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REGULATIONS FOR USE OF GEOSYNTHETICS FOR ROAD EMBANKMENTS AND SUBGRADES

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Abstract. The increased use of geosynthetics in road constructions has resulted in a need to better understanding of geosynthetics properties for the use in design and quality control. For this purpose, the regulations for use of geosynthetics for road embankments and subgrades were created in Lithuania. It was found that other European countries such as Germany and United Kingdom use not only harmonised European standards, but also has their own regulations for geosynthetics. This study indicates the relationship between regulations in Lithuania and other countries. Calculation conception and regulations for controlling characteristics were introduced first time in Lithuanian road construction market. The use of those regulations will increase the quality of construction and life time of road pavement structures.

Keywords: technical specifications, technical guides, standards, embankment, subgrade, soft soil, reinforcement, separation, geosynthetics, geotextiles, geogrids.

1. Introduction

Geosynthetics is the general term describing the flat or three dimensional products that contains from at least one synthetic or natural polymer. These products are used to solve civil engineering problems. This includes eight main product categories: geotextiles, geogrids, geonets, geomembranes, geosynthetic clay liners, geofoam, geocells and geocomposites. These polymeric products are widely used in the ground structures where high levels of durability are required. Geosynthetic products have a wide range of applications and are currently used in many civil, geotechnical, transportation, geoenvironmental, hydraulic, and private development applications (Almeida *et al.* 2013; Al-Qadi *et al.* 2011; British standard *BS 8006:2010 Code of Practise for Strengthened/Reinforced Soils and Other Fills*; EBGEO *Empfehlungen für den Entwurf und die Berechnung von Erdkörpern mit Bewehrungen aus Geokunststoffen*).

Taking road applications, geosynthetics are widely used to improve soil mechanical properties. This is very common situation when soft soils are found in subgrade. It allows to reduce the fill soil thickness, to make the settlements as uniform as possible, to build a structure on soft soils, to build embankments with steep slopes, to evade the unwanted mixing of the soils, to increase the embankment stability, to increase the durability of the structure, to reduce the building time at same time reducing the CO^2 emission (Skrinskas 2012; Vaitkus *et al.* 2012). The other area where geosynthetic products are widely used is the soil erosion control caused by water flow (Oh, Shin 2007; Zhuang *et al.* 2013). Geosynthetic products allow building embankments in water flood areas, to protect the slopes from washout caused by ground water or rain water (Rawal *et al.* 2010). It also allows to rebuild washed out slopes and to maintain the natural looks of the slope surfaces. A lot of applications are related with road pavement structure, high level theoretical analysis and calculations are performed to evaluate the performance of geosynthetics (Abu-Farsakh *et al.* 2014; Góngora, Palmeira 2012; Manivannan *et al.* 2011; Pasquini *et al.* 2013; Sert, Akpınar 2012).

Having such a wide range of geosynthetics usage it is necessary to have regulations and quality control. Every country using geosynthetic materials can have its own regulations or, if it belongs to EU, it can use the regulations that are valid in European Union (EU) (Eiksund *et al.* 2002; Wilmers 2002). In general, most of the regulations include the main descriptions, technical properties, and application areas, guidelines for design, test methods and selection of the geosynthetic materials. EU also has a number of standards to control the quality and performance of the geosynthetic materials – *BS 8006:2010*; *EBGEO*; *M-Geok E 05 Merkblatt* über *die Anwendung von Geokunststoffen im Erdbau des Straßenbaus mit den Checklisten für die Anwendung von*

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Geokunststoffen im Erdbau des Straßenbaues; TL Geok E – StB 05 Technische Lieferbedingungen für Geokunststoffe im Erdbau des Straßenbaues testing of geosynthetic material performance are performed using *EN* or *American Society for Testing and Materials (ASTM) standards*.

2. Possible ways of using the geosynthetics in road construction

While many possible design methods or combinations of methods are available to the geotextile designer, the ultimate decision for a particular application usually takes one of three directions: design by cost and availability, design by specification and design by function.

Geotextile design by cost and availability is very simple. The funds available are divided by the area to be covered and a maximum available unit price that can be allocated for the geotextile is calculated. The geotextile with the best properties is then selected within this unit price limit and according to its availability. Intuition plays a critical role in the selection process. The method is obviously weak technically but is one that is still sometimes practiced. It perhaps typified the situation in the early days of geotextiles, but is outmoded by current standards of practice.

Geotextile design by specification is very common and used almost exclusively when dealing with public agencies. In this method several application categories are listed in association with various physical, mechanical and/or hydraulic properties. A specification of this type that is used by the country road department is given. It has its typical format, listing the various common applications against minimum or maximum property values. Different agencies have very different perspectives as to what properties are important and as to their method of obtaining the numeric values.

Designed by function consists of assessing the primary function that the geotextile will serve and then calculating the required numerical value of a particular property for that function. It is necessary to evaluate a number of concepts and fundamental principles when calculating the required numeric value. As an example, let's take the soil reinforcement.

Reinforcement is incorporated in engineering fill, or inserted into natural ground either to provide steeper slopes than would otherwise be possible or to improve load carrying capacity. Reinforcement is also used to improve the performance of weak soils to support embankments or other resilient structures. Concepts and fundamental principles in calculations:

– limit state principals;
– partial factors;
– design loads;
– design strengths;
– fundamental mechanisms;
– soil reinforcing mechanisms in walls and slopes;
– soil reinforcing mechanisms in embankment foundations;
– soil reinforcement interaction;
– soil properties to be considered;
– reinforcing geometry;
– reinforcement bond;
– effects of reinforcement axial stiffness on loads;
– factors affecting tensile behaviour of reinforcement.

3. Regulations for use of geosynthetics

There are lots of regulations issued to control the geosynthetic materials design and quality. Unfortunately there are not so many regulations that are widely used, not only in the countries they were issued, but also in the other European countries.

United Kingdom has its own regulations for geosynthetics called the British standard. The well-known *BS 8006:2010* is widely used. This British standard contains recommendations and guidance for the application of reinforcement techniques to soils, as fill or in situ and to other fills. The standard is written in a limit state format and guidelines are provided in terms of partial material factors and load factors for various applications and design lives. This standard is related with *ISO* and *EN* standards valid for geosynthetic materials.

Germany uses the whole system of regulations. At first the *EBGEO*. These recommendations were created by German Geotechnical Society. In Germany, the analysis and design of reinforced fill structures, as well as the required safety stipulations, are controlled by standard for geotechnical design *DIN 1054:2005 Baugrund – Sicherheitsnachweise im Erd- und Grundbau – Ergänzende Regelungen zu DIN EN 1997-1* and other relevant standards. These recommendations are based on *DIN 1054:2005-01 Baugrund – Sicherheitsnachweise im Erd- und Grundbau* and analyses are performed using the partial safety factor approach. In addition, the European design standard *EN 1997-1 (EC 7-1) Eurocode 7: Geotechnical Design* is also referenced. For quality assurance, the *M-Geok E 05* and *TL Geok E – StB 05* are used. It is also related with some *ISO* and *DIN-EN* standards valid for geosynthetic materials.

Poland use harmonized standards that are valid in Europe and also their own quality control system. They use technical approvals called "*Aprobata Techniczna*". This document is controlled by The Road and Bridge Research Institute which is involved in research and development projects in the area of construction and maintenance of the road and bridge structures and facilities, specifically roads and road bridges, railway subgrades, railway bridges, and underground structures. However,if the production of building product has been conducted according to Polish harmonized standard PN-EN, then there is no legal basis for issuing technical approval of the Road and Bridge Research Institute.

The situation when having the control system according the harmonized *EN* standards and local regulations together is very common in the whole Europe.

4. Regulations for use of geosynthetics for roads in Lithuania

Lithuania is no exception from other EU countries. All the standards for geosynthetic materials that are valid in EU are also valid in Lithuania. Using more and more geosynthetic materials in civil engineering had led to a need of having not only the *EN* standards but also the regulations for geosynthetic materials in Lithuania.

This is made by creating two separate documents. The first is technical specifications (*Techninių reikalavimų aprašas* – abbrevation in Lithuanian – *TRA*) and the second is technical guide (*Metodiniai nurodymai* – abbrevation in Lithuanian – *MN*) for geosynthetics used in the road soil works.

TRA is made according German technical supply conditions for *TL Geok E – StB 05*. This document has three provisions:

1. Geosynthetics, that is used in road soil works, *TRA GEOSINT ŽD 13 "Geosintetikos, naudojamos* žemės *darbams keliuose, techninių reikalavimų aprašas"* expounds the requirements for geosynthetic materials, used in soil works when building new country roads and drainage systems. This document is also applied to local roads (streets), other traffic zones.

2. *TRA GEOSINT ŽD 13* implements Lithuanian standard *LST* EN *13249:2000 Geotextiles and Geotextile-Related Products – Characteristics Required for Use in the Construction of Roads and Other Trafficked Areas* (Excluding Railways and Asphalt Inclution).

3. Every building product, imported from the EU member country, from country that has signed the European Economic Area contract, or from Turkey, can be supplied to the market of Lithuanian Republic without any restrictions, if it was legally made in EU member country, country that has signed the European Economic Area contract, or in Turkey or legally imported into these countries from third parties and it is allowed to supply it in the market in that country. The free movement of construction products limitations are allowed if it does not provide an equivalent level of protection or public safety, business, animal or plant health and life protection reasons.

This document indicates what test methods have to be specified for geotextiles and geogrids according the application area. As a basis for this, the standard *EN 13249:2000* was used. Table 1 shows the modified requirements according the special needs in Lithuania.

Table 1. Geotextile and geogrid required properties and test methods according the application area

Properties	Test method	Application area				
		Separation	Filtration	Drainage	Reinforcement	Protection
Mass per unit area	*LST EN ISO 9864:2005*	*S*	*S*	*S*	*S*	*S*
Thickness	*LST EN ISO 9863:2005*	*H*	*S*	*S*	*S*	*H*
Max tensile strength[a]	*LST EN ISO 10319:2008*	*H*	*H*	*A*	*S*	*H*
Elongation at max load	*LST EN ISO 10319:2008*	*S*	*S*	*S*	*S*	*S*
Joints/seams tensile strength	*LST EN ISO 10321:2008*	–	–	–	*S/A*	–
Static puncture test[a, b]	*LST EN ISO 12236:2000*	*A*	*A*	*A*	*A*	*A*
Dynamic perforation test[a]	*LST EN ISO 13433:2006*	–	–	–	–	*H*
Friction characteristics	*LST EN ISO 12957-1:2005* *LST EN ISO 12957-2:2005*	*H*	*H*	*H*	*H*	–
Creep[c]	*LST EN ISO 13431:2000*	*A*	*H*	*H*	*A*	–
Installation damage	*LST EN ISO 10722:2000*	–	–	*H*	–	–
Long term protection efficiency	*LST EN 13719:2002*	*H*	*H*	*H*	*H*	*H*
Characteristic opening size	*LST EN ISO 12956:2000*	*S*	*S*	*S*	*S*	*S*
Water permeability normal to the plane[b]	*LST EN ISO 11058:2001*	*S*	*S*	*S*	*S*	*S*
Water flow capacity in their plane	*LST EN ISO 12958:2000*	*S*	*S*	*A*	*A*	*S*
Durability	*LST EN 13249 Annex B*	*S*	*S*	*S*	*S*	*S*
Resistance to chemical degradation	*LST EN 14030:2002 or* *LST EN ISO 13438:2005,* *LST EN 12447:2002*	*H*	*S*	*S*	*S*	*H*
Microbiological resistance	*LST EN 12225:2000*	*H*	*H*	*A*	*S*	*H*
Resistance to weathering	*LST EN 12224:2000*	*S*	*S*	*S*	*S*	*S*

Notes: *H* – required according standard *LST EN 13249* (in Europe); *A* – according standard *LST EN 13249* required in all application conditions; *S* – according standard *LST EN 13249* required for specific application conditions; – – not relevant; [a] – if mechanical properties (tensile strength and static puncture resistance) in this table are marked by letter *H*, manufacturer has to apply the data to both properties. If only one property is important – tensile strength or static puncture resistance, it is enough to apply it on the technical description; [b] – this test is not relevant for some types of materials, for example geogrids; [c] – "*S/A*" – "*S*" is relevant for road constructions, "*A*" is relevant for reinforcement under embankments or in steep slopes.

This was done in the same way for the geosynthetic barriers (Table 2). In this case, as a basis, the standard *LST EN 13361:2013 Geosynthetic Barriers – Characteristics Required for Use in the Construction of Reservoirs and Dams* was used. This document also describes the minimum parameters of the geosynthetic materials, durability requirements, explains what EN standards has to be used for each test of the material, explains the supply conditions, CE (Conformité Européenne) marking and Declaration of conformity.

MD is made according German regulations *M-Geok E 05* and *EBGEO*. This document has 6 provisions:

Geosynthetics, that is used in road soil works, *MN GEOSINT ŽD 13* expounds the requirements.

1. For geosynthetic materials, used in soil works when building new country roads and drainage systems. This document is also applied to local roads (streets), other traffic zones.

2. Geosynthetics, that is used in road soil works, *TRA GEOSINT ŽD 13* is applied together with *MN GEOSINT ŽD 13*.

3. Steel reinforcing elements are not included.

4. MN GEOSINT ŽD 13 takes unique German and harmonious EU and international standards and corresponding updates into account.

5. Products from other EU member countries that do not comply with the conditions stated in these directions together with the tests and observation made in manufacturers country are assessed as equivalent to these requirements if they also provides the required safety level: for work, health and are suitable to use for the same period time.

6. According the original purpose, *MN GEOSINT ŽD 13* is not suitable to be as contract basis or as a directive. According the secondary purpose.

7. MN GEOSINT ŽD 13 in parts or transformed can be applied to be a part of construction, supply and engineering contract.

MN GEOSINT ŽD 13 describe the main concepts of geosynthetics, explains every product in a category that is

Table 2. Required properties test methods according the application area for geosynthetic barriers

Properties	Type		Test method	
	GBR	*GBR-C*	*GBR*	*GBR-C*
Mass per unit area	*A*	*H*	*LST EN 1849-2:2010*	*LST EN 14196:2004*
Thickness	*H*	*H*	*LST EN 1849-2:2010* *LST EN ISO 9863-1:2005*	*LST EN ISO 9863-1:2005*
Permeability to liquids	*H*	*H*	*LST EN 14150:2006*	*ASTM D 5887*
Swell index	–	*A*	–	*ASTM D 5890*
Max tensile strength	*H*	*H*	*LST EN ISO 527-1:2001,* *LST EN ISO 527-3:2001*[a]	*LST EN ISO 10319:2008*
Elongation at max load	*A*	*A*	*LST EN ISO 527-1:2001,* *LST EN ISO 527-3:2001*[a]	*LST EN ISO 10319:2008*
Static puncture test	*H*	*H*	*LST EN ISO 12236:2000*	*LST EN ISO 12236:2000*
Burst strength	*S*	*S*	*LST EN 14151:2010*	*LST EN 14151:2010*
Peel strength	*S*	*S*	*LST ISO 34-1:2011*[b]	*ASTM D 6496*
Friction: direct shear test	*S*	*S*	*LST EN ISO 12957-1:2005*[a]	*LST EN ISO 12957-1:2005*[c]
Friction: inclined plane test	*S*	*S*	*LST EN ISO 12957-2:2005*	*LST EN ISO 12957-2:2005*
Foldability at low temperature	*S*	–	*LST EN 495-5:2003*	–
Thermal expansion	*A*	–	*ASTM D 696-08*	–
Resistance to weathering	*H*	–	*LST EN 12224:2000*	[d]
Microbiological resistance	–	*S*	*LST EN 12225:2000*	*LST EN 12225:2000*
Resistance to oxidation	*H*	*H*	*LST EN 14575:2005*	*LST EN 14575:2005*
Resistance to environmental stress cracking	*H*	*S*	*LST EN 14576:2005*	*LST EN 14576:2005*[e]
Resistance to leaching	*A*	*S*	*LST EN 14415:2004*	*LST EN 14415:2004*
Resistance to wetting-drying cycles	–	*S*	–	*LST EN 14417:2006*
Resistance to freezing-thawing cycles	–	*S*	–	*LST EN 14418:2006*
Resistance to roots	*S*	*S*	*LST CEN/TS 14416:2006*	LST CEN/TS 14416:2006

Notes: *GBR* – geomembrane; GBR-C – geosynthetic clay liner; *H* – required according standard *LST EN 13361* (in Europe); *A* – according standard *LST EN 13249* required in all application conditions; *S* – according standard *LST EN 13249* required for specific application conditions; – – not relevant; [a] – using specimen type 5A, when test speed is 100 mm/min; [b] – edge specimen without groove, when test speed is 50 mm/min; [c] – internal junctions of *GBR-C* can be evaluated during shear test; [d] – this parameter is not evaluated because *GBR-C* must be covered immediately after installation; [e] – suited for *GBR-C*, if *GBR-C* is in composite with *GBR*.

classified in Fig. 1. Separation, filtration, drainage, reinforcement, erosion control, protection and barrier applications are described in details. Specifications for materials, installation, work description. Design for reinforced soil and drainage systems. Test methods according *EN* standards. This document also has two design examples.

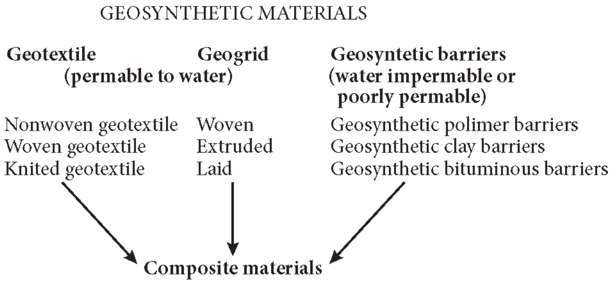

Fig. 1. Geosynthetic materials

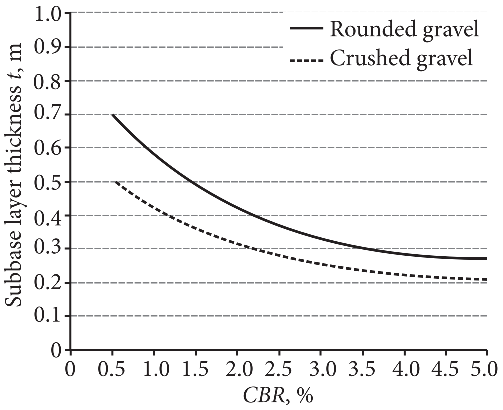

Fig. 2. Design chart for subbase layer thickness

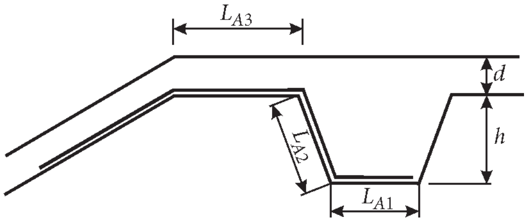

Fig. 3. Reinforcement installation in the anchoring trench

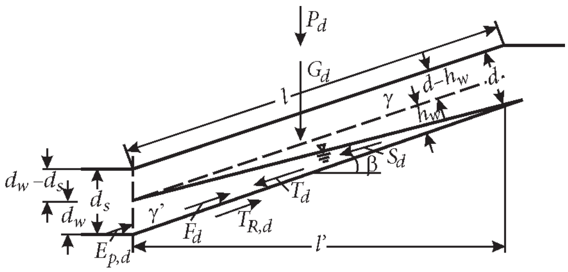

Fig. 4. Resistance to sliding

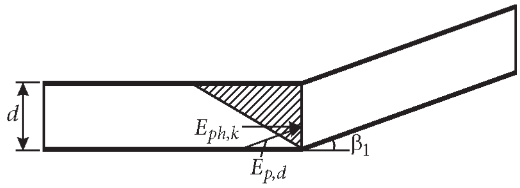

Fig. 5. Exceeding soil resistance in the bottom of the slope

The first example shows how to increase the bearing capacity of the embankment. Special design charts are used or simplify the indication of the fill soil thickness (Fig. 2). When calculating the required tensile strength for a geogrid, the long term tensile strength has to be evaluated:

$$F_d = \frac{F_{k,5\%}}{(A_1 A_2 A_3 A_4 A_i \gamma)},$$

where F_d – design tensile strength, kN/m; $F_{k,5\%}$ – tested short term tensile strength, kN/m; A_1 – creep partial safety factor; A_2 – installation damage partial safety factor; A_3 – junction and connection partial safety factor; A_4 – durability partial safety factor (weathering, chemical and microbiological effects); A_i – in some cases additional partial safety factors has to be evaluated, as an example dynamic impact from traffic loads; γ – partial safety factor evaluating tolerances of the material properties and possible tolerances of the building geometry.

The second example shows how to calculate the slope to be resistant to sliding (Fig. 3). There are four collapse types described and evaluated (Figs 4–7). The first collapse type is slope surface sliding above the reinforcement (Fig. 4). The second collapse type is exceeding the passive earth pressure in the bottom of the slope (Fig. 5). The third collapse type is the reinforcement pull out from the anchoring trench including the shear stress for the reinforcement and the lifting forces of the trench fill (Fig. 6). The fourth collapse type is the failure of the top of the slope (Fig. 7).

By using *MN GEOSINT ŽD 13*, it is the first time the standards *LST EN 13249* and *LST EN 13361* are implemented in Lithuania. *MN GEOSINT ŽD 13* can be adjusted and improved according the tests of geosynthetics, internal production control and control test results.

5. Conclusions

Creating two separate documents, technical specification *TRA GEOSINT ŽD 13* and technical guide *MN GEOSINT*

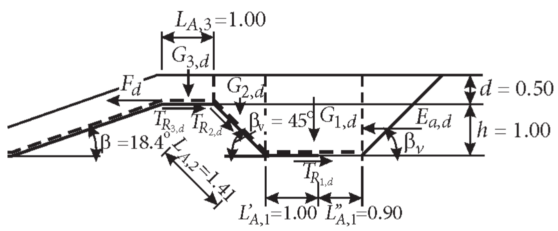

Fig. 6. Reinforcement pull-out from the anchoring trench

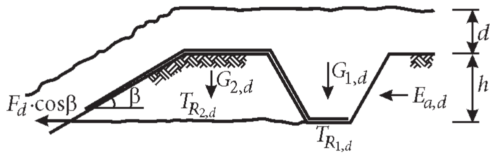

Fig. 7. Shear strength of the top of the slope

ŽD 13 for geosynthetics used in the road soil works enabled the design and material supply control in Lithuania.

For technical guide *MN GEOSINT ŽD 13* include some experience and examples of EBGEO *Empfehlungen für den Entwurf und die Berechnung von Erdkörpern mit Bewehrungen aus Geokunststoffen*. Because of that methodical directions became more universal document and for this stage of regulations for geosynthetics in Lithuania is very useful feature, because there is still no separate document for geosynthetic material design.

Technical guide MN *GEOSINT ŽD 13* additionally has *Annex 2* that shows the dependence between California Bearing Ratio and deformation modulus (E_{v_2}, E_{v_1}, E_v). This annex allows the designer to know soil deformation modulus design values when looking at the geotechnical investigations where only E_v or California Bearing Ratio values are given.

When presenting the application schemes of use of geosynthetics, the separation layer was indicated as geotextile and reinforcement as geogrid or woven geotextile. This has been done due to the fact that people that use geosynthetic materials would not use nonwoven geotextile as a reinforcement layer.

These regulations include both types of design methods, design by specification and design by function.

Technical specification *TRA GEOSINT ŽD 13* and technical guide *MN GEOSINT ŽD 13* for geosynthetics used in the road soil works specify geotextile and geogrid required properties and test methods according the application area. It ensures the use of high quality material for construction and increase life time of road pavement structures.

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