Teranap 331 TP/ 431 TP/531 TP/ 631 TP/GTX 300

Waterproofing of environmental protection works

BMI Siplast | GEOFABRICS

WORKING IN PARTNERSHIP

Reinforced elastomeric bitumen geomembranes

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Design & Installation Manual

icopal

WORKING IN PARTNERSHIP

Contents

1. Basic principles

The Teranap TP range (Teranap 331 TP, Teranap 431 TP, Teranap 531 TP, Teranap 631 TP) is a range of homogenous reinforced elastomeric bitumen geomembranes.

Teranap GTX 300 is a composite geomembrane made up by the surface heat bonding of Teranap 331 TP to a non-woven 100% polypropylene geotextile, density 300g/m².

This geotextile increases the coefficient of friction in interaction with the substrate or protection structure, so giving better stability to the geosynthetic waterproofing. It also contributes to protection against piercing by the underlying substrate or protection structure.

The Teranap TP and Teranap GTX 300 range are intended for waterproofing in the following areas:

- Environmental protection installations;
- Hydraulic engineering;
- Waste water storage;
- Landfill sites;
- Waterproofing of "cut-and-cover" tunnels, precast ducts.

NB 1: A geomembrane cannot be considered independently of the elements and materials with which it comes into contact. The geomembrane is one part of a geosynthetic waterproofing system or geosynthetic waterproofing and drainage system, as the case may be.

NB 2: The geomembrane itself and more generally the geosynthetic waterproofing or geosynthetic waterproofing and drainage systems of which it forms part, are not designed to provide stabilizing functions on natural or artificial slopes, that is, on the earthworks, cuttings or backfills over which the geomembrane is laid or is connected to existing waterproofing.

A preliminary soil mechanics study should be performed to ensure the stability of embankments (recommendation of booklet No.10 CFG).

Geosynthetic waterproofing systems are made up of the following three structures, as described by standard NF P 84-500 covering geomembrane terminology (June 98):

- **Support structure:** all elements placed between the excavated or load-bearing surface and the waterproofing structure;
- **Waterproofing structure:** made up of one or more geomembranes separated by drainage systems;
- **Protection structure:** all elements placed when necessary above and covering the waterproofing structure.

The geosynthetic waterproofing and drainage structure is made up of the same structures as the geosynthetic waterproofing structure, the difference being that the support and/or protection structures may incorporate an additional drainage system.

Comment 1: In the special case of the coverage of landfill sites, the support structure is made up of the elements lying between the waste materials and the underlying geomembrane. Similarly, for geosynthetic waterproofing or geosynthetic waterproofing and drainage systems, any elements placed above the geomembrane make up the protection structure.

The current specifications for installation are additional to the professional recommendations in force, namely:

"General recommendations for geomembrane waterproofing", booklet number No.10, 1991 of the Comité Français des Géosynthétiques (C.F.G., French Committee for Geosynthetics).

- "Recommendations for the use of geosynthetic membranes in landfill sites," booklet No.11, 1995 of Comité Français des Géosynthétiques (C.F.G., French Committee for Geosynthetics).
- "SETRA technical guide, November 2000: Geomembrane waterproofing for road runoff water drainage facilities".
- AFNOR standards series P 84.500.

1.1 Field of application

1.1.1 Purpose

This document applies to the construction of the following works:

Waterproofing of environmental protection installations:

- Effluent water deposits;
- Dams, embankments;
- Industrial waste water and deposits;
- Fire-fighting water tanks, sprinkler basins;
- Pollution protection of water table;
- Waste water storage (for settling, aeration, purification);
- Agriculture installations: irrigation canals, reservoirs;
- Roads and highways: concrete canals, aqueducts, reservoirs.

Waterproofing of hydraulic works:
- Canals;
- Dams;
- Fish breeding ponds;
- Storm water regulation ponds.

Waterproofing of reservoirs of contaminated products deposits
- Industrial and chemical waste deposits;
- Containment of industrially contaminated soils;
- Waste materials deposits;
- Mining.

Waterproofing of platforms and landfills sites
- Composting platforms;
- Industrial platforms;
- Road works: platforms, landfills and deposits of de-icing products.

1.1.2 Limits of use

The temperature of the fluid, viscous or particle-bearing material in direct contact with the geomembrane should not exceed 80°C.

The use of the Teranap TP and the Teranap GTX 300 range for works intended for the storage of fluid, viscous or particle-bearing chemically aggressive materials requires special case by case study. It is essential to consult the Siplast-Icopal technical department.

For works which are subject to under-pressure (for example water table), special studies are essential. They should be performed by a specialist hydrogeological consultancy.

2. Material description

2.1 General description

Teranap TP range of products is composed by the geomembranes manufactured from SBS elastomeric bitumen reinforced by a non-woven polyester geotextile. The Teranap TP range is a range of reinforced elastomeric bitumen geomembranes, reinforced by:
- A non-woven polyester geotextile, in 2m widths;
- A polyester geotextile reinforced by a glass fibre mat in 4m widths.
- The top surface of Teranap TP geomembranes is coated with silica sand and the underside covered with a polyester film, which is highly resistant to root penetration.

Teranap GTX 300 geomembrane is a 4m wide composite sandwiched by full surface heat bonding; under a top layer of Teranap 331 TP (not coated with sand) over an under layer of 100% polypropylene, puncture resistant geotextile of density 300 gr/m². Teranap GTX 300 under surface is not smooth but covered with a geotextile film which is particularly resistant to piercing and to penetration by roots.

The dimensions of these geomembranes comply to French standard NF 84 500 and European standards, in terms of their required application techniques.

All these geomembranes are manufactured by Siplast-Icopal (certified ISO 9001) at its Mondoubleau plant (41).

Geomembranes	Reinforcement	
	Width 2m	Width 4m
Teranap 331 TP	Polyester 180g/m²	Polyester 160g/m² +Glass fibre film 50g/m²
Teranap 431 TP	Polyester 250g/m²	Polyester 235g/m² + Glass fibre film 50g/m²
Teranap 531 TP	--	Polyester 275g/m² + Glass fibre film 50g/m²
Teranap 631 TP	--	Polyester 340g/m² + Glass fibre film 50g/m²
Teranap GTX 300	--	Polyester 160g/m² + Glass fibre film 50g/m²

2.2 Dimensional and mechanical characteristics

2.2.1 Finished product characteristics, as tested

The characteristics of products tested during manufacturing and when finished are as follows:

Geomembranes	Characteristics	Standards	Unit	Minimum values	Indicative nominal values
Teranap 331 TP 2m	Thickness	EN 1849-1	mm	2.9	3
	Weight per unit area	EN 1849-1	g/m²	3,570	3,760
	Strength at break (M x C)*	EN 12311-1	N/5cm	820 x 560	950 x 650
	Elongation at break (M x C)*	EN 12311-1	%	35 x 42	40 x 49
	Static puncturing force	EN 12236	kN	2.46	2.5
	Displacement on static puncturing force	EN 12236	mm	46	48
Teranap 331 TP 4m	Thickness	EN 1849-1	mm	3.3	3.6
	Weight per unit area	EN 1849-1	g/m²	3,840	4,150
	Strength at break (M x C)*	EN 12311-1	N/5cm	870 x 570	1,000 x 650
	Elongation at break (M x C)*	EN 12311-1	%	42 x 45	49 x 53
	Static puncturing force	EN 12236	kN	2.3	2.5
	Displacement by static puncturing force	EN 12236	mm	42	44
Teranap 431 TP 2m	Thickness	EN 1849-1	mm	3.8	4
	Weight per unit area	EN 1849-1	g/m²	4,740	5,000
	Strength at break (M x C)*	EN 12311-1	N/5cm	1,050 x 800	1,300 x 1,000
	Elongation at break (M x C)*	EN 12311-1	%	42 x 45	49 x 53
	Static puncturing force	EN 12236	kN	3.32	3.4
	Displacement by static puncturing force	EN 12236	mm	45	47
Teranap 431 TP 4m	Thickness	EN 1849-1	mm	3.9	4,1
	Weight per unit area	EN 1849-1	g/m²	4,490	4,850
	Strength at break (M x C)*	EN 12311-1	N/5cm	1,100 x 960	1,300 x 1,000
	Elongation at break (M x C)*	EN 12311-1	%	42 x 45	49 x 53
	Static puncturing force	EN 12236	kN	3.32	3.4
	Displacement by static puncturing force	EN 12236	mm	45	47
Teranap GTX 300	Thickness	EN 1849-1	mm	4.4	4.8
	Weight per unit area	EN 1849-1	g/m²	3,910	4,220
	Strength at break (M x C)*	EN 12311-1	N/5cm	900 x 900	1,200 x 1,200
	Elongation at break (M x C)*	EN 12311-1	%	45 x 45	60 x 60
	Static puncturing force	EN 12236	kN	4.4	4.6
	Displacement by static puncturing force	EN 12236	mm	56	60
Teranap 531 TP 4m	Thickness	EN 1849-1	mm	4.8	4.6
	Weight per unit area	EN 1849-1	g/m²	5,410	5,140
	Strength at break (M x C)*	EN 12311-1	N/5cm	1,470 x 1,340	1,250 x 1,140
	Elongation at break (M x C)*	EN 12311-1	%	68 x 74	58 x 63
	Static puncturing force	EN 12236	kN	4.61	4.52
	Displacement by static puncturing force	EN 12236	mm	62	60
Teranap 631 TP 4m	Thickness	Contact Siplast-Icopal			
	Weight per unit area				
	Strength at break (M x C)*				
	Elongation at break (M x C)*				
	Static puncturing force				
	Displacement on Static puncturing force				

* M: machine direction – * C: cross direction

2.2.2 General data

Geomembranes	Characteristics	Standards	Unit	Minimal values	Indicative nominal values
Teranap 331 TP 2m	Strength at break (M x C)*	EN 12310-1	N	200 x 220	--
Teranap 331 TP 4m				240 x 250	--
Teranap 431 TP 2m				220 x 240	--
Teranap 431 TP 4m				350 x 370	--
Teranap 531 TP 4m				Contact Siplast-Icopal	
Teranap 631 TP 4m					
Teranap 331 TP 2m	Cold temperature flexibility	EN 1109	°C	-15	-20
Teranap 331 TP 4m	Resistance to creep at high temperature	EN 1110	°C	100	100
Teranap 431 TP 2m	Water tightness	EN 14150	$m^3/m^2/j$	--	1.10^{-8}
Teranap 431 TP 4m	Gas tightness	ASTM D1434	$m^3/m^2/j$	--	$27.6.10^{-6}$
Teranap 531 TP 4m	Resistance to weathering	EN 12224	--	Compliant	--
Teranap 631 TP 4m **Teranap GTX 300**	Resistance to oxidization	EN 14575	--	Compliant	--

* M: machine direction – * C: cross direction

2.2.3 Angles of friction

Contact material	Test method		Angle of friction of Teranap TP range / material	
			Smooth face	Sanded face
Ottawa sand	Box shear apparatus (0.1m x 0.1m) normal stress 40 to 125kPa (1)		31.8°	36.6°
Silt	Same		24.3°	31.6°
Clay	Same		23.5°	29.6°
Sand	Box shear apparatus (0.3m x 0.3m) (2)		32°	--
Sand	Inclined plane (1m x 1m) Normal stress 4 to 5kPa(3)		--	39.5°
Rolled gravel 0/25	Inclined plane 1m x 1m CEMAGREF Bordeaux report		30°	39°
Crushed gravel 10/20	Teranap 431 TP from CER	Moist	--	44.2°
	Rouen (Box shear apparatus 0.3m x 0.3m)	Dry		45.9°

(1) “Teranap 331 TP geomembrane test evaluation report”, Laboratoire Frobel & associates, 1992.
(2) “Measurement of friction characteristics in contact with geomembranes”, 4th International Conference on Geosynthetics, The Hague, June 1990 (authors: H. Girard et G. Mathieu).
(3) “Stability of lining systems on slopes” Sardinia 1991 (authors: Y. Matichard, P Delmas, B. Soyez, H. Girard et M. Mathieu).

2.3 Specific characteristics

2.3.1 Resistance to chemical aggression

Resistance to standard chemical products is listed and available from Siplast-Icopal. Please consult Siplast-Icopal regarding project-specific data.

2.3.2 Resistance to root piercing

The polyester film (cf §2.1) bonded to the underside of the Teranap TP and Teranap GTX 300 geomembranes gives them considerable root piercing resistance. Lupin root piercing resistance values are met by Teranap 431 TP compliant to standard EN 14416, as tested by the University of Applied Sciences of Weihenstephan-Triesdor, 12 may 2010.

2.3.3 Resistance to mud-curling

After covering by a film of liquid clay, Teranap 331 TP and Teranap 431 TP are subject to repeated drying cycles under infrared lamps followed by full remoistening. After 15 cycles, the geomembrane material presented only slight superficial marbling without in-depth deterioration. Teranap 331 TP and Teranap 431 TP keep their full elasticity.

By extension, Teranap 531 TP and Teranap 631 TP present the same characteristics.

2.3.4 Resistance to rodents

Teranap TP and Teranap GTX 300 geomembranes are not attractive to rodents (test certificate No.7088/76 from Laboratoire Central de la Préfecture de Police de Paris).

2.4 Packaging

2.4.1 Standard packaging

Teranap TP and Teranap GTX 300 geomembranes are delivered in rolls.

Packaging			
Geomembranes	**Descriptions**	**2m**	**4m**
Teranap 331 TP Teranap 431 TP Teranap 531 TP Teranap 631 TP Teranap GTX 300	Type of mandrel	±	Metal
	Width of mandrel	2m	4.80m
	Interior diameter of mandrel	7cm	15cm
	Width of welding strip	Mini > 14cm Maxi < 17cm	Mini > 20cm Maxi < 25cm
Teranap 331 TP	Weight of roll	≈ 156kg	≈ 1,675kg
	Length of roll	20m (± 20cm)	100m (± 1m)
	Width of roll	2m (± 2cm)	4m (± 4cm)
Teranap 431 TP	Weight of roll	≈ 206kg	≈ 1,675kg
	Length of roll	20m (± 20cm)	80m (± 80cm)
	Width of roll	2m (± 2cm)	4m (± 4cm)
Teranap GTX 300	Weight of roll	--	≈ 1,150kg
	Length of roll	--	67m (± 70cm)
	Width of roll	--	4m (± 4cm)
Teranap 531 TP	Weight of roll	--	≈ 1,525kg
	Length of roll	--	65m (± 65cm)
	Width of roll	--	4m (± 4cm)
Teranap 631 TP	Weight of roll	--	Contact Siplast-Icopal
	Length of roll	--	
	Width of roll	--	

Teranap TP and Teranap GTX 300 geomembranes are packaged in polyethylene film, which is laid between each turn and around each roll.

Peel-off protection covers the welding path, on the film-protected side.

Geomembranes are delivered in 4m width rolls for Teranap 331 TP, Teranap 431 TP, Teranap 531 TP, Teranap 631 TP and Teranap GTX 300. The polyester film underside always faces the inside of the roll.

Contrariwise, rolls of 2m width Teranap 331 TP, and Teranap 431 TP geomembranes are delivered with the polyester underside film on the outside.

The brand name of each product is printed on an edging strip on the underside (polyester film side) as required by CE (EN 10320), for ease of identification on site.

Teranap 331 TP 4m and Teranap 431 TP 4m are Asqual certified, the relevant label being placed on each roll.

The label shows:
- Certified commercial name;
- Number of certificate in force applicable to relevant product.

Teranap 331 TP, Teranap 431 TP and Teranap GTX 300 geomembranes are covered by CE marking. Thus a traceability label is attached showing the following:
- Date of manufacture;
- Roll number;
- Product characteristics (thickness, width, length);
- CE marking (System 2 + certificate of conformance).

The supporting documents required by the CE marking for Teranap 331 TP, Teranap 431 TP and Teranap GTX 300 geomembranes are available on Siplast-Icopal website: www.siplast-international.com or on www.siplast.fr.

It is important, as part of a Quality Assurance Plan, to keep safe all labels and to identify rolls.

2.4.2 Rolls incorporating cuts

Teranap TP rolls may be cut in one or two places, identified as follows:
- By a paper marker at location of cut;
- Red adhesive ribbon wrap on outside of roll showing “roll containing cut”.

2.4.3 Non standard packaging

Lengths and widths of rolls other than those provided for under paragraph 2.4.1, are available by special order.

2.5 Complementary products

2.5.1 Cold-applied elastomeric bitumen primer: Siplast Primer

Siplast Primer is a fast drying (2h. in temperature ⩾ 12ºC) sealing compound, bitumen based, in elastomeric modified solution.

Packaging: bucket of 2, 10, 30 or 200 litres.

Note: Siplast Primer is never to be applied directly on a bituminous membrane Teranap TP or Teranap GTX 300.

2.5.2 Connections with: Parafor Ponts or Parafor Solo S

These materials can be used to build upstand flashings on concrete or steel. They come in widths of 1m.

Reference documents: Avis technique Parafor Ponts approved by SETRA, Avis Technique CSTB Parafor Solo.

2.5.3 Terastop anchoring section

Terastop is a range of flexible polyethylene extruded sections used for setting up compartments, or for anchoring the water-proofing materials to concrete surfaces.

2.5.4 Verecran 100 type interposed heat shield

In order to protect the geotextile during the welding of Teranap TP and Teranap GTX 300, it is recommended to interpose a glass fibre mat 100g/m² Verecran 100, used as a heat shield between the geotextile and the geomembrane.

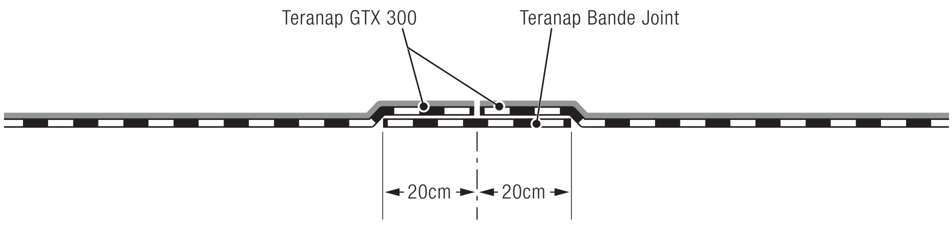
2.5.5 Joint strip: Teranap Bande Joint

Teranap Bande Joint is a strip of 4mm thick bituminous membrane covered on both sides by a thermofusible macro-perforated film.

Packaging: 40cm wide and 10m long.

For welding the abutting edges of Teranap GTX 300, use Teranap Bande Joint. Each end of two Teranap GTX 300 sheets is welded edge to edge over the strip. Coverage on each side is 20cm.

Figure 1



2.5.6 Anti-puncture geotextiles

The Geofelt range of products are non-woven geotextiles, made using long rot-resistant fibres, 100% polypropylene, available from 300g/m^2 to 1,000g/m^2 linked together by needling: Datex PR (Asqual), Acm (no Asqual).

2.5.7 Geospacers and drainage geocomposites

The Geoflow range of products is composed of drainage geospacers, consisting of three-dimensional grid of high density polyethylene (HDPE).

The Fonda range of products is composed of drainage geospacers, consisting of a sheet of polypropylene (PP) with, on one face, embossing with raised octagons, covered with either non-woven polypropylene (Fonda GTX) or with polyethylene (Fonda +) described in Avis Technique CSTB Fonda Protection.

2.5.8 Soil anchoring

The Siplast-Icopal Geogrip range of polyester soil grips may be three dimensional or other and their performance, for standard resistance to longitudinal traction forces, is in the range of 35kN/m to 80kN/m.

Higher performance products are available by special order.

When calculating the dimensions of soil grips on embankments, please consult Siplast-Icopal technical department.

3. General Recommendations

3.1 Preliminary

A geomembrane has a single function only, which is waterproofing.

Waterproofing is an independent element in an arrangement of support layer, waterproofing geomembrane and the protection layer. To minimize the stresses on the geomembrane, full account should be taken of all the recommendations outlined in more detail below, when the relevant construction operations are being prepared.

3.2 General requirements

The substrates supporting Teranap TP and Teranap GTX 300 made by civil engineering works, are cuttings, embankments and backfills. Such earthworks must be formed in full compliance to the rules of soil and materials mechanics, so as to ensure stability at all points and compliance to the particular rules in force when the substrates are in reinforced concrete (see reminder No.2, chapter 1).

4. Recommendations regarding substrates

The overall design of the support structure is a responsibility of the civil engineering contractors.

The support structure includes all the elements laid up between the excavated or load-bearing surface on the one hand, and the geomembrane on the other. The support structure is made up of:

- Preparation layer resting on the excavated or load bearing surface;
- Drainage elements when geosynthetic waterproofing and drainage systems are involved;
- The support layer supporting the geomembrane itself.

One or more of the elements making up this support structure (as schematically described above) may not be present, or may be incorporated into a single layer.

4.1 Preparation of excavated or load-bearing surface

4.1.1 Removal of vegetation

The excavated or load-bearing surface must be cleared of all vegetation and any trace of organic matter in order to avoid:

- Direct contact between stumps, snags, etc., and the geomembrane;
- Rotting of organic materials (stumps, roots, etc..), potentially causing changes in soil compressibility and the release of gas.

4.1.2 Embankments

Embankment slopes must be determined by the rules of soil mechanics. The embankments must in themselves be stable, since Teranap TP and Teranap GTX 300 have no inherent mechanical functions, and are designed simply to insure waterproofing of the works (see reminder No.2).

The following points must be taken into consideration:

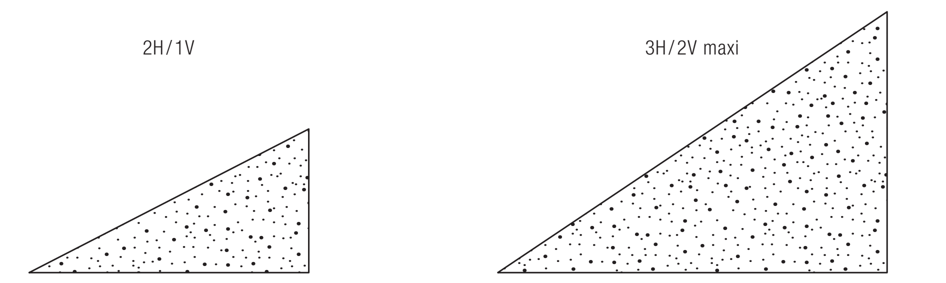
- The geometry of the works (slopes, length of inclines, …);
- Nature of materials making up the embankment and excavated or load-bearing surfaces;
- Mechanical characteristics of the various elements making up the geosynthetic waterproofing and geosynthetic waterproofing and drainage systems;
- Coefficients of friction at the interface between the various layers;
- Nature of products stored in facility;
- Manner of operation of facility (whether or not fluids are present, changes in levels, possibilities for rapid flushing …).

Although it may be possible to build the geosynthetic waterproofing or geosynthetic waterproofing and drainage systems on a number of vertical or less than vertical substrates (rocky embankments, masonry or concrete), for ease of working, a 3H/2V slope should be considered at maximum.

Reminder: less steep inclines of 2H/1V meet the following purposes:

- Facilitating the circulation of both personnel and machinery;
- Facilitating assembly work on site;
- Facilitating the laying up of protection over the waterproofing;
- Limiting the stresses exerted on the waterproofing.

Figure 2



4.1.3 Access to works

Provision should be made for a clean level storage area of sufficient load withstand the loads of truck access, mobile site machinery and stored geosynthetic rolls.

4.1.4 Fit-out at head of embankment

Provision should be made for access of temporary traffic around the facilities under construction in order to enable:

- Construction of the geomembrane anchoring trench;

- Supply of rolls to site from storage areas;
- Work on site without risk of damage to waterproofing by site machinery.

The temporary or permanent traffic path or roadway around the facility must be included into the initial design. Recommended with is a minimum width of 3m to take into account the anchoring trench and enough width for movement of site machinery.

4.1.5 Access ramps

An access ramp facilitates site machinery movement while works are in progress, and the working of the machinery used for the maintenance and cleaning of the basin.

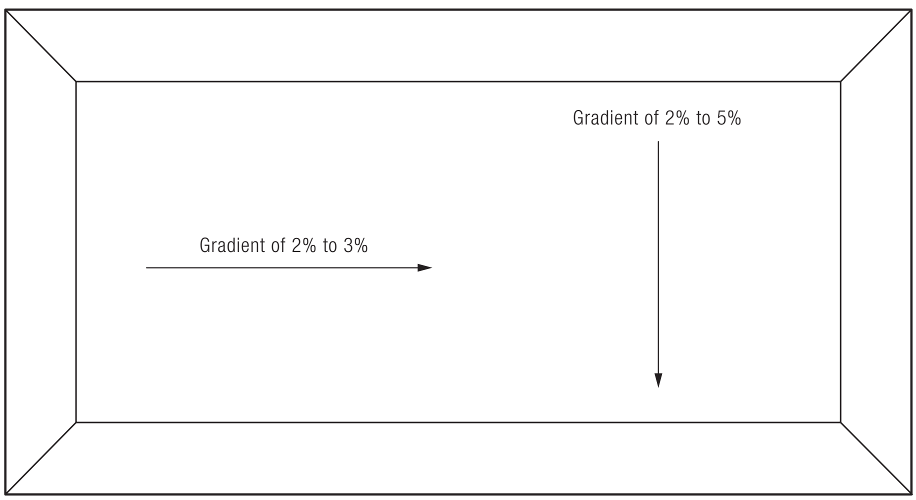
The slope should not be greater than around 15 %.

4.1.6 Drainage and maintenance

A subgrade gradient is recommended in order to:

- drain all the water at the end of rainfalls;
- avoid retention zones;
- facilitate removal of gases;
- facilitate cleaning.

Figure 3



4.1.7 Compacting

The subgrade will need to be **compacted to a minimum of 95% of the Normal Proctor Optimum**, while complying with the soil mechanics rules.

Recent filling materials (material from quarry or from fill storage area, for example) require a special compacting to limit later settling and sensitivity to erosion.

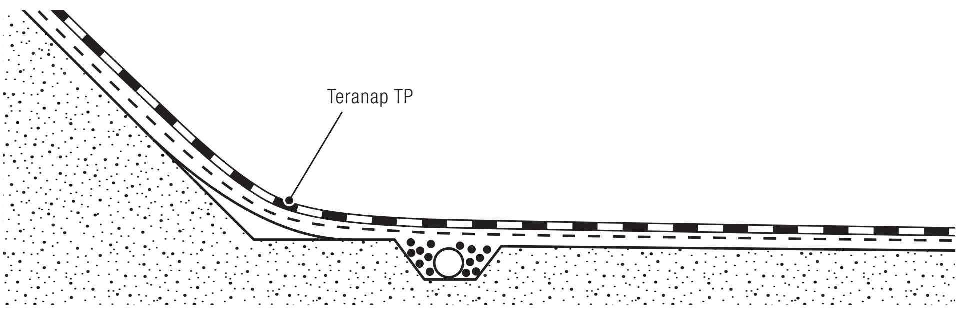
Whenever the nature of the earth in place makes it possible to use it as a support structure, without adding additional materials, during the work on the site, it is necessary to make sure that local variations in the land characteristics do not impose delimited building of a support layer.

4.1.8 Slope gradient

To avoid any possible tension of geomembranes Teranap TP and Teranap GTX 300, as well as any other welding problem on a slope, mollify it with a compacted support substrate (generally coming from the work site), and do not install any drainage in this point.

The designer should take this remark into consideration while defining the placement of the drainage.

Figure 4



4.2 Preparation layer

When the surface of the excavated or load-bearing surface is aggressive, a preparation layer will be required, using natural or other additional material, to be laid up meeting the same load-bearing standards or characteristics required from the excavated or underlying load-bearing surface itself, see section 4.1.7.

The preparation layer and its characteristics are determined by the designer and are generally made up as follows:

- **either** concrete;
- **or** bitumen coated gravel or cement;
- **or** sand or sludge;
- **or** compacted materials (maximum particle size = 10mm) or rolled materials (maximum particle size = 15mm).

4.3 Drainage beneath geomembrane

Depending on the scale of the works, on the nature of the materials making up excavated or load-bearing surface, on the results of the geotechnical studies on site, and on whether water is present beneath the geomembrane itself, there may be adverse effects on the works (under-pressure, etc…). The design should take into account the need to set up a drainage system under the geomembrane. Such a system is made up of two independent networks of conduits for the drainage of liquids, and for the release of gas if any. Gas must never be water saturated.

4.3.1 Water drainage

Should the water that might be found under the waterproofing structure be capable of adversely affecting the proper behaviour of the works, it is necessary to provide a drainage:

- either by using a coat of draining material, a minimum of 10cm thick, to be sized according to the nature of the earth;
- or by geospacer type synthetic products.

To prevent clogging the drain and entraining the soil, a filter is to be provided between the draining layer and the other layers of materials, while complying with the rules of sizing of filtering geotextiles for granular materials and the other geotextiles.

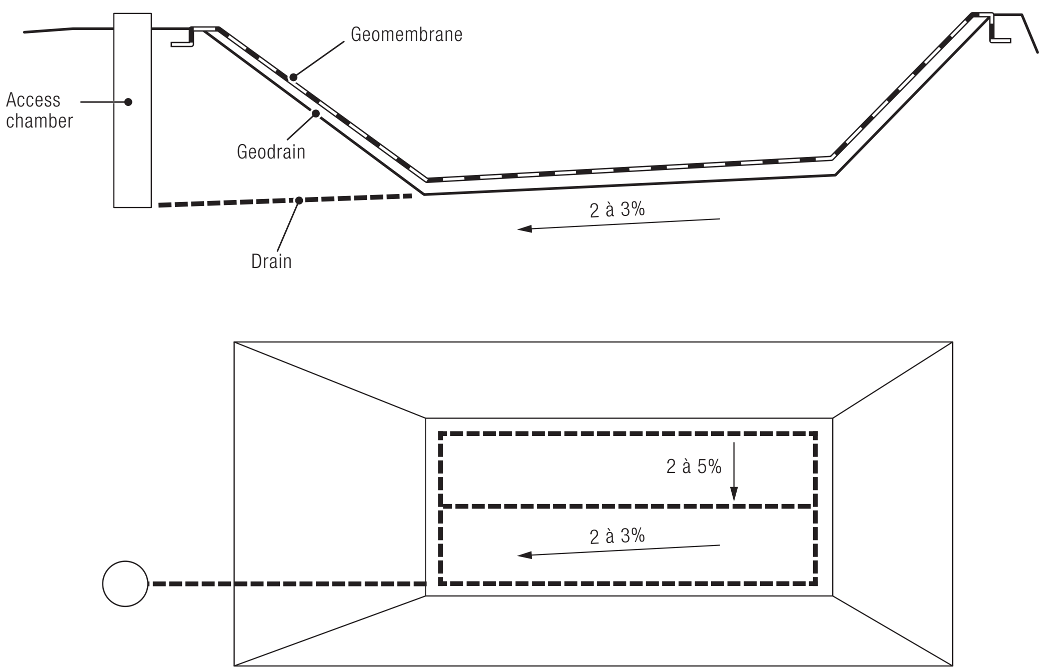
In the case of drainage by geosynthetic (as Geoflow), it is indispensable to install cut-off drains to collect and drain off the water.

In the case where the drainage system must detect and assess a leak flow, it is important to make sure that the flow collected at the outlet of the drainage networks is not increased by parasitic incoming water.

The water drainage network sizing depends upon:

- the flow of the water coming from outside the works;
- the permissible leak flow;
- the maximal permissible hypobaric pressures (underpressures) either in normal service or in the case of accidental leakage.

Figure 5



4.3.2 Drainage of the gases

The drainage of the gases does not work under flooding. Therefore a gas drainage system entails draining the water unless the substrate drains naturally. This draining is necessary to prevent hypobaric pressures.

For that purpose, the following are used:

- perforated pipes, 40 to 80mm diameter, positioned approximately every 20m (order of magnitude to be confirmed by a design as a result of special study).

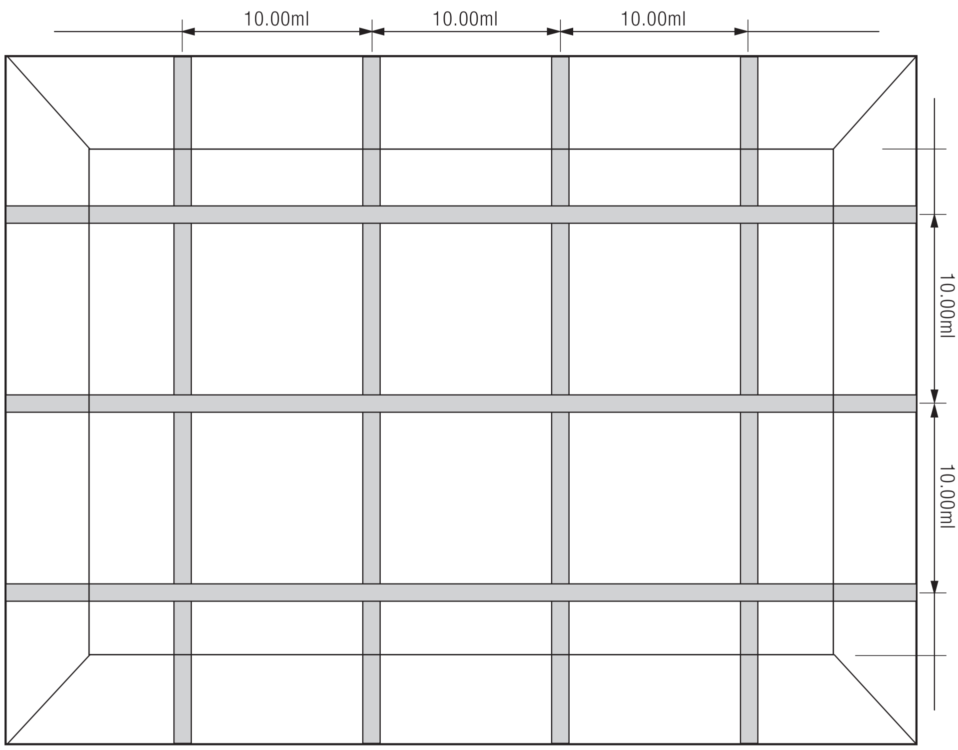
This distance is brought down to 10m if the underlying soil is relatively impermeable and in case major gas releases are predictable.

It is necessary to install a bed of draining material, a geotextile or another transmissive synthetic product between the pipes.

Geoflow type drainage geogrids, as Geoflow, have the advantage of being flexible and of fitting around the deformations of the geomembrane.

- The gas drain outlets, Siplast Aerateur DA type, are positioned at the high points and must be protected (cap and grating) to prevent any obstruction or penetration of water.

Figure 6 - Grid layout of the basin surface by strips of 1m every 10 linear meters minimum



4.3.3 Installing drainage devices

Drainage devices for water and gas shall be installed, while making sure:
- to prevent crushing the drains under rolling wheeled jobsite rigs;
- to prevent the formation of upward gradients;
- to comply with the rules for installing any geotextiles.

4.4 Preparing the substrate

4.4.1 Substrate structure

Depending on the nature and characteristics of the substrate and the backing layer, when it exists, the backing layer consists either of:
- **filler (sand, gravel, aggregate, water binding clayey sand, etc.).**
  When bringing in the filler, it is necessary to:
  - verify its particle size distribution;
  - make sure that segregation is not created at laying;
  - check the surface state and remove any aggressive element;
  - compact the natural materials, to at least 95% of the Normal Proctor Optimum.

Materials susceptible to wash-out, due to jobsite traffic and boat wake impacting, can be stabilised: treatment by various binders, less sensitive fillers, etc. The chemical characteristics (pH) of the material after stabilisation using binders, must be compatible with the geomembrane and with any geotextiles (see §2.3.1).
Jobsite wheeled rigs shall not entrain deformation or modification of the surface structure (ruts, disengagement of isolated stones, etc.) incompatible with the characteristics of the geomembrane.
- **Geotextile exhibiting the following capabilities: puncture or contaminant resistance, and/or draining and/or filtering functions.**
  The preparation layer should be overlaid with a puncture resistant Geofelt geotextile.
  Geotextile size shall be designed to take into consideration:
  - nature of preparation layer;
  - nature of geomembrane (bituminous, polypropylene, etc.);
  - depth of liquid or height of product stored.

When seeking to determine the type of Geofelt to be laid up under Teranap TP and Teranap GTX 300 geomembrane, the following table may be of assistance:

(For Teranap 531 TP and Teranap 631 TP geomembrane, please consult Siplast-Icopal)

Teranap	Depth of liquid or height of product stored	Under the geomembranes			
		331 TP		431 TP	
		Mechanical protection		Mechanical protection	
		Without	With	Without	With
Smooth concrete (HS < 1mm)	H < 3m	No	No	No	No
	H < 10m	No	300	No	No
Trowelled concrete (1.0mm < HS² < 2.0mm) Macadam	H < 3m	No	No	No	No
	H < 10m	300	300	No	300
Cement-bound graded aggregate Bituminous-bound graded aggregate	H < 3m	300	300	No	No
	H < 10m	400	400	300	300
Sand, silt, clay	H < 3m	No	No	No	No
	H < 10m	No	No	No	No
Topsoil, crusher-run material, crushed materials Dmax = 15mm, rounded materials Dmax = 50mm	H < 3m	No	No	No	No
	H < 10m	300	400	No	300
Crushed materials Dmax = 31.5mm Rounded materials Dmax = 80mm	H < 3m	300	400	No	No
	H < 10m	700	700	300	300
Crushed materials Dmax = 50mm	H < 3m	700	700	300	400
	H < 10m	Study	Study	700	700

Mechanical protection (see chapter 10: protection structure)

NB: When a geotextile is to be laid under the waterproofing structure, care must be taken to ensure removal of all of the metal pins used for temporary fixing while construction work is in progress on site

4.4.2 Concrete reservoirs (condensation)

In the case of concrete reservoirs, particularly when underground, there is a risk of condensation forming between the concrete and the geomembrane. Hence an additional low capacity draining layer is required. A 120g/m^2 geotextile may be sufficient as a separation screen.

A system for the recovery and storage of water draining to the low point must also be included, for example using a layer of gravel, draining water to beneath the point of inspection access, or using a non-return valve operating when the reservoir is flushed.

A 20cm wide cover strip must protect welded joints with overlap on both sides of the seal, whenever membranes are capped in this way.

4.4.3 Cleaning and raking

Prior to laying up the geomembrane, it is essential to clean the support surface by raking through to eliminate all foreign bodies (pebbles, stones, roots or root materials, stray tools) to remove any object liable to pierce or cause additional mechanical stress in the geomembrane.

4.4.4 Ballasting

In some extreme cases where the basin is built in proximity to or contact with the water table, ballasting at the bottom of the basin is required to avoid under-pressure causing uplift in the geosynthetic waterproofing or geosynthetic waterproofing and drainage systems.

In these cases, ballasting characteristics must be designed into the initial geotechnical study and design specifications.

4.4.5 Acceptance of substrate

Before any laying up of a geosynthetic material by the contractor, visual inspection is required of the substrate surface by the quality manager, in the company of the contractor or contractor's representative, and of the earthworks contractor responsible for the support layer. Inspection should give rise to a formal acceptance report showing the results of control tests (compacting of substrate). Such testing must be systematically adopted in all cases (see requirement of booklet No.10 CFG).

4.4.6 Test surface

Where the works are very sensitive works, or very extensive substrates are to be covered, the design may require a test surface to be laid up on site. The size and manner in which the geomembrane sample is to be applied, should be clearly defined before works takes place.

5. Application of waterproofing

5.1 Common provisions

During loading and unloading operations, make sure to avoid damaging the first turns of the rolls.

For that purpose, Teranap TP and Teranap GTX 300 geomembrane rolls are to be stored in their original packing, laid flat, parallel, on a plane unobstructed area with sufficient bearing capacity.

5.1.1 Materials handling

Materials handling is to be limited to avoid damaging the base layer by rutting. For materials coming on pallets, these are to be brought in using a lifting rig at every point of the jobsite (bottom and top of the slope) so as to correctly position the rolls and be able to unroll them manually. Constructing a cradle can facilitate the positioning of the material.

Installing geomembranes 4m wide and wider requires a lifting rig and a gantry crane.

5.1.2 Laying up the geomembrane

Bituminous geomembranes present two surfaces, one sanded, the other film covered:

- The sanded surface is designed for friction interaction;
- The film covered surface provides resistance against root penetration;

Except where special arrangements are made, the filmed surface is laid up as follows:

- Film side upwards (in which case the sanded surface is in contact with the substrate). This is required when the membrane topside is protected by soil and growing plants;
- Film side downwards in contact with substrate in all other cases.

When the works make it impossible to unroll Teranap TP and Teranap GTX 300 geomembranes out from one high point to the opposite high point, waterproofing should be laid first on the embankment, before laying up across the bottom of the excavation.

Reminder: Compliance is required at all times to the rules of the art (cf. industry recommendations in force chapter 1) in regard to the processes of laying up waterproofing (welding of strips, covering slopes, inclines..).

Figure 7

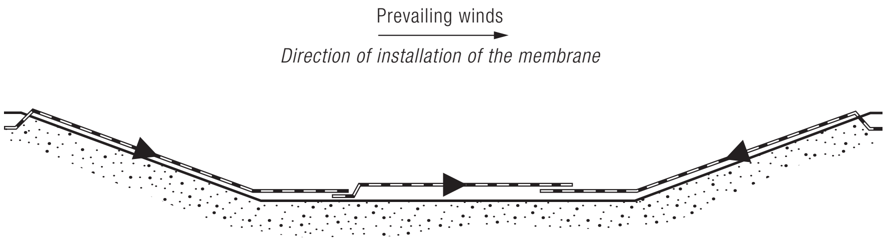
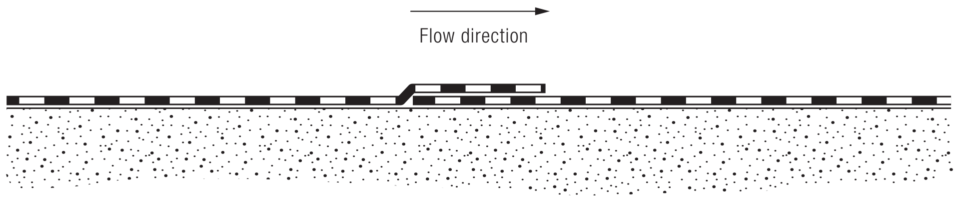


Figure 8



5.1.3 Wind precautions

To the degree possible, and if the form of the structures makes this possible, the geomembrane Teranap TP and Teranap GTX 300 are unrolled, beginning the installation by the crest of the slopes, continuing along the line of the largest grade and taking into account the direction of the prevailing winds, according to the diagram below:

5.1.4 Water flow

If the geomembrane is not protected and the water flow can affect it, the joints should be oriented according to the diagram below: figure 8.

5.1.5 Transversal joints on slopes

In principle, the use of horizontal joints on slopes is prohibited except for dealing with angles. However, in certain configurations such a connection may turn out to be necessary. In such cases, the agreement of the main contracting firm and of its technical inspection body must be obtained in advance.

Transversal joints at the bottom

Make sure to avoid two welds being lined up on two neighbouring strips (at least 1m between two longitudinal welds).

Quadruple overlap joints (points with four thicknesses of geomembrane) are prohibited.

Triple overlap joints are to be avoided; should they be inevitable, special attention is to be paid to them.

In this case, these points are to be reinforced using a weld torch and a piece of the geomembrane used in the current part.

5.2 Heat welding

5.2.1 General provisions

Welding together widths of Teranap TP and Teranap GTX 300 geomembrane is prohibited under the following climate conditions:

Rain:
- Snow;
- Strong wind (for safety reasons, left to the assessment of contractor and application personnel);
- Muddy conditions;
- Extreme temperatures (1°C ⩽ admissible temperature range for welding ⩽ 30°C).

When temperatures are at or below 0°C, all welding work requires the prior agreement from the contractor. When temperatures rise above 35°C, special precautions must be taken when moving about on the geomembrane.

The geomembrane must be clean and dry, particularly in the parts affected by welding operations. For this purpose, the protection film should be removed only immediately prior to torching.

5.2.2 Welding equipment

Strips of Teranap TP and Teranap GTX 300 are torch-bonded to achieve partial fusion of the polymer binder in the weld path.

The equipment required for the welding and smoothing of the joins between Teranap TP and Teranap GTX 300 geomembrane strips should use the elements shown below:
- Welding equipment:
  - 13kg or 30kg bottle of propane gas;
  - 3 bars pressure reduction device or adjustable

pressure reduction device (1.5 to 3.5 bars);
- Flexible tubing compliant to safety standards (length suitable for jobsite, but to no less than 10m);
- Single or double nozzle blowtorch, or flat-nozzle blowtorch;
- Guide pin.

- Equipment for smoothing:
Smoothing takes place immediately after welding before the molten weld materials cool, using a moist rag or roller.
It is also possible to use a 30kg horizontal roller, if the substrate allows or 5kg rooler on embankments.
- Additional equipment:
  - Gauging trowels No.14 or No.16;
  - Hooked blade cutters;
  - Measuring tape, cordex;
  - Gloves, etc.

Nota: Specially designed accessories are available from the blow torch manufacturers to assist work (e.g. extensions to or specialty nozzle blow torches).

A list of manufacturers is available on request from Siplast-Icopal.

5.2.3 Overlapping

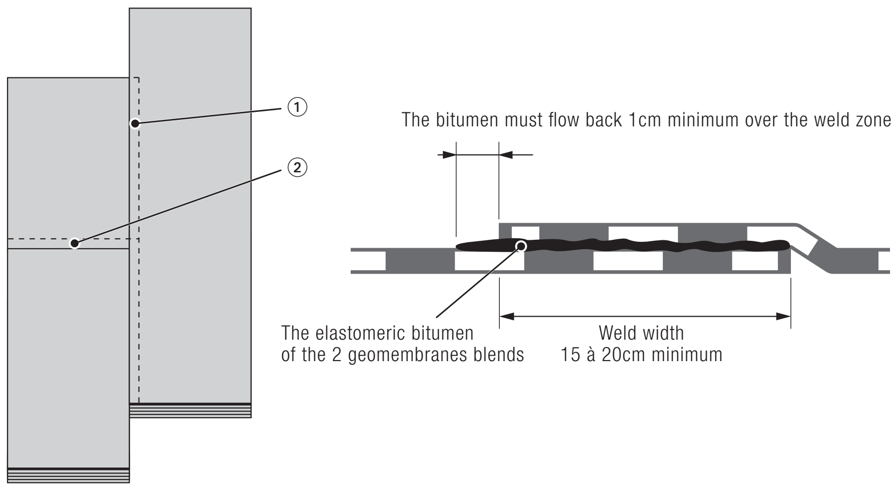
The welding is carried out as the works progress rolling the upper strip onto the neighbouring strip, permanently maintaining a bitumen bead along the overlap.

Concealed welding is utilised when a weld as the works progress is not possible. The two strips to be assembled are positioned and the weld is executed lifting the upper strip at that location and heating the two strips together before smoothing down.

Mark the width of the overlap on the lower strip.

Overlap widths		
Types of overlaps	**Teranap in 2m x 20m**	**Teranap in 4m x 80m**
① Longitudinal if welding as the works progress (unrolling)	15cm mini	--
Longitudinal if welding after positioning of the strips	20cm mini	20cm mini
② Butting edges of the strips	20cm mini	20cm mini

Figure 9



For long lines of welding on concrete, it is preferable to use membranes 1m wide which are easier to manipulate and are especially designed to have a good bond on concrete:

- In the case of a connection by simple welding without mechanical fixing, use Parafor Ponts;
- In the case of a connection by welding and mechanical fixing, preferably used Parafor Solo S, a non-surfaced product.

5.2.4 Protecting the geotextile during welding

In case a heat sensitive material is installed under the geomembrane (for example, an anti-puncture geotextile), arrangements need to be made before welding to avoid damaging this material.

A heat shield can be used, for example, a strip of Verecran 100, 50cm wide.

This band forms a temporary thermal screen and it protects the materials beneath Teranap TP.

5.2.5 Bonding

Teranap TP and Teranap GTX 300 are welded together by partial fusion of the polymer binder under the heat of a blow torch applied to the welding path.
After the self-inspection of the weld, the fusion face of the joint is chamfered by heating the upper part of the joint and crushing the fusion face with a gauging trowel.

6. Inspection of welds

The list of controls presented below is a non-exhaustive extract from a list of all the inspections that may be performed.

When a site quality insurance plan is required, the contractor selects from the inspections to be performed, listed below. This will depend on the expectations of the contractor and the requirements of the specifications.

6.1 Non destructive inspections

6.1.1 Visual inspection

During visual inspection, special attention should be given to the general appearance of the welds, taking into consideration the following criteria:

- Width of overlap;
- Absence of zones under strain;
- Treatment of triple overlap points, etc;
- Continuous presence of bitumen beading;
- Continuous trace of blowtorch heat.

6.1.2 Compressed air and point inspection

After welding at point of overlap and before chamfering, the operative must systematically subject the weld zone to the pressure from a pointed tool or gauging trowel, along the outer edge to detect whether or not there are areas of faulty welding.
If any such areas are detected, the operative should lift the overlap at this point and repair.
Check that the weld is chamfered.
This requires a compressed air at pressure no less than 500kPa along the lip of the weld prior to chamfering, to detect visually and by sound any points of poor bonding.

6.1.3 Control by vacuum

Vacuum control is used to test particular points of possible weakness, in particular zones where three way welds are performed.
A vacuum is created above the welding point giving a negative pressure of between 0.2 and 0.3 bar for a minimum period of 30 seconds. If negative pressure under the vacuum bell remains unchanged, the area tested is fully bonded and leak-tight.
To improve fault detection, a liquid containing surfactant (soapy water or detergent fluid) is applied over the area to be tested. In the presence of any fault, bubbles immediately appear when negative pressure is applied and as the pressure shown by the manometer decreases.

6.1.4 Inspection by infrared thermography

IR thermography is a technology currently under development, whereby weld performance can be tested non-destructively. The technology makes an image of differences in thermal flows generated by correctly welded and by faulty zones. Heat is applied to the welded area, for example by passing a hot resistor over the welds.
This process precisely locates areas of weak welding. However the technology is not easy to apply and requires suitable climate conditions.

6.2 Destructive testing of welds

Welds are destructively tested by subjecting them to tensile/shear stress testing. The frequency of this type of test depends on the main contracting firm's specifications.

To the degree possible, the test specimens are taken in zones that are not very sensitive.

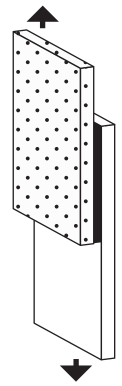
Take a weld test specimen and calculate the ratio of the joint's combined tensile-shear stress resistance according to Standard NFP 84502-1 to the tensile strength of the geomembrane in main areas according to Standard NFP 84-501.

Incipient breaks may develop in the thicker part of the welded area. However, this does not indicate a poor quality weld.

Bituminous geomembrane
combined tensile-shear stress: 16kN/m ou FS ⩾ 80%

Note 3: The values shown in the table above are taken from the Asqual bonding technique reference framework, as applied in the workshops responsible for Asqual welding certifications.

Figure 10 - Under combined tension shear stress according to NFP 84-502/1



On the jobsite, conditions of welding are necessarily different, in terms of temperature or hygrometry and the results of inspections should make allowance for this.

In the event of a welding defect, the point of failed leak-tightness should be repaired by a further torch-heated patching weld (cf §9).

If the fault cannot be located, the full welding path must be repaired.

7. Anchorings and connection of geomembranes

Anchorings and ballasting as described below should be incorporated into studies of the general stability of embankments.

7.1 Anchorings at the head

Such anchorings have a double function:

- preventing the geomembrane from slipping on slopes;
- participating in the geomembrane resistance to lifting forces brought by the negative wind load.

The geomembrane shall absolutely be fixed at the head of the slope before installing the anchoring material.

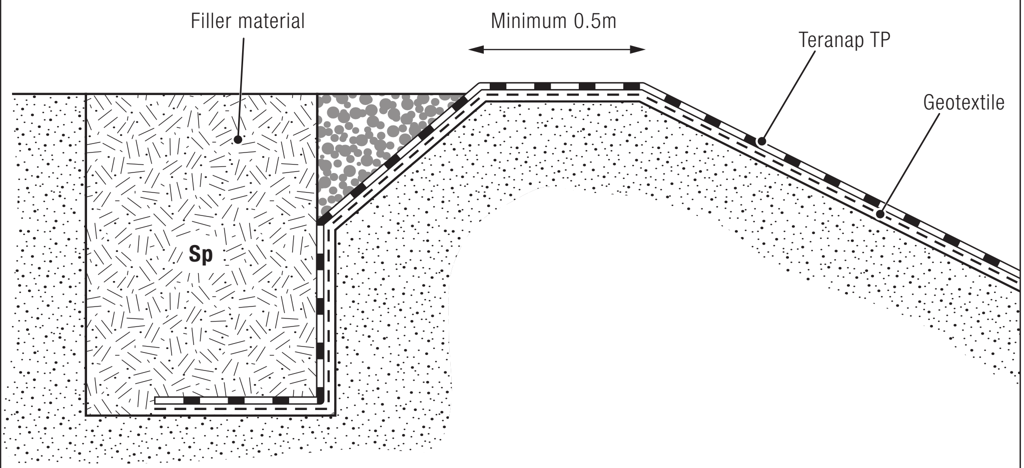
In practice, the head is anchored underground in a trench as shown on the diagram below.

Other solutions by simple ballasting are also utilised, taking the necessary precautions so that the windrow does not erode as time goes by.

Calculating the weighing sections Sp and the anchoring lengths must reckon with the relative friction conditions (soil/geotextile, soil/geomembrane, geotextile/geomembrane).

The adjacent table gives the minimal values of the section Sp of the material weighing upon the geomembrane, calculated for a weight per unit of volume of 20kN/m^3.

Figure 11



The section SP of the material, exerting weight on the geomembrane, can be less than the section of the anchoring trench.

	Sp (m²)	
Length of the sloping surface (m)	**In site with low or medium wind exposure**	**In site with high wind exposure**
< 3	0.04	0.06
3 to 5	0.09	0.16
5 to 15	0.16	0.25
15 to 40	0.25	0.36
> 15	> 0.36	> 0.49

Nota 4: In cases where it is feared that there will be major movements of earth after bringing in the water, there is every advantage in providing an anchoring at the head by provisional ballasting to enable the geomembrane to be pressed flat against the substrate after the movements are stabilised.

The definitive anchoring takes place later.

7.2 Intermediate anchorings

Intermediate anchorings are not to be used except in cases of absolute necessity. This is because they are complicated to install, expensive and generally entail degradation of the surface state of the slope.

They can be necessary in certain cases:

- on the slopes, as a supplement or as a replacement for the pressure balancing ballasting (drainage of gases, winds, etc.);
- to assume the loads generated in the Geomembrane Waterproofing System by the protection layer.

Figure 12 - Intermediate anchorings

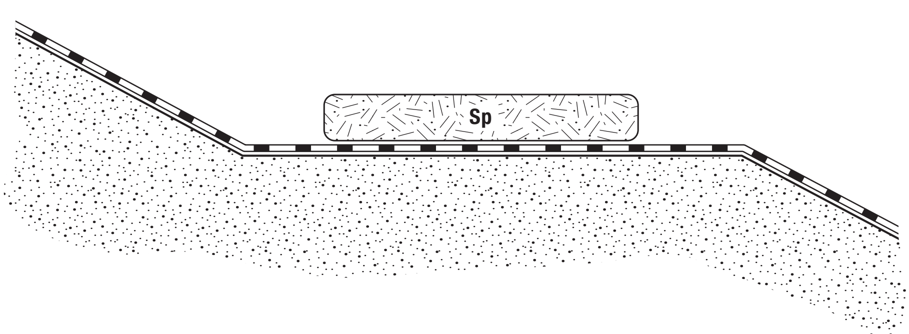
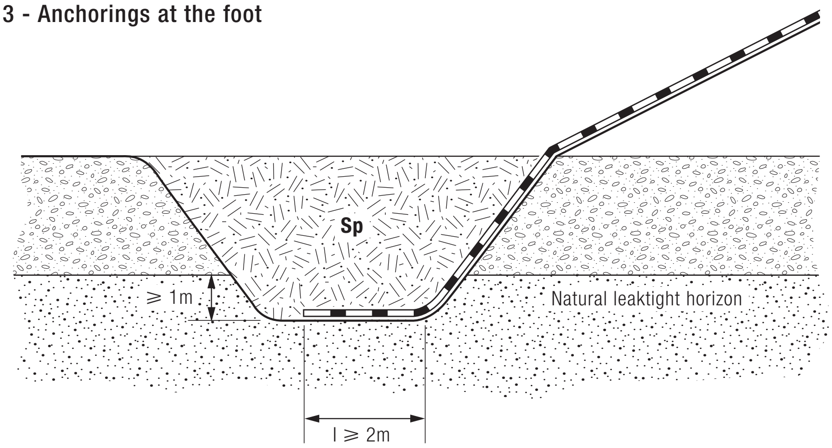


Figure 13 - Anchorings at the foot



Connecting using compacted natural leaktight material at the medium depth leaktight horizon

7.3 Anchorings at the foot

This anchoring can have two functions:

- participating in the stability of the geomembrane under wind effects;
- making sure of the waterproofing continuity between the geomembrane and the leaktight horizon.

7.4 Ballasting

Ballasting is important when laying up geomembranes, and should not be ignored.

Ballasting must take place as soon as the geomembrane is rolled out, leaving as little time as possible before the strips are assembled.

Underpressure caused by wind on the job site, or when the facilities are in operation, may lift the geomembrane, exerting forces proportional to the surface exposed to the air, so causing strain.

Ballasting is required to prevent lifting of the geomembrane and avoid any accidents to operatives and deterioration of the geomembrane itself.

Ballasting characteristics must be determined at design level to take into consideration location, frequency, type of ballasting, weight factors in relation to surface area, etc.).

Ballasting may take place for example:

- During the geomembrane roll-out phase using jute bags filled with sand or earth, regularly laid out and interconnected on the geomembrane.
- Once the geomembrane is in place and the facility is in operation: during pond flushing for example, water can be left to act as a ballasting.

7.5 Connection to concrete structures

7.5.1 General provisions

Teranap TP and Teranap GTX 300 are connected to concrete structures by means of the solutions described below. Special care must be given to compacting of embankments in zones around concrete structures, so as to avoid any differences in the degree of compaction. Differences of surface level, if they occur, can cause stress to Teranap TP and Teranap GTX 300.

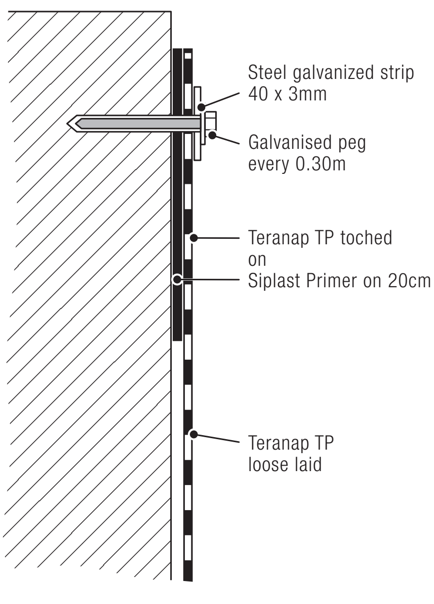
Especially critical points require the special techniques shown below. Contractor approval is required for the technical solution before work begins.

7.5.2 Mechanical fixings

The choice of mechanical fixings is the designer's responsibility. It is essential these fixings are protected against corrosion.

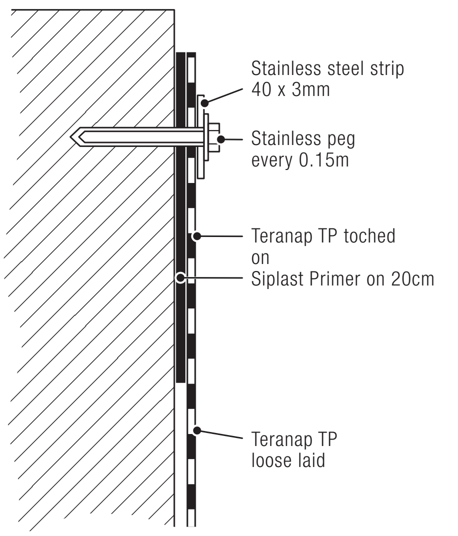
- Above the surface level of stored fluids

Figure 14



- Below surface level of stored fluids

Figure 15



Reminder 3: The design must take into consideration the chemical aggressiveness of the fluid or its viscous or particle content, and so determine the method of protection to be provided by the mechanical fixings:

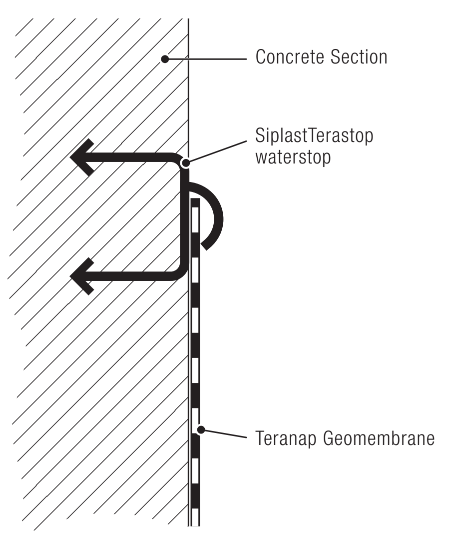
- **Either** by nature of material used (i.e: stainless steel of appropriate grade);
- **Or** by type of protection, given the material (i.e hot-galvanised steel of appropriate weight).

7.5.3 Use of anchoring sections

The Terastop section is installed against the structure's formwork.

The geomembrane is then welded to this section. §2.5.3.

Figure 16



7.6 Connection to pipe penetrating into substrate

7.6.1 General description

So far the end of the pipe should be embedded into a concrete substrate to which the waterproofing material is fixed.

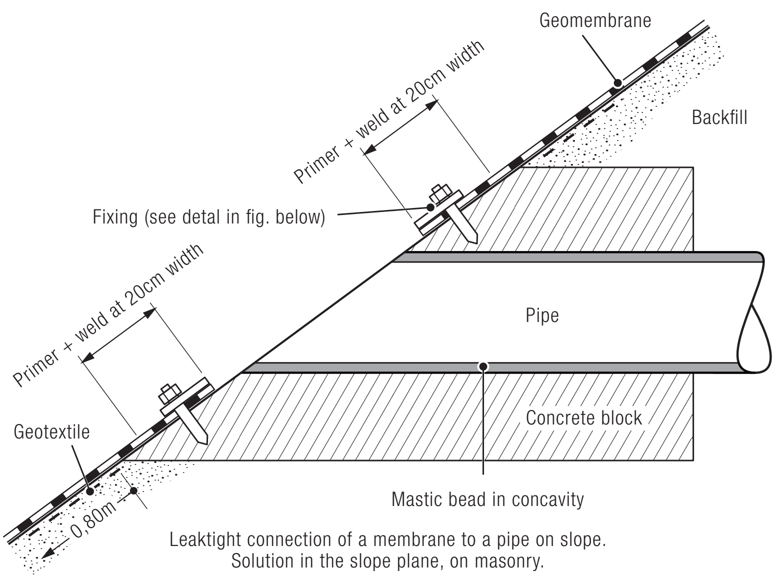
Waterproofing of the point of attachment to the pipe, is performed if necessary and/or possible using a Teranap TP geomembrane sleeve (as described in simplified diagram below 7.6.3).

This sleeve is torch-bonded to the relevant part of the construction works (cf 7.6.3).

Whenever possible, the point of attachment is torch-bonded to the concrete substrate or structure, previously coated with Siplast Primer, and is mechanically fixed to the concrete substrate or structure (see diagram 7.6.2). Siplast Primer should be applied at a rate of 250 to 300g/m^2 on concrete substrate, and at a rate of 150 to 200g/m^2 on metal substrate in order, once it is cured, to ensure full connection of Teranap TP and Teranap GTX 300 geomembranes.

7.6.2 Connection to a pipe in basins containing non-environmentally polluting effluents

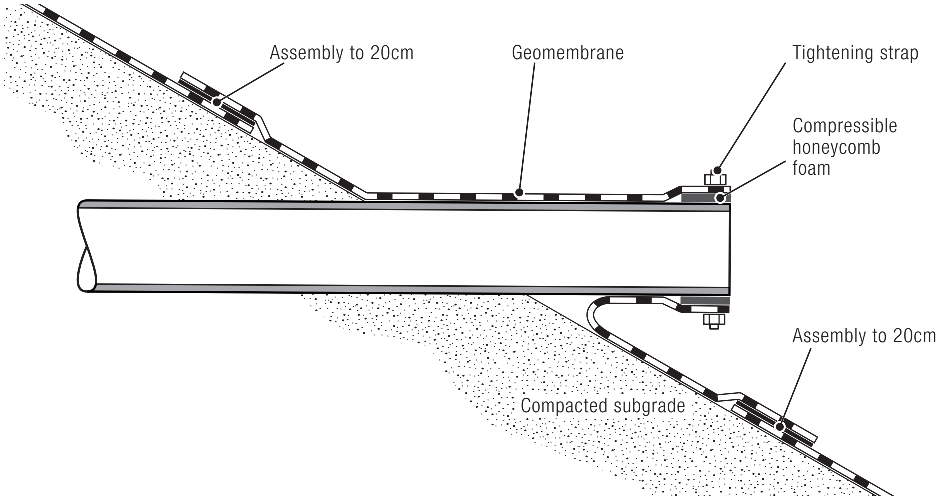
Figure 17



Leaktight connection of a membrane to a pipe on slope.
Solution in the slope plane, on masonry.

7.6.3 Connection to pipe, with or without pipe penetration into concrete structure for basin containing effluents (irrespective of whether or not environmentally polluting)

Figure 18



8. Acceptance procedures for leak tightness

Once all the materials of the protection layer are in place or once the facility has gone into service, the geomembrane surface must be inspected, and the results of weld controls must be examined by the leak tightness contractor Quality Manager, working alongside the main contractor or its representative. Such inspections and examinations should be recorded in a report specifying the acceptance procedures adopted.

9. Repair of faults in leak tightness

When the geomembrane is damaged by perforations or local tears, repairs should be performed by a patching material taken from a strip of the same geomembrane, to be welded over a length no less than 20cm around the portion of damaged geomembrane. In the event of repair after the facility is in operation for a given time, cleaning of the welding surface will be required.

In general, high pressure water cleaning (50 to 100 bars) will suffice. In this case, the connection of the new Teranap TP and Teranap GTX 300 strip of geomembrane to the existing geomembrane can be made, or a new piece of membrane patched over the damaged portion of the existing geomembrane.

10. Protection structure

10.1 Preliminary

The term protection structure refers to all the elements in situ and if necessary, to elements above the waterproofing structure. It extends the serviceable life of the facility by protecting it against the various stresses and strains which may adversely affect it both while laying up and construction work take place, as well as later when the facility is in operation.

For example:

- **Traffic from the site vehicles or machinery** (traffic is prohibited unless protection is in place)
- **Ultraviolet radiation:** The UVs are one of the main ageing factors of geomembranes. Installing a protection structure considerably increases these materials' service life. The behaviour of geomembranes under ultraviolet radiation is checked by the accelerated ageing tests.
- **Ice:** The presence of ice in contact with the Geomembrane Waterproofing System can generate strains leading to troubles such as:
  - lateral thrust when ice is forming;
  - strains during water level variations;
  - aggressions by floating blocks.
- **Waves and wakes:** The waves or wakes, created by the passing of boats or by the wind, against the bank, generate a series of alternating hydrodynamic strains.
- **Floating bodies:** The presence of floating bodies, including ice, by bumping or rubbing, can cause circumscribed tears in the geomembrane.
- **Vandalism:** Vandalism, difficult to quantify, is a parameter that can lead to applying particular protection devices: fence, total or partial protection structure, etc.
- **Wind action:** When the works are not intended to be permanently submerged by liquid.

10.2 Design

The performance requirements and make-up of the protection structure should be determined during the design stage, taking into consideration the various parameters of jobsite operations, facility operating conditions and environmental constraints.

Protection structure thickness and the make-up of its elements should also be determined at the design stage, taking into consideration the parameters affecting calculation of the geomembrane thickness (wind speed, traffic, permanent overload, length and orientation of water basin, incline of embankment, maintenance considerations, risk of vandalism, etc.)

The designer must at all times avoid contact between the geomembrane and any materials liable to puncture it. In most cases, underlays by one or more puncture-resistant geotextiles in the Geofelt ranges will suffice, with or without soil grips in the Grip range, judiciously chosen (design services available on a case by case basis from our technical department).

The supporting substrate must be designed of the correct size and characteristics to withstand the stresses from wake waves and other turbulence. In the special circumstances of canals, it is also important to make provision for sufficient excess height above water level to avoid waves splashing over the banks, causing embankments to collapse.

To avoid instability affecting the protection structure, when the basin is rapidly emptied, the design must make provision for the simultaneous evacuation of:

- Fluids stored in the facility;
- The same fluids, if they have penetrated.

Fluid drainage from between the protection structure and the geomembrane may for example take place using a product in the Geoflow range (consult Siplast-Icopal technical department)

Composition and location

10.3 Composition

10.3.1 Protection may use many materials, among them

- **Natural materials:** sand, gravel, rubble, soil. These materials are laid up to a standard depth of between 20 and 50cm.

Note: Laying up the protection layer using granular materials must be performed at less than 30°C ambient temperature for maximum avoidance of faults affecting the geomembrane. Laying up should take place in successive layers of no more than 40cm depth, moving forward without traffic of site machinery over the Teranap TP and Teranap GTX 300 geomembranes.

Even if protection **rip-rap** is set up, a 15cm deep over-layer of sand or gravel shoud be laid.

- **Hydraulic binder materials:** reinforced concrete, fibrous thin concrete with separation joint every 5m.
- **Prefabricated materials:** geosynthetics, large or small concrete slabs, interlocking paving stones.

Note: When protection is made from bonded materials, the protection structure should be set up during times of cool ambient temperature.

To reduce thermal dilation, a white geotextile or layer of sand may be set up as Teranap and Teranap GTX 300 laying up progresses.

For indication purposes, the table below shows the type of GEOFELT (minimum weight) to be used for geomembranes depending on the level of protection envisaged *(for Teranap 531 TP and Teranap 631 TP geomembranes, please consult Siplast-Icopal).*

Teranap	Depth of liquid or height of product stored	On the geomembranes	
		331 TP	431 TP
Smooth concrete (HS < 1mm)	H < 3m	700	400
	H < 10m	700	400
Trowelled concrete (1.0mm < HS < 2.0mm) Macadam	H < 3m	300	Kraft
	H < 10m	300	300
Cement-bound graded aggregate Bituminous-bound graded aggregate	H < 3m	400	300
	H < 10m	700	400
Sand, silt, clay	H < 3m	No	No
	H < 10m	No	No
Topsoil, crusher-run materials, crushed materials Dmax = 15mm, rounded materials Dmax = 50mm	H < 3m	300	No
	H < 10m	400	300
Crushed materials Dmax = 31.5mm Rounded materials Dmax = 80mm	H < 3m	700	400
	H < 10m	Study	700
Crushed materials Dmax = 50mm	H < 3m	Study	Study
	H < 10m	Study	Study

10.3.2 Location

■ **On embankments,** protections can be stabilized by a beam at the foot or suspended by anchoring in a trench at the head.

■ **On access ramps,** the protection providing a traffic load-bearing course should be made up of bonded materials (concrete or coated aggregate) separated from the waterproofing material by a geotextile suited to the particle size of the protection materials.

In the event of protection by **coated aggregate**, a 10cm layer of sand or gravel must be laid to avoid thermal shock and to facilitate compacting.

The leak-tightness of **access ramps at the bottom of the job site** is generally protected by prefabricated elements.

■ **In tidal areas.** Depending on the amplitude of waves and of the wake caused by craft, the geomembranes should be covered over by a protection structure or locally fixed. Substrate or concrete protection should be such as to attenuate wave impacts.

A protection structure or any other means to reduce the presence of floating bodies or prevent their coming into contact with a geomembrane must be provided. The risk of contact increases with the size of waves, and hence with the size of the water course or basin.

■ **Protection against vandalism.** Provisions for special protection are required from the initial design stages onwards in terms of protective enclosures, fully or partially protected structures, etc.

11. Technical Assistance

Siplast-Icopal has two training centres for waterproofing contractors, at its two production plants at Mondoubleau (41) and Loriol (26).

Siplast-Icopal technical department is at the disposal of M&E consultants and of the commissioners of work. Information is available on the following and other topics:

- Chemical compatibilities of fluids or solids in contact with Teranap TP and Teranap GTX 300 geomembranes;
- Sizing of the protection geosynthetics providing soil stability on embankments.

Siplast-Icopal can also provide on-site start-up assistance, at the request of application specialists.

12. Quality assurance plan

Works are inspected and controlled, taking into consideration the degree of potential contamination from the products stored on-site, depending on the sensitivity of the site to be protected, and its size.

For quality aspects, please consult Chapter 5 of Booklet No.11 of the French Committee of Geosynthetics.

13. Maintenance

Maintenance is essential to keep up the high standard of leak-tightness over time.

Maintenance includes:

- Periodical control of stored fluids (nature and composition to remain compatible with geomembranes);
- Removal of vegetation, of floating bodies and other objects liable to damage basin leak-tightness;
- Supervision of the effectiveness of the draining system (landfill sites);
- Keeping watch over soil movement (settlement,..);
- Checking Teranap TP and Teranap GTX 300 geomembrane integrity, if not otherwise protected.

To add length of service life to the geomembrane, the design may include planting out the geosynthetic waterproofing system.

Shrubs must be selected so their root systems are suited to the depth of topsoil protecting geosynthetic waterproofing systems, remembering that roots stabilise the soil on embankments.

Provision must be made for basin maintenance from the design phase onward.

14. Safety of approaches and of facilities

The design must provide for a number of additional features:

- Fencing (mainly round basin);
- Ladders, knotted ropes etc., to enable persons or animals to be assisted out of the water, if an accidental fall has taken place.

The design must also take into consideration special provisions when the facility is open to the public.

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