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EVALUATION OF GEOTEXTILES SEPARATION PERFORMANCE ON THE IMPACT OF TRANSPORT LOADS: EXPERIMENTAL RESEARCH – STAGE I

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Abstract. The paper deals with the performance of geotextiles separation function in road pavement structure and geotextile damage from transport loads. The experimental research consists of installation of two different types geotextiles on the bottom of the sub-base (gravel-granite mix, granite and dolomite) of road pavement structure with and without asphalt pavement. Throughout research evaluation of geotextiles damage and separation function performance depends on impact of different amount of vehicle loads has to be done. On stage I performance of separation function and geotextiles damage evaluated after 34 000 equivalent single axle loads (ESALs).

Keywords: separation, geosynthetic, geotextile, geotextile damage, road pavement structure, transport loads, equivalent single axle loads.

1. Introduction

The main function of geotextile is the separation of layers of road pavement. Geotextile is the means to keep separate layers of road pavement during the road service when structure is exposed to permanent static and dynamic transport loads.

In the absence of a base course-subgrade separator, two mechanisms may tend to occur simultaneously in pavements: soil fines attempt to migrate into the base course aggregate, thereby affecting the drainage capability of the pavement as well as its structural capacity; and the aggregate tends to penetrate into the soil due to local shear failure and compromising the pavement system strength [1]. When vertical loads are applied to a granular layer, high horizontal stresses develop within thet layer. In the absence of geotextile separator, outward shear stresses occur on the surface of the subgrade. The presence of this outward shear reduces the bearing capacity of the subgrade. Thus, pumping fines from the subgrade to the base course occurs [2]. In addition, if the soil fines are carried upward into the base course aggregate voids and reach the hot-mix asphalt layer, emulsification of the asphalt binder may result in stripping in that layer [3]. As little as 20 % by weight of the subgrade mixed in with the base aggregate will reduce the bearing capacity of the aggregate to that of the subgrade [4]. When the subgrade soils strength is higher (CBR>3 %) the performance of geotextile as a separation layer and its contribution to the road structure was found to be largely dependent on the subgrade material, the magnitude and number of loading during the service life of the road and environmental conditions. With regard to the subgrade soil, the most important factors are the subsoil grain size and the grain size distribution [5].

Research on the separation of road pavement structure using geotextile shows a positive effect. In full-scale test roads where various geotextiles were seen to prevent base contamination are seen in sections without a geotextile [6–9]. In the other study excavated geotextiles from paved roadways on different sites showed that in all situations the geotextiles performed their intended function [8]. In these situations geotextiles damage, clogging and blinding were observed, but these conditions did not appear to influence the ability of the geotextile to carry out its intended function.

The investigations of damage of geotextile, used for the separation of road pavement structure, made by Lithuanian scientists, show that damage which occurred during the road construction for implementing the function of separation, determine that the most apparent damage is puncturing the geotextile. Even the geotextile of slightest kind perfectly implemented the function of a separation, taking into account the damage, which occurred during construction [10].

After analysis of different research, the main factors influencing the separation by geotextiles, are determined by:

- subgrade material conditions (strength, plasticity, moisture content, grain size and grain size distribution);
- base layer (or subsoil) material conditions (grain size distribution, maximum grain size, aggregate angularity and percentage of fines);
- construction equipment and procedures;
- traffic conditions (the magnitude and number of loadings during the road service time);
- environmental conditions (ground water level, temperature).

2. Designing with geotextiles for separation

2.1. Burst resistance

When geotextile is installed between two layers of road pavement structure and the upper one commonly consists of bigger particles than the bottom, there is a chance, that the geotextile will be pushed into the cavities between the particles of the upper layer. This process is happening when permanent dynamic vehicle loads through the sub – base layer of bigger particles affects the layer under the geotextile, which pushes the geotextile into the cavities of upper layer. J. P. Giroud has proposed an equation for the required geotextile strength in this situation [11]:

$$T_{reqd} = \frac{1}{2} p' d_v [f(\in)] , \quad (1)$$

where T_{reqd} – required geotextile strength; p' – stress on the geotextile (slightly less than p); p – the tire inflation pressure at the ground surface; d_v – maximum void diameter of the upper layer stone $\approx 0{,}33 d_a$; d_a – the average stone diameter; $f(\in)$ – strain function of the deformed geotextile.

$$f(\in) = \frac{1}{4}\left(\frac{2y}{b} + \frac{b}{2y} \right), \quad (2)$$

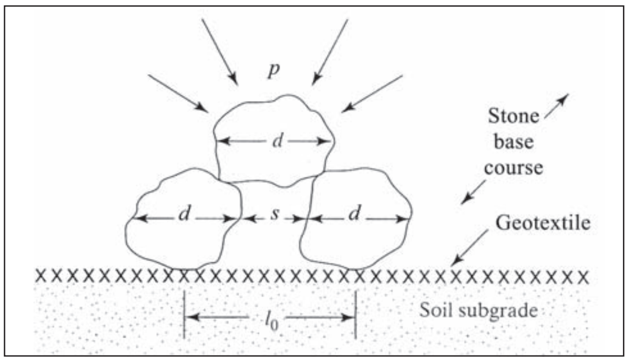

Fig 1. Geotextile being subjected to tensile stress as surface pressure is applied [12]

where b – width of opening (or void); y – deformation into the opening (or void).

2.2. Tensile strength

At the same time with the tendency to burst the geotextile there are more processes acting on it. One of these is the tensile stress being mobilised by in-plane deformation. It happens when geotextile is placed between two layers of road pavement structure and the upper particles of aggregate are forced between two lower pieces which are in contact with the geotextile. In this situation, the maximum strain influencing the geotextile must be evaluated as the upper particle comes itself down to the geotextile level. The maximum strain with no slippage, as with non – woven geotextiles, or aggregate particles breakage can be calculated; the actual situation in structure is in Fig 1 [12]:

$$\varepsilon = \frac{l_f - l_0}{l_0}(100) = \frac{[d + 2(d/2)] - 3(d/2)}{3(d/2)}(100) = 33\ \% , \quad (3)$$

where $S \approx d/2$, l_f – deformed geotextile length.

It should be noted that preceding assumptions result in a strain that is independent of particle size. Thus in the geotextile could be 33 % of given hypothetical assumptions stated above. With woven geotextiles, slippage probably occurs and the strain value would be decreased [12]. And the tensile force being mobilised is related to the pressure exerted on the stone [11]:

$$T_{reqd} = p' (d_v)^2 [f(\in)] , \quad (4)$$

where T_{reqd} – required grab tensile force; p' – applied pressure, d_v – maximum void diameter $\approx 0{,}33 d_a$; d_a – the average stone diameter; $f(\in)$ – strain function of the deformed geotextile, see Eq (2).

2.3. Puncture resistance

During the road construction works, the damage of geotextile, which can occur during its installation, must be prevented. The damage of the biggest scale is made by sharp edges of the mineral materials used for road construction. This damage occurs when mineral materials are placed directly on the geotextile. At the same time, the sharp edges of the mineral materials can puncture the geotextile under the treatment of the mechanisms used for the road construction, static and dynamic machinery loads. Koerner [12] suggests a design method for this situation – the vertical force exerted on the geotextile:

$$F_{reqd} = p' d_a^{\,2} S_1 S_2 S_3 , \quad (5)$$

where F_{reqd} – required vertical force to be resisted; p' – pressure exerted on the geotextile, approx 100 % of tire inflation pressure at the ground surface for thin covering thickness, *da* – average diameter of the puncturing aggregate or sharp object; S_1 – protrusion factor of the puncturing object; S_2 – scale factor; S_3 – shape factor.

3. Experimental research

3.1. The experiment plan

The experiment started on 31.07.2006 and is proceeded. For implementing it the test section at the local road of gravel in Lithuania, which is regularly under the treatment of the heavy vehicle traffic, was chosen. The experiment was divided into two parts. One of them was the assessment of the damage of geotextile and the implementation of the separation function, depending on the kind of the material, used for the sub-base of the road pavement structure and the impact of permanent transport loads, the other – dependence on the asphalt layer in pavement structure.

3.1.1. First part of experiment – road pavement structure with asphalt layer

The full factoral experiment was chosen, during that every factor and factor product influence for the quest value will be determined [13]. The quest value is geotextile damage – GTX_{dmg}. Geotextile damage are taken as percentage expression of total damage (puncturing) area compared to the unbroken material (%). The factors, assessed during the experiment, which influence the damage of the geotextile, and its scale, are as follows:

MM – the kind of the sub-base material;

h – the thickness of the asphalt pavement, cm;

A – ESALs (counted to 100 kN);

While planning the experiment, the supposed established point was chosen, at which the results are the best (considered as the main level). The ranges of factors variation are chosen according to the purpose to get experimental points symmetrical to the main level. The levels of factors and ranges of their variation are in Table 1.

Function for geotextiles damage:

$$GTX_{dmg} = f(MM, h, A), \tag{6}$$

Table 1. The levels of factors and ranges of their variation

Rate	Factors		
	MM	*h*, cm	*A*
Main level	MM_{ml}	3	51 000
Range of variation	MM_{ncrd} – MM_{crd}	±3	±17 000
Upper level	MM_{ncrd}	6	34 000
Lower level	MM_{crd}	0	68 000

MM_{ncrd} – non-crushed material (granite – sand mixture 0/45);
MM_{crd} – crushed material (crushed granite 20/40).

The first rate polynomial for experiment was chosen:

$$GTX_{dmg} = b_0 + b_1 MM + b_2 h + b_3 A + b_{12} MMh + b_{13} MMA + b_{23} hA + b_{123} MMhA. \tag{7}$$

Seven coefficients, which will be identified after a full factoral experiment (23), must be determined for this mathematical model [13]. The matrix of the full factoral experiment is in Table 2. During the experiment 8 different pavement structures combinations and different number of the ESALs are to be assessed at 2 kinds of geotextile damage. For each geotextile matrix of the full factoral experiment was composed. In Table 2 "+" and "–" express the factor level: "+" match the upper level, "–" – lower level.

Calculation of the coefficients of the chosen mathematical model after accomplishing the experiment:

$$b_j = \frac{1}{N}\sum_{i=1}^{N} X_{ij} K_s^i, \tag{8}$$

where j = 0, 1, 2, 3… 7 – factor number; b_0 – counted when the factor level in all tests are in upper level; i = 0, 1, 2, 3… N – test No, X_{ij} – coded values of matrix line; K_s^i – test result; N – number of tests, equal to the number of matrix lines.

3.1.2. Second part of experiment – road pavement structure without asphalt layer

For the second part the same experimental procedure is used as defined in Chapter 3.1.1. The levels of factors are in Table 3 and ranges of their variation and the matrix of

Table 2. The matrix of the full factoral experiment

Test No	Factor and factor product						
	MM	*h*	*A*	MM×*h*	MM×*A*	*h*×*A*	MM×*h*×*A*
1	–1	–1	–1	+1	+1	+1	–1
2	–1	+1	+1	–1	–1	+1	–1
3	+1	–1	+1	–1	+1	–1	–1
4	+1	+1	–1	+1	–1	–1	–1
5	+1	–1	–1	–1	–1	+1	+1
6	+1	+1	+1	+1	+1	+1	+1
7	–1	–1	+1	+1	–1	–1	+1
8	–1	+1	–1	–1	+1	–1	+1

the full factoral experiment are the same as in Table 2, just factor h is replaced by factor T.

Function for geotextiles damage and the first rate polynomial for experiment:

$$GTX_{dmg} = f(MM, A, T), \quad (9)$$

$$GTX_{dmg} = b_0 + b_1 MM + b_2 A + b_3 T + b_{12} MMA + b_{13} MMT + b_{23} AT + b_{123} MMAT. \quad (10)$$

3.2. Test section and materials

According to the made matrixes of the full factoral experiment, three test sections were installed successively (Fig 2). Test sections were installed at the 84 meters long part of the road, constructed pavement structure width – 8 meters. Geotextiles were installed on the present road covering after installation of the 5 cm thickness sand-gravel mix layer. The 30 cm sub-base of 3 different kinds of material was installed on the geotextiles. The kinds and particle size distributions of the sub-base materials are in Fig 3. On the sub-base 6 cm thickness and 28 m length 0/16-Vn [14] asphalt layer was laid.

Two kinds of the nonwoven needle punched polypropylene geotextiles were chosen for the experiment: GTX1 – one of the strongest needle punched geotextiles used for the separation of the layers of pavement structure. Its mass per unit area 300 g/m^2, and GTX2 – one of the slightest. Its mass per unit area 110 g/m^2. The characteristics of the geotextile as declared by the manufacturer are given in Table 4.

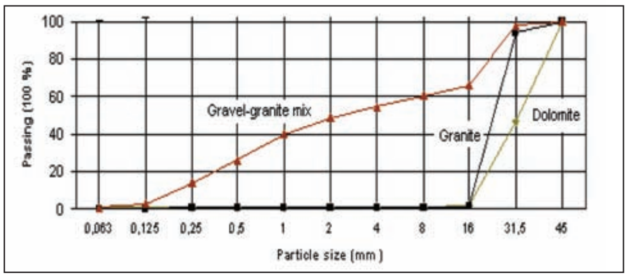

Fig 3. Particle size distributions of sub-base materials

Table 3. The levels of factors and ranges of their variation

Rate	Factors		
	MM	A, vnt	T, g/m^2
Main level	MM_{pl}	51 000	205
Range of variation	$MM_{nesk} - MM_{sk}$	±17 000	±95
Upper level	MM_{nesk}	34 000	300
Lower level	MM_{sk}	68 000	110

T – geotextiles mass per unit area, g/m^2.

Table 4. Characteristics of testing geotextiles as declared by manufacturers

Product No	Mass per unit area	Tensile strength	Strain at peak	CBR	Dynamic puncture opening
	Units				
	g/m^2	kN/m	%	kN	mm
GTX1	300	MD 17,4 CD 19,5	50	3,1	16
GTX2	110	MD 5,5 CD 6,5	60–70	1,0	32

MD – longitudinal, CD – transversal

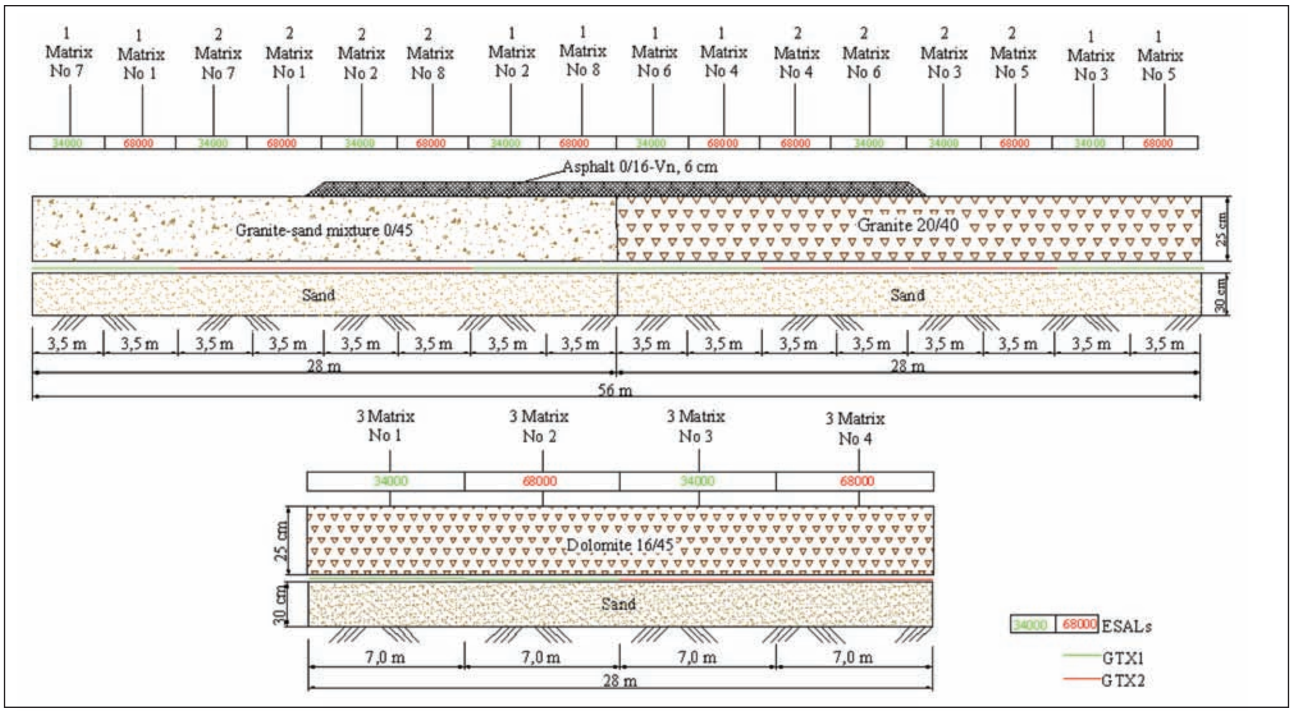

Fig 2. The longitudinal section of the test sections

3.3. The installation of the test sections

In the first section, the geotextiles were installed between the sub-base of granite-sand mixture 0/45 and the frost blanket layer of sand; in the second – between the sub-base of granite 20/40 and the frost blanket layer of sand; in the third – between the sub-base of dolomite 16/45 and the frost blanket layer of sand. The sub-base on the geotextiles was installed as follows:

- mineral material of sub-base were transported by trucks and poured on the existing road covering before beginning of geotextile (Fig 4);
- the material was spread by a bulldozer;
- layer was compacted by a vibratory roller of 12 t, which rolled over it 5 times forth and back;
- the surface of the sub-base was profiled by a grader;
- layer of asphalt 0/16-Vn was paved by paver "SUPER-1600" and compacted by a vibrating roller.

The test section was set on the weekend when the intensity of traffic is lower. After the installation of the test section the ESALs of passed heavy vehicle (Fig 5) was started to count.

4. The experiment results

The first excavation of the geotextiles was done on 21 10 2006 almost after 34 000 ESALs. During the first excavation 2 m length for the whole width of the geotextile sectors in the each section was exposed. In 1st and 2nd sections four and four and in the 3d section 2 samples of geotextile were exposed. The main amount of sub-base material from geotextiles was removed by excavator and to avoid damaging the geotextiles residual material was excavated manually (Fig 6). The separation function was performed in all excavations (Fig 7). Like in earlier research [10] the most frequent damage was puncturing the geotextile. From each excavated geotextile sample 6 independent specimens (30×30) cm were cut off. The total area of puncturing was counted in all 6 independent specimens. The mean damage (puncturing) area values of all excavated geotextiles are presented in Fig 8.

Fig 4. Geotextiles installation process

Fig 5. Heavy vehicle traffic in the test section

Fig 6. Excavation of geotextiles in the test sections

Fig 7. Performed separation function

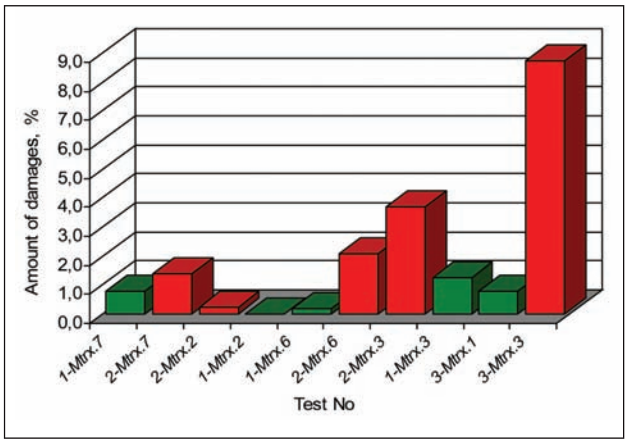

Fig 8. Mean values of geotextiles damage area (GTX1 in green, GTX2 in red)

5. Conclusions

It is necessary to accomplish all experiments and excavations of geotextiles after 68 000 ESALs to calculate coefficients of the chosen mathematical model. There are only 4 coefficients in each section after the first excavation. That is the reason for the result after first excavation to be evaluated as tendency:

1. After the first excavation and geotextiles damage evaluation it can be said that separation function was performed perfectly in all sections but puncturing of geotextiles were not spread gradually in all the area of geotextiles.
2. The most damaged geotextile was excavated from road pavement structure without an asphalt layer in which the sub-base was from dolomite.
3. Much less damage was observed in the geotextile excavated from road pavement structure without an asphalt layer in which sub-base was from granite.
4. In other excavated geotextile the amount of damage was too small to find a dependence.

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