# NEWLY DEVELOPED GEOTEXTILES SELECTION SYSTEM FOR LAYERS SEPARATION IN LITHUANIAN ROADS CONSTRUCTION

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**Abstract:** In the middle of 2008 the new geotextile selection for layers separation in roads construction system will be introduced in Lithuania. This system will change the nine-year-old interim guidelines for use of geotextiles and geogrids in roads construction. The new geotextile selection system will be based on the analysis of experimental researches done at Lithuanian roads during the 2005-2007 period results. The experimental researches were done to investigate the need of use of geotextiles interlayer in roads construction. At the same time, the installation damage subject to type of mineral material of road structure layers and construction loads were evaluated too. According to the new geotextiles selection system, the use of a geotextile interlayer is efficient between weak soil subgrade and frost proof layers and between frost proof layer and base layer from hard-grained material. Five geotextile strength classes can be determined depend on road construction factors and their variations: strength of subgrade soil, construction loads of layer above geotextile, thickness of road pavement structure above geotextile and road exploitation loads. The geotextiles have to be selected according requirements on geotextiles characteristics for each geotextile strength class.

**Keywords:** geotextile, nonwoven geotextiles, pavement, construction, damage, design method

## INTRODUCTION

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. Al-Qadi et al. (1994) confirms that when the road is in operation in the absence of a base course-subgrade separator, two mechanisms may tend to occur simultaneously over time 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 strength of the pavement system. 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. Vischer (2003) state that very fine aggregate base course produced by a contractor may cause unexpected problems concerned with the migration of particles, which requires additional costs for constructing a separating geotextile.

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 Giroud (1984) and Koerner (2005) the geotextiles used for the separation of structural layers can 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* (1998), 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 using geotextiles. Geotextiles selection system for layers separation should provide the proper use of geotextiles in roads and streets construction.

## SPECIFICATIONS OF GEOTEXTILES FOR SEPARATION IN ROAD STRUCTURES

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 (Eiksund et al. 2002). 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. According to *NorGeoSpec* (2004) not only construction equipment and procedures are considered, but also intensity of traffic. According to the normative of Germany, though the same conditions are assessed, but intensity of traffic is not taken into account (Wilmers 2002).

Lithuania has only been using geotextiles for road construction and reconstruction during the last decade. In 1998 Lithuanian Road Administration adopted the temporary 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 allowed developing a comprehensive geotextile selection method under Lithuanian conditions.

## EXPERIMENTAL RESEARCH FOR GEOTEXTILE SEPARATION FUNCTION

Scientific research in the field of separation of road pavement structure using geotextile shows positive effect of such usage. In full-scale test roads where various geotextiles were used to prevent base contamination positive results were obtained (Tsai & Holtz 1997, Vaitkus et al. 2006, Watn et al. 2002). In the other study the excavated geotextiles from paved roadways in different sites showed that in all situations geotextiles performed their intended function (Holtz 1996, Vaitkus et al. 2007a).

The main factors having the impact on the occurrence of geotextile damages and on the failure to perform the separation function were determined (Vaitkus et al. 2007b). Taking these factors into consideration, experimental research was divided into two parts:

1) To assess the dependency of geotextile damages and fulfilment of the separation function on the loading during installation. Based on Vaitkus et al. (2006) research stated that all geotextiles selected for experimental research, including the weakest, fully performed the function of road pavement layer separation. The damages that occurred in the course of its installation did not have any significant impact on the fulfilment of the function.

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.

In this chapter is presented second part of experimental research. Construction of the experimental road test section and used materials is described Vaitkus et al. (2007a).

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 (Adler et al. 1971). 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:

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

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

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

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

Where $j$ = 0, 1, 2, 3…7 is factorial number, $i$ = 0, 1, 2, 3…$N$ is number of the tests, $X_{ij}$ is 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:

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

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:

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

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.

## GEOTEXTILE SELECTION METHOD

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 1.

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:

Low – subgrade from DR, MR, OD, OM, OH, OK, HN soil in accordance with the standard LST 1331:2002;
Medium – subgrade from DL, DV, ML, MV soil in accordance with the standard LST 1331:2002;
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:

Low – the layer is constructed by the light-weight machinery and compacted by vibrating panels or rollers with the weight of ≤ 5 t;
Medium – the layer is constructed by the heavy machinery and compacted by vibrating rollers with the weight of ≥ 5 t;
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:

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

Loads due to the operation of road pavement structure:

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

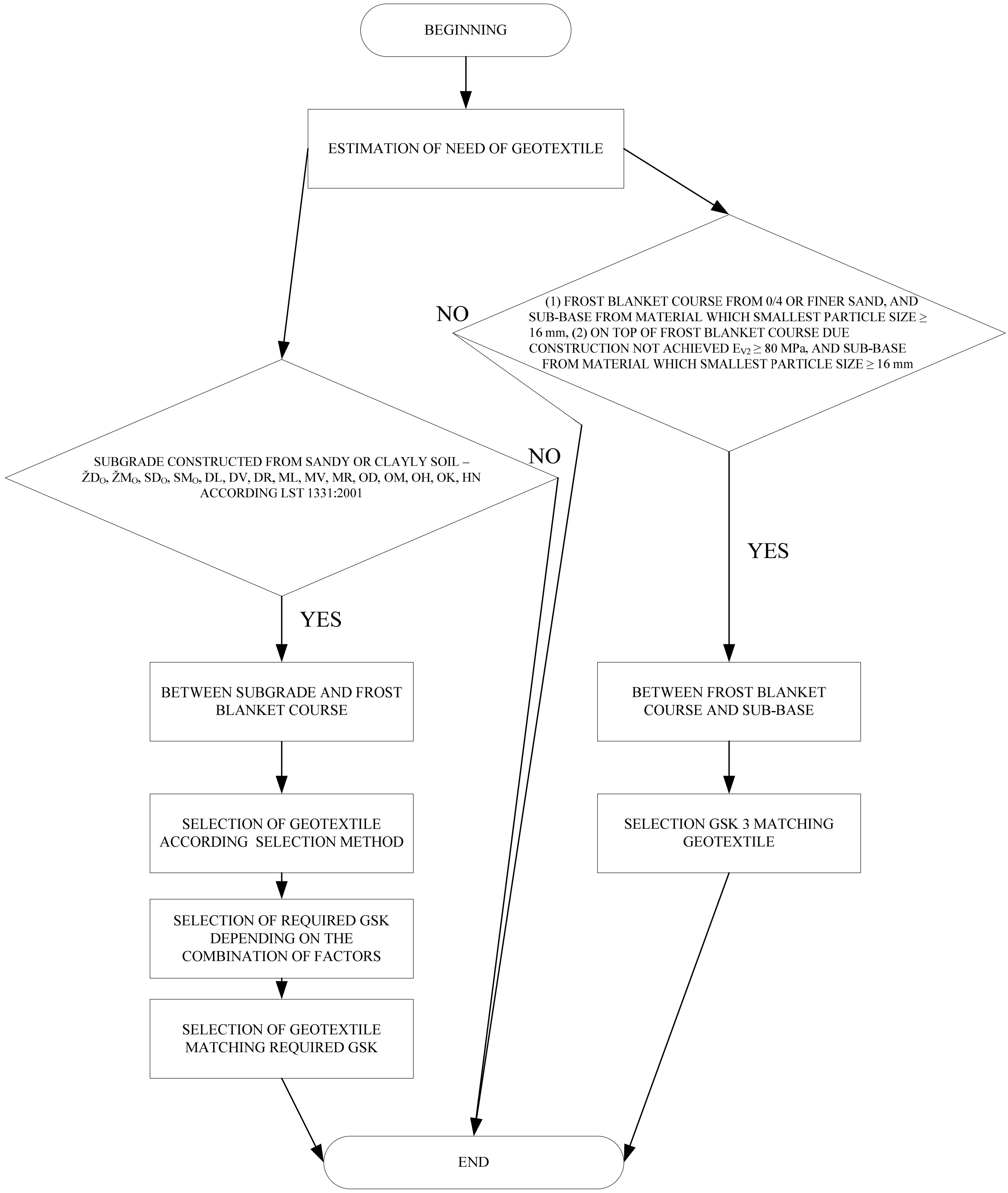


**Figure 1.** Procedure for the determination of the need for the use of geotextiles and for the selection of geotextiles

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 | Impact of 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.

## CONCLUSIONS

After experimental research and calculation of mathematical models 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.:

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

The most damaged geotextile was excavated from road pavement structure without asphalt layer in which sub-base was from dolomite. Much less damage observed in geotextile excavated from road pavement structure without asphalt layer in which sub-base was from granite.

Lithuania is still using temporary regulations for use of geotextile and geogrids in road constructing developed in 1998. This regulations for geotextile selection specifies exclusively the mass per unit area and the static puncture strength. However, other researchers have proved a direct dependency between the two characteristics. They are not sufficient to be able to fully assess the quality of separation geotextiles.

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 structure construction and in the course of road operation. Presently developed geotextile selection method is presented to Lithuanian Road Administration specialists for comments.

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