Using geosynthetics for soft ground stabilization in the approach to the Volhov River Bridge

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ABSTRACT: This paper highlights recent experience of the geosynthetics applications during the reconstruction of the roadbed on the soft grounds.   The piles foundation was used to reduce the difference settlements on the approaches to the bridge across the Volkhov River. The stripe drains are used to accelerate the settlement and reducing pore pressure in the foundation soils of embankment. Laying mattress, which was made from uniaxial geogrid, has enabled to increase the carrying capacity of the foundation. The lightweight embankment from XPS blocks have not changed the load based on the existing subgrade, which allowed refusing from the base reinforcement.

Keywords: stripe drains, reinforcement, geosynthetics, mattress

1 INTRODUCTION

The bridge over the river Volkhov was built in 1957. The width of the roadway is only 7m. Under the bridge two navigable span, vertical clearance dimension of each of them is 10m. The approaches to the bridge are made in the embankment by the height of 4.5 m on the right Bank and up to 10 m on the left. An embankment of approaches is stable and is in good condition.

Because the category of road was changed and the required vertical clearance detention exceeded the current almost 4 m, it was necessary to increase the longitudinal profile and provide widening roadway from 2 to 4 lanes.

The modern upper Quaternary sediments, glaciolacustrine, lacustrine origin underlain by rocks Lontovasskoy Suite (€ ln) of the Cambrian system are situated as a geological structure of the site to a depth of 30 meters .

Upper Quaternary lake sediments are represented by fluid and very soft consistency silts with lenses of water-saturated silty sands. The very soft and fluid consistency silts with a capacity of 1.3 – 24.3 m. fill the Volkhov river palaeovalley. Maximum capacity of silt was observed in the river Volkhov main channel. The thickness of the silt is decreases as the distance from the shore is increase and there is a sharp and irregular changes in the silt thickness .

The upper Quaternary deposits in areas of the projected bridge abutments is under laid by the Cambrian sediments of Lontovasskoy Suite (€), which are represented by clays with a capacity of up to 24 m.

2 PROJECT APPROACH

The best option and the minimum of the costs of strengthening weak soils, located at the base of the embankment were approved due to the comparing different design options.

The flood plain was covered by the 33m spans to reduce the soft soils reinforcement.

The soft subgrade reinforcement was foreseen at the stage of the project. The laying of woven geotextiles and sand piles-drains by the diameter 0.80 m. to the depth of 10 m. and with step of 2.6-3.4 m. were provided (Figure 1). The drains should be filled with sand with a filter factor of more than 6 m/day and the 10% of lime was supposed to be added to increase their effectiveness.

The calculated settlement was from 0.26 m to 1.1 m depending on the height of embankments and capacity of a weak soil layer. The calculated soils consolidation time was 2.5 years. This period corresponded to the duration of the construction phases and allowed to bring these areas up to the design position.

The roadbed body reinforcement was performed by the 3 layers of woven geotextile to uniform the setting of existing and a new embankment.

The base cone reinforcement was made by the three layers of woven geotextile to prevent the butment deformations from a deep shift in the foundations.

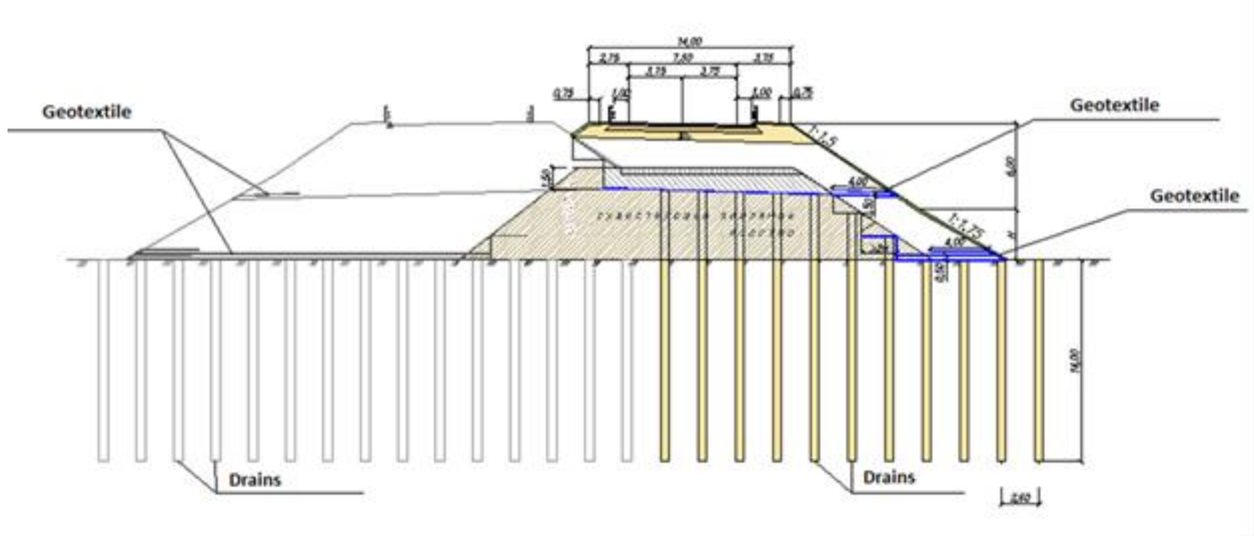

Figure 1. The design cross section.

The PGUPS was attracted by customer as a consultant to expedite the object ending as it has had an extensive experience in the application of modern technology of roadbed construction on the soft ground.

The geotechnical investigation of the site has been made together with the project organization which included laboratory studies of strength and deformation characteristics of silt at different degrees of consolidation.

The geotechnical analysis, conducted by the PGUPS, allowed offering the following constructive solutions.

Firstly, the replacement of retaining-type abutment on the abutment with separate functions was suggested. As a result, it is not necessary to build the cone and to strengthen it base.

The abutment with separate functions was made as retaining wall, which was reinforced by geogrids with a step of 45cm and was lined with concrete blocks. The transition slab laid on the retaining wall and bridge pillar.

Due to the fact that the new approach to the bridge will situate adjacent to the existing roadbed, which is located on the soft soils, the foundation from prismatic piles was made to provide the transfer of load on the solid soil. Foundation from drive concrete piles with a cross section of 40*40 cm length from 10 to 22 m and with 2.2 m. step was arranged for 20m. from the bridge. The grid foundation was arranged over the piles (Figure2). The space between the rigid strip grid foundations was covered by a flexible plate from a crushed stone layer, reinforced with three layers of biaxial polypropylene grid.

Figure 2. The grid foundation

At the site of the new embankment the vertical drains was installed to complete the intense part of settlement in 6 months. The drain tape consists of a z-shaped core, which is surrounded by a nonwoven geotextile. Due to the drainage core, structure the material provides maximum drainage capacity.

The vertical drainage installation allows to accelerate the base consolidation due to the reduction of the filter water way which is squeezed out from the weak layers, to reduce the hydrostatic and pore pressure, which in turn significantly increases the bearing capacity of the embankment foundation. The main advantage of the vertical drains device in the given geological environment is the rapid increase in the shear resistance of the foundation soils and a high installation speed. The distance between the drains is 0.8 m. and the installation depth is 8-12 m (Figure 3).

Figure 3. Drains installation

The process involves a vertical tape drain installation in the ground, using a special device, which is hung on the excavator. The drain lower end is attached to a special anchor that prevents the drain pulling from the soil. After submersible rod extraction, the vertical drain ends are cut off, leaving the ends of a length of 50 cm over the surface.

The geocell mattress from uniaxial polypropylene geogrid, which was filled by crushed stones, was arranged at the bottom of roadbed in order to ensure the bearing capacity of weak soil bases (Figure 4) .

Figure 4. Geocell mattress installation.

This design solution was tested in advance by simulation in a centrifuge. (see Figure 5).

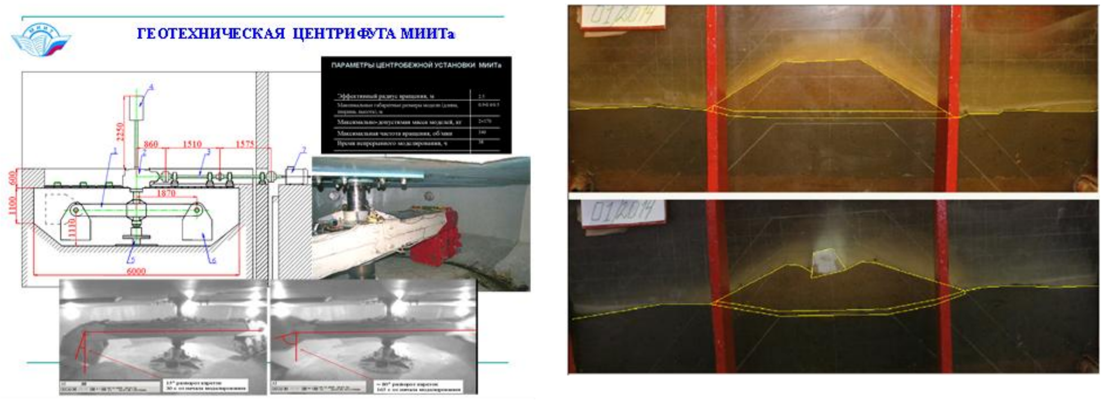

Figure 5. Centrifuge and modelling result.

The roadbed construction is necessary to be make in stages, by pre-consolidation due to insufficient bearing capacity of the foundation subgrade. The pore pressure can reach its limit during construction of new embankments on the weak soils that can cause their heaving. To prevent this, the magnitude of pore pressure and the embankment settlement monitoring was conducted..

The figure 6 shows that after the start of the backfill, the pore pressure grew, and after reaching the formation level, it had being started gradually decline, marking the filtration stage end of the foundation soils consolidation after 6 months.

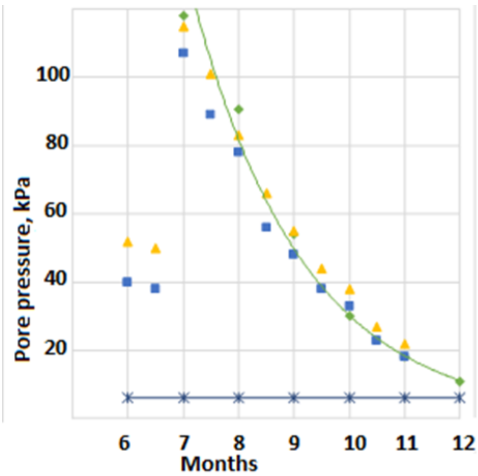

Figure 6. Dependence of pore pressure on time.

Since the soils under the existing embankment were in a consolidated state, it was proposed to use lightweight embankment to raise the design level.

The lightweight extruded polystyrene foam blocks with dimensions 2,4*0,6*0,5 m. were laid in the top of the existing subgrade in order to reduce the load on the underlying weak subsoils. The blocks were fastened together by means of rods. The blocks array was wrapped non-woven geotextile in order to achieve the greater integrity (Figure 7). A 1 mm thickness geomembrane was laid under the road pavement for blocks insulation against possible leaks of petroleum products. The polystyrene blocks were placed on the roadbed after cutting the existing pavement to a depth of 1.2 m. and they do not create additional load on the ground after the subgrade construction to the design elevations.

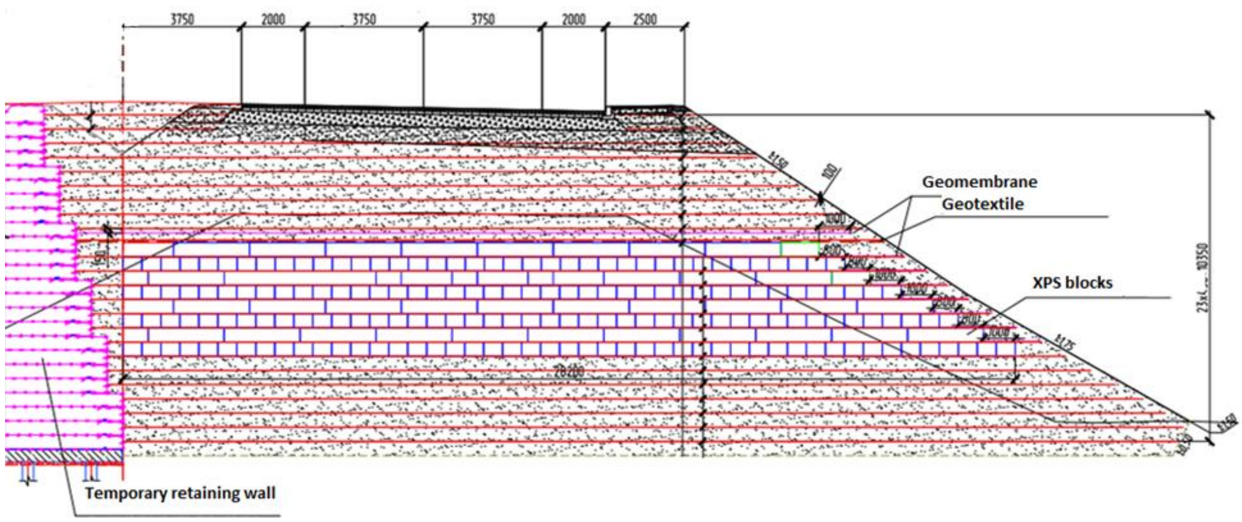

Figure 7. The design cross section

The specified design solution allows lying a pavement immediately after the subgrade construction completion.

During the construction of the first stage embankment, a temporary retaining wall, reinforced by polyester geogrid, were arranged to make the lightweight embankment on the second phase of construction. This got a possibility to ensure the safety of the passing trucks along the first construction stage roadway during cutting the soil of the existing embankment.

3 CONCLUSIONS

These design solutions were used and in the past. The uniqueness lies in the fact that they were used on a one object and have allowed to build road embankment by height to 10 m. on the silts with a capacity of 6-10m. The asphalt was lay in a year after the construction was started and the initial cost was reduced.