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17–19 May 2018, Zadar, Croatia

Road and Rail Infrastructure V

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TRACK STRUCTURE RECONSTRUCTION PRACTICE FOR THE SUBGRADE ON WEAK FOUNDATION SOILS

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Abstract

Nowadays there is a problem of the rail track structure reconstruction practice for the subgrade on weak foundation soils supply for the subgrade on the weak foundation, including the efficiency assessing of subgrade stability assessing methods on the weak silty soils. Especially this problem has a significant importance if the foundation soil is silty clay and peat soils. At the reinforcement of embankments by berms the value of stresses is reduced only by 15-20 percent. The increasing of the embankment height to decrease elastic settlements of the objects of the first group is simple and reliable method. But this method is difficult to provide because in this case it is necessary to reconstruct the contact network on the electrified lines. Subgrade and foundation in these cases follows the enlargement of the acidity. The paper presents the results of the analysis, physical modelling and monitoring carried out to assess the efficiency of several methods to reinforce the embankments foundation. There is the evaluation of the performance models for the foundation reinforce by geomatresses, filled with stone material. The simulation results showed that the embankment reinforced with geotextile has significant uniform precipitation, which can later lead to bulging of the underlying subsoil outside the contour of the slopes. The optimal solution in this case is the lightweight embankments with a core of expanded polystyrene (foam). This solution is effective to reduce the total embankment deformations on soft soils and to limit the lateral displacement.

Keywords: weak foundation, physical modelling, light embankment, geodrains

1 Introduction

The construction of the subgrade on weak soils often leads to increased pore pressure. The effective stresses stay low as the result of undrained behaviour and contractors use special stages for compaction and relaxation to improve the earthworks. The excess pore pressure dissipates during compaction and the soil shear strength is increased up to values which allow resumption construction. The main objective of this work is to estimate the viability of the decisions for the reconstruction of the approach highway embankment to the over-bridge through the Volhov River (North -Western part of Russia) and typical cross-sections for the newly-constructed railway embankment in the same region.

The geology of this area was studied up to a depth of 30 m consisted of modern overburden soils, lacustrine deposits and Lontovassky set of rock of the Cambrian system (speckled and bluish clay). The lacustrine deposits are present clay silts with fluid or fluid-plastic consistency of coarse lens in saturated sands. The in with the paleo-valley of the Volhov River is filled with silts from 1 to 24 m deep. Stabilization of the embankments on weak foundations in the highway and railway industries is provided by using berms, at high costs and big volumes

of draining soils: sand, gravel, ground columns, cement mixing etc. [1-7]. Some alternative engineering solutions include different geosynthetics: geogrids, geomatresses, geodrains and geofoms are used in the major it of them.

2 Modelling and monitoring of highway embankment

2.1 The description of the prototypes, models and the characterization of the possible deformations

A characteristic cross-section was chosen to evaluate the design solution. This reconstructed structure consists of the jointed structure with the existing old-term embankment, which had a height of 2.4 m and a 1:2.3 slope for the left slope and 1:5 for the right, and a newly-constructed part of embankments which is elevated and filled under the existing embankment. The height of the projected newly-constructed highway prototype embankment is 6 m and the slope 1:1.5 (Figure 2 a). The prototype embankment was filled using drained fine sand and this embankment had the height of 6 m too (Figure 2 b). The first models of the embankments were prepared without any reinforcement to estimate the behaviour of the embankments on these weak foundations. Several hypotheses are preliminarily suggested to solve the problem of embankment stability. There are deformations – loss of slope stability; settlements of embankments as the results of the foundation soil uplift and settlement caused by the compression of the embankment and foundation soils. The scale factor $N = 75$ was chosen for the physical centrifuge modelling.

2.2 The soil parameters of embankments foundation and modelling without reinforcement

Weak clay soil was used as foundation. Lab tests were done to estimate the main physical and mechanical parameters according to the State Standards.

The clay silt of the fluid-plastic consistency was de-fined as the results of the lab tests. The soil moisture was increased up to 50 % during the preparation of the foundation model. The foundation soil was compacted layer by layer until it reached a density value which is equal to the maximum value of the dry unit weight of the 16.7 kN/m^3 with the moisture content of was filled with 50 %. The embankment was filled with soil (existing and newly constructed in prototype terms) after the foundation preparation, see Figure 1.

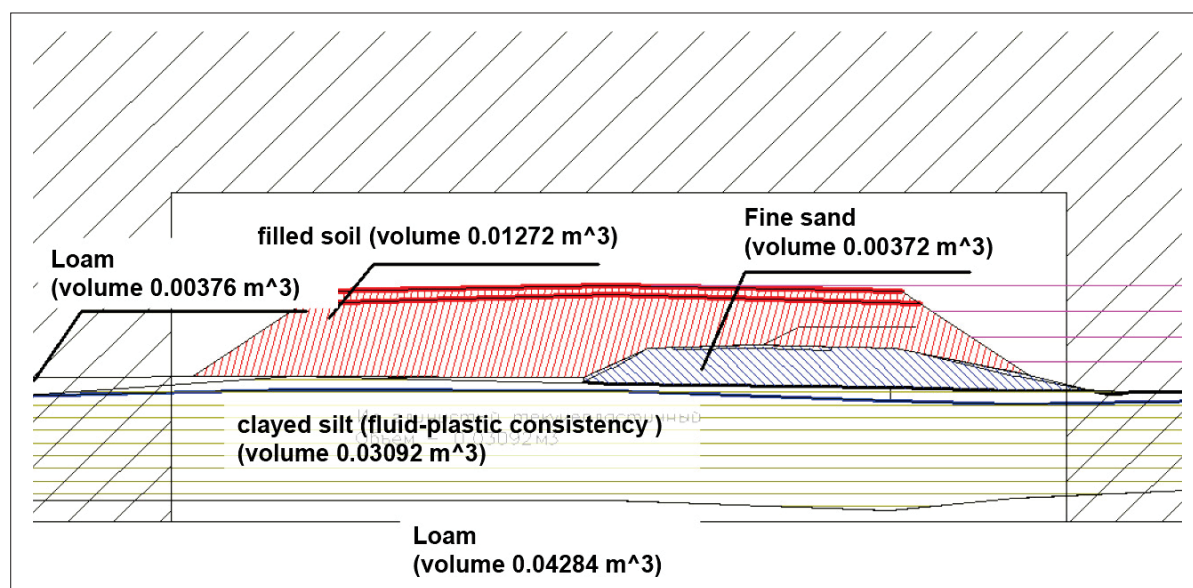


Figure 1 The view of the model preparation (for the highway embankment)

Some sample for the moisture and density of soil were taken for the estimate the physical characteristics of the model soil. Laser profile-measurements (on three cross-sections) were constructed for each model after finishing of the model preparation and the same measurements were taken after centrifuge modelling. The results of physical modelling show, that the embankment has stability, but values of displacement exceed the admissible valuation. It was decided to increase the soil moisture contest of the next experiment to 50 %.The settlements of the main top of the model at the prototype scale were equal to 0.45 m.

2.3 The results of modelling and design of reinforced highway embankments

The next model was prepared as the embankment model reinforced by vertical sand drains and geomatresses, which were filled with gravel sand, see Figure 2. The foundation soil was compacted layer by layer until it reached a density value equal to the maximum value of the dry unit weight of 16.7 kN/m^3 at the moisture of 50 %. Holes were the drilled into the found for the sand drains with depth of 1.05 m^2 . These holes were filled with sand and compaction took place after moistening.

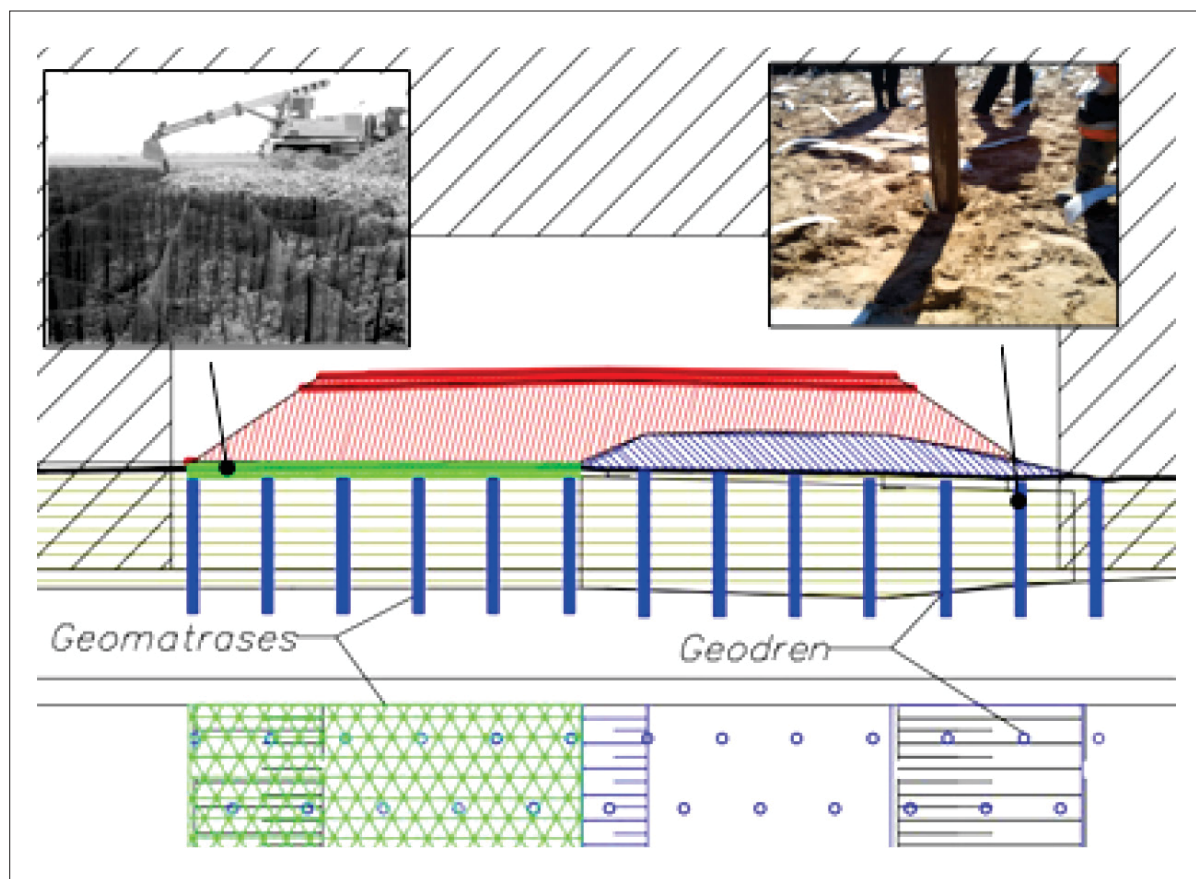


Figure 2 The scheme of the highway embankments reinforced by sand drains and geomatrases

The model of embankments was prepared after the foundation and elements – models of the geomatrasse jointed together with foundation. Then geomatrasse models were filled with coarse of 3 mm^2 and compacted. Dimensions of the models equal to scale $N = 75$. For the physical modelling of the foul lane high-way load on the top surface was chosen take a distributed static load of 45 kPa . The elements of the static load where made from ten separate paste-board sections with filling sand – lead mix filling. The settlements of the top of the model at the prototype scale were equal to 0.075 m . The results of the modelling made it possible to recommend decisions for the prototype and to con-firm stabilization of the foundation limited settlements making it possible to start the construction see Figure 3.

2.4 Prototype data, subsidiary technical solutions (geogrids and geofoam) and monitoring of the highway embankments (the Volhov river)

To increase the foundation consolidation, the vertical drains were placed on the section of a new construction site for the highway embankment. The installation of these drains led to increased water drainage and to the decreased hydrostatic and pore pressure. For the prototype conditions: the distance between drain centres was 0.8 m and the depth of installation ranged from 8 to 12 m. Floating due to buoyancy and disturbance due to strong wind must be prevented during construction [3]. Intensive consolidation stopped six months after the full filling and compaction of the embankment soil was completed.

In the triangular scheme of the placing, the distance between the drains was 0.80 m, and between the rows the distance was 0.70 m.

Some special technical solutions were used: geomattress were used to provide a foundation bearing capacity; the geofoam blocks were placed above the existent embankment on the right side to reduce own weight of the embankment.

This structure of geofoam blocks was covered by geotextile. The geomembrane, with a thickness of 1 mm, was laid under the pavement to protect the blocks. The geofoam blocks were placed on the sub-grade after cutting the existing pavement to a depth of 1.2 m and these blocks did not add load to the foundation, Figure 3.



Figure 3 The initial stage of the geomattresses, geodrains installation – prototype (a) and geofoam blocks (b)

The results of the monitoring show that this decision made it possible to lay the pavement immediately after finishing the earthworks. The monitoring of the pore pressure allowed estimation of the consolidation time for complete dissipation within 6 months.

Insufficient bearing capacity of the subgrade foundation, for construction of a new embankment on weak soils, made it necessary to fill the layers of the embankment layer in stages, using the method of preliminary consolidation.

When filling a new embankment on weak soil foundations it is possible to exceed the permissible values of pore pressure, which can lead to settlement of the foundation soil of the embankment. To prevent this, it is necessary to monitor the amount of excess pore pressure and the dimensions of the embankment.

3 Physical modelling of typical railway embankments

Successful modelling of the highway embankments during their foundation reconstruction, reinforced by geosynthetics structure, predetermined the need for modelling of a typical solution for a railway embankment in new construction sites on weak foundations. To assess the operational reliability of the design solution for strengthening the railway embankment, a characteristic cross profile was chosen. The structure consists of the embankment, filled with draining soil (sand of medium size). The height of the new project is 6 m and slope 1: 1.5 see Figure 4a. Two models of the subgrade were made for this modelling. To stabilize the structures, additional measures were envisaged to strengthen the embankment foundation. During the testing two variants of reinforcing were checked. The foundation of the first model was reinforced with geotextile mattress filled by stone material (Fig. 4). The foundation of the second model was reinforced by a geotextile semi-moat structure see Figure 4b. The following centrifuge operation modes used at RUT (MIIT) centrifuge: dispersal – 6 minutes, working stationary mode – 60 minutes, centrifuge stop – 6 minutes. The operating time of the centrifugal unit in the stationary mode at each stage of the simulation was 60 minutes, which equals to 7.7 months of the prototype scale. The time of simulation in stationary mode was counted from the moment of deviation of the carriage axis by an angle of 84° from the vertical, which, according to simulation experience, occurs when $\frac{3}{4}$ of the set angular rotation speed is reaches. The operating time of the centrifuge under steady-state conditions was 60 minutes. It corresponds to the operating time of the embankment for real conditions of 7.7 months.

The model of the embankment and foundation was made from field soils – loam and clayed silt. Achieve similarity between the physical and mechanical properties of the soil model and the full-scale prototype. When making the soil model, the density and moisture content of the soils were determined and matched actual conditions.

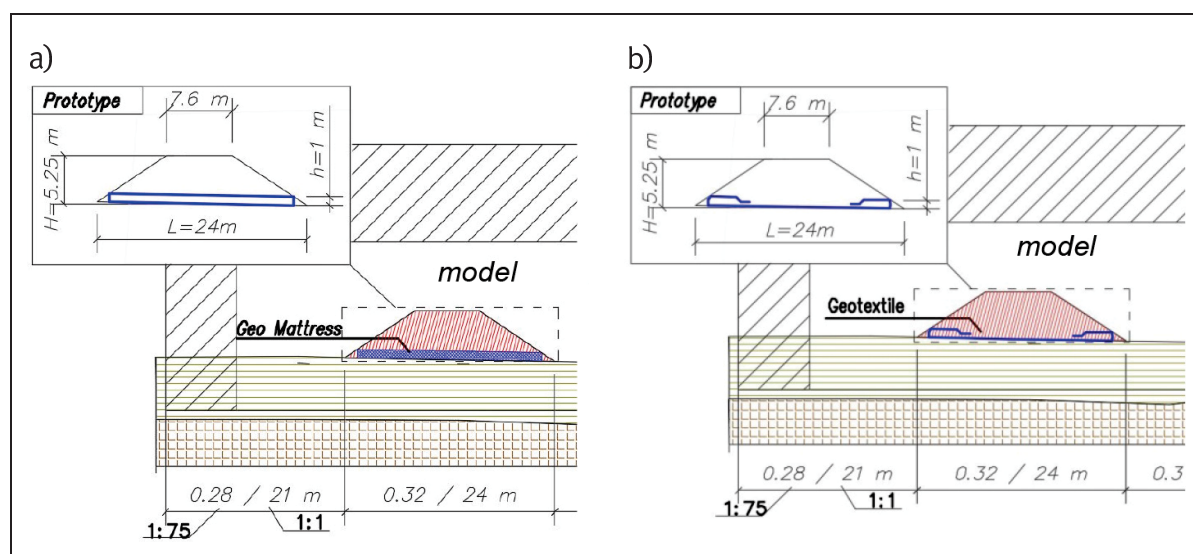


Figure 4 Scheme of model of railway embankment: a) reinforced by geotextile mattresses, b) reinforced by geotextile

The foundation soil of the embankment model was compacted to reach its maximum density at 60 % moisture content. Due to the high moisture content required for compacting the soil under manual tamping, the soil was abandoned to give the required compaction for this case. The soil compaction of the foundation with the fluid-plastic consistency was carried out by means of preliminary consolidation of the soil with the help of a press up to achieve a density of $1.5 \pm 7 \text{ g/cm}^3$. The preliminary consolidation of the foundation lasted 72 hours. Mattresses (mattress models) were filled with coarse sand of a 3-mm fraction and the sealing of this structure was made.

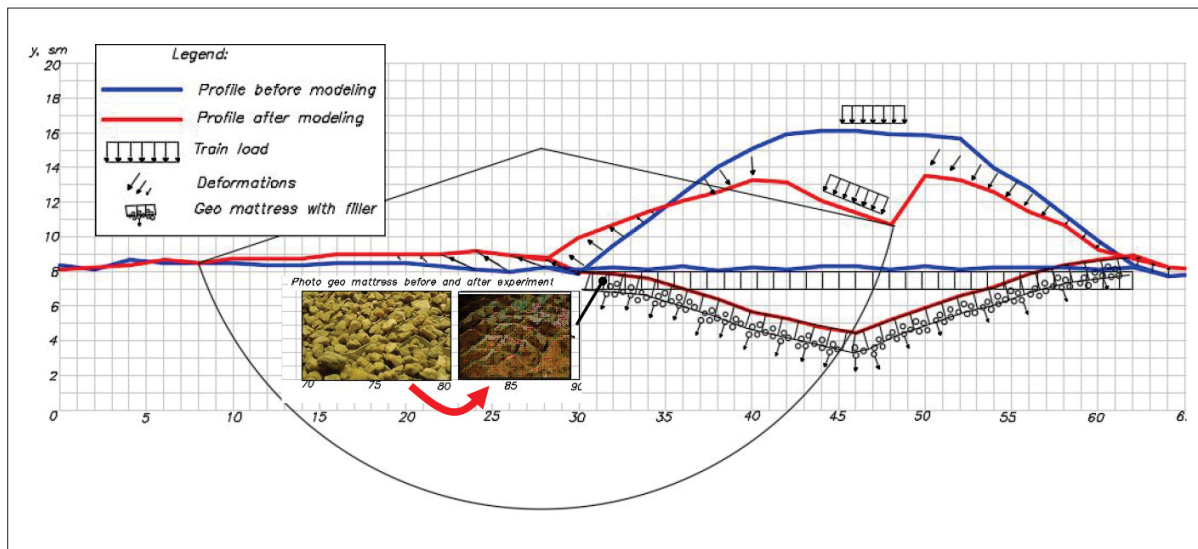


Figure 5 The results of modelling railway embankment reinforced by geomattresses

The size of geosynthetic mattresses corresponded to the scale modelling of 1: 75. The geotextile model was laid on the foundation and a layer of sandy soil was poured down with a thickness of 1 m (on the scale of the prototype). The layer was compacted and covered with geotextile model material. For modelling the impact of the rolling stock on the subgrade of the mound model in a centrifugal installation, a set of sections corresponding to a static load at a maximum stress of 80 kPa was used. The static model of the train load consists of 4 separate sections. It was found that in the model reinforced by geomattresses, the stone material of geomattresses was pushed into the foundation see Figure 5, which could be a reason for changing the characteristics of the geomatress and, as a result, could lead to the destruction of the embankment. There was an extrusion of the foundation soil on both sides of the embankment, as seen in the photographs and the cross profile.

At the same time, in the analysis of the model reinforced by geotextile, it was found that during compaction a foundation deposit during compaction of the soil of the embankment occurred and, consequently, it caused additional compaction of the soil foundation look place. At the same time, the maximum settlement along the axis of the embankment was 1.35 m and it is possible to interpret this as a uniform settlement being realized during the construction period.

After 60 minutes of centrifugation, the embankment model showed its efficiency in the given conditions, without uneven deformations. The maximum settlement of the foundation during the construction period was 1.45 m in the prototype scale. The maximum settlement of the embankment after the modelling was 1.275 m. The outburst of the ground was observed only during the construction and compaction when the embankment height reached 2.025 m.

4 Conclusion

The results of the modelling showed that stability of the embankment and stability of the foundation soil are ensured both for the variant without reinforcing and for the variant with reinforcing. The analysis of the results of modelling and physical characteristics of soils has shown that when a weak foundation model is constructed and then the clayed soils have a soft-plastic consistency, stability of the foundation soils is provided, and the appearance of elastic-plastic deformations does not occur.

When comparis results for the highway embankment and the model settlements, before and after reinforcing corresponding (among themselves) sections it was established reveals that the values of the settlements of the model with the reinforcement of the foundation by sand piles and the geomatress turned out to be considerably less than the model settlements

without reinforcement. As a result of the reinforcement of the soil foundation of the reconstructed embankment, the settlements values decreased by 50 to 83 %, compared to the embankment, where the reinforcement of the foundation was not performed. This indicates a certain efficiency and for the prototype-technical solution for increasing the stiffness of the weak foundation soils by the sand piles with a cover construction from geotextile filled with stone material. The control of the subgrade construction by monitoring the pore pressure allowed it to be completed without any losses of bearing capacity of the foundation.

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