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Recommendations for the application of geosynthetics in a railway network modernisation project in Slovakia

R. Baslik
Tectum Geosynthetic, Ltd., Bratislava, Slovak Republic

M. Matys
Department of Engineering Geology, Faculty of Natural Sciences, Comenius University, Bratislava, Slovak Republic

L. Turinic
Prodex, Ltd., Bratislava, Slovak Republic

ABSTRACT: The paper deals with the use of geosynthetics in the railway network modernisation project. A new track subbase arrangement with stiff integral biaxial geogrids on a low bearing capacity soft subgrade is presented. The experimental tests have been carried out with the aim of investigating the effects of geogrid within reinforced subbase. In situ plate load bearing capacity control tests confirm the track substructure improvement using geosynthetic reinforcement.

1 INTRODUCTION

For the application of geotextiles and geotextile-related products in Slovakia, two basic standards (Slovak Technical Standard - STN) are used. STN 73 3040 introduces the selected technical parameters and to them appropriate required values for geotextiles and geotextile-related products. Geosynthetic products used in constructions of the Slovak Railway Authority must have permission from them. STN 73 3041 refers to the technical requirements of soil structures reinforced by geosynthetics. The standard introduces the requirement for the back fill soil, geosynthetic reinforcement and other materials, as well as the requirement for the facing of the soil structure reinforced by geosynthetics. The principle for the design according to the significance of the structure, and the adoption of different reduction coefficient values for the design of reinforced soil structures according to the I. and II. limit states are presented. The designs are analogical with those of the European Standard drafts for geotechnics – ENV 1997 – 1 and others. STN 73 3041 presents the guide for the design of reinforced soil retaining walls and bridge abutments, reinforced steep slopes, embankments on soft subsoil and reinforced subbases.

The paper will deal only with reinforced subbase.

2 REINFORCED SUBBASE ACCORDING TO STN 73 3041

The purpose of laying a reinforcement into the subbase is either to improve the strength and deformation characteristics of the subbase layer, to decrease its thickness, to bear the stress developed and its spreading and reducing differential settlement, or to create an alternative solution for the construction of subbase layers in difficult foundation conditions. According to Table 1, in the design of reinforced subbase layers, it is recommended to take into consideration the maximum expected elongation of the geosynthetic reinforcement in the site.

In dealing with the design according to STN 73 3041, the type of load, design life of the structure, the type of soil used in the subbase layer, the maximum elongation of geosynthetic reinforcement and its type, the position, number and the arrangement of the reinforcement should be assessed and reviewed. The bearing capacity and settlement (if required) of the reinforced subbase layer is reviewed or is determined experimentally. Finally, the overall (external) and internal stability of the designed reinforced sub-base layer is assessed.

3 GEOSYNTHETICS IN THE RAILWAY NETWORK MODERNISATION PROJECT

3.1 *General*

The Central and Eastern European Countries joining the EU have made strong efforts to modernise their rail network. Impacted rail lines include two of the north-south and west-east TransEuropean corridors between Poland, Hungary and Ukraine, a corridor that runs across the west and north region of Slovak Republic. The new railway track will fulfil requirements for /1/ higher speed – 160 km/hr., /2/ higher load – 22.5 tons for axle, and /3/ higher traffic comfort. To fulfil these requirements, it requires not only new construction elements to the track superstructure, but also reconstruction of the track substructure. It was necessary to improve the bearing capacity of the railway subgrade. The current Slovak Railways Regulation for Railway Subgrade includes

Table 1. Recommended maximum elongation of the geosynthetic reinforcement in the subbase layers.

Geotechnical category	Structure significance	Recommended maximum elongation of the geosynthetic reinforcement, ε_{max} (%)	Examples of soil structures, where by, subbase layers are reinforced
1.	Restricted	From 8 to 10	Simple, temporary structures with design life of 5 years (casual communications-roads, stock areas, working areas)
1.	Medium	From 5 to 8	Structures with design life between 5 to 25 years
2.	High	From 3 to 5	Structures with design life from 25 to 50 years
3.	Extraordinary	From 1 to 3	Important structures with design life from 50 to 120 years (motorways, principal roads, railways, airports, bridge abutments, retaining walls, living houses, hydro-technical structures, industrial structures)

various types of soft subgrade improvement-stabilisation such as lime, cement, chemical, and asphalt stabilisation only. The use of geosynthetic reinforcement in subbase is a new improvement method of track substructure on soft subsoil.

The new recommendations of the Slovak Railway Authorities for the application of reinforcement techniques to the railway track foundation are based on the standards stated above, as well as the foreign experience analysis, laboratory and field tests and local experiences in the field of thin reinforced soil layers. According to the schedule of network realization the first section length of 50 km between Bratislava and Trnava began in 2000.

3.2 *Subbase reinforcement*

The subsoil investigation was performed to access strength and compressibility properties of subgrade. Extensive plate load bearing capacity and dynamic penetration tests were carried out. A cross section of the ground with bearing capacity values along the track axis was determined.

The method based on bringing track grating down was used. The old track structure was excavated.

After detailed geotechnical analysis of soft subsoil, a plate load bearing capacity test defines the modulus of deformation at the subgrade surface. A modulus of deformation approach based on in-situ tests in Melcice-Zlatovce track section (year 1996-97) and other empirical experiences were applied.

Geosynthetic reinforcement used in the project shall conform to the properties of Table 2. These requirements fulfil the stiff integral biaxial geogrid (SIBG). One of the types of SIBGs was used to improve the performance of weak soils to support railway track foundation.

The designer prepared a set of typical structure arrangements. Single or multi-layer geogrid reinforcement is used to increase the bearing capacity (synergistic effect) of the layer on the very soft subsoil. Onto the surface of soft subgrade the SIBG 30 x 30 kN/m was placed, as shown on Figure 1.

Table 2. Requirements for reinforcement application in truck substructure.

Property	Requirement
Tensile strength (wide strip)	> 30.0 kN/m
Elongation (strain at failure)	< 15 %
Junction strength (GRI:GG2 test method)	> 85 %
Geogrid matrix stiffness (in-plane torsion rigidity according to Kinney & Xiaolin test method)	> 0.9 N.m/degree
Agreement with application	Slovak Railways Authorities review and agreement prior to application

Reinforcing of the subbase provided to decrease an excavation soil volume. A small vertical distance between the rail level of existing line No.2 and a subgrade surface level of the reconstructed line No.1 made possible to construct the new line No.1 without special support measures between lines. It was very important economical and time benefit. The only necessary there, was to reduce a speed to 30 km/hr.

Geomat was installed on the slope as a erosion control system.

3.3 *Nonwoven and woven geotextiles in track substructure*

The installation damage of nonwoven geotextile placed within the backfill material was found out.

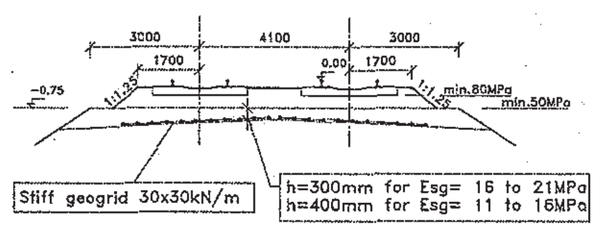

Figure 1. Typical arrangement of the track superstructure, if E_{sg} = 11 to 21 MPa.

Properties of used geotextile were: mass per unit area 300 g/m^2, CBR = 1620 N, tensile strength 8 kN/m, elongation at failure 150 %. Based on that situation and similar other experiences, Slovak Railway Authorities accepted new criteria defined by designer. The defined characteristics specify Slovak Railway requirements concerning the primary and secondary properties stipulated by the national standard STN 73 3040. Those stringent requirements on properties reflect in particular the method of application, use of crushed stone and cyclic load of railway traffic:

Only nonwoven geotextile in the track substructure:

Mass per unit area:	min. 350 g/m^2
CBR:	min. 3.5 kN
Short-term tensile strength:	min. 15 kN/m
Elongation at failure:	max. 90 %

Nonwoven geotextile under reinforcing geogrid:

Mass per unit area:	min. 250 g/m^2
CBR:	min. 2.5 kN
Short-term tensile strength:	min. 10 kN/m
Elongation at failure:	max. 115 % (recommended up to 90 %)

Width of geotextile sheet is no less than 4.5m.

3.4 *Effectiveness of geogrid*

In order to verify the effectiveness of geogrid within subbase, one set of experimental tests was recently carried out at Comenius University in Bratislava. Figure 2 shows a sketch of model box developed to investigate the effect of the cone pushed into geogrid structure. Three kinds of soil were used in a series of tests. These were:

gravel(G): particle size 2/32
mean particle size, D_{50} 9mm
grading curve in Figure 3
classified as gravel poorly graded (GP)

crushed stone(CS): particle size 2/32
mean particle size, D_{50} 10 mm
grading curve in Figure 3
classified as gravel poorly graded (GP)

clay: moisture content: 37 %
density: 1584 kg.m^{-3}
plastic limit: 27 %
classified as high plasticity clay (CH)

As reinforcing material a polypropylene SIBG was used. It has aperture size of 39 mm x 39 mm.

With the purpose of checking the effectiveness of the geogrids, the cone was pushed through thin layer of soil, which was lying on geogrid. The test started with cone position of 50 mm above the geogrid. The test ended, when the cone intersected the starting geogrid plane and penetrated approx. 10 mm into the subgrade.

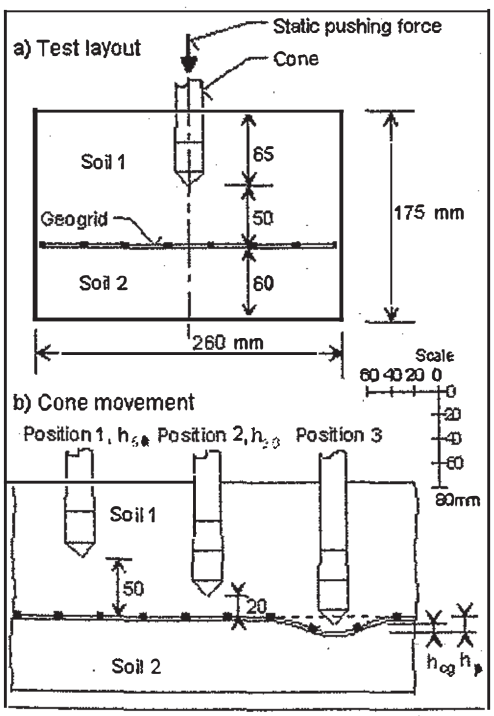

Figure 2. Push test

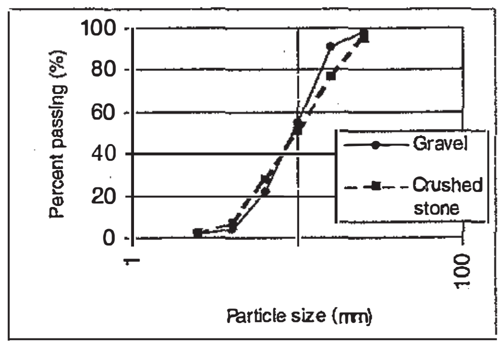

Figure 3. Particle size distribution curves.

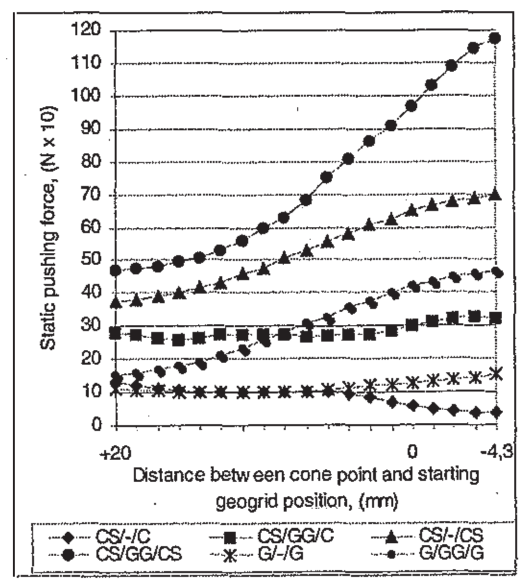

Figure 4. Results of push tests.

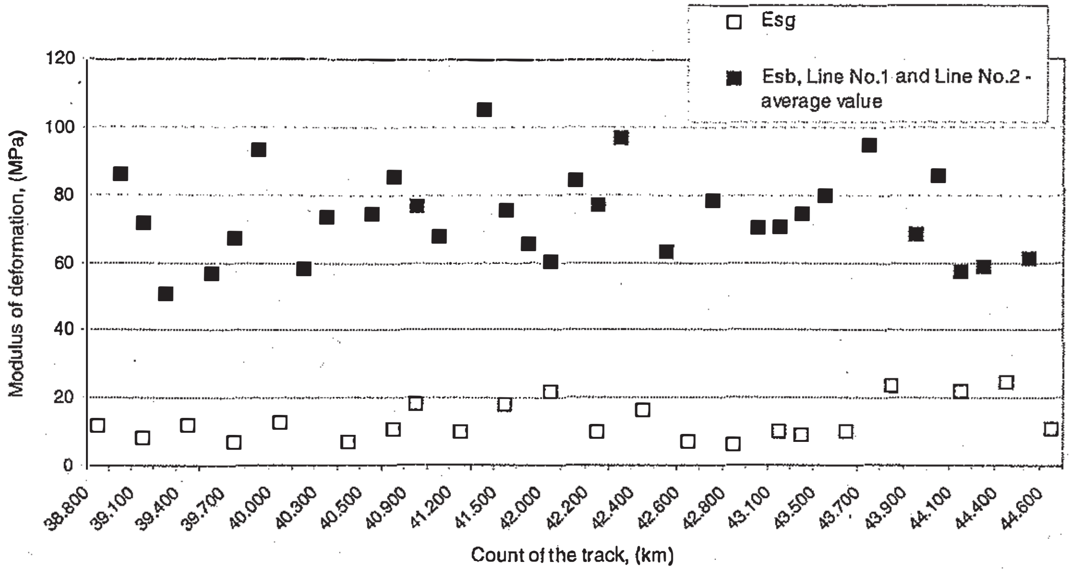

Figure 5. Results of a plate load bearing capacity control tests.

Figure 4 presents tests results. Figure provides the typical results of the relationship between static pushing force and the cone positions from h_{50} to h_{cg} (see Figure 2). Symbols are as follows:

CS/GG/C

soil above geogrid — geogrid — soil under geogrid

The cone pushing can be interpreted as a large soil particle locally pushing into geogrid. From the data is evident that the increasing of the force is mainly due to geogrid. It is also interesting to consider the influence of the subgrade stiffness on the response of the cone. Despite the limited number of tests, the strong effect of the subgrade type on the pushing force can be noted.

3.5 *Control tests*

Quality assurance plan considers plate load bearing capacity tests as a Quality Control tests. In Figure 5 are presented the results of these tests. The subgrade moduli of deformation E_{sg} were from 6.2 to 24.9 MPa. The regulation for new corridors requires a minimum modulus of deformation of 50 MPa on the subbase surface (E_{sb}).

The data presented in Figure 5 confirm that the designer succeeded in reaching the requested subbase bearing capacity with application of SIBGs. This type of geosynthetic, used in this manner in the new track substructure, can give significant technical, technological and economic benefits.

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