Contributions to the development of geosynthetics and of technical solutions with these materials

B. Vintila
Consilier Construct, Bucharest, Romania

Keywords: Geotextiles, Prefabricated vertical drains, Roads, Laboratory research, Erosion control

ABSTRACT: The issue of producing and using geotextiles was raised in our country in 1973. Based on the existing conditions in the textile and plastics industries, some types of geosynthetics and two draining prefabricates were accomplished, the same types that we use nowadays. The installation for producing the draining prefabricate has been designed and accomplished, new machines and laboratory methods for establishing some hydric and phisico-mecanical characteristics of geosynthetics have been brought to an end. The methods of execution with geosynthetics have also been tested and worked out, according to the working conditions on our road building sites. To suit the use of geosynthetics, the drafting of the instructions on this matter has been developing since 1977 and the "Technical norms..." regarding geotextiles and geomembranes were officialized in 1988. The standardisation of some of the geosynthetics' experiments began at that time.

1 PRESENTATION OF THE MOST USED ROMANIAN GEOSYNTHETICS

The recyclable fibres used to fabricate the first two Romanian geotextiles, that have been used for 20 to 25 years, come from the confections and chemical industries, at first use /6/.

The other geotextiles are made of original fibers.

We also produce polyethylene geomembranes up to 0,5 mm thick, PVC geomembranes, thickness of 1...2 mm and two draining prefabricates of 5/24 mm thickness /9/.

The existence of a wide range of alternatives of such materials allows the choosing of the most suitable one.

Most of geotextiles are made by inter-waving, delivered in width from 1 to 6 m and, when neccesary, impregnated with acrilates, having about 10% dry weight, condensed at 140...150°C. Extra consolidation doesn't make it impermeable, but it approximately doubles its resistance and makes it less sensible to the tendency of contamination with fine particles of soil.

In 1977 the geotextile called “synthetic earth” was accomplished. It is the mostly used one. The fibers are at their first use: 70% of them come from the chemical (polyester) industry and 30% from the textile industry (different synthetic fibers obtained by defibring) and they have diameters from 20 to 50 μm. They have a resistance to traction of one...15 kN/m, elongations of 50...90%, water permeability coefficients of 0.4...one cm/s10^{-1} perpendicular on their plane and of 1.5 to 3 cm/s10^{-1} in their plane.

The geotextiles made of original polypropylene and poliester fibers were first produced in 1977 and 1980. They are made either of fibers with a diameter of 4den/60 mm or 18den/100 mm (20...50 μm) in 14 variants. The resistance to traction is of 4...25 kN/m, the elongations of 60...110%, the water permeability coefficients of 1...3 cm/s10^{-1} perpendicular on their plane and of 3 to 5 cm/s10^{-1} in their plane.

A three-layer geotextile is also produced; it can be delivered in strips of 10...20 cm up to 6m in width. The exterior layers, only 0.5 mm thick, are used as a filter and they are made of very fine fibers, with diameters of only 10...20 μm. The middle layer, 7-10 mm thick, has the role of a draining body and it is made of original polyester fibers, about 25 times thicker (0.25...0.50 mm). That's why the permeability coefficient in the plane of the geotextile is about 20 times higher than the one perpendicular to this plane.

For big, important projects, the manufacturers produce geotextiles taking into account the special conditions regarding resistance, deformability, pore size, width or any other condition required by designers.

Table 1. Phisico-mecanical characteristics of bitumen-geotextiles

Characteristics	Unit	Value
Total mass:		540
- non-woven		180
- bitumen	g/ m^2	320
- polyethylene sheet		40
- limestone filer		60
Thickness under load of 2 kN/ m^2	mm	1
Resistance to traction - L_{min}	kN/m	6
-T_{min}		7
Elongation to break - L_{max}	%	80
-T_{min}		60
Test with the CBR puncture	N	1000
Temperature of thermal stabilization	°C	215
Drying temperature	°C	105
Maximum width	cm	160

Another geotextile is made of polyester fibers and bitumen emulsion, in two variants: the first one - when it is covered with a polyethylene sheet, that melts at 110°C, when the asphalt mixture is spread, and the second - when it is covered with limestone filer. The phisico-mecanical characteristics of the bitumen geotextile are shown in the first table. These geotextiles, used to make the bituminous anti-crack layers, are made of polyester to be resistant to stress and temperatures up to 200°C. The fabrication of the bitumen geotextile is made by an installation inside which the rolls are thermally stabilized, under instantaneous action of a temperature of 215°C and of the pressure exerted by a pressing flitz. These actions cancel the internal tensions inside the polyester fibers, they reduce to about 35% the initial thickness of the geotextile and, together with the bitumen particles, they raise the resistances with about 65% and simultaneously reduce elongations at break. After that, the geotextile is impregnated with a constant quantity of bitumen emulsion (total impregnation) and dried by the circulation of hot air (with a temperature of 105°C. At the end of this process either the thin polyethylene sheet is stuck or the filerisation with a limestone filer is done on the superior side of the impregnated geotextile. It is recommended that, to make the anti-crack layers, the filerized bitumen geotextile should be used /4/.

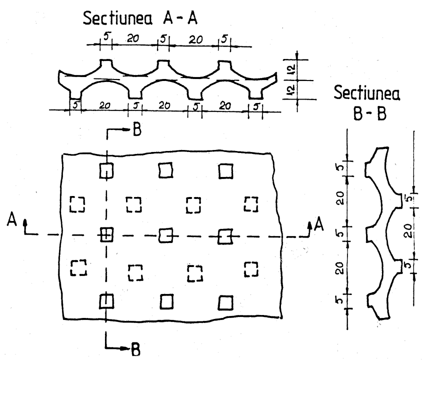

Fig. 1. Draining prefabricate

Another sown geotextile has been accomplished, made of synthetic/natural and synthetic fibers and comprises a web of perene *graminea* that varies depending on the climate in the zone where it is used.

The draining prefabricate /2/ is 24 mm thick, it has a breadth of 100 cm, a length of 10...20 m, it is delivered in rolls and no major deformations occur when exposed to pressure of 2 daN/cm^2, that acts perpendicular on it's plane.

The disposition of the cells that make up the voids and the canelures, through which the water flows, are presented in Figure 1. They also assure the product with a high mechanical resistance to bending (a sufficient rigidity).

2 NEW TECHNICAL SOLUTIONS ACHIEVED WITH GEOTEXTILES

Many designers currently foresee the use of geotextiles and the other geosynthetics for road construction or other constructions as you will see in the following lines. This paragraph presents three patented original solutions.

2.1 *Gradient protection with sowed or unsowed geotextiles*

Gradients of up to 5m can be protected by simple covering with grass using seeds of perene graminea. Longer gradients have to be protected with other devices: furrowing, plantations, sowed geotextiles, geo-webs, gauze, other thin unsowed textiles or special geosynthetics to harden the leaking of the water through the gradients.

When we use sowed or unsowed geotextiles and turf for gradient protection, the geotextile covers the whole surface of the gradient that is being covered with grass. It fixes the place of the seeds and of the young plants that are no longer moved by water and wind. They hinder the direct hitting of the ground by the raindrops and the direct contact between water streams and the ground from which the gradient is made. This way the breaking up of the soil aggregates and soils pouring on the gradients are avoided. Besides that, it assures the conditions to uniformly cover the gradients with grass, with the required density, the bending being smaller than or equal to 2:3.

It also preserves and ameliorates the fertility of the soil; the roots accomplish the structure's binding to the soil and together they oppose the erosion, consolidating the gradient's surface /6…8/.

Practically, during work we find three different situations:

a. The soil at the gradient's surface is fertile, covered with vegetation and it can be considered a soil that's fitted for agriculture. It has a dark brown or black color, it contains remains of roots and it has a smell that's characteristic to the presence of humic acids. In this case, it contains over 3% humus, 0.12% nitrogen, 0.014% P_2O_5 and over 0.018% K_2O. No soil fertilization with mineral fertilizers is necessary. The soil is broken up (about 10 to 15 cm depth) and either a sowed geotextile is laid, or seeds are spread, for example when we work with tifon. After that, the soil is raked until no seeds are seen and the surface of the gradient and this one is covered with Tifon, which is fastened with pegs (one peg for each 1.5 to 2 m^2). A layer of soil, as uniform as possible, is spread over the tifon. It is 2 to 3cm thick and discontinuous, so that the surface of the uncovered voids should be of less than 0.3 m.

b. The soil at the surface of the gradient is not fertile and it contains under 70% of sand or under 50% of clay. We proceed as for the soil fertilization with nitrous, phosphatic or photasium fertilizers, in a quantity of about 4 to 5 kilos/100 m^2 (active fertilizer) or complex NPK fertilizers, in a quantity of 10 to 15 kilos/100 m^2. The spreading of the fertilizers is done manually or mechanically.

-Lime is used on acid soils. Depending on the pH (1 to 5), 20 to 50 kilos of quick lime (CaO) or slacked lime (CaOH) is added for 1000 m^2 of gradient surface.

-The sowing is done in the same way as for point a.

c. Gradient soil is unfertile and it contains over 70% of sand (or gravel) or over 50% of clay. In this case one of the following measures can be applied:

-The soils with too much sand can be improved by adding peat (1 to 2 $m^3/100\ m^2$).

-The existing soil is covered with 5cm of vegetal soil and the sowed geotextile or tifon is applied.

-The oily clay type of soils can be improoved by adding sand and peat (1 to 2 $m^3/100\ m^2$ each).

-Acid soils are treated with CaO or CaOH (20 to 50 kilos/100 m^2).

In every case a rare, thin geotextile, with a resistance of under 5 kN/m may be used; it is made of about 30% synthetic textile recycled materials and 70% cellulose or natural textile recycled materials.

The best periods for installing turf are comprised between the 15^{th} of March and April 15 and between the 15^{th} of September and October 15. Usually, when the execution is made in these periods, no watering is needed.

2.2 *Draining screen for roads and auto-roads*

Longitudinal drains used under ditches or under road shoulders don't stop the infiltration of water into the active zone of the road. Some of the water that has leaked through the road shoulder moves towards the axis of the road up to 1 to 2.5m from the sides of the road. The horizontal permeability coefficient of the road shoulders layers is usually higher than the vertical permeability coefficient of these layers. These drains do not collect and evacuate all the water from the active zone named above.

To avoid the drenching of the sides of the roads and auto-roads by stopping the infiltration of the water from the road shoulders, special drains were designed, called "capillary barriers" and "draining screens".

A draining screen consists of one impermeable membrane, which also assures the moving of the water, that can be the draining body, two geotextile filters on both sides and a perforated tube, with a diameter of 4 to 15cm, depending on the debit of the water that needs to be collected transported and evacuated.

Two drains are formed on one side and the other. One of them collects the water from the road shoulder and the other one collects the water from the active zone. The draining prefabricate stops the passing of the water from one side to another /9/, (Fig. 2).

The draining screens are foreseen and implemented at the sides of the roads' pavements, near the kerbs, on the road shoulders, for both ways of traffic. The depth is from 20 cm to 2-3 m under the surface of the layer of the road, depending on the existing needs and on the possibilities of the equipment making the excavation of the ditch.

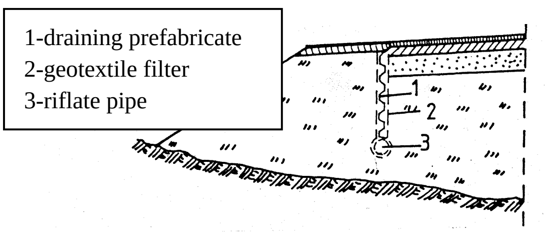

Figure 2. Draining screen for roads and auto-roads

The draining of the sides of the carriage roads, that are more intensely circulated than the traffic lanes near the axis of the road or auto-road, represents an important practical necessity, these also being the most exposed to moistening.

Gravel draining screens can be made, that contain instead of the draining prefabricate an impermeable plastic sheet, placed in the middle of the drain's ditch or on one of it's sides. It has been experimentally applied on about 1km of national road.

2.3 *The execution of the anti-crack layer using the bitumen geotextile*

Quantities of bitumen from 1.2 to 1.6 l/m^2 are used for coating, to ensure a total quantity of bitumen from 1.2 to 2.0 l/m^2, depending on the rugozity of the reinforced surface. It is recommended that the coating should be continuous on the whole surface /4/.

The advantages of using the bitumen geotextile are:

-The inter-layer between the degraded, discontinuous road pavement and the upper bituminous reinforcing layer is uniform, without folds. No possibility occurs that some portions to could be left without bitumen.

-Besides the coating we have talked about in the above lines, other layers made of bitumen or other asphaltic mixtures are no longer necessary. These ones can't always be carried out with uniform parameters, as it is necessary for other inter-layers (ex. geogrids).

-Emulsion water or water come from rain can no longer remain in this inter-layer and diminish the quality of the road rehabilitation/reinforcing works.

-If emulsion is used, it is necessary to wait for a while, before laying the asphaltic mixture, until the breaking of the emulsion. It is recommended that the work should be done with melted bitumen as we did on the Bucharest-Pitesti auto-road.

-The carrying out of the works using this type of layer is simple, rapid and economical.

-The costs are lowered with 300 to 500%.

-Bitumen is little permeable and it lowers the quantity of water that can infiltrate towards the inferior layers of the road structure.

The bitumen geotextile has been successfully used in the latest years to carry out anti-crack layers, both on intensely circulated roads and on the other roads and for the improvement of bituminous treatments works. It enlarges the time interval to the apparition and transmission of fissures with a duration about equal to other more expensive materials (at least 4 years).

The solutions with geogrids are used to carry out the anti-crack inter-layer to reinforce/rehabilitate road structures. They are 3 to 5 times more expensive, although the duration with which they delay the cracking and fissure transmission aren't sensibly higher, they are heavily implemented and they favor the producing of execution errors.

It was applied beginning with 1997 on about 130 km of national roads and on the Bucharest-Pitesti auto-road.

3 LABORATORY DETERMINATIONS

To dimension geotextile filters, drains using such filters and geotextile separation layers used for roads the tests presented in the following paragraphs are necessary. They have been accomplished in the last 20 years /1,10/.

3.1 *The determination of the permeability coefficient of geotextiles*

To determine the Darcy water permeability coefficient different devices have been imagined and are currently in use. In the following lines we present the method achieved in our country, using the nonaired water consolidometer.

The normal permeability coefficient on the plane of the plane of the geotextile sample or in this plane is determined by the passing of a specified amount of nonaired water through an lab sample or a pack of lab samples that form the final sample, put in the cell of the consolidometer (Fig. 3a, b). They are subdued to different pressures perpendicular on their plane. During the carrying out of the determinations we measure the thickness of the lab samples subdued to different pressures, piezometric levels at the entering/getting out of the water from the lab samples and also the period of time necessary for the water to pass through the sample. Using the resulted data, we calculate the permeability coefficient perpendicular on the plane of the sample (k_n) and the permitivity (P)/the permeability coefficient in the plane of the sample (k_p) and the transmisivity (T).

The permeability coefficient perpendicular on the plane of the sample is established using Darcy's relation written in the following way:

$$k_n = \frac{1000\Sigma a}{A\Delta ht}$$

where:

Σa is the thickness of the sample (cm)

Δh - the loss of hydrodynamic charge due to the passing of the water through the sample (cm)

t -the time in which 1000 cm^3 of water leak (s)

A - leaking area (cm^2).

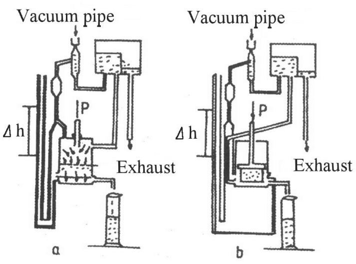

Fig. 3. The draft of the endopermeametre

The permeability coefficient in the plane of the sample is established using Darcy's relation written as follows:

$$k_p = \frac{5cm \times 1000}{a\Delta ht}$$

where 5cm is the width of the sample on the direction of water infiltration.

3.2 *Establishing pore distribution by dimension and the filtration diameter of geotextiles*

Geotextile pore distribution by dimension is necessary to design filters and other works that include these materials. This method too was elaborated in our country. Calculus most often uses the diameter corresponding to pore percentage of 90% or 95%, taken from the pore distribution curve, called D_{90}/D_{95} (Fig. 4). This diameter is called filtration diameter.

Figure 4 Device for establishing the distribution of the geotextiles` pores by dimension.

The suction-humidity curve of the respective geotextile is established and pore diameters (d_i) result from the Laplace relation between the suction (Δh_i) (cm) necessary to empty the pores and the respective diameters, for different levels of suction:

$$\Delta h_i = 0.3\ d_i \cos q$$

where q is the wetting angle (60°). The result is that, in fact, the restraint curve represents the integral pore distribution curve (by dimension) and it constitutes a good characterization of the material's pore system configuration. Any change in the pore configuration will also be reflected in the water restraint curve.

The working procedure referring to the device in figure 4 is: circular dry laboratory samples are weighted (M_d); they are saturated; the humid sample is weighted (M_h) and they are introduced inside the funnel, in direct contact with the porous plate. When starting the test, the porous plate has to be at the water level in the graduated biureta.

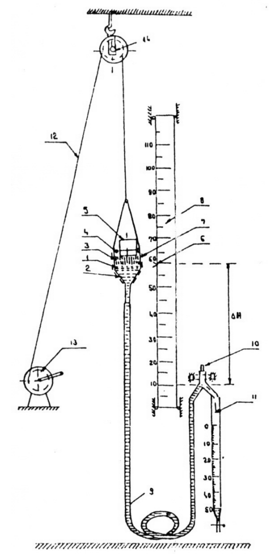

Fig.4. Device for establishing the distribution of the geotextiles pores by dimension

After that, the funnel is lifted together with the samples and the plate at different levels (from 1cm to several cm), thus carrying out the suction and the draining of the water for each level. Gathering and precise measurement of the volume of the drained water is done with the fixed graduated biureta, where water gets in at a fixed quota. This quota is at the point where the draining tube turns downwards, where a device for the airing of the tube is placed. From this quota on, we measure upwards the differences of pressure Δh_i of the water column that creates the respective suction levels.

When the pressure rises to different levels, the quantity of drained water from the geotextile sample (ΔG_i) is measured, by this establishing the pore percentages (p_i). Using d_i and p_i we draw the pore distribution curve, similar to the granulometric curve of the soil.

$P_i=V_i/G_{wsat}100$ (%)

$G_{wsat} = M_h - M_d + V_{imax}$

To gather data concerning the modification of D_{90} and D_{95} while changing the pressure on the samples, these ones can be subdued to tarred weights to obtain different pressures (0.20 to 20 daN/cm^2).

3.3 *Establishing the degree of filling with particles of soil (restraint of solid debit), in time, for geotextiles*

The degree of filling, in time, of the tubes covered in geotextiles, used for agricultural draining and other construction works, is determined on a stand where the drain is laid horizontally (Fig. 5) /12/.

The daily drained debit is measured, beginning with the first day (q_i) and continuing for a period (from one week to one month) until the filling can be considered brought to an end (q_c). If the geo-textile's flling coefficient is η_g, than its value can be established using the relation:

$$\eta_g = q_i / q_c$$

According to Darcy's relation, the same report also results for the permeability coefficients of the geotextiles:

$$\eta_g = q_i / q_c = K_{fi}/K_{fc}$$

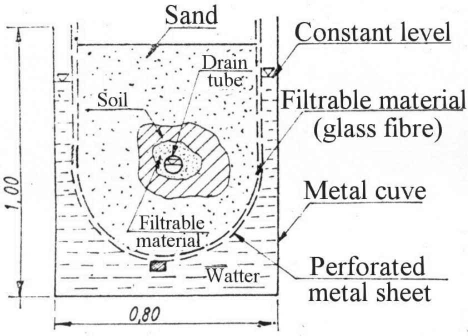

Fig. 5. Stand for determining the level of contamination of geotextile filters

Using the above formula we can calculate the permeability coefficient of a geotextile after filling K_{fc}, knowing the value of the initial permeability coefficient, established with a normal consoli-dometer.

To characterize the influence of the geotextile on draining we use the notion of hydraulic effi-ciency coefficient:

$x = K_{fc} / K_{soil}$

$x>>1$ – very favorable effect

$x>1$ – favorable effect

$x=1$ – no effect

$x<1$ – unfavorable effect.

3.4 *Testing the geotextiles and geomembranes with a pressure perpendicular on their plane (breaking test)*

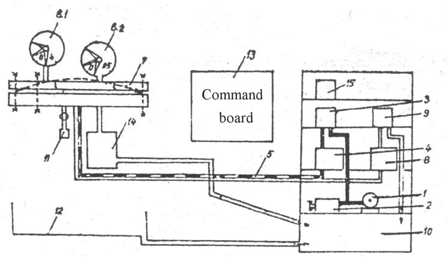

Fig.6. Draft of the stand for trying the geotextiles' and geomembranes' strength to pressure

It was also called the test of the channel. The Romanian device was inspired from a similar one accomplished by Rauman, an American researcher.

The method's principle consists in determining the pressure and the arrow where the breaking of the geotextiles and geomembranes takes place. They are subdued to a hydraulic pressure perpen-dicular on the plane of the sample that usually acts upwards.

The test is carried out in the lab using a device that can try the sample according to one of the following working conditions:

-Growing pressure, up to two atmospheres, adjustable and controllable in time, up to breaking.

-Constant pressure for a long time (fluaj).

-Variable, quasi-sinusoidal pressure, with adjustable and controllable amplitude and frequency (exhaustion).

The scheme of the installation is shown in Figure 6 /12/.

4 IMPORTANT WORKS CARRIED OUT WITH GEOSYNTHETICS

Since 1973, when the first amounts of Romanian geotextiles and foils were first delivered from the plastic factories, besides the works named above geosynthetics have been produced and used in a quantity of 50 million square meters (geotextiles, geomembranes, draining prefabricates and geogrids, alltogether). They have been used to carry out important works such as the Bucharest-Constanta auto-road, between Fetesti and Cernavoda and between Bucharest and Drajna, the rehabilitation of the National Road no.7 Bucharest-Pitesti-Rm. Valcea-Deva-Arad, the rehabilitation of the Bucharest-Pitesti auto-road and of the main highway of Bucharest. They have also been used to reinforce and repair many roads, as drains and separation layers for roads, to carry out the reinforcing of road pavements, as a filter for the connection channel at the port of Calarasi iron and steel combined works, for many works of land melioration in the 80’s and also for environment protection at the Krivoirog combined works of ferrous ore processing in Ukraine and others.

REFERENCES

Andrei, S., Strungă, V., Antonescu, I. *On Hydric Properties of Geotextiles.* Second International Conference on Geotextiles. p. 121...126. Las Vegas, 1982.

Diaconu, I. *Procedeu şi instalaţie de fabricare u unui prefabricat drenant*. Brevet nr. 144.659/1990.

Ionescu, A., Andrei, S., Strungă, V., Boştenaru, M. *Romanian recomandations conserning the use of geotextiles in civil engineering.* Third International Conference on Geotextiles. p. 863...868. Vienna, 1986.

Pătru, M., Strungă, V. *Geotextil pentru ranforsarea îmbrăcăminţilor rutiere şi procedeu de obţinere a acestuia*. Brevet nr. 113879 B1/1997.

Strungă, V.,Teleba, P. *Textil filtrant format din fibre sintetice consolidat prin coasere*. Brevet nr. 71.270/1974.

Strungă, V.,Teleba, P. *Produs stratificat din fibre sintetice destinat consolidării şi înierbării terenurilor*. Brevet nr. 71.271/1974.

Strungă, V. *Structură constructivă de protejare a taluzurilor expuse eroziunii*. Brevet nr. 75.884/1977.

Strungă, V. *Méthode de protection des talus de la route exposés à l 'éosion et à la solifluction*. Revue Générale des Routes et des Aérodromes, nr.551, p. 65...69, 1979.

Strungă, V. *Ecran drenant pentru drumuri şi autostăzi*. Brevet nr. 108.258 B I, 1994.

Strungă, V. *Drumul şi geosinteticele*. Ed. Inedit, 289 p. Bucureşti, 2000.

Vintilă, B., Fodor, G., Giuşcă, G. *Soluţii de prevenire a transmiterii fisurilor în îmbrăcăminşile rutiere*. Al X - lea Congres naţional de drumuri şi poduri. P. 273...280, Bucureşti, 1998.

Norme tehnice privind utilizarea geotextilelor şi geomembranelor la lucrările de construcşii. Ind. C 227 88. Buletinul Construcţiilor ,vol. 3, 1988.