ASOCIAȚII MATERIALE GEOSINTETICE – MATERIALE MINERALE UTILIZATE ÎN LUCRĂRI DE CONSTRUCȚII
ASSOCIATE COMPOSITES BASED ON GEOSYNTHETICS AND MINERAL MATERIALS, USED FOR CIVIL ENGINEERING WORKS

LORETTA BATALI*, HORAȚIU POPA, GHEORGHE PANTEL, NATALIA BUTNARCIUC, ERNEST OLINIC, SANDA MANEA

Universitatea Tehnică de Construcții Bucureşti, Bd. Lacul Tei, 020396, Bucureşti, România

Construction materials made of polymeric fibres (geosynthetics) are a viable alternative to traditional materials (concrete, granular materials) as proven the last years. Their use in association to mineral materials as soils or granular fills leads to composite materials having improved physical and mechanical properties and allowing to build more efficient structures both from structural and environmental point of view. Paper presents the main aspects related to physical and mechanical properties of geosynthetics, the main applications, focusing on reinforcement, filtration and drainage functions. It presents the various interactions between geosynthetics and mineral materials and the properties of the resulted composite material.

Materialele de construcții realizate din fibre polimerice (geosintetice) reprezintă o alternativă viabilă la materialele tradiționale de construcții (beton, materiale minerale granulare), aşa cum a fost dovedit în ultimii ani. Utilizarea lor în asociere cu materialele minerale ca pământurile sau umpluturile granulare duce la formarea unor materiale compozite cu proprietăți fizice şi mecanice îmbunătățite care permit construirea unor structuri mai eficiente atât din punct de vedere structural, cât şi din punct de vedere al mediului. Articolul prezintă principalele aspecte legate de proprietățile fizice şi mecanice ale materialelor geosintetice, principalele aplicații, cu accent pus pe funcțiile de armare, filtrare şi drenaj. De asemenea, prezintă interacțiunile dintre geosintetice şi materialele minerale şi proprietățile rezultante ale materialului compozit.

Keywords: *geosynthetic, mineral material, composite material, physical properties, mechanical properties, laboratory tests*

1. Introduction

1.1. General facts about geosynthetics

Geosynthetic materials, thanks to their composition, properties, durability and the fact that they don't interact with the environment, are widely used in many applications in civil engineering as an alternative for traditional materials as concrete or granular fills.

Their use in association to mineral materials as soils or granular fills leads to composite materials having improved physical and mechanical properties, allowing building more efficient structures both from structural and environmental point of view. Structures including geosynthetics usually require less material than traditional solutions, which helps also to reduce the carbon footprint.

1.2. Functions and types

Geosynthetics can be used for functions as filtration, drainage, waterproofing, reinforcement, protection against erosion etc.

Main types of geosynthetics include: geotextiles, geogrids, geomembranes, geonets and different types of geocomposites (for reinforcement, for drainage, geosynthetic clay lines, with glass fibres etc.), which are made of various polymers as polypropylene, polyester, polyethylene, polyamide etc.

Paper will focus on two functions: reinforcement and filtration and drainage (considered together).

For reinforcement applications, as retaining structures, reinforced working platforms for heavy equipment, reinforced road sub-base or asphalt layers can be used woven - high tensile resistant geotextiles, geogrids or reinforcement geocomposites.

For filtration and drainage functions are mainly used non-woven geotextiles and drainage geocomposites (made of two non – woven geotextiles and a drainage core in between). In this case the geotextile, acting as filter, will determine the apparition of a natural filter soil behind the geotextile and will allow water to pass through

* Autor corespondent/*Corresponding author*,
E-mail: loretta@utcb.ro

without excess pore pressure. The filtration geosynthetic is working together with the soil filter behind for protecting against clogging and hydrodynamic forces.

1.3. Paper content

Paper presents the main aspects related to physical and mechanical properties of geosynthetics, the main applications, focusing on reinforcement, filtration and drainage functions. It presents also the various interactions between geosynthetics and mineral materials and the properties of the resulted composite material.

For the two considered functions (reinforcement and filtration – drainage) paper shows experimental test results using standard equipment and procedures and also original ones, developed at the Geotechnical Department of TUCEB.

For reinforcement geosynthetics are presented tensile test, creep test, friction in shear box device and inclined plane device, while for filtration – drainage geosynthetics the paper presents specific experimental tests including peel test, permeability and filtration tests.

2. Brief presentation of geosynthetics and their characteristics

2.1. Geosynthetics used for reinforcement

For reinforcement purposes are used woven - high tensile resistant geotextiles, geogrids or reinforcement geocomposites.

Geotextiles are permeable fabrics made of polypropylene (PP), polyester (PET), polyethylene (PE) or polyamide (PA). They can be woven, non-woven or knitted, reinforced by thermal bonding or needlepunching [1] (Figure 1a).

Geogrids are polymeric nets with large openings (1 – 10 cm) to allow penetration of granular particles. They are generally made of polyethylene (PE, PEHD) or polypropylene (PP), but also of polyamide (PA), polyester (PET) or, more recently, from aromatic polyamides (aramide - AR) or poly-vinyl-alcohol (PVA). They are composed of ribs inter-connected by nodes. Geogrids can be: mono-, bi- or tri-axial, while nodes can be integrated, welded, knitted or glued (Figure 1b). Monoaxial geogrids have high tensile strength in longitudinal direction and are used for those applications where tensile stresses are developing in only one direction. Bi- and tri-axial geogrids are used where is required to transfer stresses acting on two or three directions, usually for soft soils reinforcement.

Geocomposites are combinations of several materials, from which at least one is a geosynthetic: geotextiles – geogrids, geotextiles – geonets etc. For reinforcement purposes are used:

• associations geotextiles – geogrids: geogrids enhance geotextile strength, while geotextiles have separation and filtration function. Are used mainly for soil or asphalt reinforcement;

• geocells: tri-dimension structures in form of honeycomb, made of polymeric strips, geotextiles of gegrids, filled with granular materials or soils, used for enhancing soft soils bearing capacity.

Figure 1c presents several types of reinforcement geocomposites (associations geogrid – geotextile).

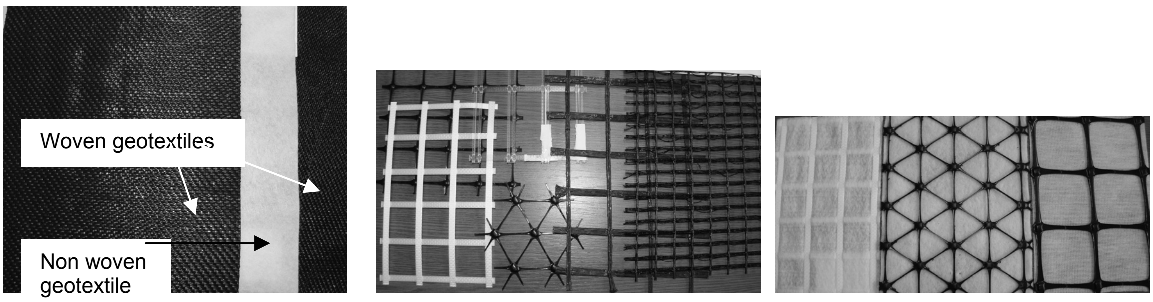
The main mechanical characteristics which have to be determined for assessing the performances of a geosynthetic reinforcement are:

- tensile strength – at rupture and corresponding to the expected strain, as well as creep tensile strength; elongation at rupture and creep;

- tensile creep strength – polymers from which geosynthetics are fabricated have rheological properties, so that, being submitted to a constant tensile force on long term, develop time-dependent deformations;

- mechanical damage resistance during installation;

- friction between fill and geosynthetic or between two geosynthetics and behaviour as a composite material together to granular material.



a) woven and non-woven geotextiles
a) *geotextile țesute şi nețesute*

b) geogrids
b) *geogrile*

c) reinforcement and separation geocomposites
c) *geocompozite de armare şi separare*

Fig. 1 - Various types of reinforcement geosynthetics/*Diferite tipuri de geosintetice de armare.*

2.2. Geosynthetics used for filtration and drainage

Geosynthetics used for hydraulic functions as filtration and drainage are: geotextiles (usually non-woven), geonets and drainage geocomposites.

Geotextiles have been presented previously (paragraph 2.1). All geotextiles are able to be used as drainage material, but at different degrees. Thin woven geotextiles have low transmissivity, while thick non-wovens have considerable void space and thus, high flow capacity. Geonets and drainage geocomposites have by far higher flow capacities, therefore geotextiles are mainly used for filtration (non-wovens generally).

For filtration and drainage purposes the relevant geotextile characteristics are: opening size (soil retention), permittivity (cross – plane permeability), permeability (in – plane permeability) and long term flow compatibility (durability). Geotextiles shall have sufficient openings (pores) for allowing cross – plane fluid flow, but openings size should also prevent clogging. Also, the mechanical characteristics as tensile strength or compressibility are important, including here also tensile – or compression creep. When used on slopes, the friction characteristics are also required to be assessed.

Geonets are usually used in association with geotextile filters for avoiding clogging. They have an open structure, similar to geogrids, but ribs are joined at acute angles, generally from 60^0 to 80^0. Geonets can be: biplanar, consisting of solid extruded ribs (the most common) or foamed extruded ribs (with higher flow capacity) or triplanar, made of solid extruded ribs (an example of geonet is given Figure 2a).

Main hydraulic characteristic of geonets is transmissivity (planar flow rate) under normal stress. Mechanical characteristics as tensile strength, compressive strength (include creep) and shear strength are also of interest. In terms of durability, a specific characteristic is the intrusion of adjacent materials. All geonets should be covered with other materials on both faces; if not covered, soil will penetrate in its apertures making flow impossible.

Drainage geocomposites are made of two geotextiles for filtration and a geonet or other draining core for in-plane flow. Draining core can be made of: nets, fibres or mono-filaments, columns etc. Three main types are known: wick drains (or prefabricated vertical drain), used mainly for consolidating soft soils, sheet (planar) drains (panels: rigid nubbed, columned or dimpled core), used for different drainage applications and prefabricated edge drains, used for highways, airfields, roads etc (Figure 2b, c). Core is made of polyethylene, polypropylene or polyamide. Core shall resist to applied stresses (normal and shear stresses) without collapse and without considerable reduction in thickness and flow shall be allowed without level increasing inside the core. Core can settle under excessive pressures, which can reduce the flow section. Usually there is a critical pressure for which transmissivity is almost nil, varying from 50 kPa and 600 kPa. Under normal stresses geotextiles can penetrate in the drainage core, thus reducing further more the flow section.

Main relevant characteristics of drainage geocomposites are: thickness, core transmissivity and in-plane flow capacity, permittivity and opening size of geotextiles, tensile strength, compressive strength and internal strength (shear or peel resistance). If used on slopes, friction characteristic are also required.

2.3. Testing geosynthetics

When testing geosynthetics two main types of tests can be performed: index tests, which are performed in standard conditions and which are used for harmonization and comparison purposes and performance tests, performed in as-in-field conditions (similar stress, materials in contact, same type of fluid etc.).

All parameters related to tensile strength are usually determined using the wide-width test [2]. This should be performed either on current sections and junctions (nodes, stitches etc.).

The second important characteristic related to reinforcement function is the friction between fill and geosynthetic. The tensile stress transfer toward geosynthetic reinforcement is obtained through friction and interlocking. In some cases, as for cohesive soils and/or rough reinforcement, an

a) geonet
a) georețea

b) drainage geocomposites
b) geocompozite de drenaj

c) columned drainage core
c) miez de drenaj cu coloane

Fig. 2 - Various types of geosynthetics used for drainage and filtration/*Diferite tipuri de geosintetice utilizate pentru drenaj şi filtrare.*

adhesion between the two materials can also appear. When using geotextiles, only friction (and possibly adhesion) will appear, while for geogrids there will be also an interlocking mechanism. These parameters can be determined using a large shear box, adapted for testing geosynthetics or an inclined plane device [3, 4]. Also, pull-out tests can be used [5].

In terms of hydraulic characteristics, tests are mainly permeability ones in various configurations.

3. Experimental tests on geosynthetics

3.1. Tensile strength

3.1.1. Experimental methods

As previously seen, tensile strength is the most important geosynthetic characteristic, being required for all products, applications and functions, including for harmonization purposes [6].

Tensile strength is expressed by force per unit width [kN/m] and should be given together with the tensile elongation (on both directions: longitudinal and transverse) at rupture and the deformation modulus (secant modulus), E.

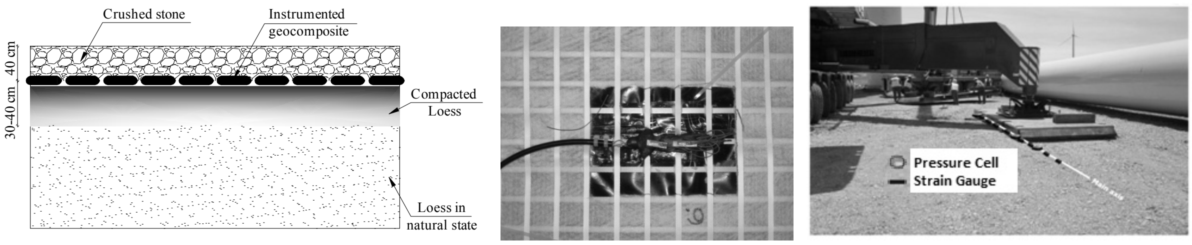
The usual test is the wide – width test on large samples (in order to accommodate large deformations of geotextiles, for example), according to EN ISO 10319.

For reinforcement applications, highly important is to estimate the deformation to be recorded on site, in order to have a good agreement between the geosynthetic deformation and fill and structure ones. Usually, the maximum tensile strength is obtained at strains which are much higher than those allowable for the structure or possible to be recorded on site. A good knowledge of the real deformation is therefore very useful.

3.1.2. Case study – reinforced working platform

A case study regarding the tensile behaviour of reinforcement – geosynthetics is presented hereafter.

A crushed stone working platform for a 750 tonnes crane was reinforced by a geocomposite made of a laid-and-welded polypropylene (PP)

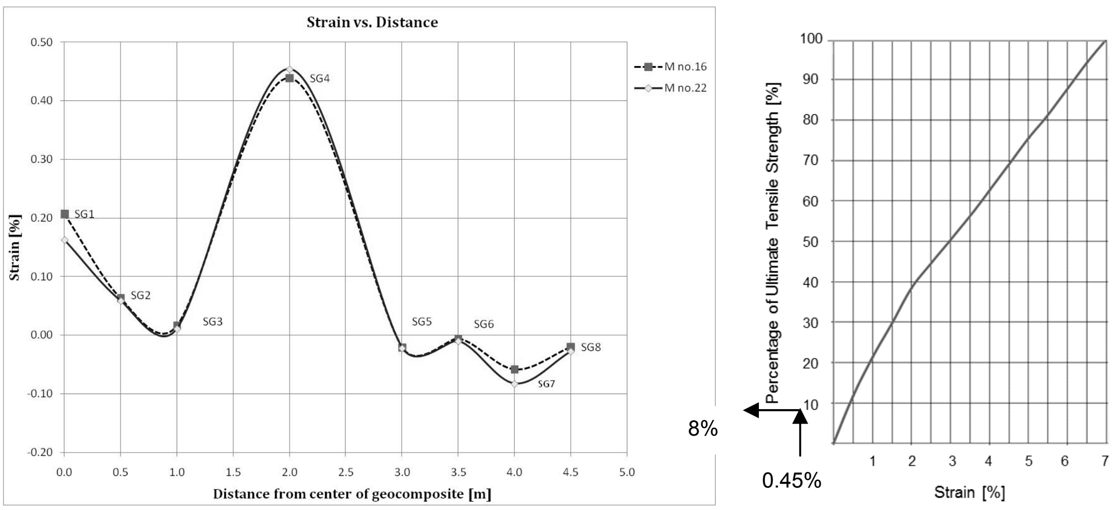


a) structure of the working platform / *a) structura platformei de lucru*

b) installation of strain gauges / *b) instalarea traductorilor de deformație*

c) instrumented platform / *c) platforma instrumentată*

Fig. 3 - Working platform reinforced with geocomposite instrumented with linear strain gauges/*Platforma de lucru armată cu geocompozit instrumentat cu traductori lineari de deformație.*



a) recorded strain versus distance/*deformație măsurată funcție de distanță*

b) real strain and stress level/*nivel real de deformație*

Fig. 4 - Measured tensile strain for the reinforced working platform/*Elongație măsurată pentru platforma armată.*

biaxial geogrid with a 150 g/m² needle punched nonwoven PP geotextile, which is firmly bonded between the cross laid reinforcement bars (as the one shown Figure 1c left side) (Figure 3a). The tensile strength of the reinforcement in longitudinal and transverse direction is 30 kN/m; the strain level at failure is ≤ 8%. The geocomposite was instrumented with 8 linear strain gauges glued on one of the geogrid's rib (max. elongation 100,000 μm/m (±10 %) and max. allowable bridge supply voltage of 8V, nominal resistance of 120 Ω) (Figure 3b, c) in order to have a better knowledge of the real behaviour of the reinforcement [7].

Strain measurements were taken during the installation of working platform and crane. Figure 4a presents the maximum recorded values for stages 16 and 22, which corresponds to maximum loading. Maximum strain value was recorded at 2 m from the centre of crane pad, when the full counterweight of 225t was directly positioned over the crane pad without having a lifting weight at the boom. The maximum strain was 0.48%. These results show that the real level of the stress and strain in the geosynthetic, compared to the overall stress – strain curve of the material, is very low (0.48% of strain corresponds to 8% of the tensile strength) (Figure 4b) [8].

This experiment proves that geosynthetic reinforcement is stressed much less than its capacity and the design should, therefore, be performed for the serviceability limit state.

3.2. Friction testing

3.2.1. Experimental methods

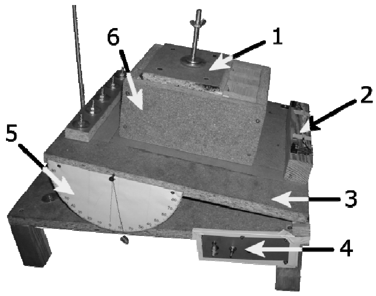
As previously stated, stress transfer from fill to geosynthetic reinforcement is dependent of friction and interlocking mechanisms. As well, for all geosynthetics installed on slopes, whatever their function, it is required to assess their friction characteristics in contact with soil/fill in place and/or with other geosynthetic materials, in order to evaluate their stability.

For friction testing the standard EN ISO 12957 – "Determination of friction characteristics, Part 1 – Direct shear test, Part 2 – Inclined plane test" is applicable.

Direct shear device adapted for geosynthetic testing is shown Figure 5. The test can be performed with the geosynthetic in contact with a standard sand - index test - or with the material in contact on site (fill, natural soil or another geosynthetic) – performance test.

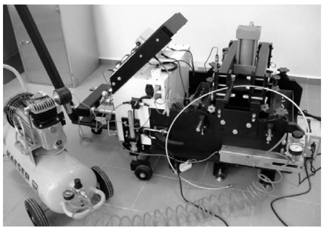
In case of inclined plane test, the friction angle between fill and geosynthetic is determined as the inclination angle for which the upper box of the apparatus, which is filled with soil, slips on the geosynthetic base, when inclined with constant rate. The major advantage of this test is that requires a much lesser normal stress than for direct shear, allowing simulating other types of applications. Some other authors developed such devices, some of them improved compared to the standard [9, 10].

Inclined plane device developed at TUCEB for testing geosynthetics is shown Figure 6. It allows testing interfaces between geosynthetics and soils/fills (not between two geosynthetics), having an upper box 150 x 130 mm. The device has been calibrated and validated prior to any test.

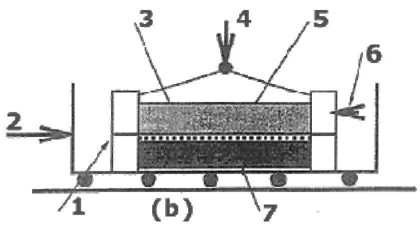


Legend/*Legendă*: 1 – stress distribution plate/*placă de distribuție a eforturilor*; 2 – off sensor for the tilting device/*senzor de oprire pentru dispozitivul de înclinare*; 3 – rigid base/*bază rigidă*; 4 – control panel/*panou de control*; 5 – inclination gauge/*sistem de măsură a înclinării*; 6 – upper box/*cutie superioară*.

Fig. 6 - Inclined plane device developed at TUCEB – Geotechnical Department / *Dispozitivul cu plan înclinat al UTCB – Departamentul de Geotehnică.*



a) device at TUCEB – Geotechnical Department
a) echipament la UTCB – Departamentul de Geotehnică



b) Scheme according to SR EN ISO 12957-1
b) Schemă în conformitate cu SR EN ISO 12957-1

Legend/*Legendă:* 1 - Standard shear box/*Cutie de forfecare standard*; 2 - Horizontal force/*Forța orizontală*; 3 - Geotextile specimen/*Probă de geotextil*; 4 - Normal load/*Incărcare normală*; 5 - Standard sand/*Nisip standard*; 6 - Horizontal reaction/*Reacțiune orizontală*; 7 - Rigid support for specimen/*Suport rigid pentru probă*

Fig. 5 - Shear box device for testing geosynthetic interfaces/*Echipament de forfecare directă pentru interfețe cu geosintetice.*

Here after are presented the results obtained by direct shear testing and inclined plane device on various type of geosynthetics used for reinforcement (reinforcement geocomposite composed of geotextile + geogrid) or drainage (drainage geocomposite), but also for geomembranes, all obtained in the Geotechnical Laboratory of the Technical University of Civil Engineering Bucharest (TUCEB).

3.2.2. Direct shear test on reinforcement geocomposite

The geosynthetic material for this test was the one used for reinforcing the working platform presented paragraph 3.1.2.

A performance test was performed in the direct shear device using the crushed stone to be used on site. Figure 7a shows the testing device and sample, while Figures 7b and c present the results. The friction angle at the interface was α = 40.84^0. For crushed stone alone an internal friction angle ϕ = 43.61^0 was determined also by shear box. Which gives an interaction coefficient, λ_0 (or friction efficiency, E_ϕ) = tanα/tanϕ = 0.91. This was further used for numerical modelling of the working platform behaviour [7]. Tests performed by the producer for same type of geogrids in contact with a standard sand 0 – 4 mm showed an interaction coefficient of 0.96 – 0.99 [11].

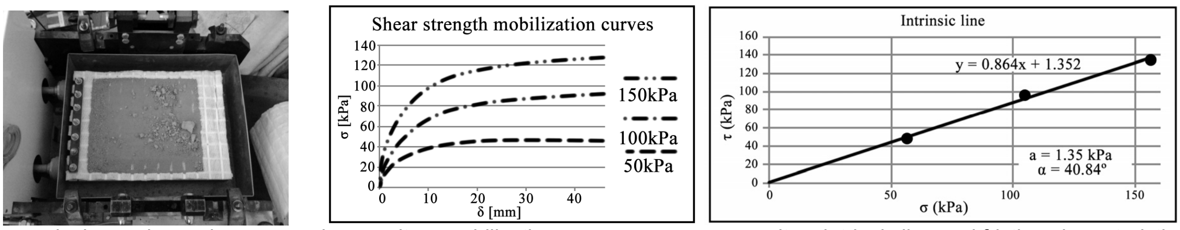
Using a geosynthetic reinforcement in the working platform structure allows to reduce the required thickness of the crushed stone layer (in this particular case) from 60 cm to 40 cm.

3.2.3. Direct shear tests on drainage geocomposite and geomembranes

Geosynthetics used in this series of tests were: two types of drainage geocomposites (GC1 and GC2) and two types of textured geomembranes (GM1 and GM2), with following tested interfaces: geomembranes – silty sand (P1), clayey sand and gravel (P2) – drainage geocomposites and geomembranes – drainage geocomposites. All geosynthetics were installed or supposed to be installed on slopes 1:3 and the interface friction angle was required in order to assess their stability. P1 and P2 are soils with which geosynthetics will be in contact. Thus, tests were performance tests. As an example, Figure 8 presents the test and results obtained for drainage geocomposite GC1 in contact with soil P2, while Table 1 presents all obtained results.

The friction angles on various interfaces were further used in a stability analysis which showed that materials GC1 and GM1 were not adapted to the site, being instable, thus being replaced by more appropriate products (GM2, GC2). Such stability analyses are recommended by national regulations (GP 107 for example) and are usually performed using wedge method [12 - 14], slices method or finite element method.

The results analysis allow to drawn useful conclusions regarding textured geomembranes. It was noticed that geomembrane GM1 had a non-uniform texture, made by spraying, which produced more variable friction resistance on

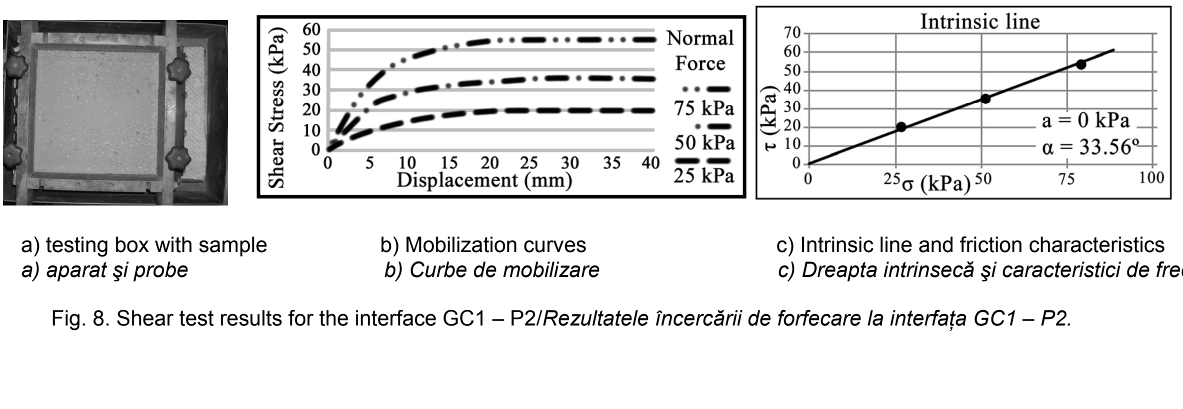


a – device and sample b – results – mobilization curves c – results – intrinsic line and friction characteristics

a – echipament şi probă b – rezultate – curbe de mobilizare c – rezultate – dreapta intrinsecă şi caracteristici de frecare

Fig. 7 - Shear test at interface reinforcement geocomposite – granular fill/*Incercare de forfecare la interfața geocompozit de armare – umplutură granulară.*

Note: The mobilization curve for 100 kPa shows a decrease for 22 mm displacements which was due to slipping of geosynthetic from clamps/ *Curba de mobilizare pentru 100 kPa prezintă o coborâre în dreptul deplasării de 22 mm care este datorată alunecării geosinteticului din clemele de prindere.*



a) testing box with sample b) Mobilization curves c) Intrinsic line and friction characteristics

a) aparat şi probe b) Curbe de mobilizare c) Dreapta intrinsecă şi caracteristici de frecare

Fig. 8. Shear test results for the interface GC1 – P2/*Rezultatele încercării de forfecare la interfața GC1 – P2.*

Table 1

Friction tests by shear box and inclined plane on various drainage geocomposites and geomembranes

Incercări de frecare prin forfecare directă şi cu planul înclinat pe diferite geocomposite de drenaj şi geomembrane

		Friction angle at interface tested by shear box/*Unghi de frecare la interfaţă prin forfecare directă*					
	Materials in contact *Materiale în contact*	Drainage geocomposite *Geocompozit de drenaj* GC 1	Drainage geocomposite *Geocompozit de drenaj* GC 2	Geomembrane *Geomembrană* GM 1	Geomembrane *Geomembrană* GM 2	Silty sand *Nisip prăfos* P1	Clayey sand and gravel *Nisip argilos cu pietriş* P2
Friction angle at interface tested by inclined plane (*in italic*)/ *Unghi de frecare la interfaţa pe planul înclinat (în italic*)	Drainage geocomposite *Geocompozit de drenaj* GC 1			18.21^0 * internal friction angle/ *unghi de frecare internă*			33.56^0
	Drainage geocomposite *Geocompozit de drenaj* GC 2				31.34^0		36.68^0
	Textured geomembrane *Geomembrană rugoasă* GM 1					32.83^0	
	Textured geomembrane *Geomembrană rugoasă* GM 2					35.75^0	
	Silty sand *Nisip prăfos* P1			*33.34^0*	*33.68^0*	40^0*	
	Clayey sand and gravel *Nisip argilos cu pietriş* P2	*34.16^0*	*34.72^0*				44^0*

interface, especially when was in contact with geotextiles. Other authors have also come to this conclusion. Dellinger et al. [15] showed that for textured geomembranes the variability is of 0.15 compared to smooth ones for which is only 0.05.

3.2.4. Inclined plane tests

Same geosynthetics as for tests described paragraph 3.2.2 were tested, but only for geosynthetic/fill interfaces. Results are given in Table 1 (values in italic).

Although less precise than shear box, inclined plane device supplied results very close to shear box ones, differences being of 1.5 – 5.7 %. In addition of allowing less normal stress, this test is also very quick, time of testing being of only 30 min.

3.3. Internal strength testing

3.3.1. Experimental methods

Internal strength can be critical for geocomposites installed on steep slopes. In this case the slip plane can pass directly through the geosynthetic. Internal strength is linked to the connections between the various components of the geocomposite.

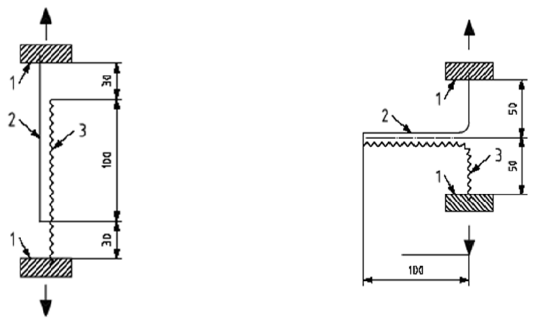
Internal strength of geocomposites can be determined according to SR EN ISO 13426-2 [16] by shear test or by peel test (Figure 9).

3.3.2. Peel tests

For the case study presented paragraphs 3.2.2 and 3.2.3. it was observed that drainage geocomposite GC1 hadn't the proper strength for taking out large traction stresses, thus being torn. In order to assess its internal strength it was firstly tried to use the sear box, but the elongation of the upper geotextile was so high, that it was not detached from the geonet (Figure 10a). Thus, it has been concluded that this type of test is not adequate. According to SR EN ISO 13426-2, both drainage geocomposites (GC1 and GC2) were tested by peeling using the Testometric FS 300HT device belonging to Construction Materials Department of TUCEB. Samples were 200 x 200 mm and were pre-peeled on 100 mm length to allow clamping. Figure 10b) presents the device during the peel test, figures c) and d) show the rupture by peeling for both geocomposites, while Figure 10 e) and f) present the results.

One can observe that results are very different for the two tested geocomposites: GC1 has a „saw teeth" stress – strain behaviour, proving that the assembly of geotextiles - geonet is not homogeneous over the surface, while GC2 has a typical „detachment" behaviour, with higher peel strength and lower amplitude of variations.

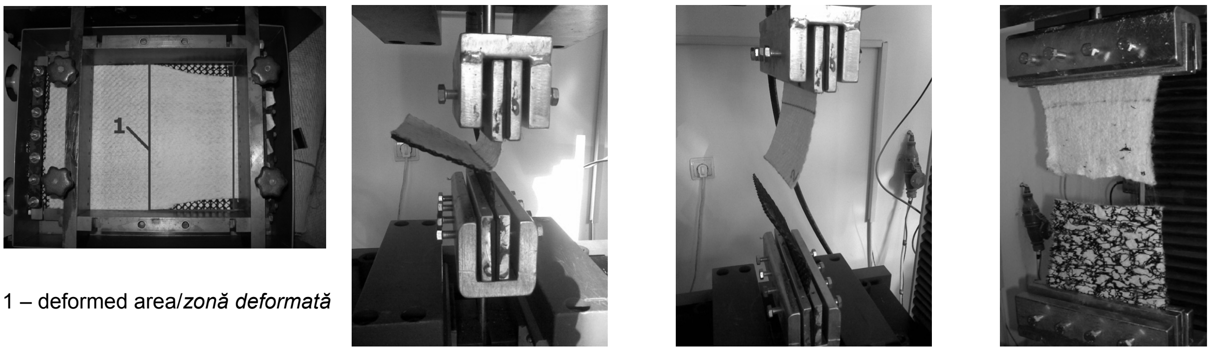
This type of test and analysis allow the designer or the constructor to properly choose the right material to be used on steep slopes and to



Legend:
1 – clamp/*clemă;*
2 – first geosynthetic component/*primul component geosintetic;*
3 – second geosynthetic component/*al doilea component geosintetic*

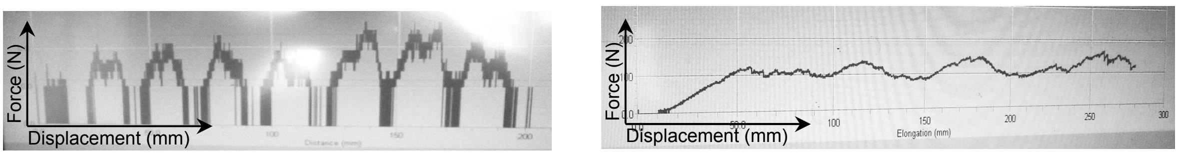
a) shear test/*încercare de forfecare* b) peel test/*încercare de exfoliere*

Fig. 9 - Tests for internal strength of geocomposites/*Încercări pentru rezistența internă a geocompozitelor.*



1 – deformed area/*zonă deformată*

a) shear box /*cutie de forfecare* b) peel test/*încercare de exfoliere* c) end of test for GC1/*final GC1* d) end of test for GC2/*final GC2*



e) peel force for GC1/*forța de exfoliere pentru GC1 (186 N/m)* f) peel force for GC2/*forța de exfoliere pentru GC2 (741 N/m)*

Fig. 10 - Internal strength testing of drainage geocomposites GC1 and GC2/*Determinarea rezistenței interne a geocompozitelor de drenaj GC1 și GC2.*

avoid accidents involving slipping and tearing of geosynthetics.

3.4. Hydraulic testing

3.4.1. Filtration performance tests

When using a geosynthetic filter (geotextile, usually) in contact with a fill or soil, the filter should be properly chosen in terms of permeability and opening size and its performance should be tested in real conditions.

This paragraph gives an example of how performance testing for filtration function can be done.

The purpose of the work presented in this chapter was to study the compatibility between a geotextile that is intended to be used for separation and filtration for the elevation of an existing fly ash and slag storage. An experimental program was carried out for determining the clogging degree of the geotextile used in contact with the slag, thus establishing if the proposed geotextile is suitable for this application [17].

The slag is, from granulometric point of view, a fine – medium sand, while the filtration geotextile is a non-woven, made of PP, with a characteristic opening size of 0.7 mm.

The hydraulic performance tests included:

Test 1 – slag alone, using a falling head permeameter (figure 12b). The resulted permeability was of 1.78 x 10^{-4} m/s.

Test 2 – slag + geotextile. The 2nd test consisted of determining the water flow through the whole system, the soil and the underlying geotextile in the constant head permeameter (Figure 11a). Results are shown Figure 12. The final permeability was of 4.8 x 10^{-7} m/s. It can be observed that after approx. 500 min the flow of water becomes constant, meaning that the maximum clogging of the geotextile material was reached. A very small quantity of slag was collected in the outflow (less than 0.5 g dry).

Test 3 – geotextile alone, using a falling head permeameter (Figure 11c with no soil sample). The testing procedure was according to SR EN ISO 11058 [18] and the ASTM D4491-99a [19].

a) constant head permeability device   b) falling head permeameter for slag testing,   c) falling head permeameter for geotextile testing

a) permeametru cu nivel constant   b) permeametru cu nivel variabil pentru cenuşă   c) permeametru cu nivel variabil pentru testarea geotextilului

Fig. 11 - Hydraulic performance tests on slag, geotextile and slag + geotextile/*Incercări hidraulice de performanță pe cenuşă, geotextil şi cenuşă + geotextil .*

Initial permeability of the geotextile was of 7.85 x 10^{-4} m/s.

Test 4 – geotextile after test 2. The fourth test consisted in determining the flow of water through the geotextile after the contact with the slag (test no. 2) (Figure 11c). It results a permeability of 6.8 x 10^{-4} m/s, 13 % lower than for the initial geotextile. Only 7.6% difference in weight were slag particles trapped in the geotextile.

All results prove that geotextile is adequate for filtration and separation in contact with the tested slag. Performance tests such as those presented here help the designer to properly choose the filtration geotextile [20].

3.4.2. Drainage performance tests

Main design parameter for drainage systems including drainage geocomposites is the in-plane flow capacity. This is normally determined in standard conditions (according to SR EN ISO 12958 [21] for 20 kPa normal stress and hydraulic gradients of 0.1 and 1).

As drainage geocomposites are prone to clogging and/or compressing (thus a reduced flow section) is important that in – plane flow capacity is determined in real working conditions (performance tests).

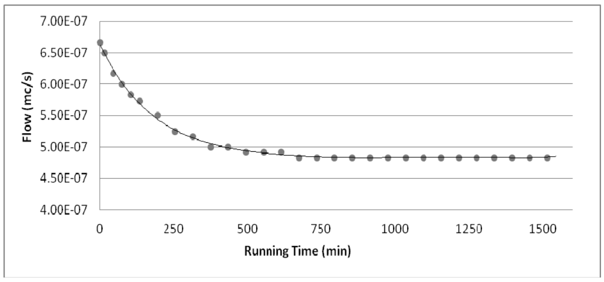
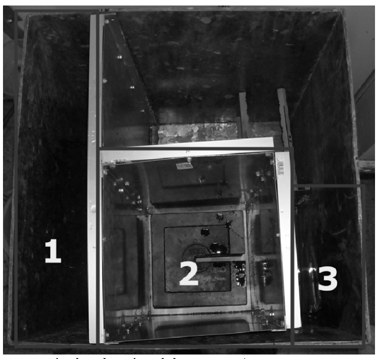


Fig. 12 - Tests results for slag + geotextile/*Rezultatele încercărilor pentru cenuşă + geotextil.*

In this paragraph is presented a device for testing drainage geocomposite for their in-plane flow capacity, developed at TUCEB – Geotechnical Laboratory and the results of some experimental tests.

Figure 13a presents the developed device, which allows a hydraulic head of up to 15 cm and a normal stress of maximum 15 kPa. Geosynthetic sample is 30 x 30 cm in size, while the net flow section is 25 x 25 cm.

The tested drainage geocomposite is intended to drain the rainfall infiltration water, being put in contact with a soil fill (gravely clay)



Legend/*Legendă:*
1 – out-flow compartment *compartiment de ieşire*
2 – sample compartment *compartiment cu probă*
3 – water supply compartment *compartiment de alimentare*

a) device/*echipament*   b) drainage geocomposite/*geocompozit de drenaj*

Fig. 13 - Device for testing the in-plane flow capacity and drainage geocomposite sample/*Echipament de determinare a capacității de curgere în plan şi proba de geocompozit.*

quite fine and with low permeability (10^{-7} – 10^{-8} m/s). The objective of experimental tests was to assess the clogging possibility and the flow capacity under the real normal stress.

The drainage geocomposite is composed of two non-woven geotextiles and a drainage core (Figure 13b). According to technical specifications, the flow rate for a normal stress, σ = 20 kPa is: 0.25 l/m/s (i = 0.1), 0.5 l/m/s (i = 0.3), 1 l/m/s (i = 1) (i – hydraulic gradient).

For this case were performed 6 performance tests: 4 with i = 0.2, 1 for i = 0.48 and one for i = 0.6. The last value, a hydraulic gradient of 0.6, corresponds to the average value possible to be encountered on site. For all cases a normal stress of 6 kPa, corresponding to the one on site.

Graph in Figure 14 presents the obtained results, which can be used for extrapolating for other values of the hydraulic gradient, especially for the standard one, i = 1. Based on Reynold's number, the flow becomes turbulent for gradients higher than 1.2.

The overall permeability coefficient under 6 kPa normal stress is 3.7 x 10^{-3} m/s.

Based on these tests the designer can verify if the chosen drainage geocomposite is adequate for the required flow rate.

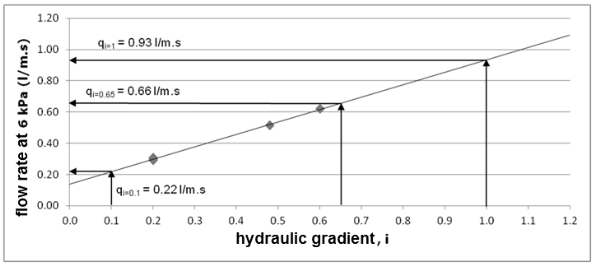


Fig. 14 - Flow rates for in-plane flow of drainage geocomposite/*Debite pentru curgerea în plan a geocompozitului de drenaj.*

4. Conclusions

In the last years, geosynthetics were widely used in replacement or addition to traditional construction materials. Their efficiency, durability, adaptability, availability and sustainability made them known and used for various functions: filtration, drainage, waterproofing, reinforcement, protection against erosion etc.

But all advantages can be obtained only if geosynthetics are properly known, investigated and chosen for every specific use, which implies tests and analyses.

Paper presents the main aspects related to physical and mechanical properties of geosynthetics, the main applications, focusing on reinforcement, filtration and drainage functions. It presents the various interactions between geosynthetics and mineral materials and the properties of the resulted composite material. After briefly introducing the geosynthetics fulfilling these functions and their properties, the paper presents the results of some experimental tests carried out at the Technical University of Civil Engineering Bucharest – Geotechnical Department, including novel devices (as the inclined plane test for friction testing or the one for testing the in-plane flow capacity of drainage geocomposites), standard laboratory equipment (large shear box or permeameters) and in situ measurements on instrumented geosynthetics.

The paper emphasizes for each type of test its importance for the design process.

REFERENCES

1. A. Găzdaru, and V. Feodorov, S. Manea, and L. Batali, Geosinteticele în construcții – vol.2. Proprietăți, utilizări, elemente de calcul, București, Editura Academiei Romane, 1999.
2. xxx, EN ISO 10319:2008 - Geosynthetics - Wide-width tensile test.
3. xxx, EN ISO 12957-1:2005 - Geosynthetics - Determination of friction characteristics - Part 1: Direct shear test.
4. xxx, EN ISO 12957-2:2005 - Geosynthetics - Determination of friction characteristics - Part 2: Inclined plane test.
5. R.M. Bakeer, M. Sayed, P. Cates, Rand . Subramanian, Pullout and shear test on geogrid reinforced lightweight aggregate, Geotextiles and Geomembranes, 1994, **16** (2), 119.
6. xxx, NP 075-02 – Technical norm for using geosynthetics in civil engineering works (in Romanian), 2002.
7. N. Butnarciuc, Evaluation of the behaviour of geocomposites used as reinforcement in working platforms (in Romanian), PhD Thesis, Technical University of Civil Engineering Bucharest, Romania, 2013.
8. L. Batali, J. Klompmaker, and N. Butnarciuc, Test field for monitoring geocomposite reinforcement behavior in a crane working platform at a wind farm, in Proceedings of the Geosynthetics 2013, Long Beach, California, SUA, April 2013, edited by Industrial Fabrics Association International, p. 204.
9. L. Briancon, H. Girard, and J.P. Gourc, A new procedure for measuring geosynthetic friction with an inclined plane, Geotextiles and Geomembranes, 2011, **29**, 472.
10. L. Carbone, J.P. Gourc, L. Briançon, N. Moraci, and P. Carrubba, What Value of Interface Friction to Select for Geosynthetic Liner on Landfill Slopes?, in Proceedings of the Geosynthetics 2013, Long Beach, California, SUA, April 2013, edited by Industrial Fabrics Association International, p. 636.
11. xxx, Bauberatung Geokunstoffe GmbH, Soil/geogrid interaction capacity – Secugrid vs. Combigrid, Report BBG, 2011.
12. X. Qian, R. Koerner, and D. Gray, Geotechnical aspects of landfill design and construction, Prentice-Hall, 2002.
13. R.M. Koerner, and T.-Y. Soong, Analysis and Design of Veneer Cover Soils, in Proceedings of 6th IGS, IFAI, Roseville, MN, 1998, p. 1.
14. R.M. Koerner, and B.-L. Hwu, Stability and Tension Considerations Regarding Cover Soils on Geomembrane Lined Slopes, Journal of Geotextiles and Geomembranes, 1991, **10**(4), 335.
15. xxx, G. Dellinger, R. Lacey, J. Allen, and R. Gilbert, Importance of Variability in the Interface Shear Strength between Textured Geomembrane and Geocomposite Drainage Layer in Landfill Covers, in Proceedings of the Geosynthetics 2013, Long Beach, California, SUA, April 2013, edited by Industrial Fabrics Association International, p. 688.
16. xxx, EN ISO 13426-2:2005 - Geotextiles and geotextile-related products - Strength of internal structural junctions – Part 2: Geocomposites.

17. xxx, Gh. Pantel, Research on some aspects of the behavior of geosynthetic materials used in landfills (In Romanian), PhD thesis, Technical University of Civil Engineering Bucharest, Romania, 2013.
18. xxx, EN ISO 11058:1999 - Geotextiles and geotextile-related products –. Determination of water permeability characteristics normal to the plane, without load.
19. ASTM D4491-99^{a}-2004 - Standard Test Methods for Water Permeability of Geotextiles by Permittivity.
20. L. Batali, and Gh. Pantel, Interaction Of A Filtration Geotextile And The Cover Soil In Case Of A Fly Ash Storage Site, in Proceedings of the 11th Slovak Geotechnical Conference, Bratislava, 3-4 June 2013, p. 69.
21. xxx, EN ISO 12958:2010 - Geotextiles and geotextile-related products. Determination of water flow capacity in their plane.

****

MANIFESTĂRI ŞTIINŢIFICE / SCIENTIFIC EVENTS

Theme:

CONMOD 2014 will be the fourth in a series of RILEM symposia after Quebec City, Canada (2006) and Delft, The Netherlands (2008) and Lausanne, Switzerland (2010). The Symposium is specifically devoted to the development and applications of numerical models to simulate and predict the microstructure, material properties (mechanical and transport properties) and long-term performance of concrete. CONMOD conferences are supposed to be a platform for researchers active in modelling of concrete at different length scales and coming from different scientific disciplines (chemistry, physics and mechanics). The goal is to be able to deal with more and more complex couplings. During this series of conferences, the background of models is discussed, for what purpose models are developed, the modelling concepts and computation techniques which are adopted, as well as the validation of models. Examples of service-life prediction are presented and compared to field data. This series of conference offer also an exchange platform for the PhD students working on the modeling of concrete materials. Accordingly, the participation of PhD student is very much encouraged.

The topics of CONMOD2014 are, but not limited to:
- Modelling of cement hydration (thermodynamics and kinetics)
- Modelling of concrete microstructure
- Modelling of transport properties
- Modelling of various degradations (in particular coupled degradations)
- Durability models (deterministic and probabilistic)
- Micro-cracks formation (influence on transport properties)
- Reactive - transport modelling
- Volume changes prediction (shrinkage and creep)
- Interface properties (ITZ, steel-concrete)
- Modelling of mechanical properties
- Modelling of early age properties (early age couplings)

Correspondence and Inquiries:
- Dr. R.W. Yang : conmod2014@tsinghua.edu.cn
- Website: http://conmod2014.tsinghua.edu.cn

****