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Performance of synthetic geomembranes used in waterproofing of Spanish reservoirs

A. LEIRO, M. BLANCO & G. ZARAGOZA
Centro de Estudios y Experimentación de Obras Públicas, Ministerio de Fomento, Madrid, Spain

ABSTRACT: This work provides to show the materials used in Spain as geomembranes. Our country has a serious problems of water and a lot of hours of sun that can produce damage of geosynthetic materials. We show the materials also the performance, requirement characteristics and evolution in function of time once applied in reservoirs or dams.

1 INTRODUCTION

At Spanish level, the waterproofing of reservoirs for agricultural purposes with synthetic materials is known for several decades (Blanco & Aguiar 1993, Aguiar & Blanco 1995, Blanco & Aguiar 2000). Possibly, the Mediterranean Area was the pioneer in this type of experiences, being fundamentally the CEDEX who checked the validity of enough materials as much thermoplastics as reasonable elastomers. The materials used by that time were thin density polyethylene (LDPE) and butyl rubber (IIR). The first of them is used buried in the reservoir and with low thickness; at the moment this aliphatic polyolefin is being substituted by its homologous the high density polyethylene (HDPE) already used as sheet conventional. The second one, the elastomer butyl rubber (isoprene-isobutene rubber) with the time has gone leaving step to other synthetic sheets that in certain properties, as the resistance to the ozone, they improved the benefits. Anyway, both materials used completed their functions and many of them have arrived to our days in a state of acceptable conservation.

Chronologically, the successor of the butyl rubber can be considered to the plasticized poly(vinyl chloride) (PVC-P) that had certain validity in the field of the roof waterproofing. Timidly, introducing first reinforced with a fabric and, later, as homogeneous material. Soon in the area of the South-east of Spain the plasticized poly(vinyl chloride) substitutes a great part to the previous materials in the waterproofing of hydraulic works for watering (Blanco et al. 1998).

This work provides to show the materials used in a country with serious problems of water and a lot of hours of sun that can produce damage of geomembranes. We show, also the performance, requeriment characteristics and evolution in function of time once applied in reservoirs or dams.

2 MATERIALS

The polymeric materials that form, for the most part the sheets that will constitute the synthetic geomembranas considered in this work are:

- Plasticized poly (vinyl chloride), homogeneous (PVC-P/h)
- Plasticized poly (vinyl chloride), with insert of glass fiber (PVC-P/fv)
- Plasticized poly (vinyl chloride), reinforced with synthetic filaments (PVC-P/hs)
- High density polyethylene (HDPE)
- Medium density polyethylene (MDPE)
- Low density polyethylene (LDPE)
- Very low density polyethylene (VLDPE)
- Ethylene-vinyl acetate copolymer (EVA/C)
- Chlorosulphonated polyethylene (CSM)
- Polypropylene (PP)
- Ethylene-propylene-diene terpolymer rubber (EPDM)
- .Butyl rubber (IIR)
- Polypropyilene/ethylene-propylene copolymer (PP/EPM)

3 TESTS

The study of the materials employees has begun determining the characteristics of the original sheets according to the spanish standards (UNE 104 300 & UNE 104 303) and even for a bigger knowledge of the material they have been studied another series of properties that they are not contemplated in actual normative, but that we were considered necessary for the evaluation of the installed material, such as the optic and electronic microscopy and content in plasticizer.

More complicated the task was presented of settling that you prove they should be carried out to know the state of the geomembrane, always abiding at the beginning of to consume the minimum quantity of material and to obtain representative data of the state of the art in that moment. With few shortcomings and with many successes they noticed a series of tests that most with the obtained experience figures today in the spanish standards (UNE 104 421 & UNE 104 423) of setting in work and control of reservoirs. The extraction of rehearsal samples and their later reinstatement can be avoided, at least, the first years endowing the structure of a field of samples located in different areas of the reservoir according to the span of this; in the event of placing alone an only a field of samples would suit to locate it in the north bank.

The rehearsals that were carried out as periodic pursuit and depending on the material type bases they are the following ones :

- Thickness
- Content in plasticizer
- Tensile properties
- Impact resistance

- Low temperature folding
- Static perforation
- Joint strength:
- Shear test
- Peeling test
- Optic microscopy
- Electron microscopy "Scanner"

3.1 *Content of plasticizer*

Until some years ago it was quite common to know the migration of plasticizers of the initial material. In our investigations it has been demonstrated that the value of the migration of the plasticizer calculated initially didn't indicate anything with relationship to the migration that will have position once in service, for it was eliminated it this characteristic of the current norm. The plasticizer loss will depend climatologically on the location speaking, of the support with the one that is in contact and with the water that stores; this loss can take place for extraction and for migration, being generally much more important is last as it can be proven in the data coming from the reservoir from San Antonio to the four years of its installation (table I). nevertheless in some reservoirs whose stability of the preservative is high, it prevails the extraction lightly . The orientation is decisive for the useful life of the plasticizer, being more important its decrease in the samples coming from the north bank. In the table II the values are presented obtained for the content of plasticizer in the material of the reservoir of Sa Rota to the nine years of their placement.

PLASTICIZER %	Area of the reservoir		
	Coronation	Intermediate	Next to the water
Content	21,6	23,6	25,1
Loss	29,9	22,6	17,7

Table I Content and loss of plasticizers in the PVC-P of San Antonio's reservoir, to the four years of having installed the geomembrane.

PLASTICIZER %	Orientation of the bank			
	North	South	East	West
Content	16,8	20,5	18,2	18,9
Loss	41,1	28,1	36,1	33,7

Table II Variation of the content of plasticizers in the PVC-P of the geomembrane of the reservoir of Sa Broken to the nine years of their placement, in function of the orientation.

3.2 *Impact resistance and static perforation*

As for the dynamic impact, to exception of LDPE, all the samples of subjected thermoplastics to study overcome, originally, the test of mechanical resistance to the percussion, since when throwing the standardised striker from a height 500 mm perforation it is not appreciated in the contact area. In the case of the rubbers the height of fall of the striker is 350 mm and it was overcome, initially, for all the elastomers except for the coming from the reservoir of Los Pozos. Nevertheless the rubbers don't usually complete initially the rehearsal, but after some months they overcome the test; the fact is attributed to processes of vulcanisation of the material of nature thermosetting contrary to the thermoplastics. LDPE like consequence of their low thickness, are logical that it doesn't overcome the rehearsal, but it is necessary to keep in mind that it will always place recovered.

The test is interesting keeping in mind the problems that can be presented during the setting in work and the later ones, fruit unfortunately of the vandalism. For general rule, as the materials go ageing the break possibility it is bigger; in the case peculiar of the PVC-P a remarkable loss of plasticizer with the rising rigidity of the material propitiates the perforation for dynamic impact.

From the static point of view the perforation test provides interesting data to near the behaviour of the subjected material to the pressure of the water and in contact with the support. A bad compacting, a laundry of banks, a break and contraction of the protective geotextil or other causes make appear a series of stony materials that they would cause break in the geomembrane. Table III presents the values of perforation resistance and the piston travelled before the perforation for the samples of the waterproofing materials used according to experimental methodology that has put on to point for this type of materials and application. In this test the break form is different for each material. The break form could allow to identify the type of used material and the travelled piston, the state of the material in the moment of the research. The one mentioned test was carried out for both faces of the geomembrane.

Material	Reservoir	Years of installation	Perforation resistance , N/mm		Traveled, mm	
			External face	Internal face	External face	Internal face
CSM	El Saltadero	7	511	456	11	11
EPDM	El Golfo	6	260	271	31	31
EVA/C	El Saltadero	9	390	392	46	50
IIR	Matavacas	27	225	225	38	36
HDPE	Payuelos	9	500	468	11	10
LDPE	Plá Mateos	6	676	500	21	14
MDPE	Cerrillo del Libro	3	551	543	51	50
VLDPE	El Saltadero	4	480	417	13	12
PP	La Contraviesa	6	194	194	44	38
PP/EPM	El Saltadero	4	270	207	42	31
PVC-P (fv)	Valle Molina	4	676	600	25	25
PVC-P (h)	La Florida	12	862	750	24	23
PVC-P (hs)	Torre Alta	11	469	378	10	9

Table III Perforation resistance

The samples of all the materials coming from the different reservoirs underwent a flexion test to low temperatures, after remaining 5 h in a refrigerating camera to a certain temperature. Later on it is observed if cracking symptoms, breaks or other superficial imperfections appear.

The temperature of having bent depends on the own constitution of the material that forms the geomembrane and it is a test to determine the quality of the material one and not because it has to support that temperature once applied. On the other hand, it constitutes an excellent fact knowing the behaviour in the time of this property and when it takes place the failure, one can think that the material has begun its degradation process that can be quite quick in some cases.

3.3 *Tensile properties*

In table IV data of the evolution are presented from the tensile strength, expressed in MPa, in function of the time for homogeneous geomembranas or with reinforcement of insert of glass fibre. Also in the table V the corresponding elongation at break is shown, in %. The values of the mentioned elongation have a tendency to the decrease with the time of application.

Material	Time of installation, months						
	0	12	24	36	48	60	72
PVC (h)	21,1	20,0	20,6	21,3	21,8	20,1	20,4
PVC (fv)	13,8	13,5	13,8	14,1	15,0	14,1	14,7
PEAD	36,0	36,5	37,5	37,7	37,1	36,2	33,5
PEMD	24,0	-	21,3	-	22,4	-	-
PEBD	26,0	-	-	20,8	20,7	15,6	14,7
EVA/C	22,5	22,3	22,0	20,2	19,4	18,7	19,2
EPDM	12,6	12,7	12,8	12,6	12,7	12,8	13,1
PP/EPM	18,0	-	17,5	-	17,9	-	-

Table IV Evolution of the tensile strength (MPa) in function of the time in geomembranes of different nature.

Material	Time of installation, months						
	0	12	24	36	48	60	72
PVC (h)	366	345	329	316	316	282	279
PVC (fv)	250	221	227	218	214	206	209
PEAD	932	862	805	816	808	817	755
PEMD	732	-	674	-	694	-	-
PEBD	564	-	-	528	386	411	443
EVA/C	888	768	771	774	733	722	737
EPDM	527	436	423	424	350	336	314
PP/EPM	800	-	739	-	739	-	-

Table V Evolution of the elongation at break (%) in function of the time in geomembranes of different nature.

3.4 *Joint strength:*

Shear test carried out in the synthetic materials has led to correct results, breaking the samples in the joint area but outside of the union among sheets. Also, in the case of the high density polyethylene appreciable differences have not been noticed among the joints made via thermal and with contribution material.

Although this test is adapted to know the state of the union among sheets, you could consider of qualitative aspect, since it doesn't allow to compare among different taking of samples, neither among materials of different nature. Everything it taken to carry out the peeling test that, contrary to the previous one, you could qualify of quantitative and it allows the evaluation and comparison among the unions of the different synthetic geomembranes. In table VI it shown obtained values for some geosynthetics of different nature.

Material of the geomembrana N/50 mm	Peeling resistance
CSM	248
EPDM	60
HDPE	1300
PP	440
PVC-P	400

Table VI. Results of peeling test

3.5 *Optic and electron microscopy*

In the evaluation of the geomembranas used as waterproof screens in the reservoirs use of a microscope Zeiss it has been made, using natural light and a special filter was introduced to attenuate the effects of the shine characteristic of the synthetic geomembranes. The microphotographs have taken to increases of (x40) and (x60) with object of seeing their textures and morphology.

The electron microscopy (SEM) or " scanner " has been carried out by means of an electron microscope, Zeiss, model DSM-492, equipped with a spectrometer of dispersion of energy of rays X, Link Isis Tetralink."

For this study it has been proceeded to the drying of the samples during a period of forty eight hours. Starting from the same one, they adhere to a metallic portamuestras with a colloidal solution of graphite in isopropanol to 20% until a continuous semiconductor layer was generated among the sample, the graphite and the portamuestras. Once concluded this process, the material is recovered with a layer of gold-palladium, for the system of Sputtering, consistent in making empty to the sample and to subject it to an atmosphere of these two elements; next the thickness of the same one is controlled so that it is homogeneous until a maximum of 30 micrometers.

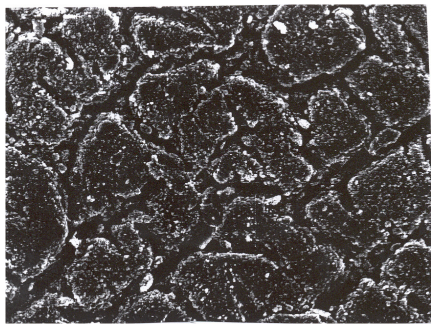

Figure 1 presents the aspect of the sheet of polypropylene installed in the reservoir of La Contraviesa after six years of their placement. The " scanner " technique showed the existence of a remarkable alteration of the material to their natural ageing.

4 COMMENTS

Undoubtedly the correct formulation of a membrane, using the appropriate resin and the preservatives of enough quality are the primordial factor for a success of the waterproofing. The ageing of the resin like all organic material is an unavoidable fact, but if it should be slowed as much as possible thanks to the employment of the diverse preservatives. A geomembrane that completes the normative one effective or the demanded technical sheets will should, also, of being installed meetly on a very prepared support and making stress in all the related with joints and anchorages should have very in bill if the material is thermoplastic or thermosetting. The geographical situation of the reservoir can have a certain transcendence when the success of the waterproofing; temperature, rain, hail, wind, ice can have negative consequences, as well as the flora and the fauna of the region. It cannot forget another type of phenomenons some natural ones as detachments or provoked as fire and the more and more accented vandalism.

In the figure 2 the perforation is presented to vegetation in the bank of a reservoir waterproofed with PVC-P (Aguiar et al. 2001).

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UNE 104 308. Materiales sintéticos. Láminas de elastómeros, sin refuerzo ni armadura, para la impermeabilización. Carácterísticas y métodos de ensayo.

UNE 104 421. Materiales sintéticos. Puesta en obra. Sistemas de impermeabilización para riego o reserva de agua con geomembranas impermeabilizantes formadas por láminas de polietileno de alta densidad (PEAD) o láminas de polietileno de alta densidad coextruído con otros grados de polietileno

UNE 104 423. Materiales sintéticos. Puesta en obra. Sistemas de impermeabilización para riego o reserva de agua con geomembranas impermeabilizantes formadas por láminas de poli(cloruro de vinilo) plastificado (PVC-P) no resistentes al betún.