INTERPLAY BETWEEN PRACTICE AND LABORATORY TESTING OF GEOSYNTHETICS

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Abstract: The paper deals with the importance of testing the mechanical characteristics of geosynthetics materials not only for mechanical characteristics of geosynthetics materials for designing activity but also for the *insitu* checking of geosynthetics materials quality. The development of Romanian practice in the use of geosynthetics is introduced and a case study of the effect of a geogrid within reinforced subbase of railway network modernization project is presented.

Keywords: geosynthetic, testing, embankment.

INTRODUCTION

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 calculation of reinforced soil with metallic isolated elements.

In order to quantify the lateral confining effect on the earth thrust (specific for two directional reinforcement), several tests were performed on reduced scale models of reinforced earth. Based on the experimental research done by Yasufuku *et al.* (2002) the confining parameters were determined and its effect (Figures 1 and 2). In Figure 3 it is shown the way that the confining effect is materialized within the force system.

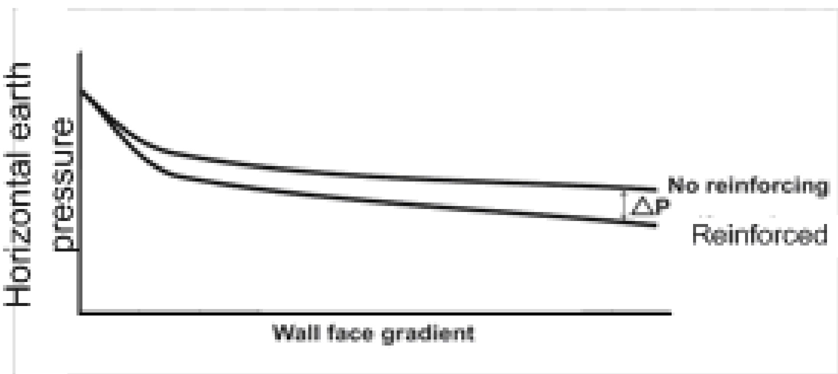


Figure 1. Confining parameters definition (Yasufuku *et al.* 2002)

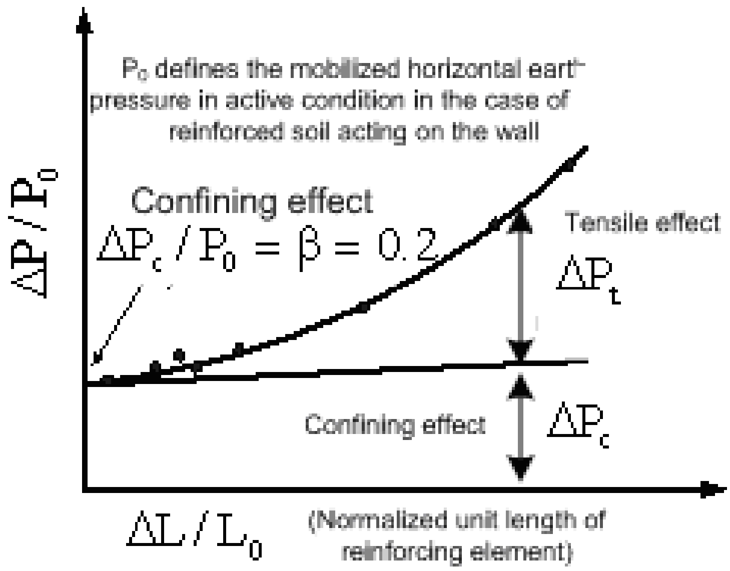


Figure 2. Confining effect vs. reinforced normalized unit length (Yasufuku *et al.* 2002)

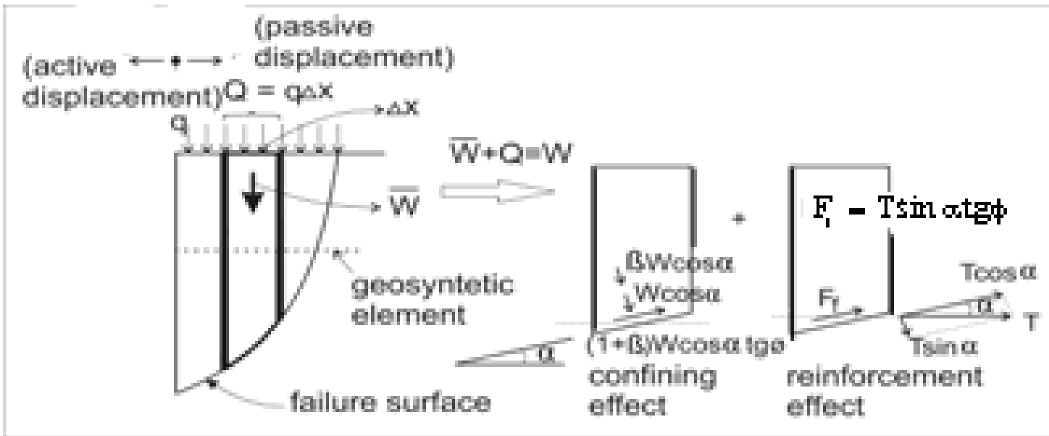


Figure 3. Modified forces system (Yasufuku *et al.* 2002)

In this way the design of retaining structures with geosynthetic material becomes more rational. Another category of more precise calculation methods used for the design of geosynthetic rammed earth are numerical methods such as the FEM methods. For example, Figures 4 and 5 present the results of a study made by the Turkish researchers Guler and Hamderi (2002). They have modelled a vertical retaining wall 9 m high with geosynthetic facing elements. On Figure 4 the failure surface is presented as a shear band that respects the Coulomb theory also used in LEM. In Figure 5 the displacement distribution can be observed for this case study. A total displacement of 15 mm has been computed. A big advantage of this category of methods consists in the possibility of utilization of different behaviour models for both the soil and the reinforcement material. This category of methods requires unfortunately very precise input, powerful computers and specialized algorithms.

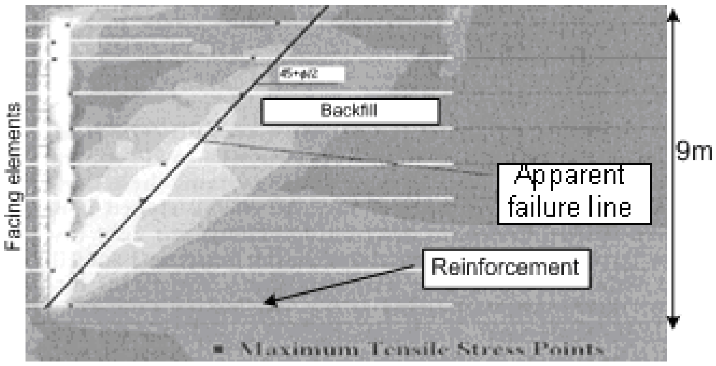


Figure 4. Failure surface obtained as a shear band (Guler and Hamderi 2002)

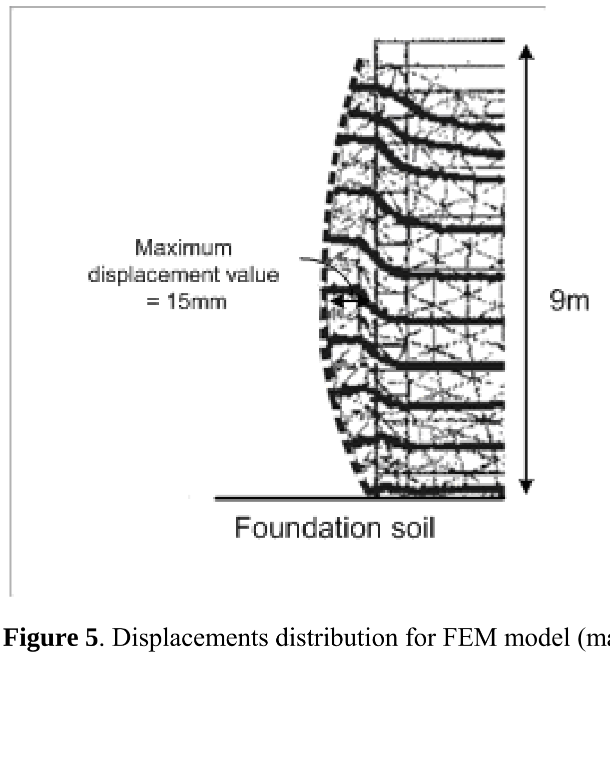


Figure 5. Displacements distribution for FEM model (max displacement 15 mm) (Guler and Hamderi 2002)

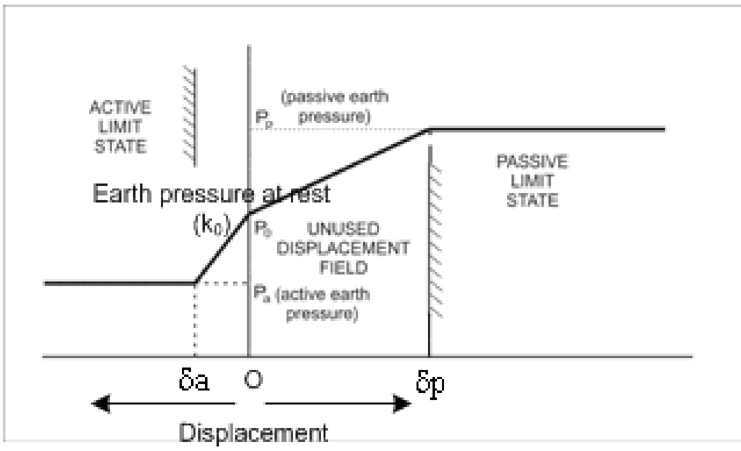


Figure 6. Displacement domains for the active and passive limit state

The major disadvantage of LEM pointed out by the numerical model method results (see Figure 4) is that it only takes into consideration displacement domains corresponding only for the active earth pressure or passive earth pressure mobilization (see Figure 6). Intermediate displacements fields are not utilized.

The importance of testing geosynthetics in the laboratory and in situ is relevant for the following reasons:

- the identification of compatible geosynthetics with certain categories of engineering works that will be designed;
- finding the stress - strain relationship for geosynthetics used in several engineering works; this is only the case for different types of stresses (tension, shearing, etc.) and for the behaviour of geosynthetics in interaction with soil; in this respect the efficiency for the geosynthetic materials used in transportation infrastructure becomes a very important target that can be the subject of laboratory research activity.
- checking the behaviour and properties of geosynthetics that are already used in engineering works; actually this is concerned with time behaviour monitoring of materials inside the structure. At the same time it is verified that the required materials for the project exist on the site;

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

THE FIRST LABORATORY FOR GEOSYNTHETICS TESTING IN ROMANIA

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

- NP 075/2002 Normative for utilization of geosynthetic materials in constructions works,
- GP 093-06 Design guide for reinforced soil structures with metallic and geosynthetics materials, indicative.

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

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

Using funds from the Romanian Government, starting in 2007, the first laboratory for testing geosynthetics in Romania was established at GEOSTUD Ltd. The laboratory has all the necessary approvals (i.e. State Inspectorate for Construction, Romanian Railway Authority) for laboratory and field testing on geotextiles, geogrids and geomembranes.

At the moment this modern laboratory is equipped with the following 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 tests on wide -width band for tensile properties of materials and seams and joint strengths and also static puncture tests (CBR tests);
- Tensiometer for on site tests for peeling, shearing and tensile strength of geomembranes and geotextiles;
- Dynamic perforation apparatus for dynamic perforation test (cone drop test);
- Apparatus for geotextile determination of thickness at specified pressures;
- Edopermeameter for geotextile 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 perforation test (cone 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 future the laboratory will develop further taking into consideration the great number of infrastructure works, especially for transportation, that are expected to start.

THE IMPORTANCE OF GEOSYNTHETIC TESTINGS

To illustrate this issue, an example is presented on the modernization of the railway network in Romania. The Central and Eastern European Countries joining the EU have made strong efforts to modernize their rail networks. 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.

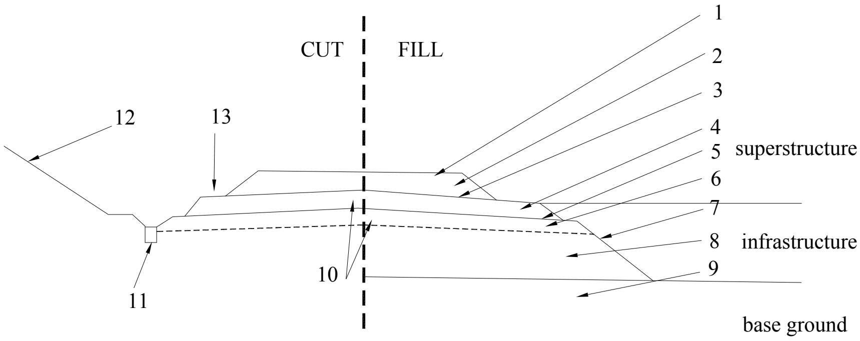
The main objectives of the Romanian railway network modernization project are the following:

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

To fulfil these requirements, it requires not only new construction elements to the track superstructure but also reconstruction of the track superstructure. It was and will be necessary to improve the bearing capacity of the railway subgrade. After 2004 in the Romanian Technical standards (NTF72-04; and NP 109-04) some technical requirements of soil structures reinforced by geosynthetics are introduced. For example, the use of geosynthetics to reinforce subbase is a new improvement method of track substructure on soft subsoil. The new recommendations of the Romanian Railway Authorities concerning geosynthetic reinforcement techniques for railway track foundations are based on the standards above mentioned as well as other countries experience of analysis, laboratory and field tests.

Until now, taking into account the new recommendations, approximately 100 km length of rail between Bucharest and Campina have been modernised.

Next, to justify the importance of tests on geosynthetics, some recommendations from the mentioned standard for the modernization of the railway network will be presented. First, in Figure 7 is presented the general terminology used.



1 sleepers
2 rail prism
3 rail platform
4 rail subbase
5 superior surfaceof compacted soil
6 formation strata
7 embankment slope
8 embankment body
9 base ground
10 rail platform zone
11 drainage sistem
12 cutting slope
13 rail bench

Figure 7. General terminology

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 8)

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 in 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* $[MN/m^2]$	SSCT† $[MN/m^2]$
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

* rail platform
† superior surface of the compacted soil

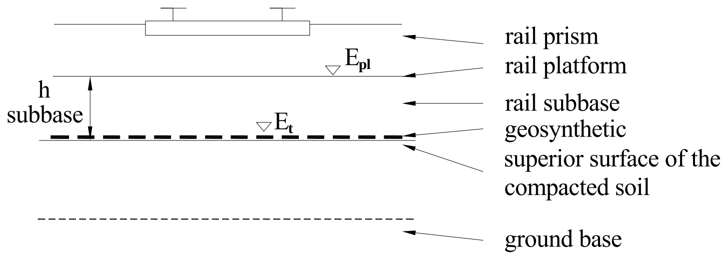


Figure 8. Rail subbase thickness determination. Calculation sketch.

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 using the equation:

$$E_{tr}= E_t \cdot y$$

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 geogrids 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 the diagram presented in Figure 9. The determined thickness is rounded up to an integer multiple of 5 cm.

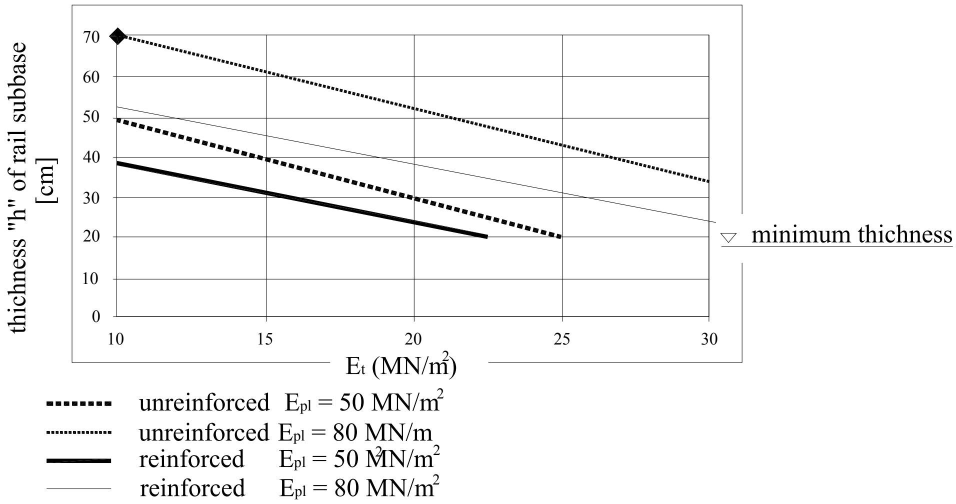


Figure 9. Determination of thickness subbase diagram.

If the deformation modulus of the superior surface of the soil has values Et <10MN/m^2 some measures to improve the mechanical properties of subbase stratum should to be considered. These measures can be:

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

SOME RESEARCH ACTIVITY RESULTS

As a consequence of above presented research results one can see that the interplay relationship between geosynthetics and granular fill is very important. In the laboratory some aspects correlated with the relationship mentioned for the problem in Figure 10 were studied. The stress-strain graphical relationships for a non-cohesive material unreinforced and reinforced with geogrid are presented.

By processing Figure 10 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 an inverse proportional variation with the overburden pressure (Figure 11)

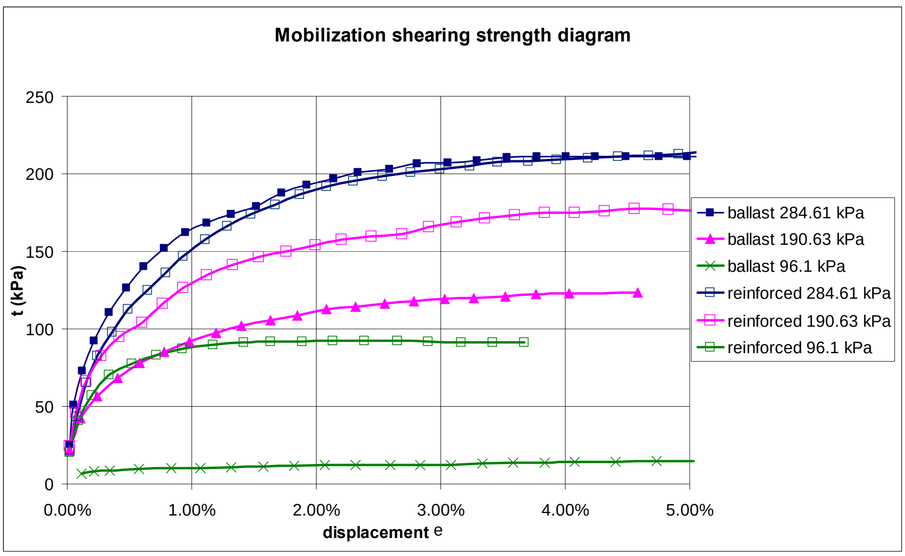


Figure 10. Mobilization of shearing strength diagram for reinforced soil/unreinforced soil

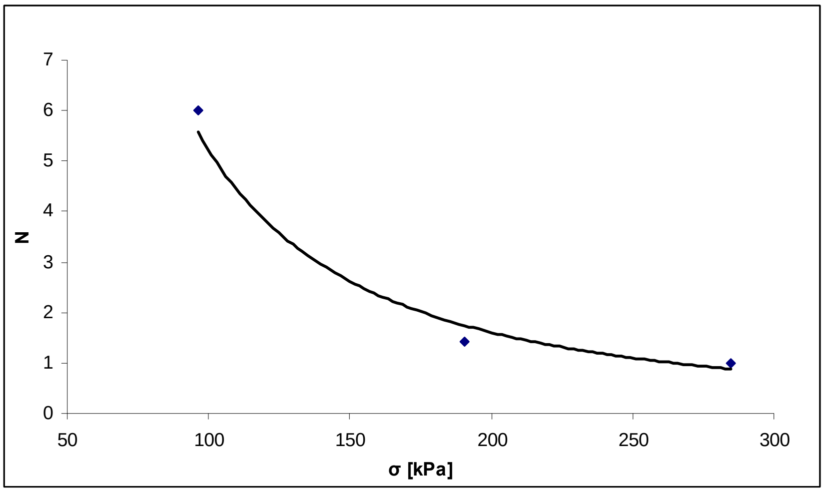


Figure 11. Efficiency coefficient N variation with the normal stress values

This research conclusion can be observed in the results presented in Figure 9. By processing the information shown on Figure 9 it is found that the general tendency of subbase thickness reduction (economical aspect) variation with Ept values, correlated with the initial soil deformation modulus values Et. Figure 12 shows results can be useful for the design activity.

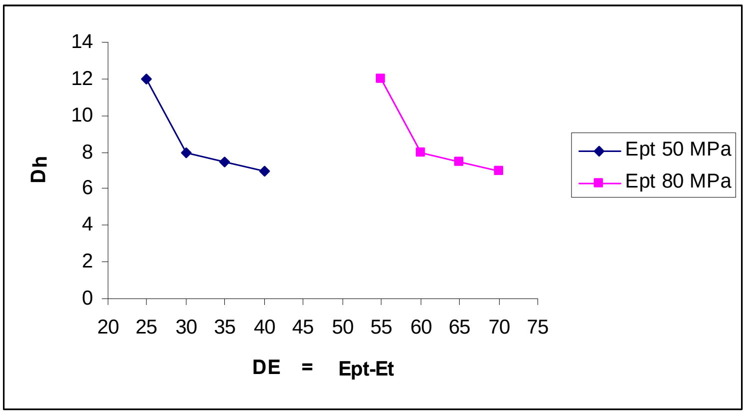


Figure 12. The graph between Ept and variation of subbase thickness

CONCLUSIONS

As a consequence of the future development of the Romania technical norms, it is necessary to stipulate geosynthetic quality control testing. This paper reflects the importance of field and laboratory tests for proper design activity, corresponding to new as well as to existing geosynthetics works. Some examples presented show the implication of this action on design and execution of modernization works for the Romanian transportation infrastructure network.

The paper highlights the importance of laboratory testing and research activity on geosynthetics behaviour for quality site control and for proper design activity. For example, as demonstrated by the results presented, there is an important correlation between material physical state of non-cohesive material and the required values for deformations modulus. The importance of stress – strain correlation for improvement calculations of retaining structures with geosynthetics is also shown.

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