandy soils, the filtering cloths, with their stabilization load pockets used, are applied to stabilize the slopes of drainage channels I.5-2.5 m deep.

Structurally, the stabilization (figI) is made in the form of stratified zones of glass-fibre or synthetic fabric(glass fabrics - glass nets; glued, knitted - sewn, non-woven and reinforced cloths; polymer soft filter materials) and as stabilization load pockets made of the same fabric filled with coarse debris materials(coarse sand, gravel-sand mixtures, rubble and others).

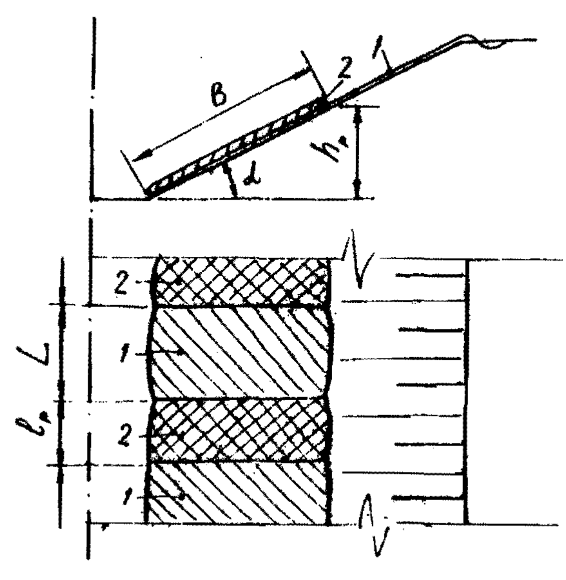

Fig.I Slope stabilization by means of the fabric with stabilization pockets.

I - fabric

2 - pocket

The fabrics must have a sufficient design tensile strength – R>I.5÷2 kg/cm. They must also be resistant to weather and hydrochemical effects.

When calculating the resistance value of the fabric stabilization, the design tensile strength given should be used

$R_z = K_d R$, kg/cm

where K_d – factor of deformation; $K_d \approx 0.I$ for glass-fibre fabrics; $K_d \approx 0.05 \div 0.I$ for synthetic ones.

The glass-fibre fabrics: ССТЭ, ССФ, АССТ, ТСФ have been tested as filtering ones.

For normal action of stabilization in non-suffusion soils it is essential that the water permeability of the fabric and the pocket coarse aggregate should be 5–IO times greater than that of the protected soil, no particle of the protected soil skeleton penetrating into the filter. In suffusion soils along with the requirements mentioned it is necessary that fine particles brought by the seepage flow from the soil should not clog up both the opened pores of the filter fabric and the material of the filling.

The condition of the glass filter being unclogged for non-cohesive suffusion soils is written in the form:

$$D \geqslant (3.3 \div 4.4)\ d^{max},$$

where D – pitch diameter of glass filter pores in cm

d^{max} – maximum diameter of soil suffusion particles in cm.

The coarseness and gradation of the pocket filling material may be neglected as the fabric itself protects it from scours and colmatage.

Choosing the distance L between the pockets one should bear in mind the fact that the filter fabric must resist, to a certain extent, the net effect of forces in the surface layer:

$$L \leqslant \frac{2 R_z m_c}{\gamma_s \delta K_f},$$

where m_c – coefficient of conditions of the fabric action; $m_c = 0.30$;

k_f – factor of safety; $k_f \geqslant I.IO$;

δ – design thickness of pocket stabilization load in cm;

γ_s – volumetric mass of the material of stabilization load in kg/cm^3.

The width of the stabilization load pockets l_p may be chosen taking into account the conditions of the necessary mass of the stabilization load according to the formula:

$$\ell_p \geqslant \frac{L}{\frac{a}{\delta} - 1},$$

where a – assigned thickness of the pocket in cm.

Being based on the hydraulic conditions of the stabilization action and non-admission of a great bed compression by the pockets, one may assume a = IO cm when the width of the channel bottom is b <I m and a = IO–20 cm and when b > Im, but in both cases $a > I.25\delta$.

When the stabilization parameters L, l_p and the width of the stabilization zone

$B = \frac{h_p}{\sin\alpha}$ (fig. I) are known the pocket filling mass Q_p will be

$$Q_p = \gamma_s\, a\, \delta\, B.$$

The width of the stabilization load is determined by the formula:

$$\delta = \delta_1 + 0.5\, h_w \frac{\gamma_w K_s}{\gamma K_\gamma},$$

where δ_1 – value defined by the diagram given in fig. 2 in cm

h_w – height of seepage in cm

γ_w, γ – density of water and of stabilization load material, respectively (in kg/cm^3)

K_s, K_γ – coefficients of soil permeability and of stabilization load, respectively (in cm/sec)

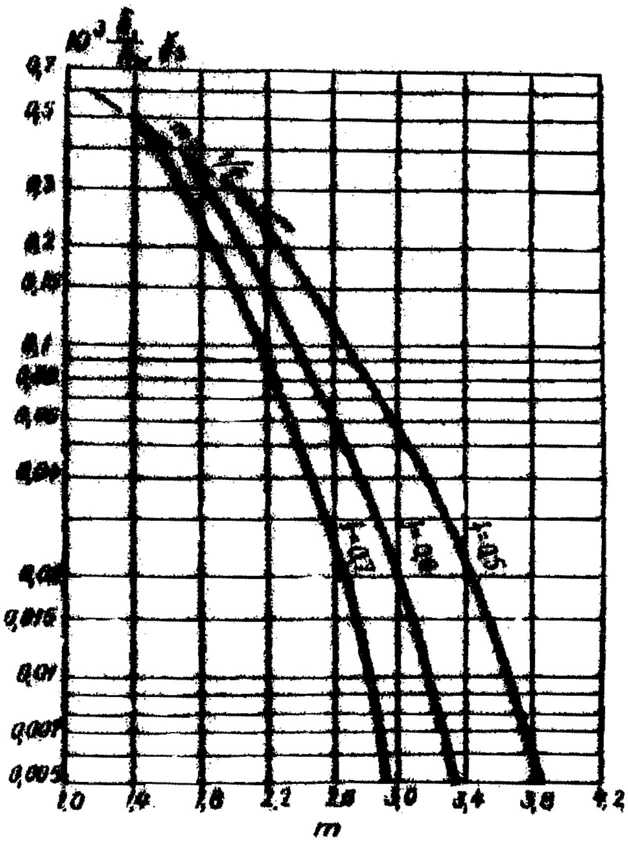

Fig.2 Determination of the component γ_1 of sand slope stabilization loads.

Pockets are filled on the building site, with **special mechanisms being employed (e.g. trailer spreaders equipped with conveyers used for feeding coarse grain**ed materials directly into pockets). To obtain full value of the mechanisms, however, it is essential that the pocket width be not less than 40-50 cm. A strip with pockets is prefabricated.

The investigations of the slope stabilization by means of the French filtering synthetic fabric "Bidim" (Rhône - Poulenc-Textiles) were carried out in the Fluid and Soil Mechanics Laboratory of the Grenoble university. A slope of uniform medium sand, with the coefficient of permeability being 0.0012 cm/sec was made in an experimental soil gutter 5 cm high by 42 cm wide. The slope was stabilized with the fabric, the weight of which was 300 m/m, the width 0.32 cm, the coefficient of permeability 0.59 cm/sec. The stabilized slope was tested at 45 cm head of water.

The results of different diagram studies (free placement, **anchoring into** the soil massif, anchoring at the toe and edge, stabilization loads with coarse debris materials) have shown that anchors used with a stabilization load are the most effective means to stabilize slope surfaces (fir. 3a,b)

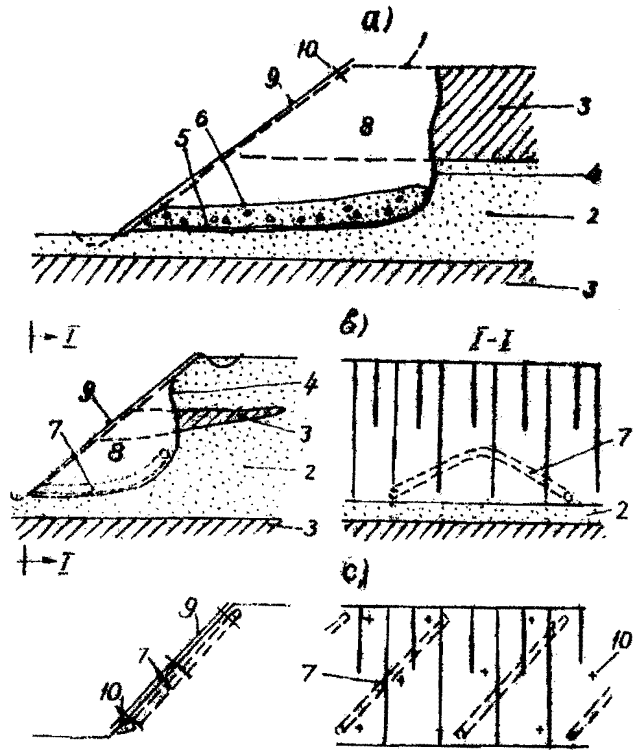

Fig. 3 The schemes of restoration and stabilization of filter slopes.

a - under the water action at gross head;

b - under the water action at local head;

c - in heaved soils;

I - initial slope profile;

2 - water-bearing layer;

3. - impervious and weakly permeable to water layers and lens;
4 - the profile after failure;
5,6 - lower and upper fabric layers;
7 - the plastic drain wrapped with fabric;
8 - filling of local soil up to the initial profile;
9. - flexible clothes
IO - cramps,posts;

The survey of the stabilization of the 6 m high top slope of the earth dam "Valcros" (near Tulon I970) has shown that the slopes stabilized with fabrics are sufficiently stable under the action of percolation pressure and meteorological factors.

During last years drainage channel slopes, road cuts and fills have been stabilized by planting grass over vegetable layers instead of their turfing. It takes not less than two years to create a strong turf blanket on such slopes and during these years the slopes are being subjected to the action of cloudbursts, the water of snowmelts and mechanical damages.The blanket made of a synthetic fabric net put over the sown slope allows to protect the grassy turf from all the above-mentioned damage factors.

The slope surface stabilization by the synthetic fabrics prevents the slopes from being scoured and slumped. However, under certain conditions such a method may not be effective enough, for example in case of slopes subjected to the action of pressure underflows.Surface drainage does not relieve seepage head (gross head) in the depth of the massif. Collapses in such cases are progressive, gradually spreading from the slope wedge beyond its edge.Field observations of drainage channels have shown that in most cases pressure zones are not larger than a few meters, resulting from various and changing nature of soil stratifications (morainic, marshy and others). The deformation development in pressure zones will result in irregular channel work. It is necessary to take it into consideration at the design stage, while choosing a method of stabilizing slopes but it is rather difficult to do it because of the lack of detailed data of engineering geological examinations in relation to a future channel route.

The restoration method of the collapsed zones (fig3a) was used for such conditions. The fabric layer 5 is placed on the zone of the sliding masses, sandy-gritty soil being spread over it, and then the soil layer again covered with the fabric 6. Then the filling with the local soil 8 is performed until the initial slope profile is restored. Taking into account subsequent consolidation, the filling is fashioned into a cambered profile. The reinforced layer of a deep drainage performed in the way mentioned (i.e. the layer of coarse debris soil between two fabric ones)provides both the relieving of seepage pressure inside the slope and stability as regards landslide deformations.

Similar deformations occur in stratified slopes when subsurface water is under local head (fig.3b). An effective means under such conditions is draining excessive water by means of a horizontal pipe drainage.The plastic drain wrapped with the glass fabric is laid along the contour of the slide. The drain is brought out to the surface at the toe. Then the profile restoration is made in the similar manner. The observations conducted for more than 5 years have shown that the restored zones of the profile retain stability.

When the height of a collapsed slope is more than 5 meters it is advisable to make a slope drain more powerful using the following technique. A shallow furrow or trench is dug parallel to the contour of the collapse. The trench is covered with the fabric and then filled with a coarse debris material. The filling is also covered with the fabric. The identical scheme is illustrated in fig.3b. This drain has a considerable water debit and it is of great importance under the conditions of groundwater with great debit.

The slopes made of heaved clayey and silt soils are usually stabilized by turf which, grown fast to the surface, becomes resistant to rupture. However, in many cases turfing does not make soil resistant enough to the slide of thawed surface layers down the slope.

Slope deformations are brought about by seepage flows appeared during thawing and directed parallel to the slope surface. To prevent such deformations it is advisable to drain the heaved soil surface layer with the help of plastic drain cuttings wrapped with glass fabrics, the drains being laid beneath the slope surface in shallow trenches at an angle to the edge (fig.3c). Such drains prevent free water from accumulating and clayey soils from transforming into a yield state. The local slope stability of the heaved soil surface layer stabilized by means of flexible clothes in conjunction with the surface drainage will be provided in the most unfavourable periods of spring thaws. Anchoring the flexible clothes in cohesive soils is carried out with cramps and posts.