Audrius VAITKUS

GEOTEXTILE SELECTION METHODS FOR THE LITHUANIAN ROAD AND STREET STRUCTURES

Summary of Doctoral Dissertation
Technological Sciences, Civil Engineering (02T)

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Vilnius LEIDYKLA TECHNIKA **2007**

VILNIUS GEDIMINAS TECHNICAL UNIVERSITY

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VILNIAUS GEDIMINO TECHNIKOS UNIVERSITETAS

Audrius VAITKUS

GEOTEKSTILIŲ PARINKIMO METODAI LIETUVOS AUTOMOBILIŲ KELIŲ IR GATVIŲ KONSTRUKCIJOMS

Daktaro disertacijos santrauka
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General characteristic of the dissertation

Topicality of the problem. The structural strength of roads and streets as well as the uniformity of strength are ensured by a design strength of subgrade, sub-base and pavement layers, characterized by a deformation modulus, the value of which depends on the properties of materials used for the pavement structural layers and thickness of the layers. During construction of road or street pavement structure and its operation the continuous static and dynamic vehicle loads may cause the intermixing of the subgrade soil with the frost blanket course. Analogical process could happen between the frost blanket course and the sub-base constructed from the large particles of aggregate. Eventually, the intermixed materials of the different structural layers of road or street can have the impact on the strength and durability of the whole structure.

In order to prevent the aggregates of different structural layers from becoming intermixed during road or street construction or in the phase of operation the geotextile inter-layers have been world-widely used in the recent 15 years. Based on the recommendations of U.S. researchers the geotextiles used for the separation of structural layers should be selected according to the existing formulas. However, these formulas are valid only for the road structures without asphalt concrete pavement. Another method for selecting geotextiles – specifications and recommendations of different countries. At present there are no generally accepted European specifications regulating the selection of geotextiles intended for separating road or street pavement layers. The reason is that different European countries have different climatic and geological conditions. Thus, each or several countries, where these conditions require separation of pavement structural layers by the geotextile, have their own normative documents or recommendations.

Lithuania has only been using geotextiles in road and street construction and reconstruction during the last decade. In 1998 Lithuanian Road Administration adopted the temporary regulations on *Using Geotextiles and Geogrids for Road Construction*, which are still being used by road designers and suppliers of geosynthetics. The regulations are based on the German experience and their specifications for the use of geotextiles on roads. However, when adapting these regulations no experimental research was carried out or evaluation of their suitability to Lithuanian conditions.

In recent five-year period the increased number of vehicle ownership and the growth of traffic volume on Lithuanian roads and streets caused the need to construct new roads and streets. To ensure the durability of new roads and streets, safety and comfort for the road users it is necessary to apply new advanced technologies. One of them – separation of structural layers by using geotextiles. The need for the use of geotextiles and the need to identify a suitable method of geotextile selection for the Lithuanian roads and streets determines the topicality of this work.

Aim and tasks of the work – to increase the durability of road structures by developing the geotextile selection method for the Lithuanian road and street structures.

The following tasks must be solved to achieve the aim of the work:

1) To analyze the impact of geotextile damages on the ability to fulfil the function of separation.

2) To analyze and assess the world-wide used methods for the selection of geotextiles.

3) To assess the main factors influencing the occurrence of geotextile damages during the road or street construction and operation.

4) To develop a theoretical geotextile selection method for Lithuanian conditions.

5) To carry out experimental research with a purpose to justify or to deny the assumptions of a theoretical model.

6) Based on the analysis and assessment of the results of experimental research to suggest the geotextile selection method for the fulfilment of the function of separating aggregate layers of the Lithuanian road and street pavement structures.

7) To carry out the evaluation of economic effect of the use of geotextiles to fulfil the separation function.

Scientific novelty. The novelty of this scientific work is that until now no investigation has been carried out on the intermixing of aggregates of the road structural layers during road construction and operation due to static and dynamic vehicle loads under Lithuanian conditions and it was analyzed for the first time. Also, for the first time a detail analysis and assessment was performed of the need of geotextiles and the geotextile selection method for the separation of structural layers.

A comprehensive experimental research made it possible to determine the suitability of geotextiles for performing the function of separation during construction and operation of roads and streets. The determined main factors, having the impact on the geotextile damages and the fulfilment of separation function, as well as the developed geotextile selection method make the relevance of the scientific work.

Methodology of research includes the development of a theoretical geotextile selection method, the planned experimental research, analysis and assessment of the results of experimental research, correction of the developed theoretical method.

Practical value. The geotextile selection method, developed on the basis of the analysis of the results of experimental research, will be put into practice. The use of geotextiles, selected on the basis of the developed geotextile selection method for the separation of structural layers, is cost effective.

Defended propositions

1) Geotextile damages having occurred during the installation of structural layers of the road pavement over the geotextile have no significant impact on the fulfilment of the function of layer separation.

2) The main factors having the impact on the occurrence of geotextile damages during the geotextile installation and road operation are as follows: a) loads during the installation of road pavement structure (traffic of the road building mechanisms on the layer constructed over the geotextile); b) grading and size of the largest aggregate particle of the layer constructed over the geotextile; c) thickness of the structural layers over the geotextile; d) traffic loads during the road operation.

3) Mechanical properties of the geotextiles are directly dependent on the degree of geotextile damage.

The scope of the scientific work. The scientific work consists of the general characteristic of the dissertation, four chapters, conclusions, list of literature and list of publications. The total scope of the dissertation – 104 pages, 44 pictures and 28 tables.

The introduction describes the existing problem, the need for the use of geotextiles for the separation of road and street structures. Also, the relevance of the research, the scientific novelty and originality of the dissertation, its aim and practical importance.

Chapter 1. Road structures, their strength and durability. When the road is in operation the road structure weight and temporary loads lead to two simultaneous processes between the construction layers (i. e. between the sub-base and the frost blanket course and between the subgrade and the frost blanket course): first, the subgrade soil particles migrate into the frost blanket course and second, large particles of the aggregate of the road sub-base and the frost blanket course migrate into the weaker lower layer. As a result, at the beginning the filtering properties of the frost blanket course decrease, and then the strength of the upper layers is reduced.

A geotextile inter-layer can be an effective measure for separating road structural layers of unbound materials. However, separation of the road structural layers of unbound materials by using a geotextile inter-layer can be implemented only when constructing a new or reconstructing an old road structure. A volume of works in constructing and reconstructing the road and street structures in Lithuania is annually increasing. Therefore, it could be stated that in Lithuania when constructing and reconstructing roads and streets it would be rational to use a geotextile inter-layer for the separation of layers of unbound materials.

Chapter 2. Analysis of the geotextile selection methods for the separation of structural layers. Until now there have been no generally accepted normative documents in Europe regulating the selection of geotextiles intended for the separation of structural layers. Geotextiles are usually selected on the basis of specifications and recommendations of a particular country or based on the experience of designers and manufactures. In 2002 the Nordic countries developed a unified system for specification and control of geotextiles in roads and other trafficked areas – the NorGeoSpec. The system is aimed at the North European countries.

Since 1980 Germany has been successfully using GRC, a Geotextile Robustness Classification. At first, it classified the robustness of geotextiles against mechanical damage into 4 classes. Later, having adopted a Norwegian proposal in 1994, the classification was extended to 5 classes. To find out a GRC for a given site, Germans classify the fill material into 5 levels according to the diameter and the sharpness of aggregates. The types of loading are classified into 4 levels and depend on the installation and construction works.

Lithuania has only been using geotextiles for road construction and reconstruction during the last decade. In 1998 Lithuanian Road Administration adopted the temporal regulations *Using Geotextiles and Geogrids for Road Construction*, which are still used by road designers and suppliers of geosynthetics. The regulations are based on the experience of German specialists and their standards specifying the use of geotextiles on roads, however, no on-site research or adoption to local conditions has ever been done. Therefore, to ensure a proper use of geosynthetics in the pavement structure of Lithuanian roads and streets, the specifications should be revised. Also, it is important that the experimental research is carried out.

The *NorGeoSpec*, a system of geotextile selection and control used in the Nordic countries, specifies the strength characteristics of non-woven geosynthetics and maximum tolerance. However, the static puncture strength and mass per unit area, the characteristics of utmost importance for German and Lithuanian designers when selecting geotextiles, have only tolerance values specified. Some researchers have proved a direct dependency between the mass per unit area and the static puncture strength.

In order to develop a rational geotextile selection method for separating different layers of road and street pavement structures the following questions have been raised:

1) Between which layers the geotextile inter-layer shall be installed?

2) In what cases the geotextile inter-layers shall be installed?

3) What type of geotextiles shall be used for the separation inter-layers?

4) Which geotextile properties are the most important for the fulfilment of the separation function?

5) What are the factors having the largest impact on the occurrence of geotextile damages?

The answers to the above questions will give a possibility to develop a comprehensive geotextile selection method under Lithuanian conditions.

Chapter 3. Experimental research of the use of geotextiles for the separation of road and street structural layers. Having analyzed a number of literature sources the main factors having the impact on the occurrence of geotextile damages and on the failure to perform the separation function were determined. Taking these factors into consideration, experimental research was divided into three parts:

1) to assess the dependency of geotextile damages and fulfilment of the separation function on the loading during installation;

2) to identify and assess the dependency of geotextile damages and fulfilment of the separation function on traffic loads during road operation, on the materials used for the installation of pavement structure and on the thickness of pavement structure over the geotextile;

3) to identify and assess the dependency of mechanical properties of the geotextiles on the variation in the amount of geotextile damages.

Part of the experimental research to identify and assess installation damages. Investigations were carried out in 2005 on the main road of the Republic of Lithuania A1 Vilnius – Kaunas – Klaipėda. On the investigated road section, within the pavement lane to be widened, two 15 m long test sections were selected. In each of them 5 types of separating geotextile were installed, produced by different manufacturers. Their mass per unit area was 110 g/m^2; 130 g/m^2; 170 g/m^2; 200 g/m^2 and 300 g/m^2, respectively. In the first test section the separating geotextiles were placed between the subgrade and the frost blanket course. In the second – between the frost blanket course and the sub-base. A cross-section of the structure is given in Figure 1. In the first test section a 45 cm thick frost blanket course was constructed of the frost resistant gravel of a good structure (the largest particle size 30–35 mm). The course was erected by separately compacting two 30 cm and 15 cm thick layers. For both layers a vibratory roller of 12 t was used for sand compaction, which rolled on each layer 5 times forth and back. In the second test section the 27 cm thick sub-base of the crushed dolomite 0/63 was constructed over the geotextile. The largest particle size of the layer amounted to 60 mm. The layer over the geotextile was compacted by a vibratory roller of 8 t by rolling over it 5 times.

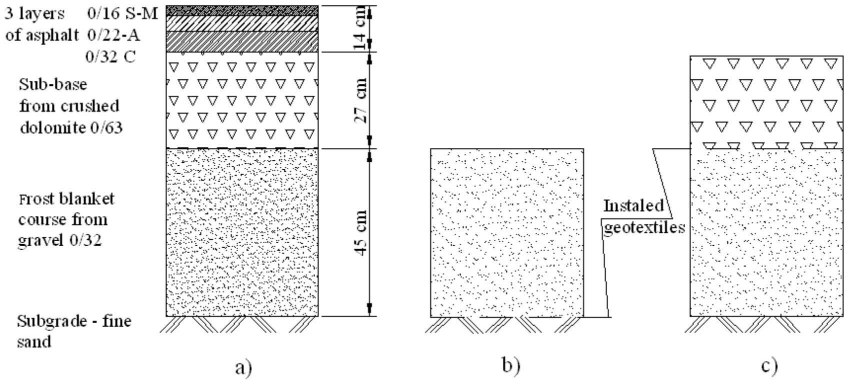

Fig 1. A cross-section of a new road structure and the levels of geotextile installation: a) cross-section of the road structure, b) geotextile separating the subgrade and the frost blanket course, c) geotextile separating the frost blanket course and the sub-base

After the installation of relevant structural layers over the geotextiles in both test sections and after their design values of static deformation modulus were reached by compacting the layers, the excavation and sampling works were carried out. To avoid the damage of the test materials during excavation all the works were performed manually. In the process of investigation, damages of the separating geotextiles were assessed on the basis of the visual on-site assessment methodology of the British Standard BS 8006, annex D. The following geotextile damages were identified in the test sections: general abrasion, cuts and puncturing. The most frequent damage of the test geotextiles was puncturing, therefore, a percentage expression of the sum of the total punctured area (%), if compared to the total area of undamaged material, was selected as a comparative indicator of geotextile damages. The obtained comparative indicators are given in Figure 2.

In the result of investigation it can be stated that all the damages in geotextiles, having occurred during installation of pavement structural layers over the geotextiles, had no significant impact on the fulfilment of the separation function of the layers. A visual assessment of the test geotextiles indicates that geotextile puncturing is the most significant damage having a negative impact on the separation of the structural layers of the road pavement.

The results of experimental research deny the propositions of the scientists, which were analyzed in chapter 1 of the dissertation that the main damages in geotextiles occur in the process of their installation. The results of this investigation showed that even the weakest geotextile used for the separation function is able to carry the loads of installation and to perform the separation function of the layers (in a typical structure of the Lithuanian road pavement). Therefore, it is necessary to undertake another experimental research to identify and assess the dependency of geotextile damages and fulfilment of the separation function on the vehicle loads during road operation, the materials used for the installation of pavement structure and on the thickness of pavement structure over the geotextile.

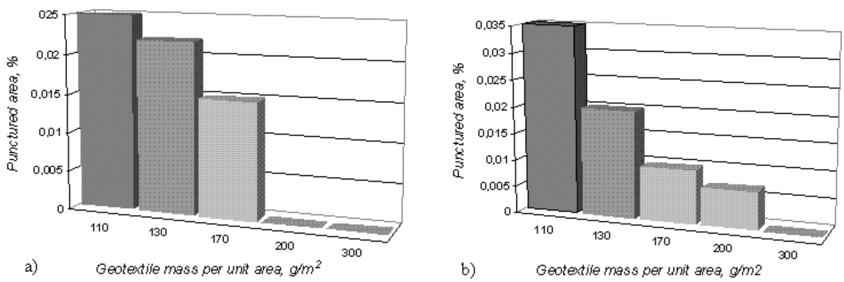

Fig 2. The obtained comparative indicators: a) from the first test section, b) from the second test section

Part of the experimental research to identify and assess damages caused by vehicle loads during road operation. Part of the experimental research to identify and assess damages caused by vehicle loads during road operation was started on 31 July 2006 and finished on 14 April 2007. For the research purposes a gravel road of local importance was selected under continuous heavy loading (about 150 veh./day). This part of the experimental research was further divided into two parts: one of them – aimed at the assessment of tendencies in the occurrence of geotextile damages and fulfilment of the separation function, depending on the materials used for the construction of the sub-base, when the road structure has asphalt concrete pavement, the other – has no asphalt concrete pavement. This experimental research was carried out to assess the tendencies in the occurrence of geotextile damages and fulfilment of the separation function, depending on the materials used for the construction of the sub-base and on the number of equivalent standard axel loads (ESALs) estimated to 100 kN.

A full factorial experiment was chosen, during which every factor and the factor product influence on the quest value will be determined. The quest value is the geotextiles damage – GTX_{dmg}. Geotextile damage is taken as a percentage expression of the total damage (puncturing) area compared to the undamaged material, (%). The factors, assessed during the experiment, having the impact on the damage in the geotextile, and its scale, are as follows:

MM – the type of the sub-base material;

h – the thickness of the asphalt pavement, cm;

A – ESALs (estimated to 100 kN).

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

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

Rate	Factors		
	MM	h, cm	A, units
Main level	–	3	51000
Range of variation	–	±3	±17000
Upper level	MM_{ncrd}	6	34000
Lower level	MM_{crd}	0	68000

MM_{ncrd} – non-crushed material (granite - sand mixture 0/45);
MM_{crd} – crushed material (crushed granite 16/32).
*the main level and range of variation for the type of sub-base material isn't determined.

Function for geotextile damages:

$$GTX_{dmg} = f(MM, h, A). \qquad (1)$$

The first rate polynomial was chosen for the experiment:

$$GTX_{dmg} = b_0 + b_1 MM + b_2 h + b_3 A + b_{12} MMh + b_{13} MMA + b_{23} hA + b_{123} MMhA. \qquad (2)$$

Having done a full 2^3 factorial experiment, eight coefficients of mathematical model were determined. On the main level the coefficient is:

$$b_0 = \frac{\sum_{i=1}^{N} GTX_{dmg(i)}}{N}; \qquad (3)$$

$GTX_{dmg(i)}$ – the scale of geotextile damage, determined by i th test, %; N – number of tests.

Other coefficients of the selected mathematical model are calculated by the formula:

$$b_j = \frac{1}{N} \sum_{i=1}^{N} X_{ij} GTX_{dmg(i)} ; \qquad (4)$$

j = 0, 1, 2, 3…7 – factorial number; i = 0, 1, 2, 3…N – number of the test; X_{ij} – coded values in a row of a matrix.

For both geotextiles a matrix of a full factorial experiment is written (Table 2). In this matrix "+" and "–" gives the levels of factors, indicating the higher and the lower level, respectively. In the process of experiment 4 combinations of different road pavement structures and two geotextiles were assessed after the passage of a different number of ESALs.

Table 2. The matrix of a full factorial experiment

Code of load and structure		Factors and factors product						
GTX1	GTX2	MM	h	A	MM·h	MM·A	h·A	MM·h·A
1-No 5	2-No 5	–1	–1	–1	+1	+1	+1	–1
1-No 6	2-No 6	–1	+1	+1	–1	–1	+1	–1
1-No 7	2-No 7	+1	–1	+1	–1	+1	–1	–1
1-No 8	2-No 8	+1	+1	–1	+1	–1	–1	–1
1-No 1	2-No 1	+1	–1	–1	–1	–1	+1	+1
1-No 2	2-No 2	+1	+1	+1	+1	+1	+1	+1
1-No 3	2-No 3	–1	–1	+1	+1	–1	–1	+1
1-No 4	2-No 4	–1	+1	–1	–1	+1	–1	+1

Based on the matrices of a full factorial experiment on 29–30 July 2006 on the existing road with a gravel pavement two 56 and 28 metres long test sections were constructed. Width of the newly erected road pavement structure was 8 m. Before placing the geotextile the existing road surface was profiled and provided with 5 cm thick sand layer. Over the geotextiles three different-type 25 cm thick sub-base layers of crushed granite and sand mixture 0/45, crushed granite 16/32 and crushed dolomite 16/45 were constructed. In 28 m long section, the asphalt concrete 0/16-Vn layer was erected 6 cm thick and 6 m wide. Two types 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 weakest (its mass per unit area 110 g/m^2).

The first excavation of geotextiles after the passage of 34000 ESALs was carried out on 21 October 2006, the second – on 14 April 2007 after the passage of 68000 ESALs. During each excavation the samples of geotextiles with the size of 2,0 m × 6,0 m were taken out from the road pavement structure, based on the relevant codes of geotextile damage matrices and loads, and were visually assessed. From each of the geotextile samples in an accidental order 6 specimens of the same area (30 cm × 30 cm) were cut out. Each specimen was placed on a light spreading base and the area of punctures was calculated as well as the sum of the punctured areas. Punctures with a diameter < 3 mm were not taken into consideration.

A constant member of the mathematical model of the geotextile GTX1, selected for experimental research, was calculated on the main level according to the formula 3 and is equal to b_0 = 0,34. Other coefficients of this model were calculated according to the formula 4. In this case a mathematical model, described by a polynomial, which reflects the degree of the geotextile GTX1 damage due to the above mentioned factors, their scale and interaction will have the following expression:

$$GTX1_{dmg} = 0{,}34 - 0{,}06MM - 0{,}24h - 0{,}04A - 0{,}04MMh - \\ 0{,}04MMA - 0{,}04hA + 0{,}11MMhA. \tag{5}$$

A constant member of the mathematical model of the geotextile GTX2, selected for experimental research, was calculated on the main level according to the formula 3 and is equal to b_0 = 1,23. Other coefficients of this model were calculated according to the formula 4. In this case a mathematical model, described by a polynomial, which reflects the degree of the geotextile GTX2 damage due to the above mentioned factors, their scale and interaction will have the following expression:

$$GTX2_{dmg} = 1{,}23 - 0{,}82MM - 0{,}08h - 0{,}25A + 0{,}05MMh + \\ 0{,}09MMA - 0{,}11hA - 0{,}04MMhA. \tag{6}$$

The analysis of the results of experimental research showed that the main factors having the influence on the occurrence of geotextile damages during its installation and in the phase of road operation are as follows:

1) loads during the installation of road pavement structure (traffic of the road building mechanisms on the layer constructed over the geotextile);
2) grading and size of the largest aggregate particle of the layer constructed over the geotextile;
3) thickness of the layers of road pavement structure over the geotextile;
4) traffic loads during the operation of road pavement structure.

Chapter 4. Geotextile selection method for the use in the Lithuanian road and street structures. The recommended procedure for the determination of the need for the use of separating geotextile and for the selection of geotextile is given in Figure 3.

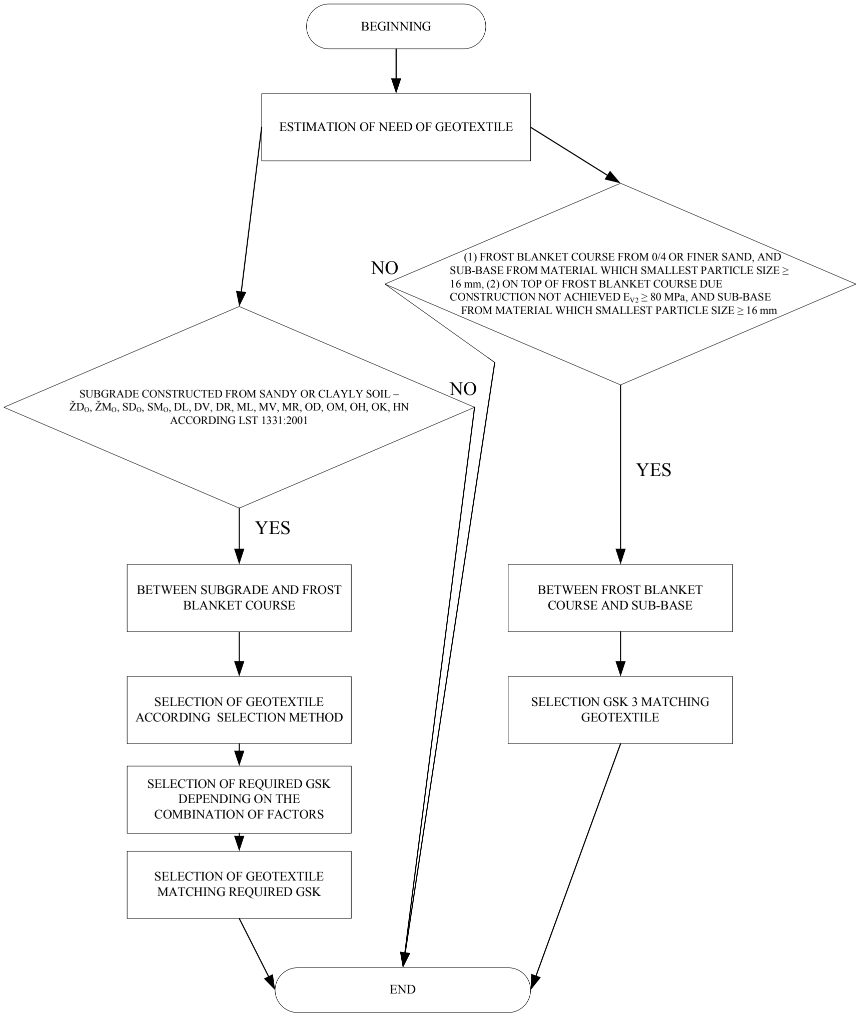

Fig 3. Procedure for the determination of the need for the use of geotextiles and for the selection of geotextiles

During geotextile installation as well as the road operation the inter-layer of the separating geotextile falls under the effect of certain factors, which have the impact on the occurrence of geotextile damages or the failure of partial or full fulfilment of the separation function. These factors are divided into the levels of the damage factors, which are corresponded by the five geotextile strength classes (GSK1, GSK2, GSK3, GSK4 and GSK5).

On the basis of the geotextile selection method the following factors are marked out having the impact on the geotextile damages and fulfilment of separating function:

Strength of the subgrade soil:

1) Low – subgrade from DR, MR, OD, OM, OH, OK, HN soil in accordance with the standard LST 1331:2002;
2) Medium – subgrade from DL, DV, ML, MV soil in accordance with the standard LST 1331:2002;
3) High – subgrade from $ŽD_O$, $ŽM_O$, SD_O, SM_O soil in accordance with the standard LST 1331:2002.

Loads due to the installation of the layer over the geotextile:

1) Low – the layer is constructed by the light-weight machinery and compacted by vibrating panels or rollers with the weight of ≤ 5 t;
2) Medium – the layer is constructed by the heavy machinery and compacted by vibrating rollers with the weight of ≥ 5 t;
3) High – the layer is constructed by the heavy machinery and compacted by vibrating rollers, the traffic of building machines is allowed.

Thickness of the layers of road pavement structure over the geotextile:

1) Low – the total thickness of structural layers over the geotextile ≤ 50 cm;
2) High – the total thickness of structural layers over the geotextile > 50 cm.

Loads due to the operation of road pavement structure:

1) Low – index of heavy traffic < 18 000 or design load A < 10 millions;
2) High – index of heavy traffic ≥ 18 000 or design load A ≥ 10 millions.

Dependency of geotextile strength classes on the combinations of factors, having the impact on the structure during its installation and operation, is given in Table 3. Based on this table the required geotextile strength class is chosen.

Based on Table 4 the geotextile is selected, corresponding to the respective GSK. This table gives the required geotextile properties identified from the analysis of the results of experimental research, carried out by the scientists. Most of these properties are set in the standard EN 13249 Geotextiles and Geotextile-Related Products. Characteristics Required for Use in the Construction of Roads and Other Traffic Areas.

Table 3. Geotextile strength classes depending on the combinations of factors, having the impact on the geotextile damages and on the fulfilment of the separation function

Installation loads	Layers thickness over the geotextile	Road operation loads	Strength of the subgrade soil		
			Low	Medium	High
High	Low	High	GSK 4	GSK 5	GSK 5
		Low	GSK 3	GSK 4	GSK 5
	High	High	GSK 3	GSK 4	GSK 5
		Low	GSK 3	GSK 4	GSK 5
Medium	Low	High	GSK 3	GSK 4	GSK 5
		Low	GSK 2	GSK 3	GSK 4
	High	High	GSK 2	GSK 3	GSK 4
		Low	GSK 2	GSK 3	GSK 3
Low	Low	High	GSK 1	GSK 3	GSK 3
		Low	GSK 1	GSK 2	GSK 3
	High	High	GSK 1	GSK 2	GSK 2
		Low	GSK 1	GSK 1	GSK 2

Table 4. Required values for the geotextile properties on the basis of geotextile strength classes

Geotextile characteristic	Maximum tolerance	Geotextile strength class				
		GSK1	GSK2	GSK3	GSK4	GSK5
		Required geotextile characteristics				
Tensile strength*, kN/m	–10 %	5	7	10	13	15
Elongation at max load, %	–15 %	60	55	55	50	50
Min energy index, kN/m	-	1,4	1,8	2,5	2,9	3,4
Max cone drop diameter, mm	+20 %	33	28	24	19	14
Static puncture strength, kN	–15 %	1,1	1,6	2,2	2,7	3,2
Min velocity index, 10^{-3} m/s	–25 %	120	100	100	80	70
Characteristic opening size, µm	+25 %	150	150	130	100	100
Max tolerance for mass per unit are	-	–12 %	–12 %	–12 %	–10 %	–10 %

* values along geotextile tensile direction.

Evaluation of the economic effect after the use of geotextile inter-layer

Evaluation of the economic effect was divided into three parts:

1) when geotextile inter-layer is installed between the sub-base and the frost blanket course;

2) when geotextile inter-layer is installed between the frost blanket course and the subgrade;

3) when geotextile inter-layer is installed between the sub-base and the frost blanket course and between the frost blanket course and the subgrade.

Evaluation of the economic effect shows that the use of geotextile inter-layers selected on the basis of the developed geotextile selection method for constructing and reconstructing Lithuanian roads and streets is cost-effective. The costs of geotextile and its installation are paid back already in the phase of installation. This is obvious from the cost-benefit ratio which, in individual cases, varies from 1,76 to 2,12.

General conclusions

1. The analysis of the results of experimental research showed that the geotextile damages caused during the installation of road pavement structure layers over the geotextile have no significant impact on the fulfilment of the separation function. It was also determined that the most significant geotextile damages having a negative impact on the separation function are punctures. The damages (punctures) of the tested geotextiles make 0–0,035 %, if compared to the area of undamaged geotextile.

2. The analysis of the results of experimental research aimed to determine the geotextile damages caused by traffic loads during the road operation showed that during road operation the geotextile is damaged 200 times more, if compared to the geotextile damages caused during the installation of road pavement structure layers. The damages (punctures) of the tested geotextiles make 0,01–6,7 %, if compared to the area of undamaged geotextile.

3. The main factors were identified having influence on the occurrence of the geotextile damages during pavement installation and in the phase of road operation, i.e.:

a) grading and size of the largest aggregate particle of the layer constructed over the geotextile;

b) thickness of the pavement layers over the geotextile;

c) loads during the pavement installation (traffic of the road building mechanisms on the layer constructed over the geotextile);

d) traffic loads during the operation of the road.

4. The analysis of the results of experimental research aimed to define the change in the mechanical properties of the geotextiles indicated a high correlation between the degree of damages in the geotextile specimens and the

average values of static puncture strength (CBR). Correlation coefficient of GTX1 indices is (–0,84), of GTX2 – (–0,88). Knowing the degree of geotextile damages it is possible to predict (calculate) the resistance of geotextile to static puncture strength (CBR), when a geotextile inter-layer is placed between the frost blanket course and the sub-base.

5. Developed geotextile selection method reflects the need for the use of geotextile, takes into consideration the factors having the impact on the occurrence of geotextile damages during pavement installation and in the course of road operation. The use of geotextiles for separation function selected based on the developed method is cost-effective. The costs of geotextile and its installation are paid back already in the phase of road construction, the cost-benefit ratio varies from 1,76 to 2,12.

List of published works on the topic of the dissertation

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2. VAITKUS, A.; ČYGAS, D.; LAURINAVIČIUS, A.; JUZĖNAS A. A. Evaluation of Geotextiles Separation Performance on the Impact of Transport Loads: Experimental Research-Stage I. *The Baltic Journal of Road and Bridge Engineering,* 2007, Vol II, No 1, p. 45–50. ISSN 1822-427X print, ISSN 1822-4288 online.

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GEOTEKSTILIŲ PARINKIMO METODAI LIETUVOS AUTOMOBILIŲ KELIŲ IR GATVIŲ KONSTRUKCIJOMS

Mokslo problemos aktualumas. Įrengiant automobilių kelio ar gatvės dangas ant žemės sankasos bei vėliau jas eksploatuojant dėl nuolatos pasikartojančių statinių bei dinaminių transporto priemonių apkrovų gali prasidėti žemės sankasos grunto bei apsauginio šalčiui atsparaus sluoksnio medžiagų sąmaiša. Analogiškas procesas gali vykti ir tarp apsauginio šalčiui atsparaus sluoksnio bei dangos pagrindo medžiagų. Ilgainiui kelio ar gatvės konstrukcijos sluoksnių medžiagų tarpusavio sąmaiša mažina dangos stiprį bei tvarumą.

Siekiant išvengti atskirų konstrukcijos sluoksnių mineralinių medžiagų tarpusavio susimaišymo, tiesiant kelius ar gatves bei juos eksploatuojant, pastaruosius 15 metų pasaulyje plačiai taikomi geotekstilės tarpsluoksniai. Jungtinių Amerikos Valstijų mokslininkai geotekstiles parinkti rekomenduoja naudoti skaičiavimus pagal formules, tačiau jos tinka tik keliams be asfaltbetonio dangos. Kitas geotekstilių taikymo būdas – atskirų šalių sukurtos normos bei rekomendacijos. Europoje nėra vieningų norminių dokumentų, reglamentuojančių geotekstilių naudojimą automobilių kelių bei gatvių konstrukcijos sluoksniams atskirti. Tai galima pagrįsti tuo, kad Europos valstybėse yra skirtingos klimatinės bei geologinės sąlygos. Taigi kiekviena ar keletas valstybių, kurioms pagal jų sąlygas aktualu kelio konstrukcijos sluoksnius atskirti geotekstilėmis, turi savo normas ar rekomendacijas.

Lietuvoje geosintetinės medžiagos tiesiant ir rekonstruojant automobilių kelius bei miestų gatves naudojamos tik pastarąjį dešimtmetį. 1998 metais Lietuvos automobilių kelių direkcija išleido laikinuosius nurodymus „Geotekstilės ir geotinklų naudojimas tiesiant kelius“, kuriais iki šiol vadovaujasi projektuotojai ir geosintetinių medžiagų tiekėjai. Šie nurodymai yra parengti vadovaujantis Vokietijos specialistų patirtimi ir jų parengtais dokumentais geosintetinėms medžiagoms naudoti tiesiant kelius. Pritaikant šiuos nurodymus nebuvo vykdomi eksperimentiniai tyrimai, bei nustatomas tinkamumas Lietuvos sąlygoms.

Lietuvoje pastaraisiais metais ženkliai išaugo naujų kelių ir gatvių tiesimo bei rekonstrukcijos apimtys. Kelių ir gatvių tvarumui, eismo dalyvių saugumui bei komfortabilumui užtikrinti, būtina taikyti naujas pažangias technologijas. Viena tokių technologijų yra kelio ar gatvės konstrukcijos sluoksnių atskyrimas geotekstilėmis. Geotekstilių naudojimo reikalingumo bei tinkamo parinkimo būdo nustatymo poreikis Lietuvos automobilių keliams ir gatvėms lemia šio darbo aktualumą.

Darbo tikslas ir uždaviniai – didinti automobilių kelių dangų tvarumą, sukuriant geotekstilių parinkimo metodą Lietuvos automobilių kelių ir gatvių konstrukcijoms.

Darbo tikslui pasiekti reikia išspręsti šiuos uždavinius:

1) Nustatyti geotekstilių pažaidų įtaką atskyrimo funkcijai realizuoti.

2) Analizuoti ir apibūdinti kitose valstybėse taikomus geotekstilės parinkimo metodus.

3) Nustatyti pagrindinius veiksnius, turinčius įtaką geotekstilės pažaidoms susidaryti, įrengiant bei eksploatuojant automobilių kelią ar gatvę.

4) Sukurti teorinį geotekstilių parinkimo modelį Lietuvos sąlygoms.

5) Atlikti eksperimentą teoriniame modelyje iškeltoms prielaidoms pagrįsti arba paneigti.

6) Remiantis eksperimentinių tyrimų rezultatų analize, pasiūlyti geotekstilės parinkimo metodą Lietuvos automobilių kelių ir gatvių konstrukcijų sluoksniams atskirti.

7) Nustatyti ekonominį efektą, gaunamą atskiriant kelio konstrukcijos sluoksnius geotekstilėmis.

Mokslinis naujumas. Šio mokslo darbo naujumą sudaro tai, kad kelio konstrukcijos sluoksnių mineralinių medžiagų susimaišymas tiesiant bei eksploatuojant kelius, Lietuvos sąlygoms, iki šiol nebuvo tyrinėtas ir analizuojamas pirmą kartą. Taip pat pirmą kartą detaliai analizuojamas ir apibūdinamas geotekstilės poreikis bei atrankos būdas.

Mokslo darbo nuosekliais eksperimentiniais tyrimais nustatytas geotekstilės tinkamumas atskyrimo funkcijai, tiesiant ir eksploatuojant kelius bei gatves. Eksperimentiniais tyrimais nustatyti pagrindiniai veiksniai turintys įtaką geotekstilės pažaidoms susidaryti ir atskyrimo funkcijai realizuoti bei sukurtas geotekstilių atrankos metodas sudaro mokslo darbo originalumą.

Tyrimų metodiką apima teorinio geotekstilės atrankos modelio sukūrimas, planuoti eksperimentiniai tyrimai, eksperimentinių tyrimų rezultatų analizė ir apibūdinimas, sukurto teorinio modelio koregavimas bei geotekstilės parinkimo metodo sukūrimas.

Praktinė vertė. Eksperimentinių tyrimų rezultatų analizės išdavoje sukurtas geotekstilių parinkimo metodas bus taikomas praktikoje. Pagal sukurtą metodą parinktų geotekstilių naudojimas kelio konstrukcijos sluoksnių atskyrimui yra rentabilus.

Ginamieji teiginiai

1) Geotekstilės pažaidos, susidarančios įrengiant kelio konstrukcijos sluoksnius ant jos, neturi ženklios įtakos sluoksnių atskyrimo funkcijai. Geotekstilės pradūros yra reikšmingiausios pažaidos, turinčios neigiamą įtaką kelio konstrukcijos sluoksnių atskyrimui.

2) Pagrindiniai veiksniai, dėl kurių gali susidaryti geotekstilės pažaidos tiesiant ir eksploatuojant kelią, yra šie:

a) virš geotekstilės įrengiamo sluoksnio mineralinės medžiagos granuliometrinė sudėtis bei grūdelių dydis;

b) dangos konstrukcijos sluoksnių storis virš geotekstilės;

c) technologinės apkrovos (kelių tiesimo mašinų eismas virš geotekstilės įrengtu sluoksniu);

d) apkrovos eksploatuojant kelią.

3) Geotekstilės mechaninės savybės tiesiogiai priklauso nuo geotekstilės pažaidų laipsnio.

Darbo apimtis. Darbą sudaro bendra darbo charakteristika, keturi skyriai, išvados, literatūros sąrašas, publikacijų sąrašas ir priedai. Bendra disertacijos apimtis – 104 puslapiai, 44 iliustracijos, 28 lentelės ir 3 priedai.

Pirmame disertacijos skyriuje analizuojama kelio konstrukcijos skirtingų sluoksnių medžiagų susimaišymo įtaka kelio dangos stipriui ir tvarumui. Analizuojami ir apibendrinami kitų mokslininkų atliktų tyrimų, susijusių su geotekstilių panaudojimu atskyrimo funkcijai, rezultatai.

Antrame disertacijos skyriuje analizuojami geotekstilės parinkimo būdai bei metodikos. Pateikiama geotekstilių poreikio nustatymo procedūra bei teorinis geotekstilių parinkimo modelis.

Trečiame disertacijos skyriuje aprašomi eksperimentiniai tyrimai, atliekama gautų rezultatų analizė ir apibendrinimas. Siekiant nuosekliai įvertinti kelio konstrukcijos sluoksnių atskyrimo funkcijos atlikimą geotekstile, buvo atlikti trys eksperimentiniai tyrimai: 1) geotekstilės pažaidų bei atskyrimo funkcijos kitėjimas nuo apkrovų įrengiant dangos konstrukciją; 2) geotekstilės pažaidų bei atskyrimo funkcijos kitėjimas nuo dangai įrengti naudotų medžiagų, dangos storio virš geotekstilės ir automobilių eismo apkrovų eksploatuojant kelią; 3) geotekstilės mechaninių savybių kitėjimas nuo jos pažaidų laipsnio.

Ketvirtame disertacijos skyriuje pateikiamas siūlomas geotekstilių parinkimo metodas Lietuvos automobilių kelių ir gatvių konstrukcijoms. Nustatytas ekonominis efektas, gaunamas atskiriant kelio konstrukcijos sluoksnius geotekstilėmis.

Bendrosios išvados

1. Analizuojant eksperimentinių tyrimų rezultatus nustatyta, kad geotekstilės pažaidos, susidariusios įrengiant dangos konstrukcijos sluoksnius virš geotekstilės, neturi ženklios įtakos sluoksnių atskyrimo funkcijai atlikti. Taip pat nustatyta, kad reikšmingiausios geotekstilės pažaidos, turinčios neigiamą įtaką kelio dangos sluoksniams atskirti, yra pradūros. Bandomųjų geotekstilių pažaidos (pradūros), susidariusios eksperimento metu, įrengiant dangos konstrukcijos sluoksnius virš geotekstilės, sudaro 0–0,035 % lyginant su nepažeistos geotekstilės plotu.

2. Analizuojant eksperimentinių tyrimų rezultatus nustatyta, kad eksploatuojant kelią geotekstilė pažeidžiama iki 200 kartų labiau lyginant su geotekstilės pažaidom, susidarančiom įrengiant kelio dangos konstrukcijos sluoksnius. Išbandytų geotekstilių pažaidos (pradūros), sudaro 0,01–6,7 % lyginant su nepažeistos geotekstilės plotu. Taip pat nustatyti pagrindiniai veiksniai, turintys įtaką geotekstilės pažaidoms susidaryti tiesiant bei eksploatuojant kelią:

a) virš geotekstilės įrengiamo sluoksnio mineralinės medžiagos granuliometrinė sudėtis ir didžiausių medžiagos grūdelių matmenys;

b) dangos konstrukcijos sluoksnių storis virš geotekstilės;

c) apkrovos įrengiant dangos konstrukcijos sluoksnius (kelių tiesimo mašinų eismas virš geotekstilės įrengtu sluoksniu);

d) transporto apkrovos eksploatuojant kelią.

3. Eksperimentinių tyrimų rezultatų analizė rodo stiprią priklausomybę tarp geotekstilės bandinių pažaidų laipsnio bei statinio pradūrimo atsparumo vidurkių reikšmių. GTX1 rodiklių koreliacijos koeficientas (–0,84), o GTX2 – (–0,88). Žinant geotekstilės pažaidų laipsnį galima prognozuoti (apskaičiuoti) geotekstilės statinio pradūrimo atsparumą, kai geotekstilės tarpsluoksnis įrengiamas tarp apsauginio šalčiui atsparaus sluoksnio ir dangos pagrindo.

4. Lietuvos automobilių kelių ir gatvių konstrukcijų sluoksnių atskyrimui geotekstiles rekomenduojama parinkinėti taikant autoriaus sukurtą geotekstilių parinkimo metodą. Šis metodas nurodo geotekstilės naudojimo poreikį, įvertina veiksnius, turinčius įtaką geotekstilės pažaidoms susidaryti tiesiant ir eksploatuojant kelią ar gatvę, bei įgalina parinkti tinkamą geotekstilę atskyrimo funkcijai atlikti. Pagal sukurtą metodą parinktų geotekstilių taikymas, atskyrimo funkcijai atlikti, yra racionalus. Geotekstilės ir jos įrengimo kaštai atsiperka jau įrengiant dangos konstrukciją, tai rodo naudos ir kaštų santykis, kuris kinta nuo 1,76 iki 2,12.

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GEOTEXTILE SELECTION METHODS FOR THE LITHUANIAN ROAD AND STREET STRUCTURES

Summary of Doctoral Dissertation
Technological Sciences, Civil Engineering (02T)

Audrius Vaitkus

GEOTEKSTILIŲ PARINKIMO METODAI LIETUVOS AUTOMOBILIŲ KELIŲ IR GATVIŲ KONSTRUKCIJOMS

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