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Reinforced earth in pipeline construction

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ABSTRACT: Results of researches on reinforced earth application in pipeline construction in Russia are given. Reinforcing interlayers based on rubber-cloth tapes provide pipelines stabilization on swamped and flooded territories, water erosion protection, increase the bearing capacity of filled bases. Method of basic parameters of reinforcing arrangements determination are suggested as well as fields of their application. The practical application of the developments in various regions of Russia corroborates the validity of arrangements suggested.

1 INTRODUCTION

Pipelines in Russia are constructed in very complicated engineering-geological conditions, this leads to structures stability loss, erosion disturbances, landslides and effects the pipeline systems reliability. One of the ways of the above problems is earth reinforcement with the aim of:

-providing the stabilization of pipelines on swamped and flooded territories;

-increasing the bearing capacity of reservoirs, structures, access roads, etc. filled bases;

-embankments slopes, rivers banks, ravines, etc. stabilization.

In USA, Canada and in european countries when pipeline laying earth reinforcement with geotextile was applied for pipeline stabilization in swamps, sea pipeline protection and during stabilization works in submarine passages ranges.

In Russia geotextile is known since 1976. It was applied at highway engineering in West Siberia. In 1982 when gas collector at Urengoi formation constructing geotextile and backfill were used for pipeline stabilization at design marks.

At present when pipeline construction side by side with geotextile, glass-fibre grids and rubber-cloth tapes are used.

2 MATERIALS

Rubber-cloth tape is a material consisting of several cloth interlayers (polyamid, polyester, cotton) that serve as a frame, and layers of resin-cured rubber.

Rubber-cloth tapes exhibit such qualities as high strength, durability conforming to pipeline service life, neutral reaction to environmental influence, decay resistance. Table I shows the comparative characteristics of materials used in Russia for earth reinforcing.

Table 1. Materials characteristics.

Material	Characteristic			
	Surface density, kg/m^2	Thick-ness, mm	Unit rupture load, kN/m	Ultimate elongat-ion, %
Geo-textiles	0,14-0,60	0,46-5,50	9-42	45-215
Glass-fibre grids	0,26-0,45	0,80-1,00	45-56	1-6
Rubber-cloth tapes	2,50-12,00	3,00-12,00	150-600	10-15

Rubber-cloth tapes show such qualities as low deformability, flexibility and elasticity. This allows their application as reinforcing interlayers in highway engineering in conditions of weak soils and for anti-erosion arrangements. High strength of the material makes it possible to use it for stabilization the pipelines with the diameter 1420 mm.

3 PIPELINES STABILIZATION

Method of pipelines stabilization with the backfilling and with the help of rubber-cloth tapes is applied in buried main and oil pipeline constructing on territories of predicted flooding, on periodically flooded alignment sections as well as on swamped territories with peat thickness less than 0,5 m. Rubber-cloth anchor arrangement is a flexible flat porous arrangement of rubber-cloth tapes with the thickness 5 - 10 mm. The tapes are joined together with steel ties. For anti-corrosion purposes the ties are coated with the protective priming. Rubber-cloth anchor arrangements (I) are laid onto the pipeline (2) being in design position in the bottom of a trench (3) (fig. I).

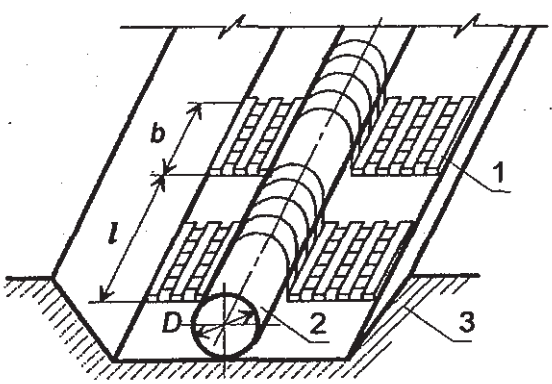

Fig. 1. Pipeline stabilization with the rubber-cloth anchor arrangement.

The ballasting ability of anchor arrangement is displayed due to porous rubber-cloth tape constraint with the soil prisms that are between trench and pipeline walls. The ballasting ability of rubber-cloth anchor arrangement depends on geometrical dimensions of a pipeline and a trench, mechanical-and-physical properties of filling and the level of a trench flooding.

We have carried out the experiments on the estimation of the holding capacity of pipeline soil filling without soil reinforcing and with the rubber-cloth anchor arrangement reinforcing. The experiment procedure is the following: the pipe of 720 mm diameter, 3 m long is placed into the trench of 1,6 m depth. The trench is filled with the back filling - a loam. Then the soil filling was fully water - saturated. The next step is pipe pulling out with the crane-pipelayer. The vertical displacements are estimated with the help of the level and the holding capacity of the soil filling with - and without reinforcing is evaluated with the dynamometer.

The results of site investigations show the ballasting ability of the rubber-cloth anchor arrangement (2) to be 1,5 - 2 times more than that of the filling only (I) (fig. 2).

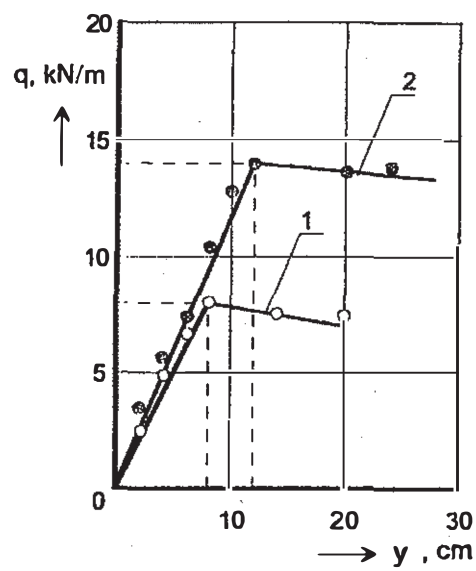

Fig. 2. Results of ballasting ability determination.

Reinforcing with the synthetic materials (geotextile, glass-fibre grids, rubber-cloth anchor arrangement) can be applied in conditions of sand and clayey filling with the exception of frozen filling when:

$$q < 23{,}8\,D - 0{,}62$$

where q - pipeline load acting vertically upwards without pipeline dead load, kN/m; and D - pipeline outside diameter, m.

4 FILLED-UP BEDS

In underlaying sandy and clayey soils with shear strength $R_S \geq 75$ kPa, modulus of deformation $E \geq 5$ mPa the reinforcing interlayer (3) of rubber-cloth tapes with 3-5 mm thickness must be laid onto the filled-up bed surface (2) (fig. 3b). In underlaying weak water-saturated soils with $R_S < 75$ kPa and $E < 5$ MPa the reinforcing interlayer (3) must be laid at the boundary between the underlaying layer (I) and filled-up bed (2) (fig. 3b). The above arrangements can be used when reservoir bases constructing, in highway engineering along the road alignments, in developing oil and gas fields.

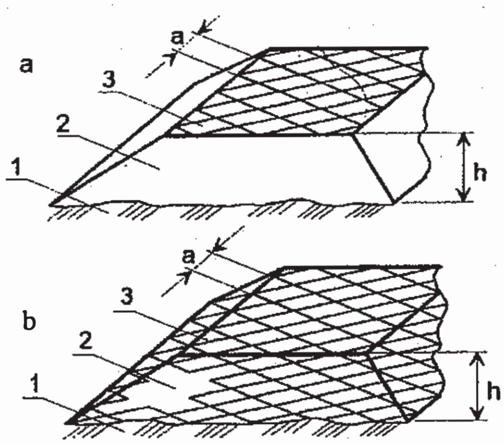

Fig. 3. Filled-up beds.

The settlement of reinforced filled-up bed is a function of external load parameters, underlaying and filled-up soil characteristics, geometrical dimensions and elasticity modulus of reinforcing interlayer and filled-up bed thickness. The experiments have been carried out in the laboratory according to the following procedure: in a tray different pavements were modelled and stamp tested. The stamp diameter was 0,1 m, the pressure - 0,55 MPa, the sand was used for the filled - up bed models, the models of the reinforcing interlayer were constructed of the rubber-cloth tape. While testing the filled-up bed thickness changed between $0{,}5D_S$ and $3D_S$. The conditions of low-bearing interlaying soils were modelled in a tray. The models settlement was measured with the deflectometer. Figure 4 shows the experimental results of model highway settlement determination in weak water-saturated soils. The dimension (a) increase leads to settlement (s) increase and at $a \geq 1{,}5\ D_S$ (D_S is a stamp diameter) the reinforcing doesn't influence the value (s). The same is with the filled-up bed height $h \geq 5Ds$. However, with $a=0{,}9D_S$ and $h=D_S$ the settlement value equals that of the filling without reinforcing with the thickness $h=2D_S$. The experiments show the elasticity modulus of the reinforced bed to be twice less than that of the unreinforced bed.

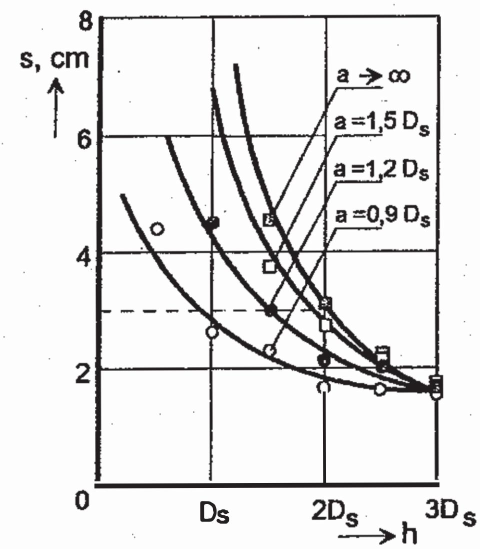

Fig. 4. Results of model beds investigation.

Figure 5 shows the methods of the dimension (a) determination in dependence on filled-up soil height (h) and design resistance of the underlaying soils (R).

5 ANTI-EROSION POROUS ARRANGEMENT

The arrangement is applied for anti-erosion protection of: river slopes with steepness up to 30°, ravines slopes with steepness up to 35°, washed-out regions in river beds, embankments and excavations slopes. Anti-erosion porous arrangement is made of separate elastic, high strength, rubber-cloth tapes with thickness 10-12 mm and width (h), pointwise joined in definite places. The arrangement is transported as a rolled mat. In place of its setting the stretching of mat tapes is made untill three-dimensional, diamond-shaped cells are formed with the edge length (l) that is less than the cell

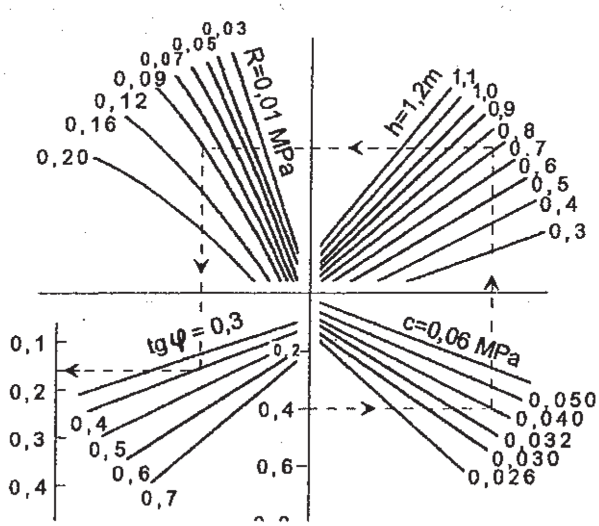

Fig. 5. Nomogram for the dimension (a) determination.

diagonal (a) (fig. 6). Unrolled adjacent mats are interlocked and form the solid cover along all the area of anti-erosion arrangement. Along the perimeter the arrangement fastens to the soil bed.

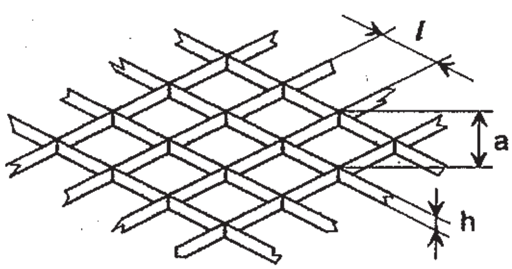

Fig. 6. Anti-errosion porous arrangement.

Depending on hydrodynamic effect the arrangement cells are filled with clay, loam, sand, sand-gravel mixture, gravel. The grahpical interpretation of the dimension (a) dependence on the slope steepness (α), filled soil charateristics and hydrodynamic flow influence that are described by the generalized parameter (γ) is given below (fig. 7).

6 CONCLUSION

As a result of researches conducted, the reinforcing interlayers are worked out based on rubber-cloth tapes of high strength and durability. The application of such tapes for earth reinforcing in

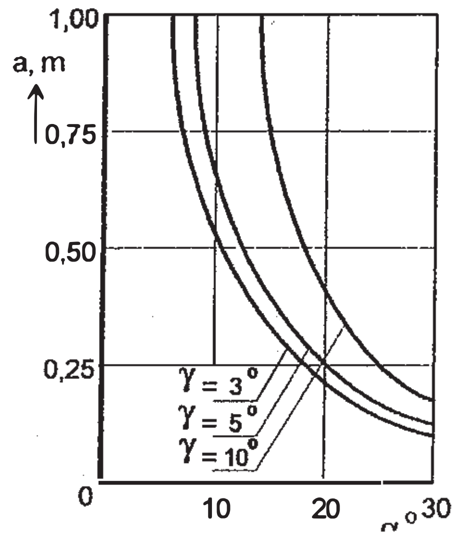

Fig. 7. The cell dimension determination.

pipeline construction allows: to increase the bearing capacity of pipelines fills 1,5 - 2,0 times; to decrease the filled soil dimensions with maintaining its bearing capacity; to increase the modulus of elasticity twice; to exclude the slope erosion. Fields of application of the above suggestions are outlined, engineering methods of design and technological schemes of construction are worked out. The practical application of these developments was realized when pipelines of 219-1420 mm diameter constructing in conditions of swamps, river crossings and highway engineering along the road alignments in weak soils in regions of Central Russia, Urals, Povolzhje and West Siberia. Earth reinforcement allows to exclude a large amount of reinforced concrete blocks, steel anchors, stone, crushed rock and to decrease transport expenses.

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