Since 1963

WATERPROOFING SPECIALISTS AND CONTRACTORS
WITH GEOMEMBRANES

ROAD, RAIL AND METRO TUNNELS

1 – Baixa Chiado, Lisbon metro tunnel, Portugal.

Effective waterproofing of underground structures is one of the most efficient ways to enhance safety and function as well as increase useful design life. Thanks to the inclusion of a waterproofing geomembrane, costly special maintenance due to the unexpected deterioration of the structure can be eliminated or minimized.

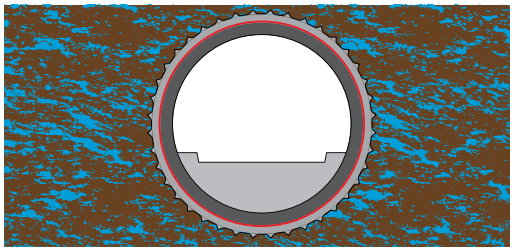
At high head, infiltration water may cause fissuring, jacking or washing out effects in the concrete. At lower head water influx at unwanted locations in the concrete may cause damage to the traffic and equipment inside the tunnel. Through the insertion of a geomembrane waterproofing system, groundwater is prevented from entering the tunnel and compromising the service of the structure, and the inner concrete lining is protected against deterioration.

Geomembrane systems can be installed as waterproofing liners in new tunnels, or as a repair measure for existing deteriorated tunnels. In new construction, the geomembrane is installed over a smoothing layer of sprayed concrete or over an outer lining. In rehabilitation works, the geomembrane is installed directly onto the deteriorated lining.

Providing Dry
and Underwater Installations

The waterproofing geomembrane can be applied to the entire tunnel cross-section (fully tanked), to the crown and walls in an “umbrella” type configuration (drained), or specifically to the problematic areas.

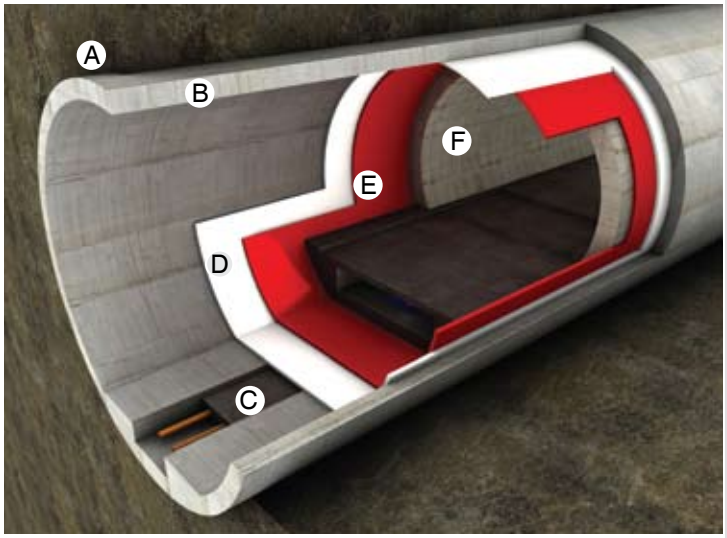
Fully tanked solution



2 – The fully tanked solution. Application of the waterproofing system all around the tunnel cross-section. No drawdown of the groundwater table. The tunnel inner lining is in compression.

In the case of tunnels in weak or loose rock and soils, or in urbanised areas where the minimisation of settlement is vital, the tunnel is required to be fully tanked. A fully watertight tunnel excludes water inflow from the surrounding ground, and therefore the lining has to be designed to withstand full water pressure (figure 2).

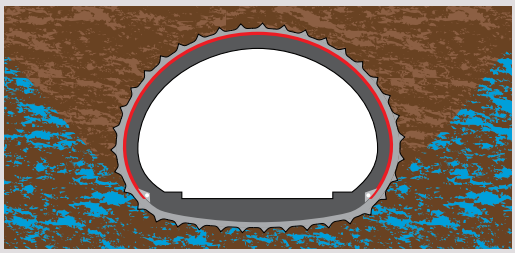
A *- Ground*
B *- Outer sprayed concrete lining*
C *- Temporary drainage*
D *- Geotextile antipuncture layer*
E *- Waterproofing geomembrane over whole tunnel cross-section*
F *- Inner concrete lining*



3 - Fully tanked tunnel arrangement.

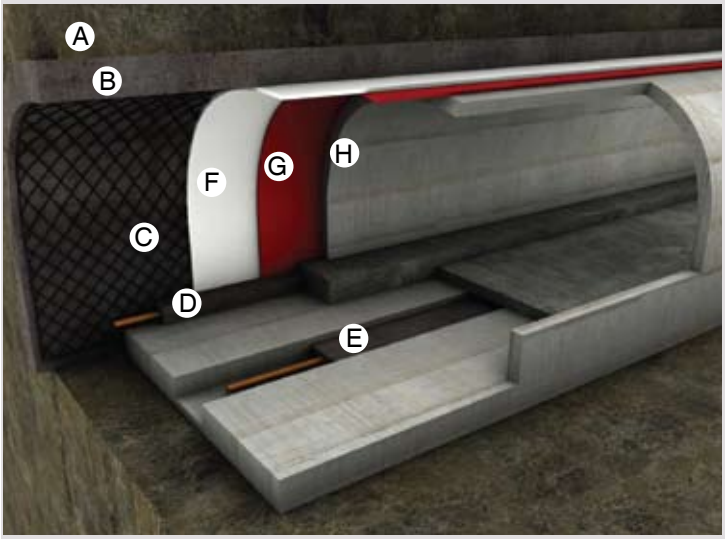
Reinforcement of the inner lining is likely to be necessary to provide structural capacity and for crack control. Once reinforcement is introduced, precautions must be taken to protect the geomembrane from puncturing.

Drained solution

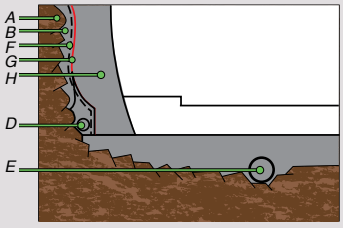


4 – The drained solution. Application of the waterproofing system limited to the crown and tunnel walls. Drawdown of the groundwater table. The tunnel inner lining is in slight compression (ground overburden only).

For situations where it is necessary to ensure that pressure does not develop behind the lining, a drained system should be used, figure 4.



5 – Drained tunnel arrangement.



A *- Ground*
B *- Outer sprayed concrete lining*
C *- Drainage layer (optional)*
D *- Drainage system at haunch*
E *- Drainage system at invert*
F *- Geotextile antipuncture layer*
G *- Waterproofing geomembrane over crown and walls*
H *- Inner concrete lining*

6 – Sketch of a typical drainage system.

Water behind the lining is usually collected in the haunches or invert by means of a drainage system that relieves the tunnel from water pressure (figures 4 and 5).
The maintenance of the drainage system is a major concern when designing drained tunnels. To avoid failure of the drainage system due to sintering/clogging, design should make an allowance for water build up.

The details described herein are state-of-the-art practice for modern underground structures worldwide. The CARPI tunnel waterproofing system consists of a thermoplastic impermeable flexible geomembrane installed over an antipuncture geotextile layer.

Waterproofing system installation

The geotextile, which protects the geomembrane from puncturing, creates a sliding surface below it avoiding that excessive stresses are applied to the geomembrane, and prevents interlocking between outer and inner concrete linings should differential movement occur. The geotextile is secured to the subgrade by nails equipped with special disks (roundels).
The disks, which provide temporary anchorage of the geomembrane to prevent it from hanging away from the vault of the tunnel, are designed to avoid that excessive stresses are applied on the geomembrane in correspondence of the roundels before concreting of the inner lining occurs.

The flexible geomembrane is placed over the geotextile and heat welded to the back surface of the roundels (figures 7 and 8). The flexible geomembrane typically has permeability at least three orders of magnitude lower than new concrete and thus provides the watertight seal whilst also spanning joints and cracks, covering any damage to the sprayed concrete lining and accommodating any movement.

8 – In the foreground the geotextile fixed to the substrate. In the background the geomembrane heat welded to the roundels (Lisbon metro tunnel, Portugal).

7 – The geomembrane being placed onto the geotextile already secured to the sprayed concrete substrate (Lisbon metro tunnel, Portugal).

9 – Installation of the geomembrane in the invert (Capo Calava' tunnel, Messina-Palermo highway, Italy).

10 – Installation of the circumferential waterstop onto the geomembrane in the tunnel invert (Dobrovskeho tunnel, Czech Republic).

Post-grouting between the geomembrane and the tunnel inner concrete allows addressing unlikely potential localised leaks and restoring imperviousness to the tunnel. Grouting is done by injecting into re-injectable hoses that are previously attached to the geomembrane.
Compartmentalisation, which is optional but recommended, restricts the field of leak detection and creates a system for future local repair.

Following the installation of the waterproofing geomembrane and before casting of the inner concrete lining, PVC waterstops are heat welded onto the waterproofing geomembrane at the perimeter of each compartment. The concrete is then cast, embedding the waterstops.

11 – Post-grouting arrangement at a waterstop cross joint (Dobrovskeho tunnel, Czech Republic).

12 - Longitudinal compartment seal made by welding the waterstop to the geomembrane. The waterstop is then embedded into the concrete inner lining (Klimkovice tunnel, Czech Republic).

13 – Fiorenzuola tunnel on the high speed rail section between Bologna and Firenze, Italy.

14 – Vaglia tunnel on the high speed rail section between Bologna and Firenze, Italy.

15 – Klimkovice tunnel, Czech Republic.

Inner concrete lining installation

The inner concrete lining is usually constructed in two stages, one stage for crown and walls and another for invert. Since, as recognized by international experience, perfect placement of the concrete and filling of all voids at the vault is practically impossible to be achieved 100% of the time, an allowance for grouting is made to prevent faulty concrete arising in the inner lining, particularly in the crown. Grouting is carried out once the concreting is complete, using horizontal injection hoses, previously attached to the geomembrane (see figure 16) or placed at the top of the reinforcement.

16 – Injection hoses attached to the parent geomembrane.

Reinforced inner linings will require anchoring steel bars to support the steel reinforcement cage before concreting. In order to prevent seepage in correspondence of the anchorage steel bars and all other geomembrane crossings, a special detail is required, see figures 18 and 19. If reinforcement is self supported however, no anchoring is required. New design trends seek to avoid or minimize penetration of geomembrane.

17 – Drained tunnel (Pontebba tunnel, Italy).

18 – Anchoring steel bars protruding through the geomembrane (Baixa Chiado, Lisbon metro tunnel, Portugal.

19 – Watertight seal around a steel insert crossing the geomembrane (Mont Jovet tunnel, Italy).

Performance

The use of flexible geomembranes to impart waterproofing provides a safer environment for all tunnel users and at the same time protects the tunnel fittings.
Thermoplastic flexible geomembranes are the preferred option because of their high durability and excellent tensile strength that allow them to bridge over cracks and accommodate movement. Proven application and welding practices, and accurate quality control, ensure that an easy and leak-free installation can be achieved.

20 – Inner lining on the Krasikov tunnel, Czech Republic.

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