Durability of nonwoven geotextiles for the mechanical protection of PVC geomembranes in dams and reservoirs.

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ABSTRACT: Nonwoven geotextiles have proven to be an essential element in the installation of waterproofing systems in dams and reservoirs, especially in the case of use with PVC geomembranes. The paper first illustrates the properties to be taken into account for a correct design and an appropriate technical specification. The protection function is the main item to consider in this application, so a proper dimensioning of the mechanical performances is necessary, with a special focus on energy absorption and puncture resistance. The mechanical performance of such geotextiles has to be evaluated both in the medium term, in order to guarantee the installation to the installation stage, and also in the long term, in order to guarantee the behaviour of the system over the years. Depending on the site's chemical and environmental conditions affecting the service life of the geotextiles, such as pH values, orientation and inclination of the slope and latitude, the different polymers and grade of polymers of the geotextiles can offer customized and appropriate performances. Also the interaction with the geomembrane layer must be considered to make the choice of the appropriate geotextile. This applies to the case of geotextiles that are heat-coupled to the geomembrane in the factory, as well as in the case of geotextiles installed separately from the geomembrane. The European Harmonized Standard EN 13254:2014 Geotextile and geotextile-related products – Characteristics required for the use in the construction of reservoirs and dams - among other properties also addresses the durability of geosynthetics. The paper will correlate the standard with field experience on specific projects. The variables to be considered to ascertain the durability of geotextiles will be examined in the paper, which will report the results of durability test in the field, carried out during more than ten years. A method is suggested for determining the influence of resistance problems on the installation procedures, and also for maximizing the safety of the overall project.

Keywords: geomembranes, geotextiles, waterproofing, protection

1 INTRODUCTION

The use of PVC geomembranes for the waterproofing of both old and new dams, as well as in the construction of canals and reservoirs, has been developed more and more in the last decades due to the many advantages compared to alternative solutions.
Flexibility and reliability of these materials associated with time-saving and rigorous installation protocols have determined their success on the market.

An important role for the good behaviour of the waterproofing geomembrane system is played by the geotextiles layers, both when the geomembrane is exposed and when it is covered.
The functions performed by the geotextiles are essential for the protection of the waterproof layer and for cavity bridging; sometimes also a drainage function is requested.
More and more often the geotextile is required to contribute to the dimensional stability and to improve the mechanical performances of the waterproofing geomembrane itself.
All this is possible when the protection geotextile and the geomembrane are heat-bonded together already in the factory and reach the work site as a composite lining material, able to improve both the quality of the work and the economic impact of the installation.

2 INTERACTION GEOTEXTILE-GEOMEMBRANE

About the interaction of geotextiles with PVC geomembranes there are some variables to be taken into account.
PVC and polyolefins are not electrically friendly one to each other, and the proper adhesion of the two layers is given by a balance between the pressure, the speed, and the temperature of the heat-bonding process, to be fine-tuned with the properties of the surface of the geotextile given by the structure of the geotextile, such as diameter and length of the fibres, finishing of the surface, density of the needle-punching, and by the behaviour of the polypropylene fibres to heat, as the different grades and the different tenacity of the fibres could determine an “orange peel” effect when the geomembrane cools down.
The adhesion itself between the PVC and the geotextile has to be strong enough to enable a safe installation, and must withstand the shear strength due to the inclination of the slope, which in dams’ applications can be nearly vertical. On the other hand, it should not be too strong, because very often it is necessary to peel the two layers in order to weld the edges of the geomembrane sheets.
In that case it is necessary to prevent any fibres to be trapped into the PVC layer because this could create welding problems due to the different specific weights of PVC (1.37) and PP (0.91).

3 FUNCTIONS AND PROPERTIES

The critical properties traditionally related to the protection function are mainly protection efficiency, tensile strength, puncture resistance and energy absorption, to be measured through international standards such as EN 14574 (Geosynthetics. Determination of the pyramid puncture resistance of supported geosynthetics), EN ISO 10319 (Geosynthetics -- Wide-width tensile test), EN ISO 10318 (Geosynthetics -- Part 1: Terms and definitions), EN ISO 10307 (Geosynthetics -- Static puncture test (CBR test), EN ISO 13374 (Geosynthetics -- Dynamic perforation test (cone drop test).
Too often in the past the focus of the designers has been limited to the specification of the level of performance to be guaranteed at the time of the installation. The reason of this attitude is the focus on what still remains the most critical time in the life of a geosynthetic product, which is the installation process, when the possibility of mechanical stresses is very high, because of transport, storage, handling of the products, people walking and even vehicles riding on them.
Of course this is still essential and necessary, but the guarantee to survive to the installation stage it is not enough for applications destined to minimum service lives to be measured in decades.
To this purpose the service life aspects are getting more and more important and in this direction is moving also the technical activity of CEN TC /189 and ISO TC/221, the technical

committees for the elaboration of the technical standards on geosynthetics. In the case of CEN TC/189 the output of the activity also represents a compulsory normative according to EU regulation on construction materials CPR 305/2011, because of the mandate received by the European Commission.
All the mechanical and chemical properties just recalled are even more delicate and to be carefully evaluated in the case of geocomposites where the geotextile is heat-bonded to the PVC geomembrane not on the work site, but already in the factory.
This solution enables to dramatically improve the quality of the system, determining a much better dimensional stability and mechanical performance, but it is also necessary to take into account some more implications due to the interaction between the PVC and the geotextile layer.
So e.g. it is not the same to choose a polypropylene or a polyester geotextile, or any title and grade of fibres.
This kind of choice will take into account both the environment where the products are destined to be installed, and the compatibility with the PVC in relation with the adhesion needs, the required peeling behaviour, the welding capability of the joints, not only during the installation but all along the designed service life of the project.

4 BOUNDARY CONDITIONS FOR INSTALLATION

About the environment where the geocomposite has to work it is necessary to evaluate the chemical situation where the geocomposite will be installed, first of all the grade of alkalinity. As the polyester polymer is obtained by a condensation process with the release of a molecule of water, an alkali environment with a sufficient temperature determines a hydrolysis of its molecules, typical is the case of fresh concrete castings.

European Harmonized standards such as EN 13254 (Geotextiles and geotextile-related products. Characteristics required for use in the construction of reservoirs and dams) identify durability as an essential property to be declared by the manufacturers in the Declaration of Performance, and they refer to standards like EN ISO 12224 (Geotextiles and geotextile-related products. Determination of the resistance to weathering), EN 14030 (Geotextiles and geotextile-related products. Screening test method for determining the resistance to acid and alkaline liquid), EN 13438 Geotextiles and geotextile-related products. Screening test method for determining the resistance to oxidation).
These laboratory tests on durability performances of geosynthetics answer only partially to the needs we are discussing, especially the weathering test where the need to simulate the ageing processes in an accelerated way only gives an index tests roughly enabling to compare different products. E.g. the irradiation imparted by the lamps of the EN ISO 12224 standard corresponds to 50 MJ/m^2, i.e. few days of irradiation on average European rates.

5 UV EXPOSURE EXPERIMENTAL ACTIVITY AND VALIDATION ON SITE

The UV exposure of the products is also a major item to be carefully evaluated. On the internet are available accurate tables with the irradiation rates for any latitude, enabling to forecast the irradiation in kLangleys on the geosynthetics depending on inclination and azimuth.
An estimation of irradiation should be done in relation both to the definitive configuration of the project and to the time table of the project, where unexpected delays can also occur.
Since the year 2001 at Manifattura Fontana a program for the exposure to the weather samples of different types of geotextiles is carried on. The irradiation is measured with a pyranometer DELTA OHM LP Pyra 02, with the recording of the full spectrum and the UV band as well as the temperature variations.

At fixed intervals the residual strength is tested and reported in diagrams like the one reported in Figure 1.

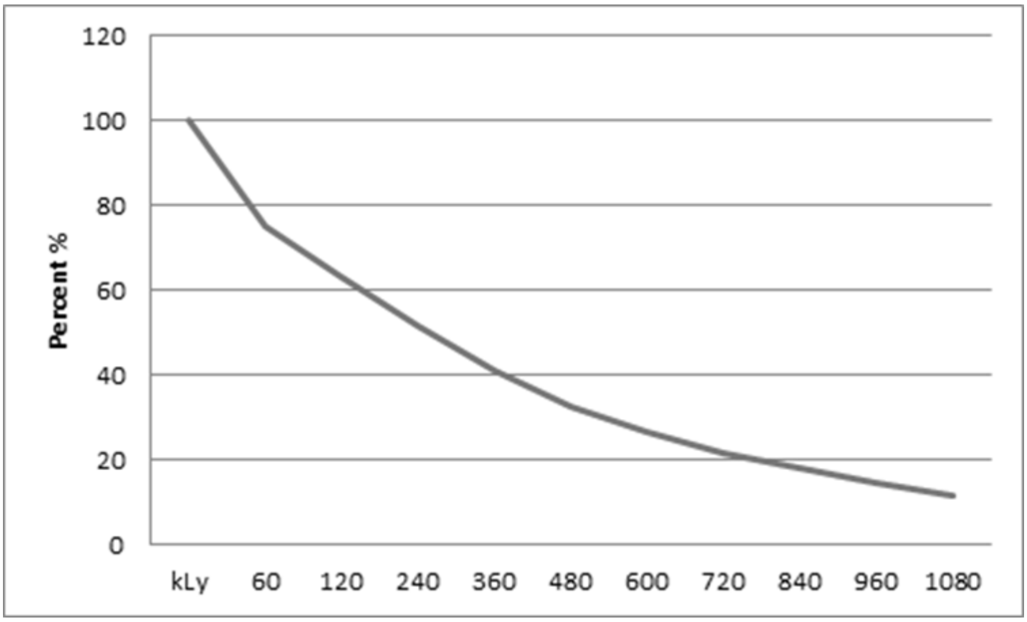

Figure 1: Residual tensile strength of Drefon® S500 geotextile

In this way it has been possible to analyse the behaviour of the products under many hundreds of kLangleys and it is possible to predict the long term performance of specific products in given conditions of work.
An example of the application of the method is the project for the Bill Young reservoir, in Tampa Bay, FL, USA.
The application is a very sensitive one as the reservoir is destined to the drinking water supply of the area.
In this case the designing of the waterproof system has been extremely accurate, as it has been the choice of the products to install. The choice for the waterproofing layer fell on a SIBELON® PVC geomembrane produced by Renolit for Carpi Tech, heat-bonded on the lower side with a 200 g/m^2 polyester nonwoven geotextile Drefon® PS and on the upper side with a 500 g/m^2 polypropylene nonwoven geotextile Drefon® S, as illustrated in Figure 2.
The choice to have a geotextile protection heat-bonded on both sides has been driven by the necessity to protect the lower side from the possible puncturing by the base layer and the upper one against the possible damages against the placement of the cover layer in stones and soil-cement.
The technical capability to supply the geomembrane already heat-bonded on both sides was ensuring an installation very precise and much quicker at the same time.
The function of the upper PP geotextile was essentially the protection of the geomembrane against the gravel to be laid on top. On the paper, the UV resistance performance of the geotextile was not a major issue, as the system was destined to be covered in a short time.
A durability problem came to evidence, when, for unexpected reasons, part of the covering of the already installed geotextile had to be delayed by some months.
The irradiation conditions in that very sunny area correspond to an irradiation of about 160 kLangleys per year on a flat surface.
The protection function was at risk. The possibility of installing a further temporary wearing protection geotextile was considered, with a related cost increase for providing, installing and eventually removing it.
The results of the quality control tests on the protection geotextiles were showing a puncture resistance CBR performance about 30% higher than the MARV figures specified (Figure 3)

and considered sufficient to withstand the mechanical solicitation of the stones of the aggregate of the cover layer.
This circumstance was giving a 30% safety factor and has been crossed with the long term degradation diagram of the geotextile installed.

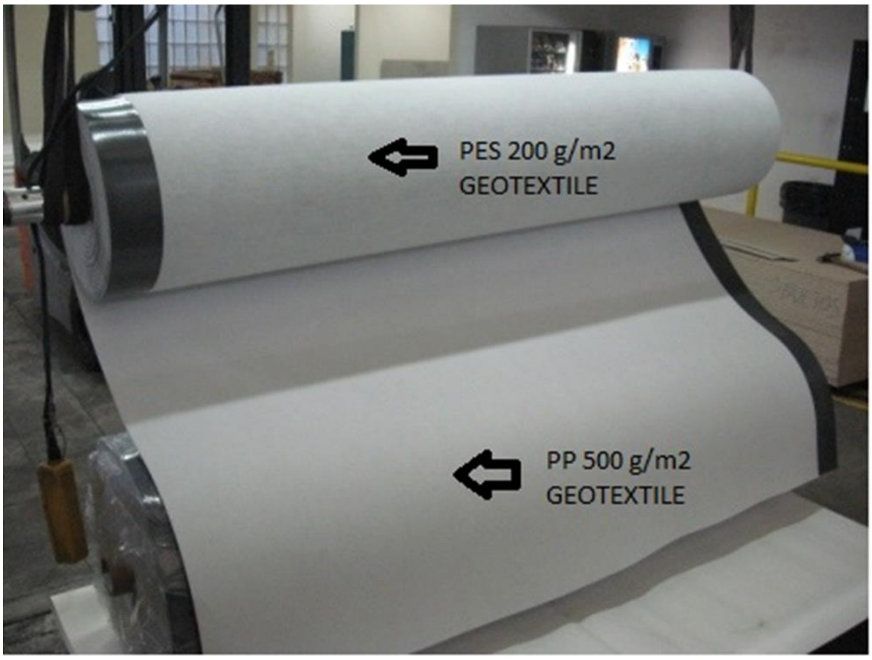

Figure 2: structure of the composite material nonwoven geotextile-PVC geomembrane-nonwoven geotextile

TABLE 1A.
MATERIAL PROPERTIES
CLIENT: CARPI
PROJECT: Bill Young Reservoir

Date Received: 3/21/2013
Date Reported: 4/11/2013
Client Sample ID: Roll #127 Lot #1300374127
Material Description: Geotextile (PP GT 500g/m²)

QC'd By: Maria Espitia
PGL Job No.: G130237
PGL Control No.: 89908

METHOD	DESCRIPTION	SPECIMENS 1	2	3	4	5	6	7	8	9	10	Avg.	Std. Dev.	Min	Max	Proj. Specs. Minimum
ASTM D5199	Thickness (mils)															
Procedure A	*Apparatus: Dead weight dial micrometer with 56.4mm (2.22in) dia presser foot and a pressure of 2kPA (0.29psi) provided by a 509gm weight. Loading time: 5sec Specimen Size: 4" x 4"*															
		150	149	152	149	148	146	146	152	155	152	150	3	146	155	130
ASTM D5261	Mass per Unit Area (g/ m²)															
	Test Specimen Size: 4" x 8"															
		526.2	524.8	521.9	535.4	535.0						528.7	6.2	521.9	535.4	500
ASTM D4595	Wide- Width Strip Tensile															
	Test was performed as directed in D4595, dry condition. Instron Tensile Testing Machine equipped with 2 in x 8 in Curtis Sure Grips was used. Full scale force range used for testing: 3000lbs															
	Tensile Strength (lbs/ ft.)															
	MD	2727	2816	2741	2967	3012	2933					2866	121	2727	3012	2120
	TD	3279	2837	3335	3257	3093	3233					3172	183	2837	3335	2230
	Elongation at Break (percent)															
	MD	100	101	104	100	91	103					100	5	91	104	68
	TD	100	101	94	92	97	89					95	5	89	101	68
ASTM D6241	Static Puncture Strength (lbs)															
	The specimens were tested in accordance with ASTM D6241. Specimens were conditioned for 1 hr in the laboratory at 21+/-5° C (75+/-3.6oF) and at 60%+/-10 Relative Humidity. Specimens were secured between the holding plates ensuring that they extended to or beyond the outer edges of the clamping plates.															
		1609	1614	1595	1733	1761	1874	1766	1597			1694	104	1595	1874	1260
	Deflection @ Maximum Force (in)															
		2.7	2.7	2.6	2.7	2.7	2.5	2.6	2.5			2.6	0.1	2.5	2.7	

Figure 3: Performance tested on the 500 g/m² polypropylene protection geotextile

Taking into account the orientation and the inclination of the slope, it has been possible to calculate the time needed in Florida to impart the irradiation rate able to reduce by 30% the initial performance of the geotextile. This time has been determined in about 70 sunny days and this was giving a reasonable safety window for the re-start of the works, after which, special measures had to be taken, such as the reduction of the height from which the stones were to be dropped.

Figure 4: the laying of the geomembrane in the Bill Young Reservoir project

Figure 5: Placement of cover stones

6 CONCLUSIONS

In constructing sealing systems for dams and reservoirs, PVC geomembranes have proven themselves as a very reliable solution. The system needs an appropriate protection, basically under the geomembrane, both during the installation and during the service life of the project.
An adequate specification of the mechanical performances of geotextiles destined to act as protection layers is necessary as stated in international standards like EN 13254 (Geotextiles and geotextile-related products. Characteristics required for use in the construction of reservoirs and dams).

Figure 6: The soil-cement finishing over the sealing system in the Bill Young Reservoir project

The mechanical performance has to be evaluated together with durability, taking into account the conditions of the site, the expected exposure to weathering agents as well as the behaviour on the field of the products involved.
A simple procedure has been described in order to evaluate the maximum period of exposure to weathering allowed in a project.
The example reported in the paper demonstrates the opportunity to provide some extra-safety factor in order to sustain also unexpected possible durability stresses on the products.

7 ACKNOWLEDGEMENTS

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