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EXPERIMENTAL MONITORING THE EFFICIENCY OF REINFORCED GEOCOMPOSITE IN CONSTRUCTION LAYERS OF RAILWAY SUBSTRUCTURE

Summary. In the paper authors present the results of experimental measurements realized in testing stand, which was built for evaluation of reinforced effect of geocomposite MACRIT GTV/50-50 B that was applied into railway substructure.

BADANIA DOŚWIADCZALNE WPŁYWU WZMOCNIENIA GEOKOMPOZYTEM WARSTW KONSTRUKCYJNYCH PODTORZA KOLEJOWEGO

Streszczenie. Autorzy prezentują wyniki pomiarów realizowanych etapowo na stanowisku badawczym, które wybudowano w celu oceny efektów wzmocnienia konstrukcji podtorza z wykorzystaniem geokompozytu MACRIT GTV 50/50-B. W artykule opisano metodykę badań, zaobserwowane fizykalne charakterystyki zastosowanych gruntów oraz wyniki statycznych badań obciążeniowych dla różnego uziarnienia i grubości warstwy (150 mm – 600 mm). Efekt eksperymentalnej oceny trzech testowanych konstrukcji stanowi projekt nomogramów służących do wymiarowania konstrukcji podtorza kolejowego.

1. INTRODUCTION

Basic assumption of the safe and trafficable railway is long-time reliable spreading of the train set loading, which affects throughout rail, railway bed and subbase to the subgrade surface without permanent cracks of the particular construction levels of sleeper subgrade is. In the case of insufficient loading capacity of subgrade surface, special deformation problems rise in the railway construction, especially in the railway substructure, which influence the quality and traffic reliability of the railway.

Increasing the loading capacity of railway substructure is possible with various methods, as for example the changing subgrade surface of small loading capacity with stabilization of surface soils or with the strengthening of sleeper subgrade construction. In the present time the geosynthetic reinforced elements, named as reinforced construction layers,

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application into railway substructure, have ever more utilization in the process of increasing the railway substructure loading capacity.

In the Department of Railway Engineering and Track Management (DRETM), in the latest years there is realized the experimental monitoring of geosynthetic elements effect on construction layers of railway substructure body. For that reason, the outer and internal testing stand was built in the department laboratory to test the various profiles of the reinforced construction layers of railway substructure.

Further more, in the paper will be presented the methodology and up to time results of experimental testing of railway substructure with using geosynthetic reinforced element MACRIT GTV/50-50 B (the first and second stage) and not reinforced construction of railway substructure (the third stage), with various characteristics of construction layer material (subbase layer of different granularity curve) and with respect with aproximately equal loading capacity of subgrade surface.Artykuł nie powinien być dłuższy niż 8 stron. Należy go dostarczyć w postaci wydruku oraz w postaci elektronicznej na dyskietce 3,5'' lub na płycie CD.

2. CHARACTERIZATION OF THE TESTING STAND AND METHODOLOGY OF EXPERIMENTAL MEASUREMENT

Experimental monitoring of the particular constructions of railway substructure was realised in the great internal testing stand of DRETM.

Testing stand (Fig. 1) has the following dimensions in length x width x height: 3400 mm x 1950 mm x 1200 mm. Because of preservation of cross – and lengthwise stand stability, its bottom and walls are reinforced with transversal and vertical angle steel ribcages (reinforcements). In its upper level there is steel beam, which is possible to fix in three positions in length of the stand and which is like a counterweight during static loading tests.

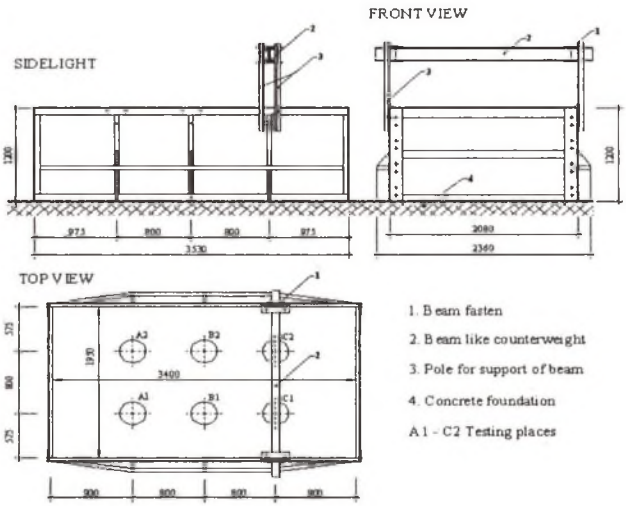

Fig. 1. Testing stand of DRETM
Rys. 1. Stanowisko testowe DRETM

Testing stand is fulfilled with soil, up to height 600 mm, which is characterised like sandy clay (results from soil laboratory tests are described in chapter 4) according to the granularity analysis. The average value of static transform (deformation) module of the subgrade surface E for experimental measurements was about 7-8 MPa before building the particularly layers, and after experimental measurements and after taking off the whole material of subbase construction was about 9,5 – 10,5 MPa.

Before the subbase building, there was found out maximal and minimal volume weight for broken sand (to determine the compaction criterion, formulated via relative lying down I_D according to the Slovak Technical Standard STN 72 1018) and necessary heightening before the compaction so way to be kept the required thickness of subbase. Decreases after compaction were found out with special experiment done in the bin with 305 mm in diameter for the subbase thickness after compaction 100 and 150 mm.

Further building of tested construction was as follows:

- Bedding, tightening and fixation of geosynthetic material MACRIT GTV/50-50 B on the subgrade surface in the edge of stand with steel pike in case of geosynthetic material application.
- Bringing subbase material into calculated height to have layer of thickness 150, 300, 450 or 600 mm (measured with levelling) after compaction with vibrating-plate-compactor ViDo 25/40 to the required compaction criterion.
- Gradually working in each particular layer:
  - 6 static loading tests.
  - 15 dynamic tests before and 15 after static loading tests (in places around $A_1, A_2, B_1, B_2, C_1, C_2$ position).
  - 3 tests of volume weight with hole method in the positions where static loading tests were done.
  - Determination of humidity and swept away elements of subbase material.

No compacted sheet of material with thickness about 100 mm was left near the stand walls, to eliminate the influence of rigid stand walls. After realisation of all above measurements, the subbase material was taken off and control tests of loading capacity of subgrade surface were done.

3. METHODOLOGY OF FINDING THE DEFORMATION CHARACTERIS-TICS OUT

Deformation characteristics of evaluated construction layers of railway substructure and subgrade surface were found out with static loading test and so with dynamic loading test for control, with convention with amended annexes No. 20 of regulation [4]. The compaction quality of built-in materials was found out according to the regulation [4].

The view on instrument arrangement for static loading test in tested stand is shown on figure 3.

The loading capacity of the particular layers of tested railway substructure and subgrade surface was measured with static loading tests. Main loading levels 0, 25, 50, 75 and 100 kPa and unloading levels 75, 50, 25 and 0 kPa were chosen, to find the loading capacity of subgrade surface in 2 cycles. In case of testing subbase material there were chosen following loading levels: 0, 50, 100, 150, 200 kPa and unloading was done in levels: 150, 100, 50 and 0 kPa.

For each loading level, value of deformation was read after compaction consolidation via 3 digital sensors MITUTOYO, placed regularly into triangle in the edge of solid circle board. From such readings was determined:

- Static transform module E,
- Static deformation module E_{def1} and E_{def2}

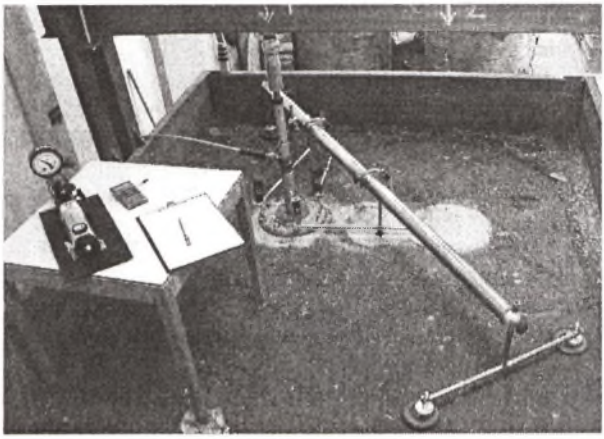

Fig. 2. The view on instrument arrangement for static loading test
Rys. 2. Aparatura do testowania statycznego

Static transform module ***E*** is characterised according to the [1] with equation:

$$E = \frac{1{,}5.p.r}{y} \qquad [\text{MPa}] \qquad (1)$$

where p is specific pressure to loading board (0,1 MPa, or 0,2 MPa),
r is radius of loading board in meters (0,15m),
y is the whole average pressure of loading board in meters, in the second loading cycle,
1,5 is constant considers surrounding patterns and actions, which are necessary to consider during loading with circle board.

Static deformation module E_{def} is calculated according to the equation [4]:

$$E_{def} = \frac{\pi}{2} \cdot (1 - \mu^2) \cdot \frac{r \cdot m \cdot \Delta p}{\Delta y} \qquad [\text{MPa}] \qquad (2)$$

where E_{def} is deformation module in MPa,
μ is Poisson number (estimated in span from 0,15 to 0,30 in dependence on bulk material characteristics),
r is radius of loading board in meters,
m is coefficient of the board shape (for circle board it is 0,785),
Δp is contact potential changing (in case of subgrade surface, the value under consideration is 0,5 MPa, in case of subbase it is 0,1 MPa),
Δy is change of board squeeze under potential change, in meters.

For quality evaluation of the compaction, done with static loading test, the proportions of transform modules from the second and first loading cycle were considered as target

values. The deformation module E_{def1} was determined from the first loading cycle and E_{def2} from the second cycle. Compaction was considered to be adequate, when the proportion of both of deformation modules for subbase reached value E_{def2}/E_{def1} *2,2* and for subgrade surface E_{def2}/E_{def1} *2,5*. The range of compaction work was chosen so that reached values were similar to those one in situ (according to the experience they are about 10 – 20 % higher then minimal required values).

4. CHARACTERISTICS OF BUILT-IN MATERIALS IN TESTING STAND

Physical characteristics of materials used for tested construction of railway substructure that was placed in great testing internal stand were evaluated in the laboratory of DRETM separately for subgrade surface material and for subbase material.

4.1. Description of Reinforced Geosynthetic MACRIT GTV/50-50 B

Geosynthetic material ***MACRIT GTV/50-50 B*** (Fig. 3) is polystyrene geocomposite, compound with non-woven geotextile (ensures separating and filtrating function) and reinforced geogrid ARTER. Geotextile protects geogrid before damage when the cover layers are built-in and compacted and so it brings higher assurance during geocomposite building-in.

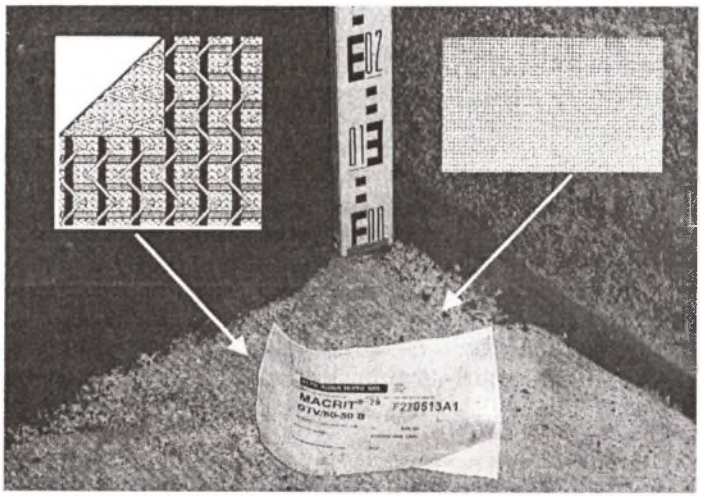

Fig. 3. Structure of geocomposite MACRIT GTV/50-50
Rys. 3. Struktura geokompozytu MACRIT GTV/50-50

The reinforced effect of geogrid ARTER is reached thanks to directionality Oriented Structure (D.O.S) that causes that the reinforced fibres have been straighten already during production.

Technical parameters of geocomposite MACRIT GTV/50-50 B:

- Pulling force (longitudinal/transversal) [kN/m] 50/50.
- Elongation (longitudinal/transversal) [%] 12/12.

- Pulling force during 2% elongation [kN/m] 11/12.
- Pulling force during 3% elongation [kN/m] 15/16.
- Pulling force during 5% elongation [kN/m] 27/27.
- Basic weight [g/m^2] 500.
- Maximal width [m] 100

4.2. Subgrade Surface

Soil from locality Žilina – Solinky was applied for subgrade surface so to reach required bearing capacity about 7-8 MPa. The soil samples from subgrade surface of testing stand were brought from the localities, where the static loading stands done.

For soil classification according to the system USCD, we have to make granularity analysis to find out the Atterberger limits: humidity in the yield limit w_L, humidity in the plastic limit w_P and plastic index I_P. Laboratory evaluation of samples granularity composition was done according to the [5]. Atterberger limits were calculated according to the [7] and [8] and humidity according to the [6]. These tests were adjusted vie software SOILAB.

On the base of above laboratory results, soil was classified in terms of [9] as *sandy clay with symbol F4=CS*. Further characteristics of subgrade surface soil:

- Humidity in the plastic limit w_P [%] 14,9.
- Humidity in the yield limit w_L [%] 26,2.
- Humidity w [%] 22,0.
- Volume weight of humid soil ρ [kg/m^3] 2081.
- Volume weight of dry soil ρ_d [kg/m^3] 1707.

4.3. Subbase

Broken stone of fraction 0-32 mm was used to build-in subbase of tested railway substructure. In the first stage of experimental measurements the subbase material conforms from the view of its granularity [9], in the second and third stage we admixed to the previous material 30% of broken stone weight of fraction 0-4 mm. His mix material conformed required demands concerning to the granularity curve in subbases according to the [10].

Granularity curves of material applied into subbase of tested railway substructures are visible in figure 4 with required granularity limits presented in [9] and [10].

On the base of granularity analysis, the subbase material was classified as *gravel with good granularity with symbol G1=GW*.

Before experimental measurements, we have measured granularity, minimal volume weight ρ_{dmin}, maximal volume weight ρ_{dmax}, number unequal-granularity C_u and the number of curvature C_c in subbase material. In the process of subbase building, we took from each particular tested construction layer 3 samples to determine volume weight of humid ground ρ, volume weight of ground after dry out ρ_d, humidity w wash-away elements and relative settlement I_D.

Complex outline of reached results from samples taken from the particular layers of tested subbase that were calculated according to the demands described in [10] is shown in tables 4.1 and 4.3.

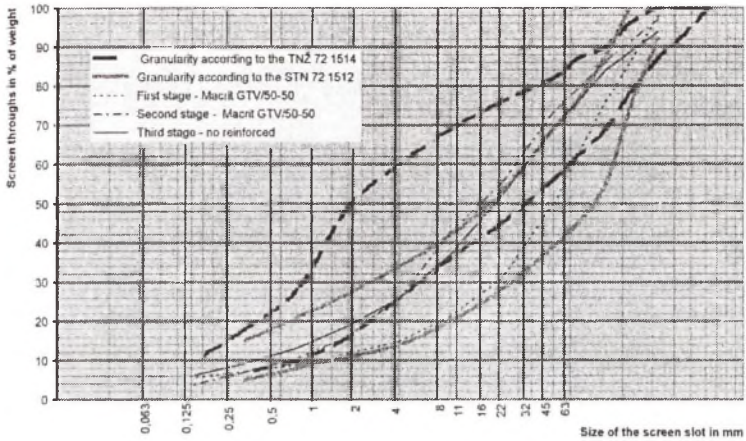

Fig. 4. Granularity curves of subbase material
Rys. 4. Krzywa ziarnistości dolnej warstwy materiału

Table 1

Outline of measured parameters of subbase material – 1st stage

Characteristics of material / construction thickness	0,150 m	0,300 m	0,450 m	0,600 m
Minimal volume weight $\rho_{d,\,min}$ *[kg.m^{-3}]*	1635			
Maximal volume weight $\rho_{d,\,max}$ *[kg.m^{-3}]*	2156			
Volume weight of humid soil ρ *[kg.m^{-3}]*	2087	2140	2181	2204
Volume weight of dry soil ρ_d *[kg.m^{-3}]*	2030	2083	2128	2130
Humidity w [%]	2,8	2,7	2,5	3,5
Wash-away elements	5,65	5,31	5,37	5,66
Relative settlement I_D	0,81	0,89	0,96	0,96
Number of unequal-granularity C_u	> 15			
Number of curvature C_c	> 1			

Table 2

Outline of measured parameters of subbase material – 2nd stage

Characteristics of material / construction thickness	0,150m	0,300 m	0,450 m	0,600 m
Minimal volume weight $\rho_{d,\,min}$ *[kg.m^{-3}]*	1504			
Maximal volume weight $\rho_{d,\,max}$ *[kg.m^{-3}]*	2047			
Volume weight of humid soil ρ *[kg.m^{-3}]*	2023	2065	2017	1986
Volume weight of dry soil ρ_d *[kg.m^{-3}]*	1950	1996	1955	1922
Humidity w [%]	3,7	3,5	3,1	3,4
Wash-away elements	5,92	5,89	6,70	5,63
Relative settlement I_D	0,86	0,93	0,87	0,82
Number of unequal-granularity C_u	> 15			
Number of curvature C_c	> 1			

Table 3

Outline of measured parameters of subbase material – 3rd stage

Characteristics of material / construction thickness	0,150m	0,300 m	0,450 m	0,600 m
Minimal volume weight $\rho_{d,\,min}$ $[kg.m^{-3}]$	1709			
Maximal volume weight $\rho_{d,\,max}$ $[kg.m^{-3}]$	2093			
Volume weight of humid soil ρ $[kg.m^{-3}]$	2078	2116	2121	2117
Volume weight of dry soil ρ_d $[kg.m^{-3}]$	2004	2046	2051	2044
Humidity w $[\%]$	3,7	3,5	3,5	3,6
Wash-away elements	6,08	6,20	5,63	5,72
Relative settlement I_D	0,80	0,90	0,91	0,89
Number of unequal-granularity C_u	> 15			
Number of curvature C_c	> 1			

5. EVALUATION OF LOADING TESTS AND PROPOSAL OF DIMENSIONAL NOMOGRAMS

In the table 5.1, there are shown average values of equivalent static transform module E_{ekv} in the particular layers of subbase (layers divided according to the thicknes of broken stone of fraction 0-32 mm) of all tested constructions in the subgrade surface bearing capacity about 7-8 MPa. Values of equivalent static transform module E_{ekv} in particular construction layers of subbase are define as average value from ***6*** results of static loading tests that was done in the following places (see figure 2.1): $A_1, A_2, B_1, B_2, C_1, C_2$.

Table 4

Average values of equivalent static transform module E_{ekv} in the particular subbase layers of fraction 0-32 mm during obtaining the average compaction module E_{def2}/E_{def1}

Description of tested place	Static transform module E_{ekv} *[MPa] / average compaction module* E_{def2}/E_{def1}		
	1st stage	2nd stage	3rd stage
Subbase of thickness 0,150 m	14/*2,2*	17/*2,0*	14/*2,1*
Subbase of thickness 0,300 m	37/*1,7*	33/*1,6*	30/*1,7*
Subbase of thickness 0,450 m	*62/1,6*	55/*1,7*	43/*1,7*
Subbase of thickness 0,600 m	80/*1,6*	62/*1,8*	52/*1,8*

On the base of results of static loading tests, which were done in great internal testing stand of DRETM, it is possible to determine progress of equivalent static transform module E_{ekv}.

Figure 5 represents the proposal of nomogram for dimensioning the railway substructure that is valid for the following composition of railway substructure:

1. subgrade surface about 7-8 MPa,

2a. with geocomposite MACRIT GTV/50-50 B,
2b. without geocomposite MACRIT GTV/50-50 B,
3. subbase is broken stone of fraction 0-32 mm with two various granularity curves of graded thickness from 150 mm to 600 mm.

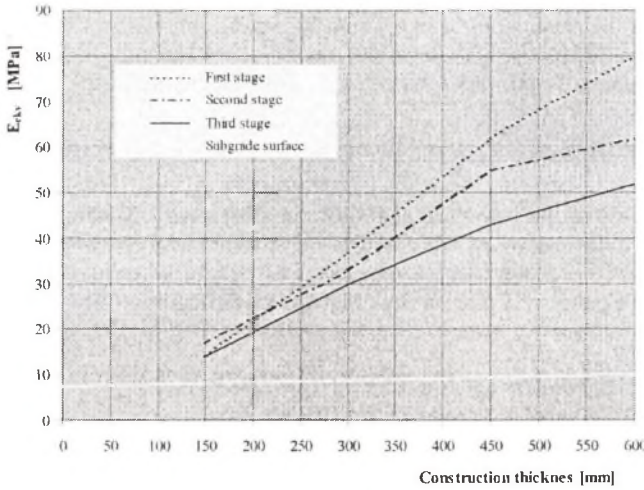

Fig. 5. Progress of equivalent static transform module E_{ekv} for tested constructions of the railway substructure
Rys. 5. Zmiana modułu statycznego E_{ekv} dla testowanych konstrukcji podtorza kolejowego

6. CONTRIBUTION

Three stages of experimental measurements that have been realized in the railway substructure bring results, on the basis of which we can confirm not only expected effect of used geosynthetic but also the influence of chosen subbase material on the resulted bearing capacity of the whole railway substructure.

Lower values of equivalent transform module on the particular subbase surfaces in the second stage of experimental measurements (in about 12% till 30%) have been predicted because of granularity for subbase material required in [10] has higher proportion of the fine fraction 0 – 2 mm (nearly 70%) in comparison with granularity defined in [9] (about 42%). This higher proportion of the fine fraction causes lower permeability of the built in subbase, but we reach higher bearing capacity. However there is higher danger that high proportion of fine fraction increases the ability of the crushed material to keep the humidity and so it will be frost susceptibill and will show primary and secondary frost effects.

With comparison values of equivalent static deformation module E_{ekv} of reinforced and no reinforced construction ***we can confirm the expected reinforced effect of geocomposite MACRIT GTV 50/50-B***. The increasing bearing capacity, which is expressed with equivalent static deformation module E_{ekv} in the dependence with thickness of subbase construction is as follows:

a) first stage/third stage from about 20 to 53%,
b) second stage/third stage from about 10 to 20%.

In the case of thickness of subbase construction 0,150m, reinforced effect of geocomposite MACRIT GTV/50-50 B was ***not recorded***. First of all the results of the first stage of experiment allow assuming the availability of geocomposite MACRIT GTV/50-50 B, like the geosynthetic material, for applying in such a technology aimed to increase the bearing capacity of railway substructure in Slovak Railways. However, one question is open, the behaviour of this material during long-time traffic loading.

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Abstract

In the paper authors present the results of experimental measurements realized in testing stand, which was built for evaluation of reinforced effect of geocomposite MACRIT GTV/50-50 B that was applied into railway substructure. There is described the methodology of experimental measurements, observed physical characteristics of used grounds and results of static loading tests for various granularity and thickness of subbase material (150 mm – 600 mm). The main result of experimental evaluation of two tested subbase material is proposal of nomograms for dimensioning railway substructure with or without application of topical geosynthetic material.