APPLICATION OF REINFORCING GEOTEXTILE INTERLAYERS FOR THE PURPOSES OF SUBGRADE RECONSTRUCTION ON SOFT SOILS

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ABSTRACT: Two sections of Minsk Ring Road located on swampy flood land were rehabilitated in 2001-2002. When designing the subgrade reconstruction, widening in particular, four possible options for sections on soft soils were considered: (i) construction of elevated road; (ii) installation of concrete piles; (iii) application of vertical sand drains; and (iv) floating embankment. Upon detailed analyses the floating embankment option was accepted. To speed up the process of embankment settlement stabilisation on soft soils and to increase their strength reinforcement with continuous polypropylene geotextile fabric of local manufacture was used. This allowed to complete reconstruction during one construction season and to provide considerable labour and material savings.

During the years of 2000-2002 reconstruction of Minsk Ring Road was carried out with two locations crossing the swampy flood land of the Tsna river. The existing embankment height above the swamp surface was 2.5-2.8 meters on the first section (km 43.7 – km 43.9) and 1.0 – 3.0 meters on the second section (km 42.8 – km 48.5).

In the course of reconstruction the existing subgrade of 13.0 – 15.0 meter width was widened up to 33 meters, mainly from one side. Therewith the mark of the embankment top varied insignificantly: on the first section embankment raising constituted 0.2 – 0.3 meters and 0.7 – 0.8 meters on the second section.

The status of the existing subgrade constructed as the “floating embankment” in early 60-s was good. Considerable embankment settlements after completion of the road construction were not registered. Slope stability was provided. No fluctuations of the embankment were observed under traffic loads, which proved its dynamic stability.

The swamps in the Tsna river flood land were drained. In terms of geology swamp soils are represented by peats and under laying organic-mineral silts (sapropel soils). The depth of peat layer varied from 1.0 to 3.0 meters and that of sapropel from 2.0 to 14.0 meters. Desides on the second section there is 0.5-3.0 meter depth sandy interlayer between peat and sapropel.

According to the data of engineering and geological studies performed in 2001 swamp soils are characterised by the physical and mechanical parameters presented in Table 1.

When designing the subgrade widening four possible options of the road way lying across the observed sections on soft soils:

- elevated road of 9 meter span on pile foundation;
- embankment on reinforced concrete piles driven into the mineral bottom layer for 2.0 – 3.0 meter depth with 4 and 3 meter spacing and with prestressed concrete slabs of 6 x2 meter size, geotextile fabric and embankment soil being placed on the top;
- floating embankment with partial substitution of peat layer up to the ground water level and geotextile reinforcing of the embankment body. To speed up consolidation of soft soils temporary surcharge in the form of additional layer of 1.5 - 2.0 meter depth was should be applied.

Table 1 Physical and Mechanical Parameters of Soft Soils

Description	Parameter Value			
	Peat		Sapropel	
	Km 43.7-43.9	Km 48.2-48.5	Km 43.7-43.9	Km 48.2-48.5
Natural moisture, %	492	400	107/120	180
Porosity coefficient	8.4	8.0	3.9/2.1	4.3/2.1
Dry soil density, g/cm^3	0.2	0.17	0.5/0.8	0.5/0.8
Shear strength, MPa	0.02	0.025	0.045/ 0.09	0.06
Strain modulus, MPa	-	-	3.0	3.0

Technical and economic comparison of the above options showed that the first option cost 3-4 times exceeded the cost of option two and 6-7 times of option three and option four. Except the higher cost it was impossible to implement the first option within the specified construction period and due to technical reasons.

Implementation of the second option would require application of the large quantity of reinforced concrete elements (more than two thousand of piles and one thousand of slabs). Therewith on sections, where the depth of soft soil deposit is 16.0 meters and more, application of articulated piles would be required, which would make carrying out of the works more complex during winter time.

Option with vertical sand drains was not accepted also due to the fact that there is no specialized contractor in the Republic to fulfil this type of the works.

When selecting the technical solution it was necessary to take into consideration that the embankment part to be widened and the adjacent existing embankment should perform as a single unit to prevent heterogeneous

settlement, which may result in longitudinal cracks and pavement irregularities.

To create uniform conditions for deforming of both embankment parts it is necessary to make the rate of their settlement on compressible soils equal and to undertake additional measures against lateral deformations of the padded embankment, which is very important for prevention of lateral cracks. To obtain equal stiffness of both embankment parts the best option would be to adopt similar structures, i.e. of floating type.

Taking into account these peculiarities and requirements for compatible performance of the existing and the newly constructed embankment parts, complex decision was undertaken according to which the embankment stabilization was obtained due to application of temporary surcharge, reinforcing of the embankment body with geotextile interlayers anchored in the body of the existing embankment and making of lateral surcharging benches.

Under surcharge action acceleration of consolidation should be achieved with its intensive part to be completed during 6 months maximum. But the most important in this case is stabilization of settlements and making their rates equal to the rates of the existing embankment.

Reinforcing interlayers should perform (provide) even load distribution on the embankment base, absorbtion of tensile stessses in the result of transverse deformations of the padded embankment part, while lateral surchaging benches shall be a sort of counterbankets allowing to increase the total embankment stability and also to limit the value of its transverse movements due to soft base consolidation.

After detailed consideration of the proposed options and cost, labor and material comparison the “floating embankment” option was accepted including partial excavation of peat layer up to the ground water level (for the purposes to increase the embankment depth, to reduce settlement, to preserve the swamp hydrological balance and to prevent disturbance of the lower sapropel layers. The “floating embankment” option was also proved by stable condition of the existing embankments being in operation for an extended period.

The calculations performed also proved the possibility to implement the above option. According to calculations strength and stability of soft soils shall be provided. The maximum forecasted embankment settlement was 70 cm including 35 cm of sapropel settlement. Estimated duration of soft soil consolidation was 9 months.

The results of forecasted calculations of embankment settlements showed that under condition of 1.5 – 2.0 m surcharge application major processes of embankment stabilization should take place during 5-9 months from the date of embankment construction completion.

Reinforcement of the embankment body was made of continuous geotextile punched fabric having surface density of 500 g/m2 minimum and breaking load of 500 H minimum. For reinforcement purposes polypropylene geotextile fabric of local manufacture was used.

Subgrade construction on swampy sections was carried out in the following method. Peat excavation up to the ground water level on section one (km 43.7–km 43.9) was made for 1.3 meter depth and on section two (km 48.2 – km 48.5) for 1.5-2.5 meter. Peat excavation was made for the total width of the designed subgrade from both sides of the existing embankment. Continuous monitoring was arranged to control excavation process, so that to prevent its passing ahead of the trench backfilling by 1.5 shift sections (25-30 meter). Trench backfilling to the level above 0.2 m was made with sand draining soil with 2m/day filtration coefficient. After that the sand layer was compacted with pneumatic rollers.

Settlement marks were installed on the compacted sand layer (lane centerline, embankment edge, location of connection with the existing embankment) in order to monitor the settlements of the constructed subgrade with reference to permanent marks installed along the edge of the swamp on mineral soil. To monitor the soft base behavior settlement marks were installed along both sides of the embankment outside its bounds.

Two layers of geotextile fabric were spread on the compacted and leveled sand layer with shifting of the second layer for half width of the strip. Adjacent strips were spread with overlapping, welded by gas burner and fixed to the sand layer with metal clamps. Spreading of geotextile was made to the whole width of the embankment foot with extension of the ends to the slope of the existing embankment and soft base outside the foot.

After backfilling and compaction of the first 0.5 meter thickness soil lift, ends of the geotextile strips, extended to the slope and outside the embankment bounds, were turned up on the placed sand layer to 3 meter width and fixed with anchors. Then subgrade was constructed according to the existing method including lift by lift backfilling. Spreading of geotextile reinforcing interlayers to 3 meter width and at 0.5 meter intervals by height were also made in locations of connection with the existing embankment and on the level of the sand sub-base of road pavement.

In the course of embankment construction daily levelling of settlement marks was made with their extension if necessary. Results of embankment settlement monitoring were used for calculation of the embankment settlement rate. In case actual settlement rate exceeded the estimated value or if inconsiderable lifting of the swamp surface outside the embankment foot backfilling of soil was stopped. After soft base stabilization under the weight of the constructed embankment lift by lift backfilling of soil was continued.

After design marks were reached a soil lift of temporary surcharge of 1.5-2.0 meter thickness was filled to the whole width of subgrade.

Time period of backfilling of embankments with surcharge was 2-3 months. Embankment surcharge was kept for 4-5 months. During this time settlement of embankments stabilized and its maximum value constituted 48.7 cm on the first section and 48.0 cm on the second one. After that temporary surcharge soil was removed and road pavement placed.

CONCLUSION

Monitoring of settlements of embankments on swamps have been continued until now from the date of road pavement completion. Value of the embankment and road pavement settlement being in operation from September 2002 to October 2003 constituted 0.8-2.5 cm on the first section and 1.0-3.8 cm on the second section. These settlements are of attenuating character and have not affect the road pavement evenness. No visible deformations and asphalt pavement defects have been observed.

Thus application of geotextile interlayers for reinforcement of embankments on swamps allowed to complete reconstruction of the Ring Road section during one construction season and to open traffic. Considerable reduction of material consumption and construction period was provided combined with good quality of civil works.