

Teranap 431 TP

Waterproofing of Underground Works
Cut & Cover trenches, structural rafts & walls



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1. Description of the “Teranap TP for Underground Works” system

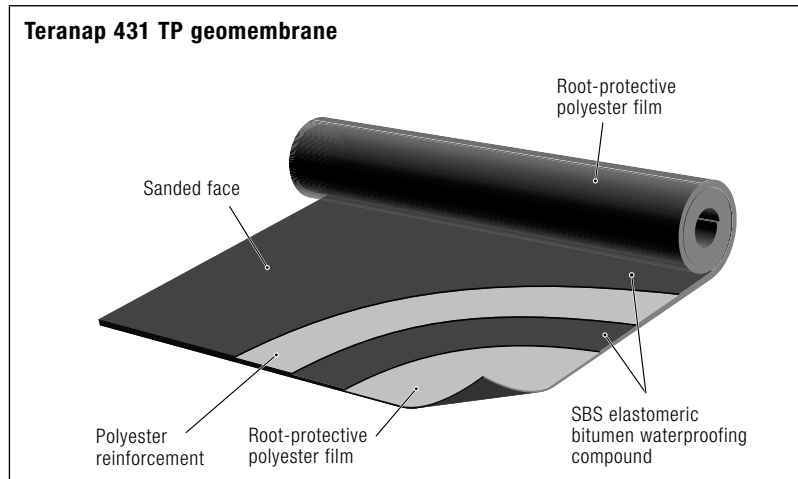
The Teranap TP Underground Works waterproofing system is part of the bituminous geomembrane waterproofing range. It includes:

- a) A Teranap 431 TP waterproofing geomembrane of elastomeric bitumen, 4mm thick, with a non-woven polyester reinforcement.
- b) The PE-EVA Terastop waterbars for partitioning, compatible with the SBS bitumen of the Teranap TP.
- c) The 200mm wide elastomeric bitumen strips for partitioning, of Parafor Solo S or of Teranap Joint Cover Strip.
- d) Covering strips of Teranap 431 TP whenever this is used on the raft underface; consisting of either Parafor Solo S, 150mm minimum width, or of Teranap Joint Cover Strip.
- e) Parafor type elastomeric bitumen membranes for dealing with details and connections.
- f) A Siplast Primer cold insulation mastic sealing compound.
- g) The Neodyl packing cord, of butyl or of neoprene, diameter 2cm, for dealing with active joints.
- h) Injection flanges and pipes « PIM ».

The bottom and top protection geotextiles and the injection arrangements are not part of the system. Their characteristics are just mentioned for information in § 4.6. and 4.7.

The Parafor Solo S membrane is described in a CSTB Technical Assessment « Single ply waterproofing roof covering, SBS modified bitumen membrane base », Reference 5/03–1678, issued 17 November 2003.

The Parafor Ponts and the Siplast Primer membrane are described in a SETRA Technical Assessment « Civil Engineering Works – road bridge waterproofing », Reference F AT ET 02-09, issued December 2002 .



2. Fields of application of the “Teranap TP for Underground Works” system

The Teranap 431 TP geomembrane can be used to waterproof underground works in the following cases:

2.1 Upper surface of cut & cover trenches and vaulted works without hydrostatic pressure

In this case:

- The Teranap 431 TP geomembrane is unrolled loose-laid and the laps are welded together by gas-torching.
- The partitioning into compartments is done using Parafor Solo S strips in 200mm or Teranap. Joint Cover Strip (cf. § 4.7).

- Bottom and top protection systems using geotextiles are installed (cf. § 4.6).

2.2 Underface of structural rafts and walls with or without hydrostatic pressure

In this case:

- Partitioning into compartments, the Terastop waterbar is welded to the Teranap 431 TP (cf. § 4.7).
- The upstands are mechanically fixed for hydrostatic pressures higher than 0.01 MPa.
- Bridging of Teranap 431 TP torched overlaps using strips of Parafor Solo S, 150mm minimum wide, or using Teranap Joint covering strip.

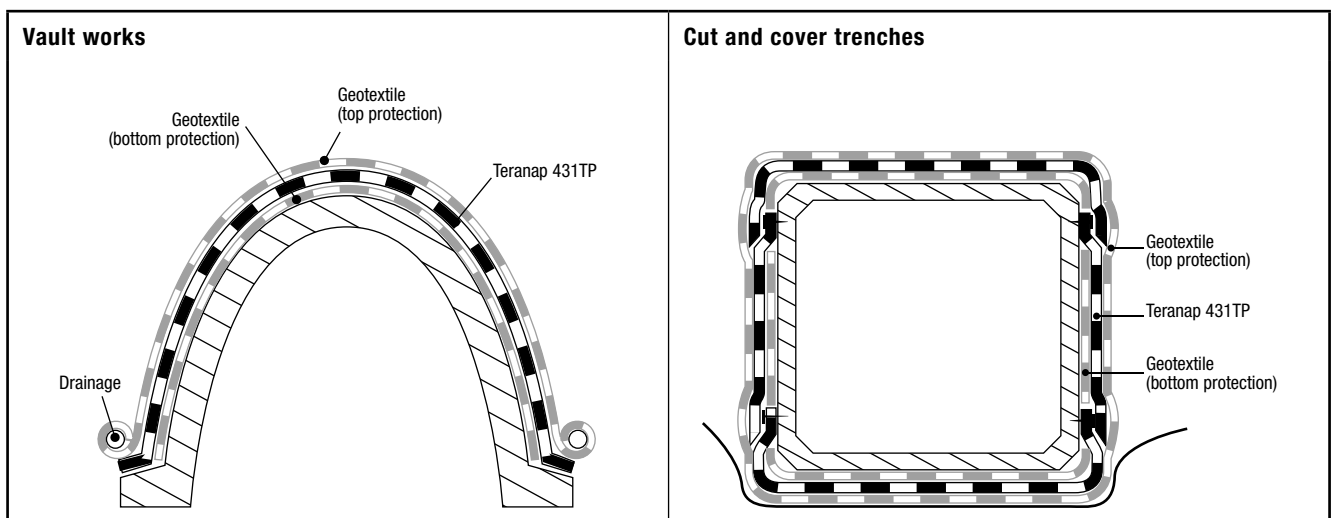
2.3 Underface of rafts and walls on permanent shuttering

In this case:

- Partitioning into compartments, the Terastop waterbar is welded to the Teranap 431 TP.
- The Teranap 431 TP geomembrane can be installed all the way up the sidewall if the works are completely or partially submerged.
- For heights greater than 3m, Teranap 431 TP is mechanically fixed with a bridging using Parafor Solo S, 150mm wide, or Teranap Joint covering strip. This arrangement does not apply in the case of vaulted works.
- Bridging of Teranap 431 TP torched overlaps by strips of Parafor Solo S, 150mm wide.

Composition of the “Teranap TP for Underground Works” system

Elements of the system	Trench on permanent shuttering			Top slabs
	Raft	Sidewalls	Shells	
Bottom protection geotextile	Yes	Yes	Yes	Yes
Teranap 431 TP geomembrane (waterproofing)	Yes	Yes	Yes	Yes
Top protection geotextile	Yes	Yes	Yes	Yes
Mechanical fixing	No	No	Every 3m of height	No
Waterbar for partitioning into compartments	Yes	No	No	No
Strip for partitioning into compartments	No	Yes	Yes	Yes



3. Relation to French Regulations

The following are defined as underground works:

- Covered (cut & cover) trenches;
- Partially covered vertical shafts;
- Structures under road grade, road type, motorway type and railroad type, as described in the Tunnels and Underground Works journal no. 168 of November/December 2001;
- Underground civil engineering works, regular stations and main stations of rail transportation, storage works, plant rooms and car parks, whenever they are not within the bounds of a surface work, having the legal title of a building.

Whenever the works have their waterproofing system out of contact with the pavement, but with a variable particle size distribution and backfill thickness, French Regulations concerning waterproofing of underground works are specified in the following documents:

- Leaflet 67 of the General Technical Clause Book of Public Works Contracts (CCTG in French). Title III, concerning the waterproofing of underground works, brought into application by Edict no. 92-72 of 16 January 1992;
- The Experts' Assessment of Working Group no. 9 of the AFTES⁽¹⁾ make it possible, in particular, to supplement the list of waterproofing products and techniques not covered until now by Article 4 of Chapter III of Leaflet 67, Title III;
- The recommendations of AFTES concerning the waterproofing and drainage of underground works;
- AFTES publishes recommendations supplementing the legislative text in force, so as to follow the evolution of techniques and jobsites. These recommendations are published in the « Tunnels and Underground Works » journal.

The Technical Assessments from the CETU⁽²⁾. These Technical Assessments are information and assessment documents that give an authorised opinion concerning the applicability and future behaviour of a waterproofing system in the application field considered.

The CETU Technical Assessments are, little by little, going to replace the AFTES Experts Assessments. Until now, the Teranap TP underground works have held an AFTES Expert's Assessment. The CETU Technical Assessment is going to be requested soon.

Whenever the works of a waterproofing system on a cement concrete substrate is directly in contact with the pavements (sub-bases and wearing courses) the applicable regulations are:

- Leaflet 67 of the General Technical Clause Book of Public Works Contracts (CCTG in French), Title I, relative to the waterproofing of road bridges with cement concrete substrates, brought into application by Edict no. 85 404 of 3 April 1985.
- The French Technical Assessments of the SETRA. Since 1995, a Technical Assessment procedure has been introduced under the Secretariat of the SETRA, with the participation of the professions concerned [Chambre Syndicale Française d'Étanchéité" (French Waterproofing Association Chamber), "Union des Syndicats de l'Industrie Routière Française" (USIRF) (French Road Industry Association Union), "Syndicat National des Formulateurs de Résines Synthétiques" (SNFORES) (National Association of Formulators of Synthetic RESines), "Office des Asphaltes" (Asphalts Office)] the contracting authorities and the main contractors.
- The document of recommendations for the use of main contractors drafted by the Department of Civil Engineering Works of SETRA and published in March 1983: STER 81. It comprises three sub-files:
 - ▶ The St sub-file: surfacing of decks of Civil Engineering Works;
 - ▶ The E sub-file: waterproofing of decks of Civil Engineering Works;
 - ▶ Sub-file R: wearing courses of decks of Civil Engineering Works.

It is also accompanied by two documents of updating:

- ▶ n°1 concerning the complexes by equipment for High Working Rate (MHC);
- ▶ n°2 concerning techniques for circumscribed repairs to the waterproofing.

⁽¹⁾ AFTES: Association Française des Tunnels et de l'Espace Souterrain (French Tunnel and Underground Works Association).

⁽²⁾ CETU: Centre d'Études des Tunnels (Tunnel Studies Centre).

4. Installation of the “Teranap TP for Underground Works” system

4.1 Application guidelines

The ambient temperature shall be higher than 0°C. For welds on concrete, the substrate temperature shall be higher than 2°C. Works shall not be undertaken if it is raining continuously or in case of strong winds (risk of the geomembrane lifting up).

4.2 Storage on worksite

On the worksite, before installation, the rolls of Teranap 431 TP shall be stored laid one on top of the other and shall be kept in their original packing.

4.3 Specifications about the substrate

The substrate will need to comply with Article no. 9 of Leaflet 67 Title III, as well as with the recommendations from AFTES.

The substrate shall contain no holes or convexities. Any sharp angles shall be chamfered. Any rough points of more than 3mm are to be eliminated.

Before welding the strips of Parafor or of Teranap Joint covering strip for partitioning into compartments, the substrate will need to have undergone:

- careful removal of dust;
- elimination of all traces of slurry and of poorly bonded materials;
- elimination of excrescences and rough points by grinding or polishing;
- resurfacing of zones with major macro-roughness and dressing of small cavities.

When preparing the substrate, a special study will need to be carried out.

4.4 Safety

Before undertaking the works, the contracting firm shall provide safety systems (scaffolding, harnesses, ropes, etc.) that will enable the jobsite personnel to work completely safely. This is because the works concerned by this document are generally quite high (> 3m) before backfill.

4.5 General guidelines

4.5.1 Guidelines for the geomembrane

The Teranap 431 TP geomembrane contains:

- one sanded face;
- one face covered with a polyester film.

The sanded surface is to be placed in contact with the works or with the underlying layer. In general, it is installed starting with the peak of the vault or, in the case of permanent shuttering works, from the top horizontal part. The geomembrane plies are generally installed across the works' axis.

Naturally professional practice concerning the installation of waterproofing (connecting strips, slopes, etc.) is to be respected.

The geomembrane is loose laid in the regular part. It can be welded at the foot of the works or connected to the raft's waterproofing.

4.5.2 Rolls with cut-outs

The Teranap 431 TP rolls may contain one or two cut-outs, signalled by:

- a paper mark at the location of the cut-out;
- a red scotch tape circlet, noted «roll containing cut-out».

4.5.3 Guidelines for overlap welding

The side-laps shall contain an overlap corresponding to the weld strip:

- 15cm for the Teranap 431 TP, 2m wide;
- 20cm for the Teranap 431 TP, 4m wide.

The welding width at the end-laps shall be a minimum of 20cm. The welds are to be inspected in a particularly careful manner. Make sure that the whole surface of the overlap is properly welded.

Teranap 431 TP in 2m wide rolls (rolling direction: polyester film on the outside)

After unrolling and positioning the plies, the weld is done by lifting the upper ply and heating the two plies together before smoothing down. The smoothing down is to be carried out immediately in back of the welding, while the bitumen is still hot, by applying pressure with a cloth or of a spatula (gauging trowel), for example.

Teranap 431 TP in 4m wide rolls rolling direction: polyester film on the inside

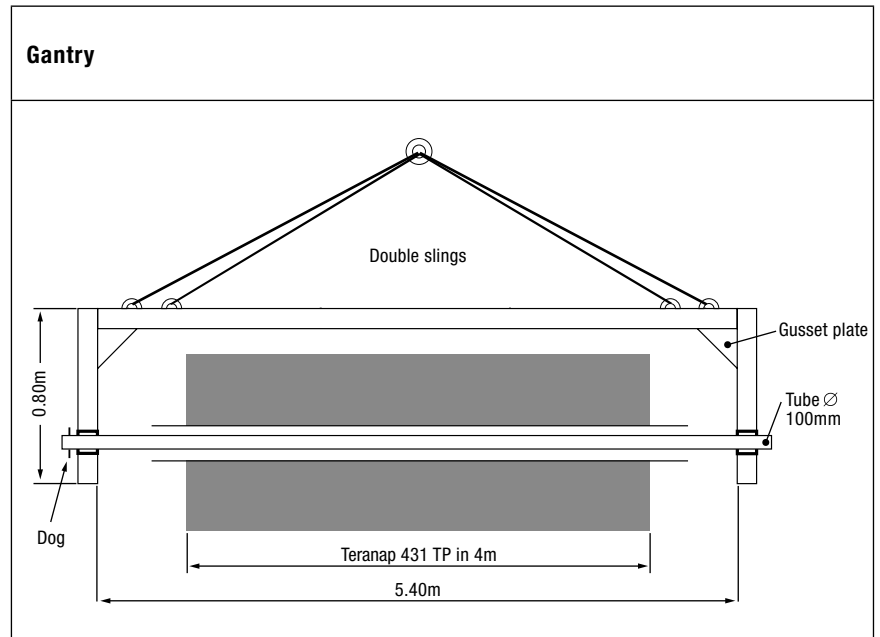
Installing the Teranap 431 TP in rolls of 4m mandatorily requires a mechanical handling system. The following diagram shows an example of a gantry as handling system.

A sheet steel plate (diameter 20cm) is welded at one extremity of the roll tube (diameter 100mm) and, at the other extremity a dog prevents the tube from being pulled out of the line.

4.6 Protection layers

The nature and characteristics of the bottom end and to geotextile protection shall comply with the recommendations of the AFTES and restated in the table below.

The geotextile is laid in the same direction as that of the Teranap 431 TP plies. The overlap between Geotextile plies is 15cm. This is done by welding with hot air or with low flame from the blow torch.



Nature and characteristics of the supplementary protection in the case of backfill

Backfill height	h < 0.50m	0.50 < h < 2.00m ⁽¹⁾	h > 2.00m	All heights ⁽¹⁾	
Nature of backfill	Rolled aggregate 0/200mm Class C1 ⁽²⁾ Aggressivity 2 to 3	Rolled aggregate 0/200mm Class C1/D1 Aggressivity 2 to 3	Rolled aggregate 0/200mm Class C1/D1 Aggressivity 2 to 3	Crushed aggregate 0/50mm Classes D1/D2/R Aggressivity 2	Crushed aggregate 0/150mm Classes D3/R Aggressivity 4
Bottom protection	Geotextile ≥ 700g/m ²	Geotextile ≥ 700g/m ²	Geotextile ≥ 700g/m ²	Geotextile ≥ 700g/m ²	Geotextile ≥ 700g/m ²
Top protection	Geotextile ≥ 700g/m ²	Geotextile ≥ 700g/m ²	Geotextile ≥ 700g/m ²	Geotextile ≥ 1500g/m ²	Geotextile ≥ 2200g/m ²
Supplementary protection	Concrete screed ≥ 6cm ⁽³⁾	Sand ≥ 10cm + warning wire netting ⁽³⁾			
Minimal rating for resistance to puncturing under concentrated dynamic load	Rating 2	Rating 2	Rating 2	Rating 1	Rating 0

(1) Supplementary protection for a height less than 2.00m applies to all kinds of backfills.
 (2) Ratings and aggressivity criteria of backfills defined in "Tunnels et Ouvrages Souterrains" TOS no. 183.
 (3) For vaulted works, the sand layer 10cm thick can be replaced at the highest point of the work by a geotextile 1500g/m², plus a warning wire netting, placed 10cm above the geomembrane waterproofing system (DEG in French) or a single top protection, consisting of a geotextile ≥ 2200g/m², replacing the sand and the geotextile of 1500g/m², covered by a warning wire netting, located 10cm above the waterproofing geomembrane system.

4.7 Partitioning into compartments

As covering, it is recommended that there be a maximal compartmenting surface of 350m². The partitioning into compartments is done with strips of Parafor in 200mm or Teranap Joint covering strip, fully welded on the concrete substrate,

after laying the Siplast Primer at 250g/m². Under the raft, it is recommended that the maximal compartmenting surface be 250m². The partitioning into compartments is done using Terastop Waterbar. It is directly welded to the Teranap.

System for monitoring and injection that accompanies the partitioning into compartments

This system has two functions:

1. Monitoring the efficiency of the waterproofing geomembrane system.
2. Facilitating repairs by injecting a water active resin.

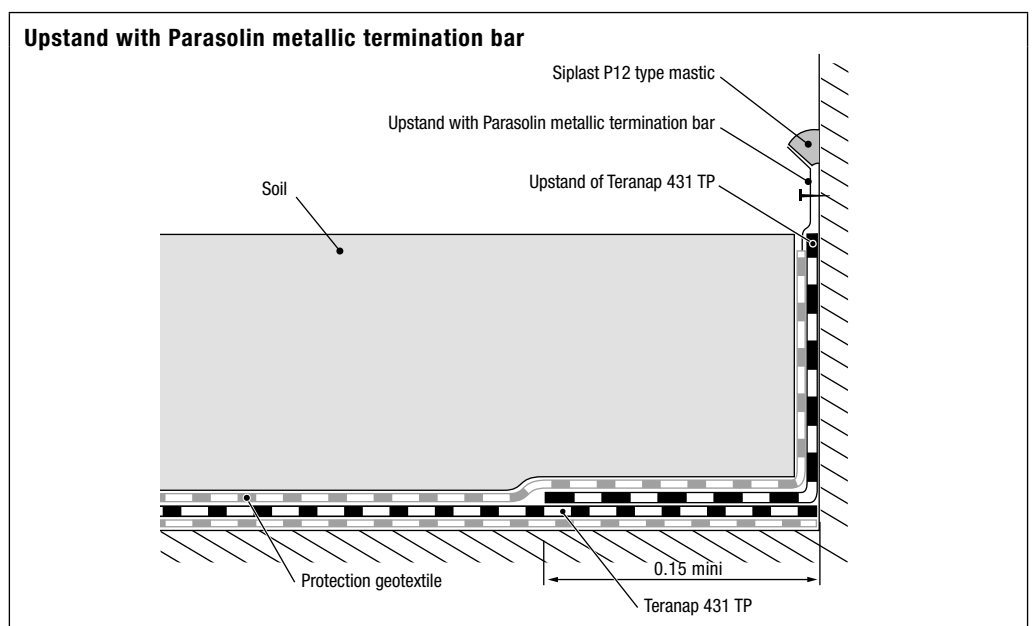
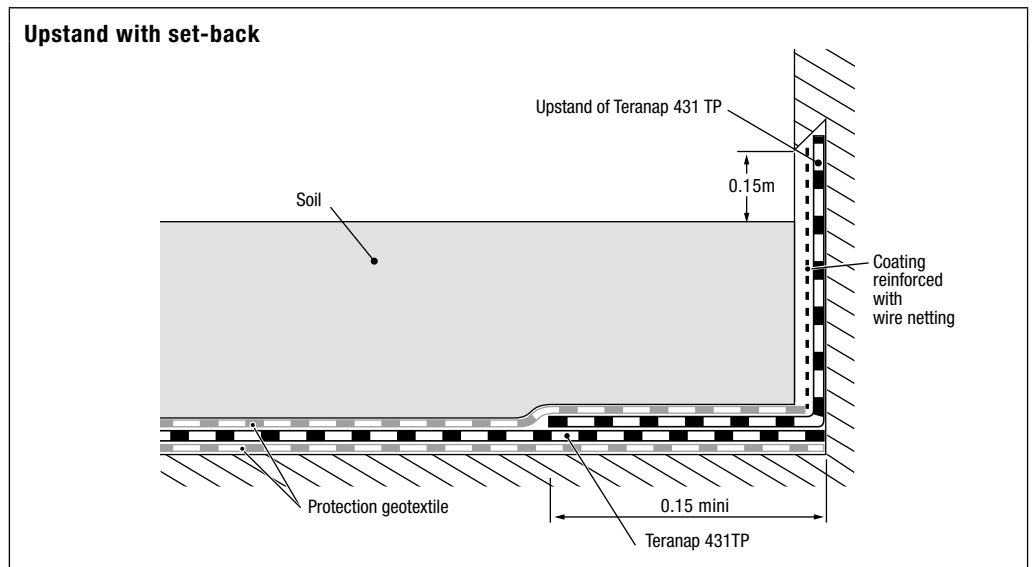
At the upper slabs of structural works, conventional injection systems (connection pipes + flanges) are used. At the shell and vaults, the works formwork

spaces are to be used in the place of pipes. The number of these pipes per horizontal compartment shall be equal or greater than 5.

4.8 Dealing with details and connections

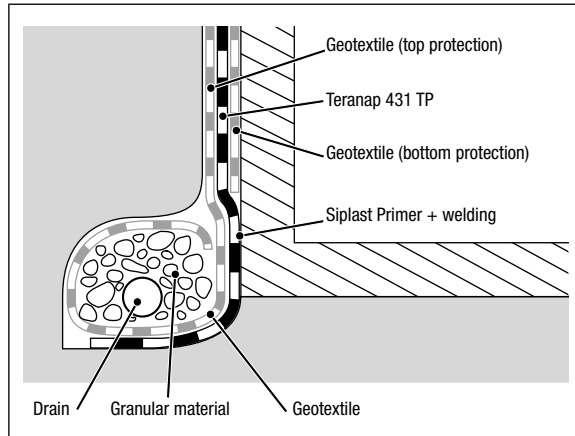
4.8.1 Dealing with upstands

In the case of a structure partially located above the covering backfill, it is possible to base oneself on the following figures when building the upstands. A mechanical protection of the upstand will mandatorily need to be installed.

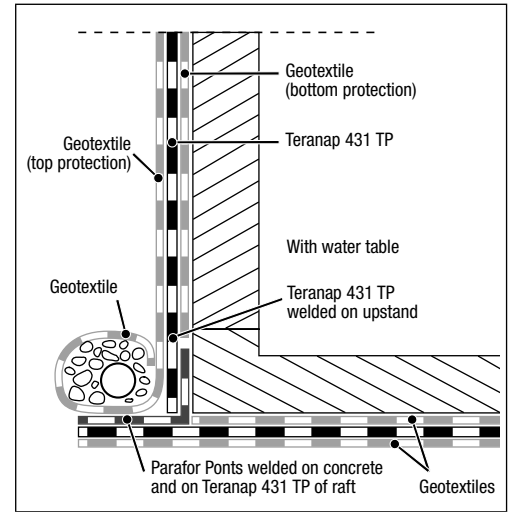


At the foot of the structure, many types of situation may arise, here are some configurations:

Teranap 431 TP brought down below the level of the structure

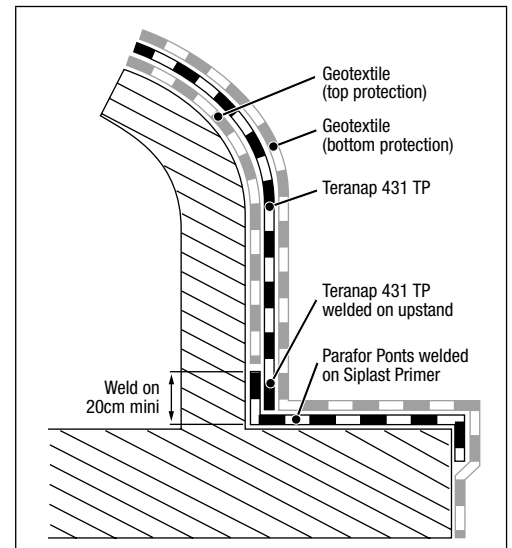
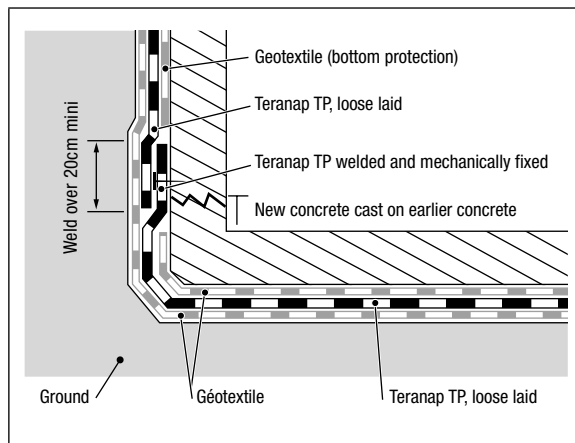


Parafor Ponts welded on concrete and on Teranap 431 TP

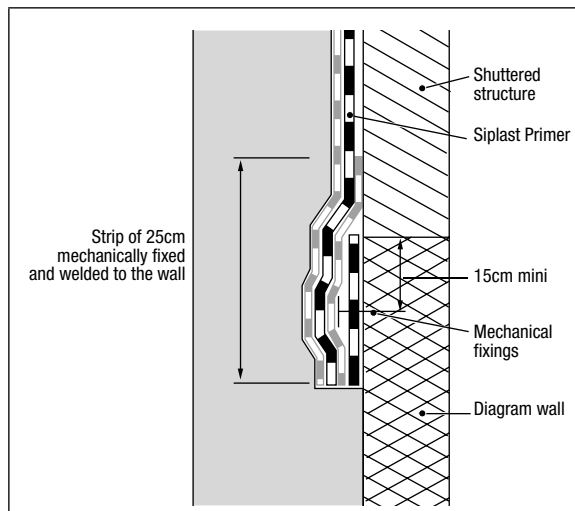


or:

Teranap 431 TP is connected to the waterproofing of the raft



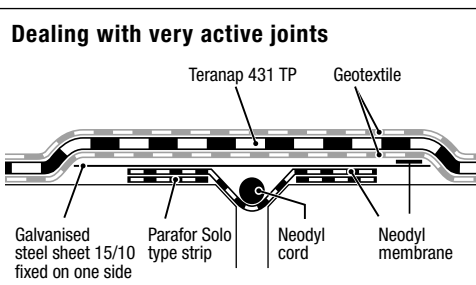
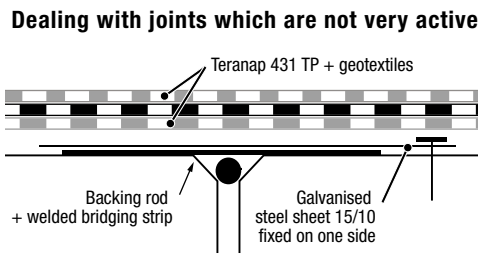
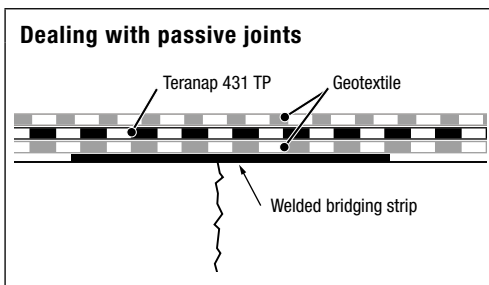
Teranap 431 TP is connected to the waterproofed part of the structure



4.8.3 Dealing with joints

Dealing with passive joints on zones of new concrete cast on earlier concrete

The passive joints are reached by a Parafor Solo S 20cm bituminous strip, fully torched on both sides of the joint after application of the Siplast Primer at 250g/m². The geomembrane is unrolled, loose laid, above that strip.



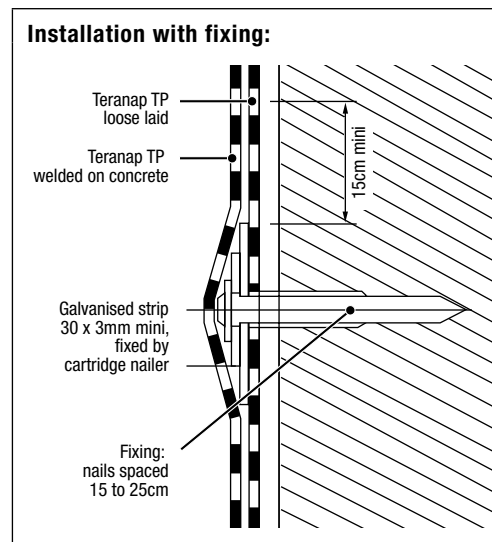
Dealing with active expansion joints

Active joints are dealt with by installing Neodyl cord (diameter 2cm) in the reserved recess then by welding a Parafor Solo S 25cm elastomeric bitumen strip on both sides of the joint after application of Siplast Primer. The joint is mechanically protected by using galvanized steel sheet 15/10mm thick, mechanically fixed to one of the sides of the joint. The Teranap 431 TP geomembrane is then unrolled, loose laid, above the joint. For joints subjected to major expansions (thermal gradients, for example), the Neodyl membrane is to be used as a bridging strip. This membrane is fully welded. It is welded only on both sides of joint on an underlayer (Parafor Solo S for example).

This technique can also be used for dealing with active joints on the shells.

4.8.4 Fixing details

The mechanical fixings are to be bridged according to the following diagram:





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