From Theory To Practice In Testing Of Geosynthetics

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ABSTRACT
The paper deals with the importance of testing the mechanical characteristics of geosynthetic materials or the design activity, and also with the “in situ “checking of geosynthetics quality. A case study about the effect of geogrid within a reinforced subbase of railway network modernization project is presented.

1. INTRODUCTION

Due to the European integration of Romania, a new important stage begins especially for the development of transportation infrastructure and for construction area. Thus the foundation grounds with acceptable conditions for constructions have become rare and therefore the improvement of soil properties is a very important national issue. Geosynthetics represent without doubt a solution verified on numerous works in Europe and around the world. The use of these materials in Romania has many unsolved technical and organizational problems. Among the most important problems is choosing the most efficient materials for design works or in other words insuring the quality for compatibility purpose and practical result. Thus we observe that the quality certificates delivered by the manufacturer are not sufficient but there is a need to have official laboratories to verify the properties of geosynthetics used for different engineering works. Different departments from town halls, the Romanian national company of motorways and national roads, the National Company for railways and environmental engineering have reached the same conclusion. As a result the Romanian government has financially encouraged the development of a geosynthetic laboratory in order to verify the properties of these materials during design activity and life work.

2. THE FIRST LABORATORY FOR GEOSYNTHETICS TESTING IN ROMANIA

Along with the Romanian integration in the EU, there is a necessity for the development of road and railway network, which is for the whole infrastructure. As a consequence, the first Romanian normatives for the geotextiles and geosynthetics use have also come into view. These are:

- NP 075/2002 Normative for utilization of geosynthetic materials in constructions works,
- GP 093-06 Designing guide for reinforced soil structure with metalic and geosynthetics materials, indicative

All these normatives are in complete agreement with the European norms for geosynthetics, for example:

- BS 8006: 1995 Code of Practice for strengthened/reinforced soils and other fills

Using funds from the Romanian Government, starting with 2007, the first laboratory for testing geosynthetics in Romania was established at GEOSTUD ltd. The laboratory has all the necessary approvals, (that is: State Inspectorate for Construction, Romanian Railway Authority) for laboratory and field testing on geotextyles, geogrids, geomembrane.
At the moment this modern laboratory is equipped with these apparatus:

- Electronic precision balance for mass per unit area test;
- Tensile test machines of 2.5 t and 5 t. The machines are used for tensile test on wide -width band for tensile properties of materials and seams and joints strength respective static puncture test (CBR tests);
- Tensiometer for on site tests for peeling, shearing and tensile of geomembraines and geotextiles;
- Dynamic perforation apparatus for dynamic performation test (cone drop test);
- Apparatus for geotextile determination of thickness at specified pressures;
- Edopermeameter for geotextiles normal to the plane and in plane permeability determination;

- Direct shearing apparatus with large box of 30 x 30 cm for determination of friction characteristics;
- Permeameter for determination of water permeability characteristics normal to the plane, without load;

The tests that are usually run for geosynthetics are the following:

- Wide-width tensile test SR ISO 10319;
- Tensile test for joints / seams by wide - width method SR EN ISO 10321;
- Static puncture test (CBR test) SR ISO 12236;
- Dynamic performation test (con drop test) SR EN 918
- Determination of thickness at specified pressures - Part 1: Single layers (SR ISO 9863-1);
- Test method for the determination of mass per unit area of geotextiles and geotextile-related products (ISO 9864:2005);
- Determination of friction characteristics - Part 1: Direct shear test (ISO 12957-1:2005);
- Determination of water permeability characteristics normal to the plane, without load: SR EN ISO 11058

For the next period the laboratory will certainly expand taking into consideration the great number of infrastructure works especially for transportations..

3. GENERAL ASPECTS CONCERNING THE RETAINING STRUCTURE DESIGN

The design of retaining structures reinforced with geosynthetic materials is usually based on the limit equilibrium methods (LEM). The main advantage of this method is the easiness of determining the force system, based on the analogy with the classic retaining structures. Initially, these methods were adapted for the calculus of the reinforced soil with metallic isolated elements. During time some monitoring results pointed out that is necessary to introduce some corrections as the lateral confining effect (from Yasufuku et al, 2002) which changes the general , internal forces system between soil slices (fig 1).

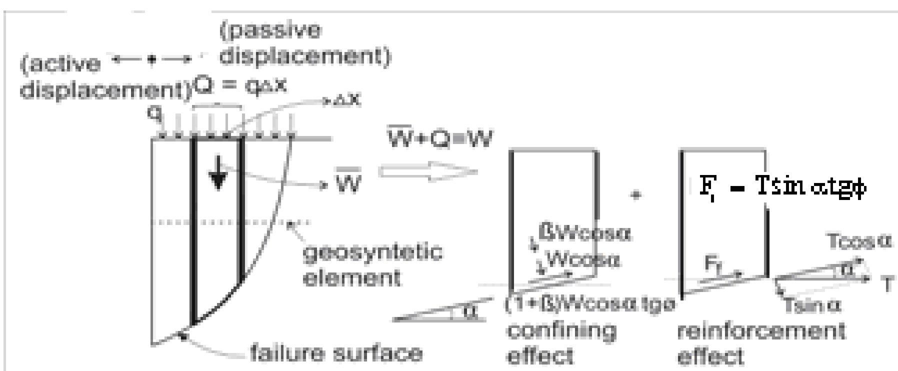

Figure 1. Modified forces system

A more exact calculation method used for the designing of geosynthetics retaining wall is the numerical method such the F.E.M. The major disadvantage of LEM pointed out by the numerical model method results is that it only takes into consideration displacements domain corresponding only for the active earth pressure or passive earth pressure mobilization (see Figure 2). Intermediate displacements field is not used. (Chirica, A. et al 2008)

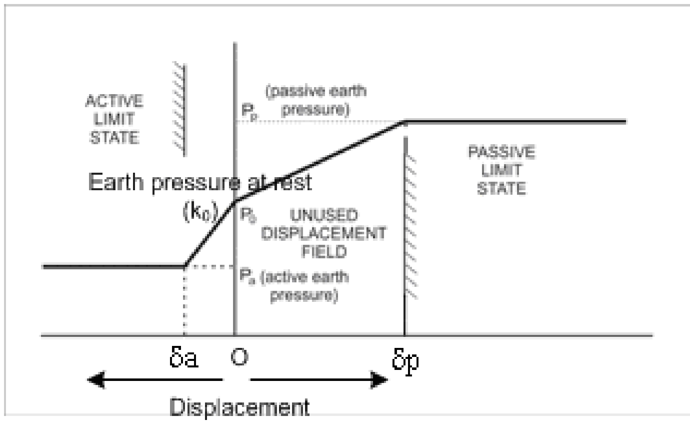

Figure 2. Displacement domains for the active and passive limit state

The first two aspects are closely related with the work design, while the third is very important for the execution quality control.

4. INTERPLAY BETWEEN GEOSYNTHETICS AND DESIGN QUALITY, STUDY CASE

To illustrate this issue, we will present as an example the modernization of railway network in Romania. The Central and Eastern European Countries joining the EU have made strong efforts to modernize their rail network. Impacted rail lines include some so called Trans European corridors that run across Romania, in order to assure the economical links between Romania and other European countries.
The main objectives of the Romanian railway network modernization project are the following:

- higher speed – 160 km/h
- higher load – 22,5 tons for axle
- more traffic comfort

Fulfilling these requirements involves new construction elements to the track superstructure and also the reconstruction of the track superstructure. It was and will be necessary to improve the bearing capacity of the railway subgrade. After 2004 some technical requirements of soil structures reinforced by geosynthetics have been introduced in the Romanian Technical standards (NTF72-04; and NP 109-04). For example the use of geosynthetics reinforced in subbase is a new improvement method of track substructure on soft subsoil. The new recommendations of the Romanian Railway Authorities concerning the reinforcement technique with geosynthetics of the railway track foundation are based on the standards above mentioned as well as other countries experience analysis, laboratory and field tests.

Until now, taking into account the new recommendations, approx. 100 km rail between Bucharest and Campina were modernised. Next, to justify the importance of tests on geosynthetics, some recommendations from the above mentioned standard for the modernization of the railway network will be presented.

The thickness of the subbase of the railway is established with the static deformation modulus at reloading Ev 2 that represents the dependence between the static load of a loading plate and the value of settlements during the test. The static deformation modulus at reloading is determined during the geotechnical verification of the rail platform. The minimum values requested for the upper face of the embankment and the base course is shown in table 1. The Epl values (the deformation modulus at base course level) are set for maximum load per axle of 22,5 kN (Figure 3).
For designing the thickness of the railway subbase it is necessary to know the static deformation modulus at reloading for the upper surface layer of the embankment under the most unfavourable weather conditions (during spring and thawing), especially if the embankment is made of cohesive soils sensitive to climatic conditions.

Table 1. Minimum values for Ev 2

Line type			RP[1] [MN/m²]	SSCT[2] [MN/m²]
New rail	Current line for European corridors and main rails		120	80
	Current line for secondary lines		100	60
	Other lines		80	45
Maintenance	Existing lines	V<160km/h	80	45
		V≤160km/h	50	20

[1] rail platform
[2] superior surface of the compacted soil

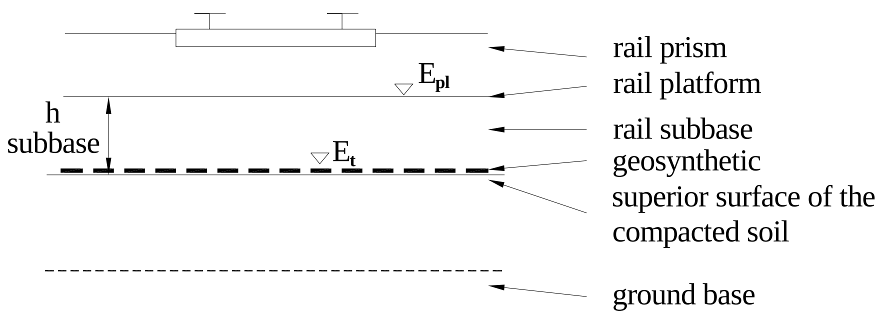

Figure 3. Rail subbase thickness determination. Calculus sketch.

To determine the bearing capacity, the deformation modulus of the upper face of the embankment will be corrected with a correction coefficient ‘y’, which reflects the humidity influence. The reduced deformation modulus (Etr) for the upper face of the embankment is determined with the equation:

$$E_{tr}= E_t \cdot y \qquad [1]$$

Where Etr is the reduced deformation modulus for the upper face of the embankment in MPa, E_t is the deformation modulus measured in MPa, “y” is the correction coefficient related to the consistency index of soil Ic. The value of the correction coefficient “y” for gravel and sand is shown in table 2.

Table 2. “y” correction coefficient values for non cohesive soils

Soil type	“y” correction coefficient value
Sands with particle size under 0.06 mm < 5% Gravels with particle size under 0.06 mm < 35%	1.0
Sands with particles under 0,06 mm between 5 and 35%	0.9

The values of the correction coefficient ‘y’ for cohesive soils are presented in table 3.

Table 3. "y" correction coefficient values for cohesive soils

Soil type	Consistency index at E_t determination		
	Ic<0.5	0.5,Ic<1.0	Ic>1
	"y" correction coefficient value		
Silt and clay with gravel < 35 %	1.0	0.9	0.8
Silt and clay with sand < 35 %	1.0	0.8	0.6
Silt and clay with low plasticity index W_L < 35 %	1.0	0.7	0.5
Silt and clay with medium plasticity index $W_L \leq 35\ \% \leq 50\%$	1.0	0.6	0.4
Silt and clay with high plasticity index W_L > 50 %	1.0	0.5	0.3

For the existing embankments of the rail lines that are to be modernized or repaired for which the rehabilitation of the railway foundation and an eventual reinforcement with geogriles is necessary, the minimum required thickness for the drain materials beneath the foot of the sleeper is determined depending on the required deformation modulus at the subbase (Ept) and on the reduced deformation modulus at the upper face of the embankment (Etr). The required thickness of the subbase with and without reinforcement is determined according to diagram presented in Figure 4. The determined thickness is rounded in plus at integer multiple of 5 cm.

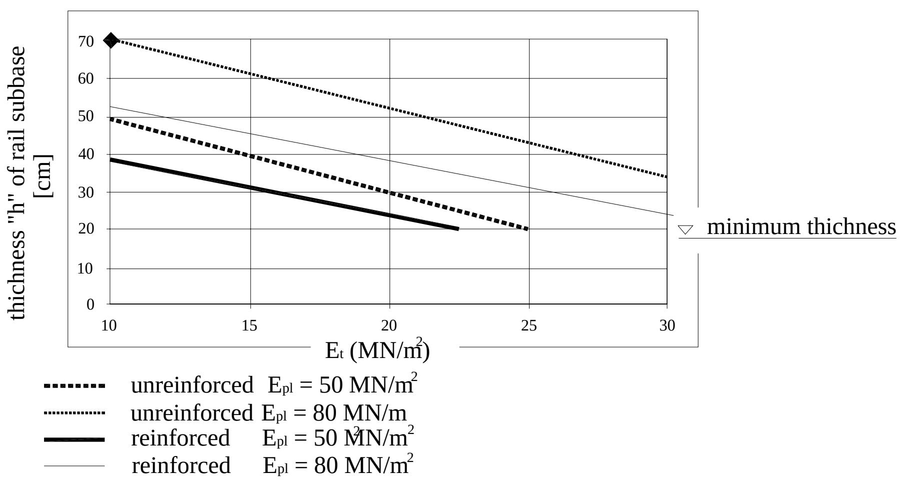

Figure 4. Determination of thickness subbase diagram

If the deformation modulus of the superior surface of the soil has values Et <10MN/m2 some measurements to improve the mechanical properties of subbase stratum should be considered. These measurements can be:

- partial or total removal of formation strata;
- mechanical or chemical stabilisation;
- reinforcing with geosynthetics.

5 SOME RESEARCH ACTIVITY RESULTS

As a consequence of above presented research results one can see that the interplay relation between geosythetics and granular fill is very important.

In the laboratory we studied some aspects correlated with the relation problem in Figure 5 The stress strain graphical relations for a non cohesive material unreinforced and reinforced with geogride are presented.

By processing Figure 5 one can obtain the correlation between the friction angle ϕ for the two analysed cases (unreinforced – geogrid reinforced). One can see that the efficiency coefficient N (defined by the ratio between shear strength resistance τ_{fr} for reinforced and unreinforced soil τ_f) has a inverse proportional variation with the overburden pressure (Figure 6).

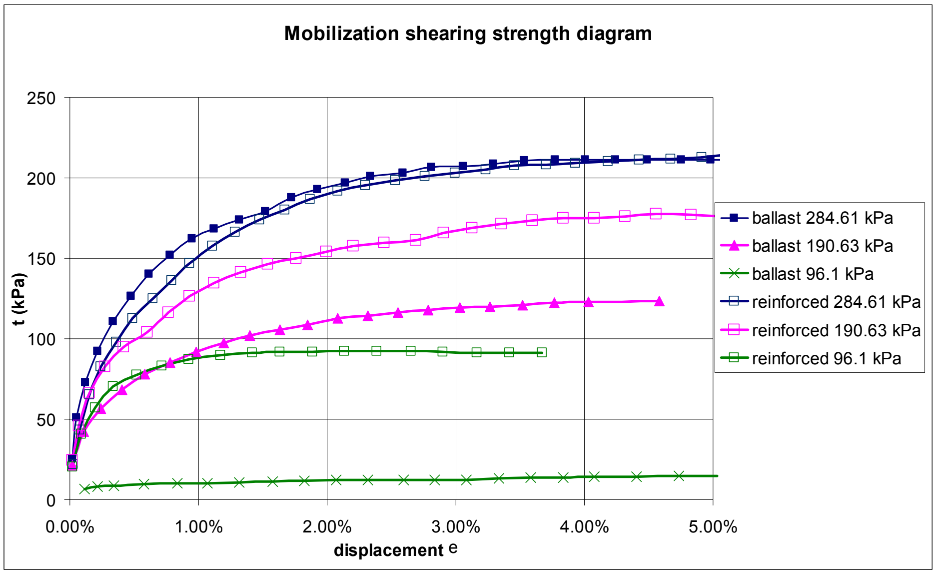

Figure 5. Mobilization of shearing strength diagram for reinforced soil/unreinforced soil

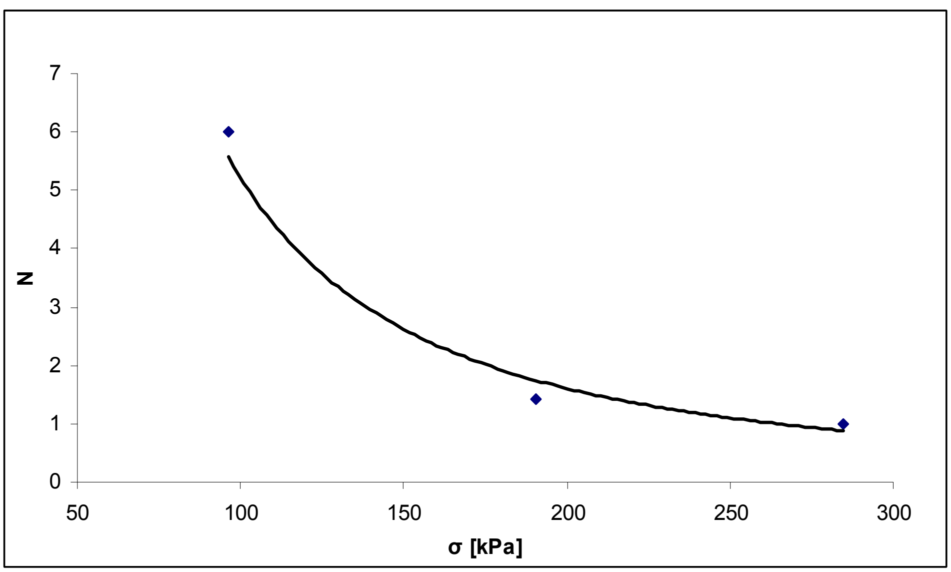

Figure 6. Efficiency coefficient N variation with the normal stress values

This research conclusion can be observed with the graph presented in Figure 4. By processing the graphs on the Figure 4 it is obtained the general tendency of subbase thickness reduction (economical aspect) variation with the Ept values correlated with the initial soil deformation modulus values Et. The Figure 7 results can be useful for the design activity.

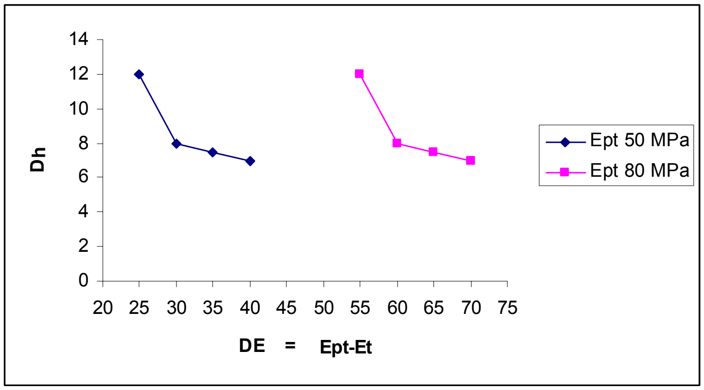

Figure 7. The graph between Ept and variation of subbase thickness

6 CONCLUSIONS

As a consequence of the future development of Romania, technical norms to stipulate the necessity of geosynthetic quality control appeared. This paper reflects the importance of field and laboratory tests for the right design activity corresponding to new and the existing geosynthetic works. Some examples show the implication of this action on design and execution of the modernization works for the Romanian transportation infrastructure network. The paper points out the importance of laboratory testing and research activity on geosynthetics behaviour for the quality site control and for the proper designing activity. The results illustrate the importance of the correlation between the physical state of a noncohesive material and the required values for deformation modulus. The paper also exemplifies the importance of stress – strain correlation for the improvement calculus of retaining structure with geosynthetics.

1. REFERENCES

Chirica, A., Barariu, A., Talos, L. and Baicu, A. (2008). Interplay between practice and laboratory testing of geosynthetics, The 4 th European Conference of Geosynthetics, IGS-UK , Edinburgh, ENGLAND.

NP 109-04 Normativ privind proiectarea liniilor si statiilor de cale ferata pentru viteze pana la 200 km/h), Normative for designing of rails and stations for railways for speed up to 200 km/h.

NTF 72-04. Infrastructura feroviara. Terasamente de cale ferata. Prescriptii tehnice metodologice pentru controlul calitatii executiei la linii noi), Railway infrastructure normative. Railway bed. Technical prescriptions and methods for quality control executions at new rails.

Yasufuku N., Ochiai H., Omine K. and Ninomiya Y. (2002). Evaluation of confining effect in geogrid-reinforced retaining wall related to the practical application. The 7th International Conference of Geosynthetics Taylor & Francis/Balkema, Nice, FRANCE, 1289-1294.