Usage of geosynthetic materials in the geotechnical practice

Utilisation des materiaux synthetiques en geotechnique

A.A.Bartolomey, V.G.Ofrikhter & A.B.Ponomaryov – *Perm State Technical University, Perm, Russia*

ABSTRACT: Nowadays the construction sites do not meet the compact civil engineering requirements under the actual ecological and antropogeneous urban conditions because of unstable (e.g. soft, wet, technogeneous) soils they are built on. The standard engineering practice results in considerable material expenditures being unequal to the economic effect to come in these complicated conditions

RÉSUMÉ: Dans les conditions de la construction dense compte tenu de formée écologique et le facteur humain, dans les villes, à présent, les constructeurs doivent utiliser les chantiers déposé structuraux instables (faible, en état de la saturation complée d'eau, les ordure de construction, de vie, technique etc.). L'utilisation des approches connues de construction dans les conditions donneés de problème de génie géologiques, amène en général aux dépenses considérables financières incommensurables avec la retombée économique attendue

1 INTRODUCTION

When using the geosynthetic materials, the engineers can transform the soils properties according to their purpose. But the structures are not used at a large scale in the soil conditions of Russia at all. That is why special dies of soil foundations should be developed. At present the researchers of the Perm State Technical University study the geosynthetic materials effects in the soil foundations in the industrial, civil and transport engineering.

2 SILTY - CLAYEY SOILS FOUNDATIONS REINFORCEMENT

The soil reinforcement is considered to be a perspective trend in the field of foundations erection on the soft soils. It improves soil consolidation and excludes expensive materials, constructions and techniques to be used. Thus, material and labour expenditures can be saved to a higher extent.

To study the reinforcement effect on the soil bearing capacity, the model and full-scale tests were carried on the saturated, silty - clayey soils when changing the water content due to the model tests, the optimal structures and field to use the reinforced clayey soil were defined (Bartolomey et al. 1996).

But the model tests could reflect only the qualitative picture of the phenomenon. So, to gain the quantitative data, the full-scale tests were carried on clayey soils (Bartolomey et al. 1999). During the tests the strain-deformed state of the reinforced foundation was to be studied.

The full-scale tests were carried on the test-site built on the soils of the wet clay having soft plastic consistency. The reinforcing material was pulled into the soil for 0.15 m. The glass cloth with the breaking load 390 kN/m and elongation at rupture 0.2% was a reinforcing material used. The reinforcement pulling into the soil was equal to the diameter of a die, and the total diameter of the reinforcing interlayer was 1.8 m. The strains and deformations were measured in the active foundation zone where the tests took place. The stiff die with the diameter 0,6 m was used in the tests. The structure of the die allowed to take measures of the contact strain on the bed. The control tests on the non-reinforced foundation were carried on to compare the results. In these tests the load was risen to fail the die stability, in the case of reinforced foundation – the rupture of reinforcing interlayer. The results of the tests on the die are depicted on Figure 1.

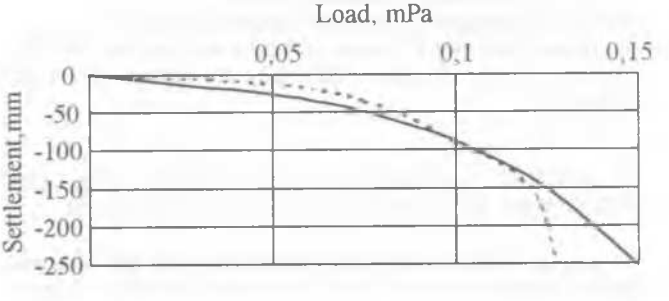

Figure 1. Settlement dependence on the load under the reinforced and non-reinforced foundation tests (- - - - non-reinforced soil, ——— reinforced soil)

The results of the tests show that foundation reinforcement increases actually the bearing capacity of the foundation in 1.5 times. The effect of the reinforced foundation under the load differs greatly from the non-reinforced one. There is no real loss of reinforced foundation stability in the range of the given load on the die even when the reinforced interlayer has been ruptured.

The test results were used in the erection of steel tanks for coagulated water storage having the volume of 630 m^3 one by one. The diameter of the tank was 10.5 m, height – 8.5 m. The bearing ground of the foundation was the loam of mushy consistency characterized by: the specific weight – γ=1.86 kN/m^3, humidity – w=0.3, the compression module of deformation E=2.37 mPa, the specific bond c=14.0 kPa, the angle of inner friction φ=12°. The designed resistance of the soil was 83 kPa.

The two tanks were put on the beds reinforced by a synthetic nets with the strength limit on rupture 390kN/m. The measures of the displacements for the marks attached to the walls of the tanks were taken during hydro-tests. The measures taken resulted in the following values of the vertical marks displacements: maximal settlement – 19.5 mm, maximal difference of the settlements in the two adjacent marks on the distance of 6.0 m between each other – 4,0 mm, the maximal difference in the settlements of the two diametrically opposite marks – 6.5 mm, the maximal tilt of the foundation – 0.00062. The values obtained

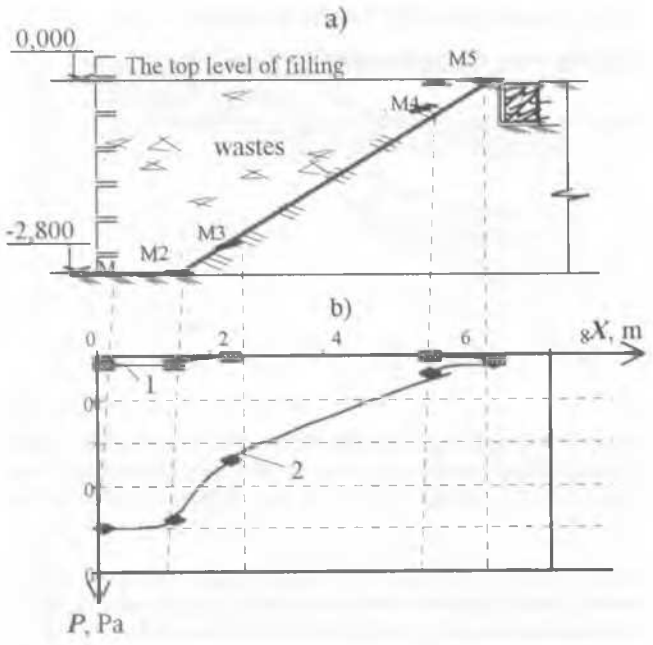

Figure 2. Definition of the normal pressure in the soil foundation: M_1... M_5 – the load-cell strain gauges of the total pressure

are much lower than the tolerance limited ones according to the normative documents and that fact indicates the high stiffness of the foundation made of reinforced soils and it proves the effectiveness of these structures when they are used in civil engineering.

3 SYNTETIC MATERIALS USED IN THE CIVIL AND INDUSTRIAL WASTES STORAGES CONSTRUCTION

At present, standard engineering practice of civil and industrial wastes storages does not satisfy the required level of the environmental protection.

To add up, they are rather expensive. The most burning problem is to build the toxic wastes storages. As a matter of fact, the storages used to be built on the unfit territories where the soil conditions are characterized by the low bearing capacity. So the local soil has to be changed by the imported one on the construction sites of the storages. The imported soil is represented by sand crushed rock while the slurry wall is made of cement or concrete.

Geosyntetic materials (geomembrane and geotextile) increase reliability and decrease engineering expenditures. They can be used together with imported materials to be in lower quantities in several folds. The given engineering practice was used in the erection of oil field wastes polluted by radioactive materials, in the Osinski district of the Perm region.

Taking into consideration the degree of the erection responsibility and complexity of geological conditions in the construction site, the storage erection and prolonged full-scale test were started at the same time. The aim of the full-scale test was to obtain the values of the actual strains and deformations being directly under a geomembrane in the foundation and in the slopes of the storage bowl on the different stages of loading. The load-cell strain gauges were attached into the soil foundation according to the definite diagram of the total pressure. The data from the strains gauges were taken both before the starting point of the storage loading (after the attachment of geomembrane into the storage fowl) and on the different stages of wastes loading. Measured results are shown on Figure 2. The testing resulted in data depicting strain-deformed state of foundation and strain redistribution in the geomembrane.

This gives the possibility to predict "wastes storage – soil foundation" system work.

4 FILLED-UP CLAYEY SOILS CONSOLIDATION ACCELERATION DUE TO THE DRAINAGE INTERLAYER FROM SYNTHETIC MATERIALS

When there are no construction sites, it stands to reason to use the saturated soils to erect the road-bed. The saturated soils are wide-spread in Russia and in some region in the North and Siberia all local soils are actually wet. The standard engineering practice on the soil artificial moisture-proofing (e.g. treatment by lime and cement) is applied only in the cases when the layers are comparatively weak (20-40 cm). It is unreliable for strong layers from the economical and technological points of view. And civil engineers have to use original saturated soils.

Nowadays, famous technological practice can predict the earth embankments caused by saturated soils. And special measures such as the soil drainage and reinforcing interlayers can be taken to solve the technological problems (VSN 49-86 1988) the soil drainage is the effective way to increase the road-bed consolidation. It occurs in the arrangement of drainage layers in the body of the road-bed to accelerate the saturated soils consolidation.

The algorithm to calculate the drainage layers for the consolidation acceleration in this case must conclude the following steps (Giroud 1983):

1. To define the speed of soil moisture-proofing during the consolidation process;
2. To define the water volume drifted along the geotextile;
3. To prove the parameters and to choose the geotextile element.

Due to geosynthetic materials used, drainage material volume can be decreased, the drainage effectiveness can be increased by decreased rate of clogging, the drainage material and soil cannot be mixed, the water drift can be accelerated, and the earth erection stiffness can be increased.

At present, in Russia geotextile materials are produced for the drainage constructions composing the regenerated synthetic fibers from the old domestic articles. They have the surface density 350-400 g/m^2 and the width is about 3 mm and they are especially waterproof in the bed-plane, but they overcome the sand interlayer with thickness of 60 cm in the drainage effect.

Now in the Russian Federation the geotextile materials are not much used primarily because there is no normative base of the geotextile usage and secondarily, the range of the main obstacle disregarding their wide-spread use in various branches of civil engineering. All these facts advanced the research work of the scientists working at the Department of foundation, basements and materials at the Perm State Technical University. They focus their attention on the earth erection effects when using synthetic materials under the geological conditions in the Western Urals. They are especially interested in the geotextile elements effects on the earth erections consolidation when clayey soils are fully saturated. Geotextile element is studied as a reinforced element and a filter capacitor. Geotextile materials are proved to be used in transport engineering as well.

5 STABILITY PREDICTION OF THE SLOPING ROAD EMBANKMENTS BEING REINFORCED BY GEOSYNTHETIC MATERIALS

The numerical analysis advanced by the finite elements method was carried out to find out the reasons of the earth embankment stability. The stress-strain state of the high earth embankment (maximal height 15.4 m) was checked just on the spot of the highway built in 1998. It was completely ruined in spring 1999 (there were cracks in the asphalt-concrete pavement and the earth embankment stability was at a zero point (Alekseev et al. 1999).

To rise the total stability of the earth embankments, many technological methods can be used. But after the technical and economical comparison of the variants it was agreed that the most effective technological practice became the usage of the geosynthetic reinforcing interlayers in the body of the earth em-

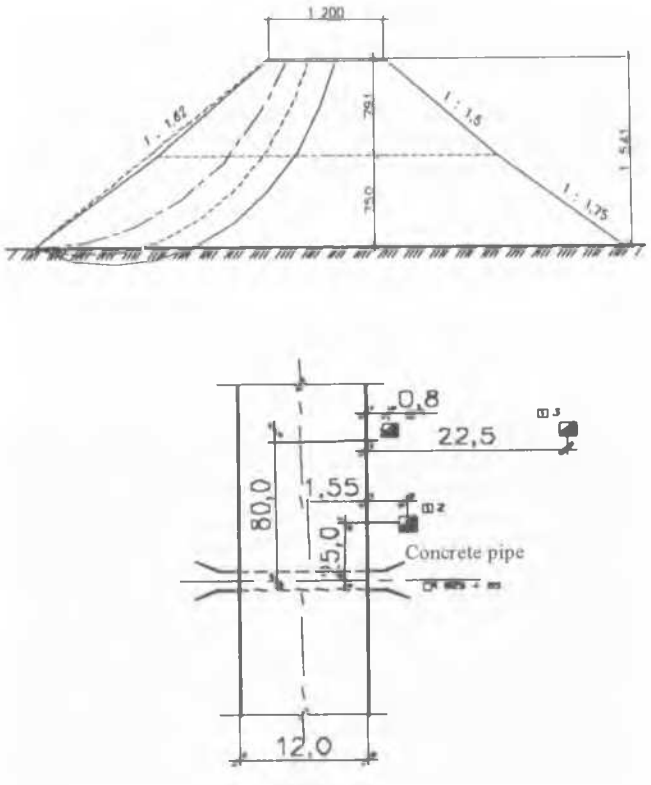

Figure 3. Embankment stability calculation results

- on the basis of the worst soil characteristics – pit No 1 (K_y=0.749)
- on the basis of the best soil characteristics – pit No 2
- in the case of the reinforced embankment – pit No 3 (K_y=1.433)

bankments. The finite elements method enables the embankments and foundations soils to acquire various qualities. We can also study the components of the strained state when there is an optimal distribution of soil qualities along the embankment cross-section. Non-uniformity and anisotropy present a special testing too.

The initial calculation data are the geometrical parameters, describing dimensions and contour of the road embankment (height and width of the embankment, slope laying); physico-mechanical characteristics of the foundation soil and embankment (the modulus of elasticity, Poisson's ratio, soil stability, cohesion coefficient), the reinforced scheme (the amount of reinforced layers, the distance between them, reinforcement strength parameters), the calculation in the units drifts and strain in each finite element of the calculated field.

On the basis of the calculations conducted stress-strain state was analyzed. The following factor were also taken into consideration such as the factors effecting the high embankments stability, the steep of a slope, the slope configuration, the effect of loading benches, the soil properties, the embankment engineering practice, the amount of reinforcing layers and, finally, reinforcement strength characteristics. The embankment body must be reinforced by a step of 0.5 m along the height of 7 by synthetic nets with calculated resistance on rupture 100 kN/m (Figure 3).

6 CONCLUSIONS

The usage of synthetic reinforcing materials is an effective way to obtain the high embankments total stability.

REFERENCES

Alekseev, V.I., Kleveko, V.I., Ponomaryov, A.B. 1999. Causes for high road's embankment failure. *Foundations under Urals geological conditions. 1999:* 43-47 Perm: PSTU.

Bartolomey, A.A., Kleveko, V.I., Ofrikhter, V.G., Ponomaryov, A.B. 1996. Use of geosynthetic materials for increase bearing capacity of clayish beddings. *Geosynthetics: Application, design and construction. Proc. First European Geosynthetics Conference EUROGEO 1. Maastricht, 30 September – 2 October 1996:* 459-461 Rotterdam: Balkema.

Bartolomey, A.A., Kleveko, V.I., Ofrikhter, V.G., Ponomaryov, A.B. 1999. The use of synthetic materials in the highway engineering in the Urals. *Geotechnical Engineering for Transportation Infrastructure. Proc. Twelfth European Conference On Soil Mechanics And Geotechnical Engineering, Amsterdam, 1999:* 1197-1202 Rotterdam: Balkema.

Giroud, J-P. 1983 Geotextile drainage layers for soil consolidation. *Civil engineering for practicing and design engineers Vol.2 1983*: 275-295 Chicago: Pergamont Press.

Kleveko, V.I., Novodsinski, A.L., Ponomaryov, A.B. 1999. Reinforced soil's foundation for steel reservoirs on the weak soils. *Foundations, bridges & roads design. Proc. Interuniv Conf., Perm, 1999:* 18-19 Perm: PSTU /in Russian/.

Ofrikhter V.G., Ponomaryov A.B. 2000. Burial place for radioactive waste. *Proc. Second European Geosynthetics Conference EUROGEO'2000. 2000:* 907-909 Bologna: Patron Editore.

SNiP- 2.01.28-85 (Russian code). 1985. *Remediation and burying farms for toxic industrial wastes. 1985* Moscow: Stroyisdat /in Russian/.

VSN 49-86 (Russian departmental building code) 1988. *Guidelines on increasing the bearing capacity of road embankments by using synthetic materials. 1988* Moscow: Transport /in Russian/.