

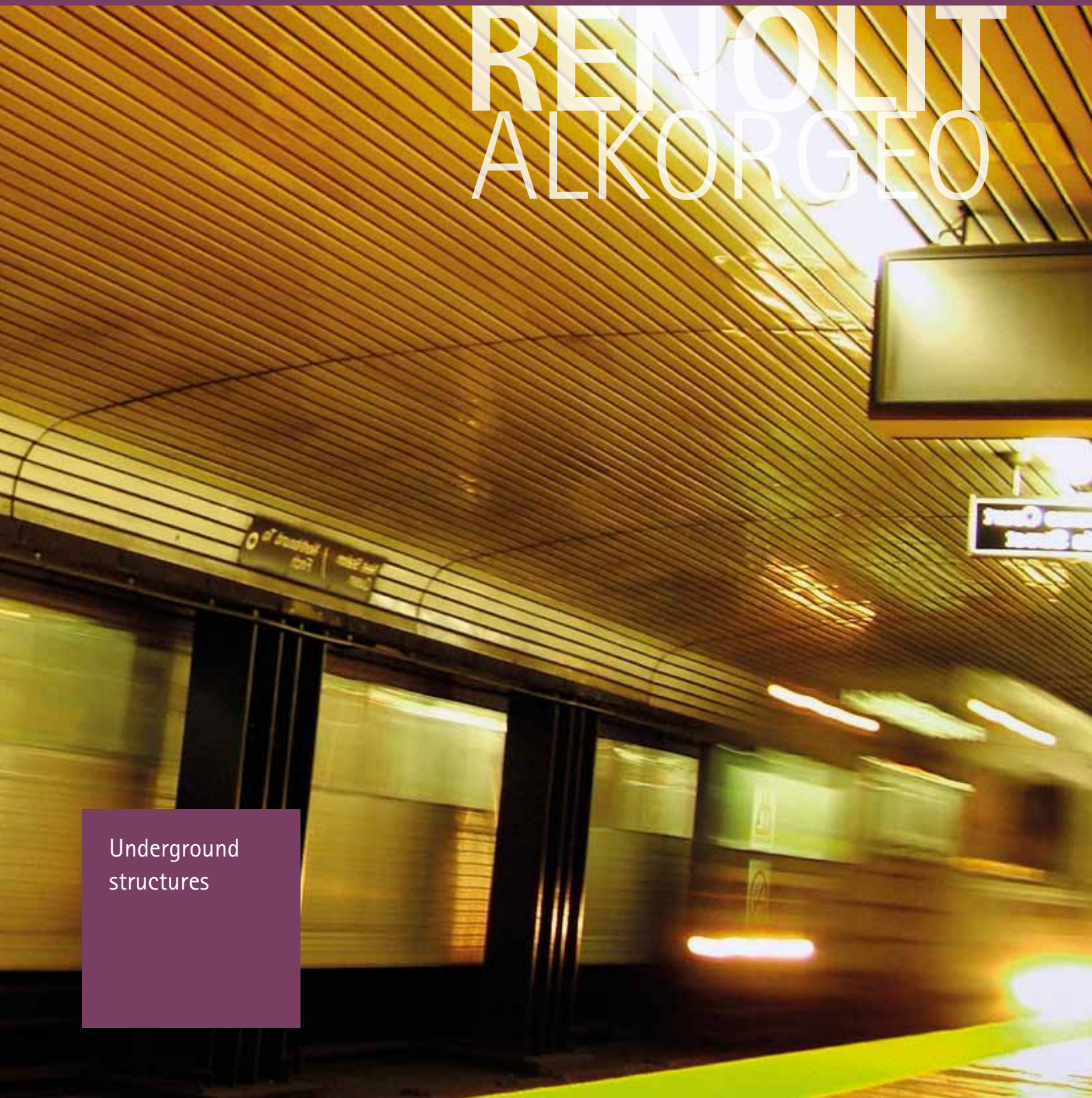


Rely on it.

Waterproofing of cut and cover tunnels

RENOLIT ALKOR GEO

Underground
structures



RENOLIT ALKORGEO

Underground structures



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Geomembrane recommended

RENOLIT group manufactures and markets a complete range of PVC, PE or PP geomembranes in response to a wide variety of applications. Experience has shown that the PVC geomembrane is the most suitable for waterproofing of cut and cover building due to its excellent mechanical properties, handling and durability.

Its high resistance to puncture is valuable to withstand the mechanical aggression caused by the implementation of backfill and to resist high pressure carried out on the geomembrane by the weight of the building : RENOLIT ALKORPLAN 35034 – 35036 – 35041.

Conception of the waterproofing system

Foundation Slab

- lean concrete
- geotextile of 500 g/m²
- PVC geomembrane of 2,0 mm (1,5 mm)
- Geotextile of 500 g/m²
- PE sheet of 0,25 mm as gliding layer
- Protective concrete

In order to control and use as repair systems, water stops and injection pipes are installed.

The surface of control areas should not overpass 100 m² of the foundation slab

The foundation slab has to be separated through water stops from the wall section.

Vertical Faces

Vertical faces with working space

- geotextile 500 g/m²
- PVC geomembrane 2,0 mm (1,5 mm)
- geotextile 500 g/m²
- protection layer (card board, concrete blocks)
- backfill

Vertical faces without working space

- retaining wall
- separation layer (e.g. Styrofoam 4 cm or similar)
- geotextile 500 g/m²
- PVC geomembrane 2,0 mm (1,5 mm)
- Geotextile
- concrete wall

The same control and repair system is used as for the slab. The water stops are placed in the joint or just near the joint between the slab and the wall. The surface of control areas has to be determined following the situation on site.



Installation of the waterproofing system

Waterproofing with working space

Lining of the bottom slab

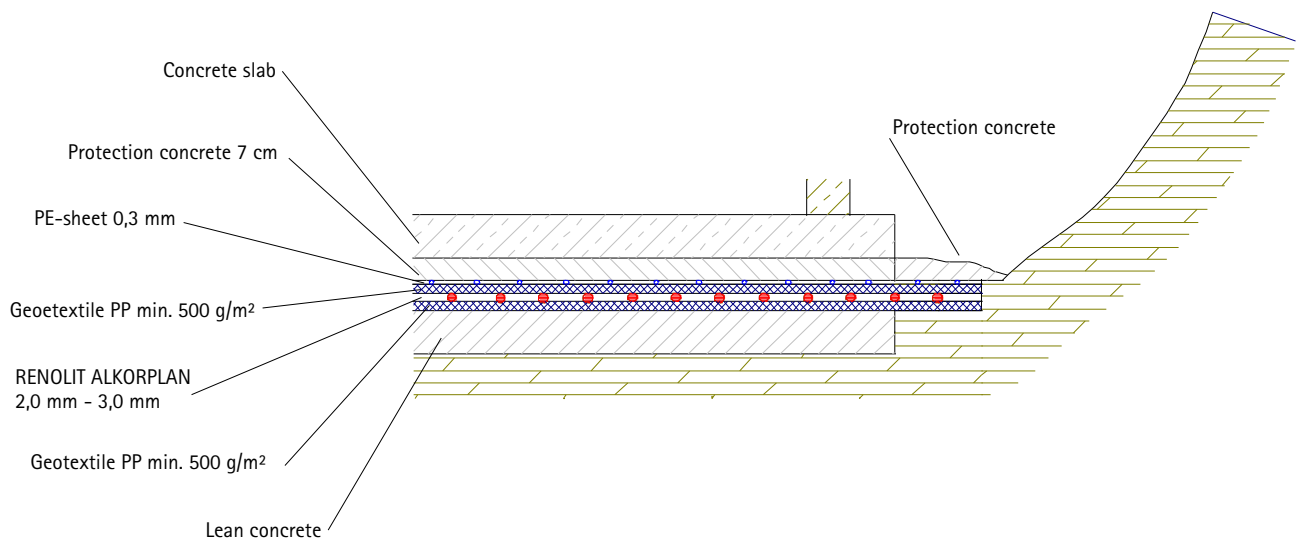
Once the lean concrete is poured, the lining system has to be installed, consisting of:

- Geotextile PP minimum 500 g/m²,
- Geomembrane of PVC in a thickness, of at least 2,0mm
- Protection layer which can be a PVC sheet of 1,5 mm to 2,0 mm (RENOLIT ALKORPLAN 35020) or a geotextile of minimum 500 g/m².

It is absolutely recommended to put a PE-sheet on top of the geotextile in case this material is chosen as a protection layer, to achieve a gliding between the lean concrete and the concrete slab. Besides the PE sheet avoids the penetration of liquid cement into the geotextile.

This protection layer is installed outside the water stops (if any), which must remain free.

- At the end a last layer of protective concrete has to be poured. In case of using water stops the concrete should not be poured over them, otherwise the compartment system will not work.



Waterproofing of bottom slab with working space

Lining between Slab and Wall

The lining system is over passing the concrete slab on each side, in order to connect the waterproofing system of the wall. The waterproofing system - over passing the bottom slab - has to be protected (e.g. porous concrete) until the walls are constructed. Depending on the height of the wall, it will be constructed in successive steps. After finishing the concrete works of the wall (first section), the protective concrete (shown in the drawing above) will be removed, the connection between waterproofing system slab and wall can be executed.

A very sensitive point for the lining is the change from horizontal slab to vertical wall. Local pressures at the corners mean serious stress; therefore it is very important to work on these areas with great care.



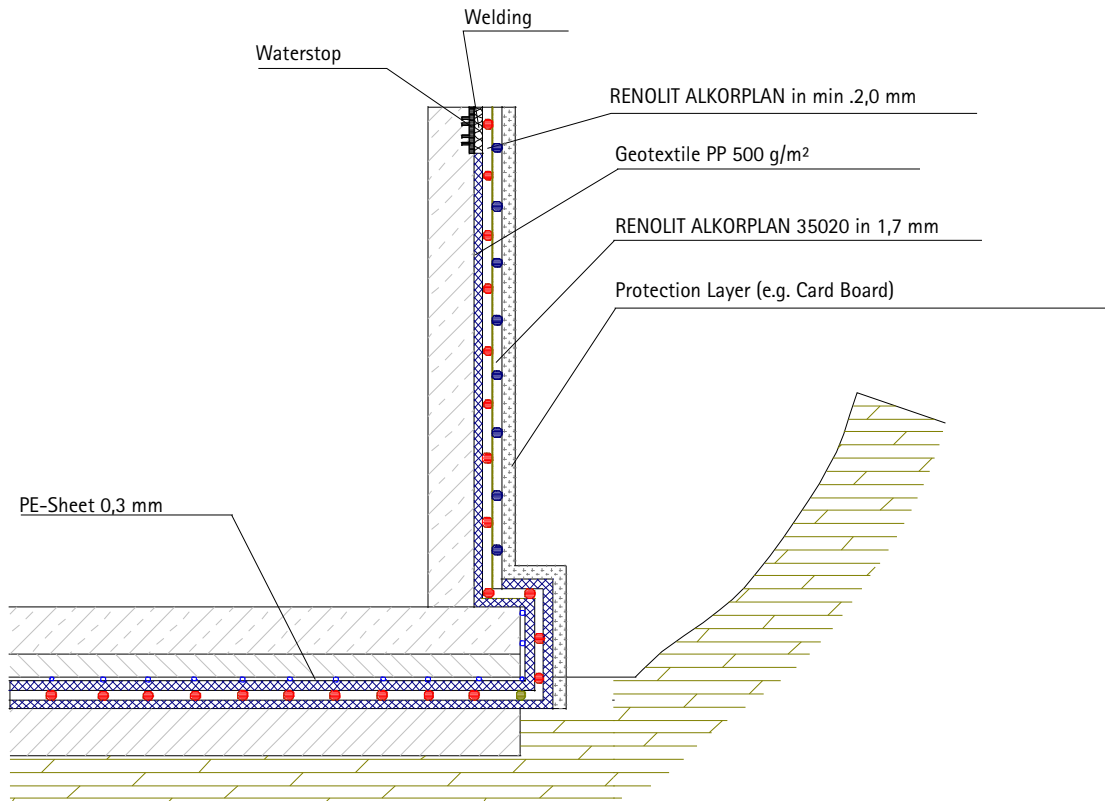
Lining of Vertical Faces

The fixation on top of the wall can be done in different ways. There is the possibility of placing a water stop into the upper side of the shuttering. After the concreting the shuttering is removed, the water stop cleaned and the membrane welded to the water stop. This is for sure a good technical solution and creates in addition a compartment system.

In case the backfill follows the concrete works of each wall section the waterproofing will be fixed temporarily.

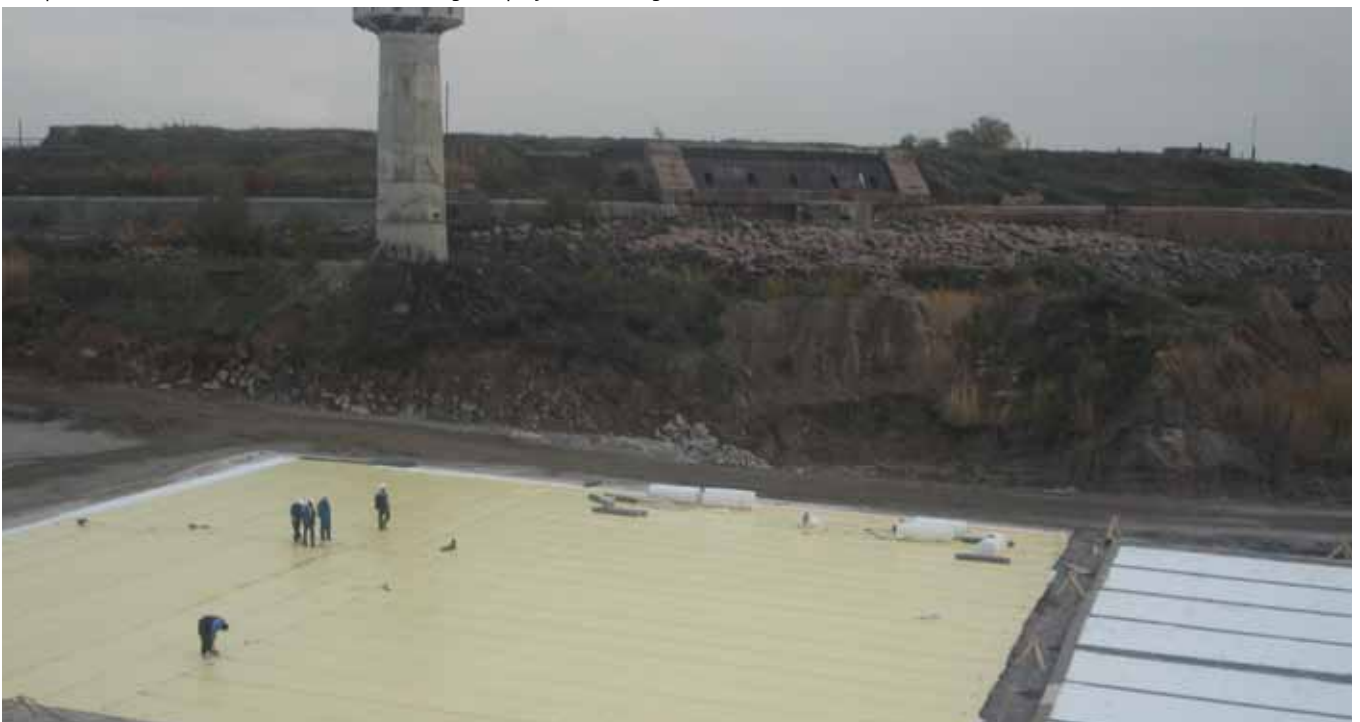
To continue the waterproofing work, the backfill is brought to the desired height and the concrete of the next section of wall is executed. After the shuttering of this section is removed the waterproofing follows. The temporary fixation underneath will be removed and the geomembrane welded to the fixation to guarantee water tightness.

This procedure will continue until the projected work has been finished. The final fixation on the highest level can then be done with the help of a water stop or a mechanical fixation.



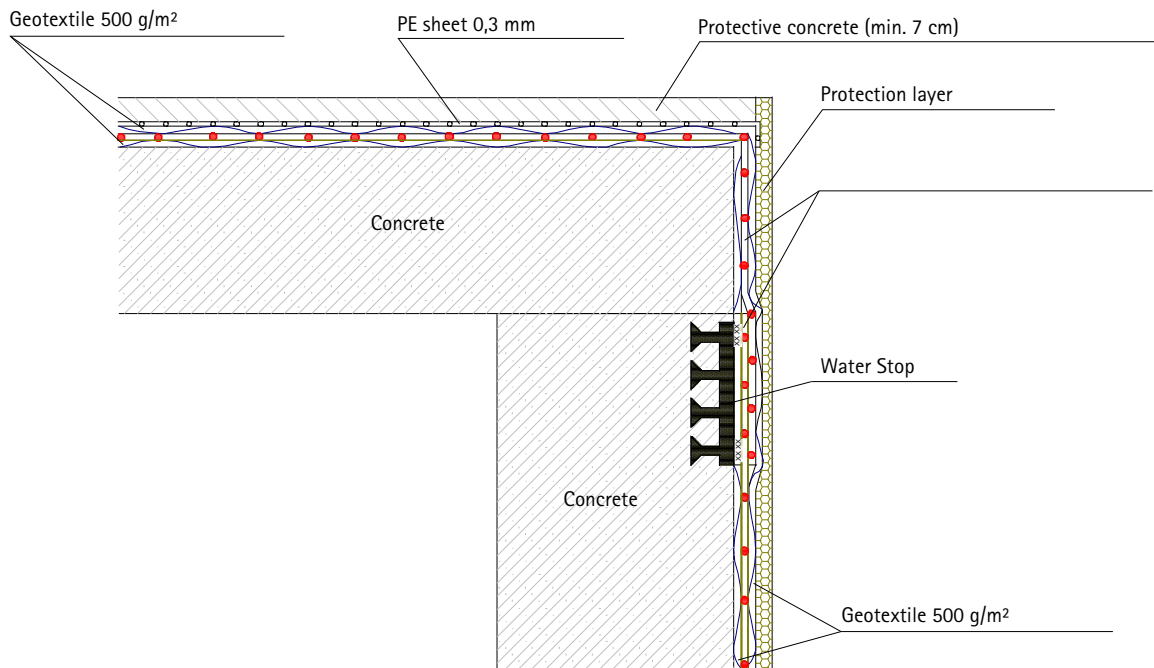
Waterproofing of the wall

This procedure of work will continue till reaching the projected ending.



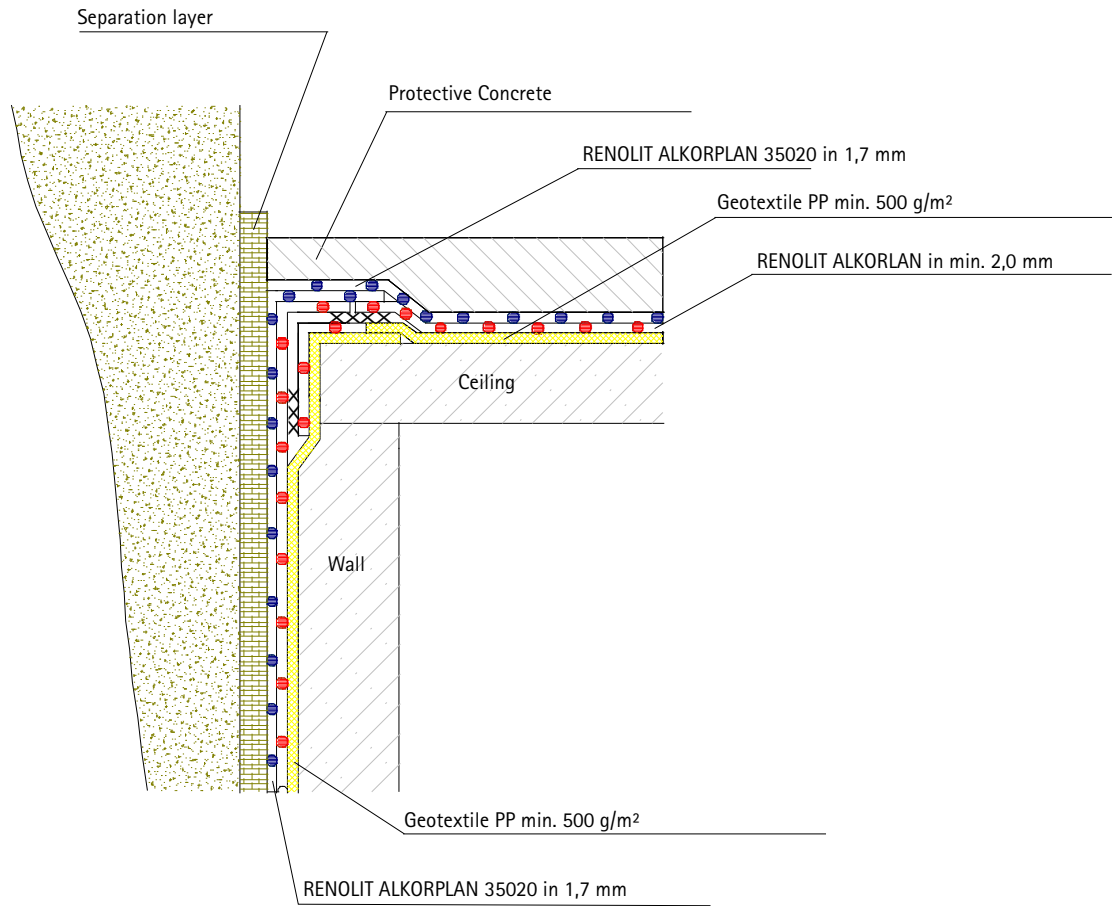
Waterproofing of the ceiling

The joint between wall and ceiling can be executed in different ways. A technical good solution is to use a water stop to fix the geomembrane to the wall and make there the joint for the horizontal lining of the ceiling slab.



The surface of the ceiling has to be clean and free of debris and stones, without holes. The system of waterproofing is identical to the raft.





Connection Wall Ceiling Slab
With working space



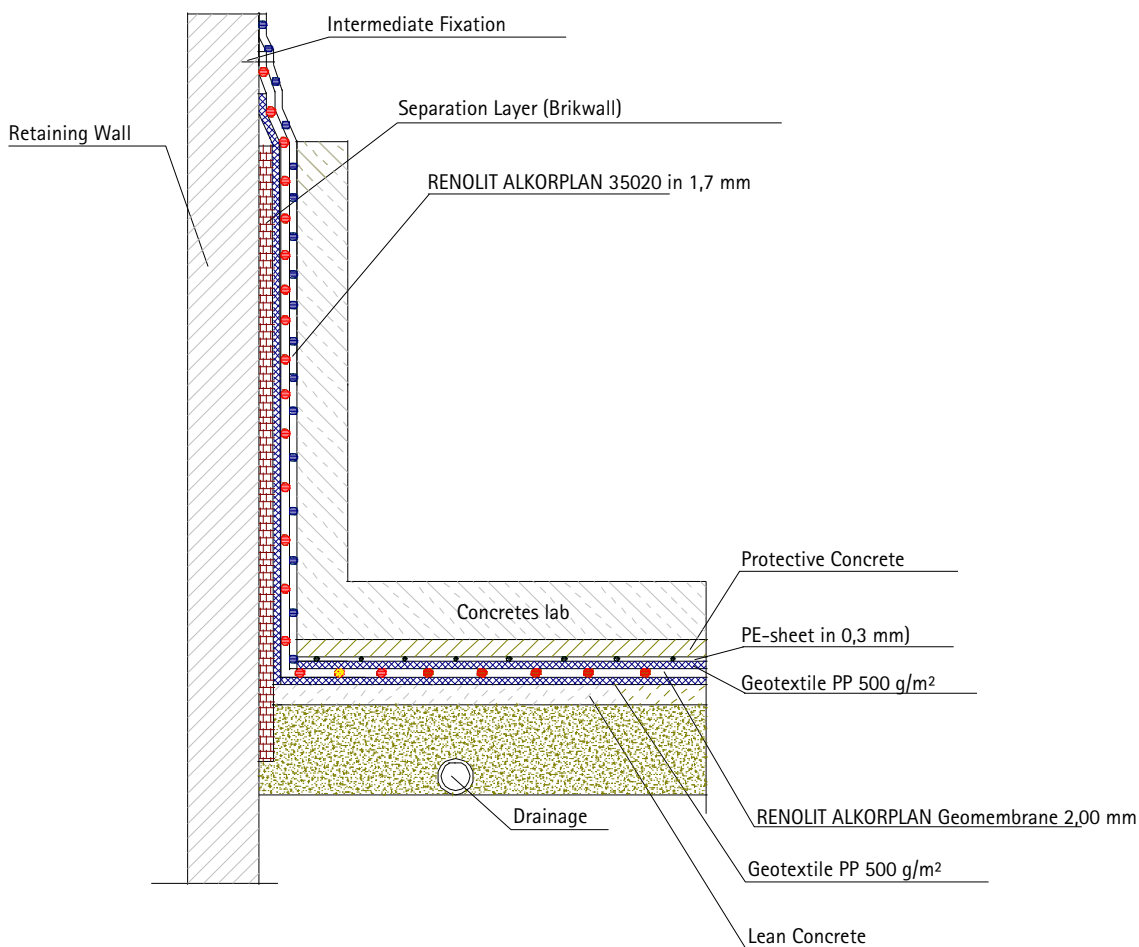
Waterproofing without working space

Waterproofing of the raft

The execution of the waterproofing of the bottom slab without working space is similar to the one with working space, besides the connection point for the wall lining. The waterproofing has to be fixed temporary to the retaining wall at a specific height to guarantee a safe connection with the waterproofing of the wall. The temporary fixation has to be removed before continuing with the concreting of the vertical faces. A geotextile has to be placed between the retaining wall and the geomembrane.

Lining of Vertical Faces

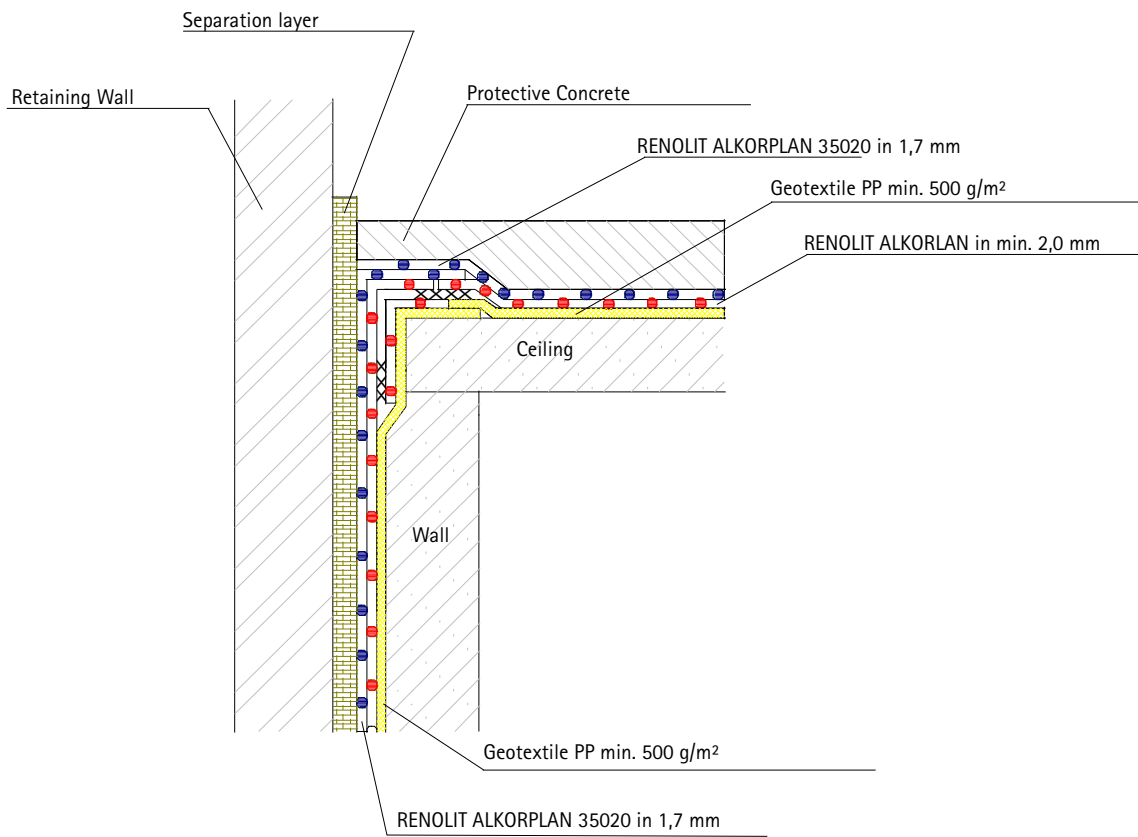
The waterproofing works are carried out before the concrete works of the walls. The waterproofing has to be brought to the height over the next concrete section of the walls and fixed temporary over this level on the retaining wall. When the lining works continue, the temporary fixation is removed, the next part of the lining system welded to the installed membrane and placed over the vertical surface of the next section. If the construction continues in this way, the described method will be repeated.



Intermediate Fixation of the Lining System

Waterproofing of the ceiling slab

The surface of the ceiling has to be clean and free of debris and stones, without holes.
The system of the waterproofing is identical to the raft.



Connection Wall Ceiling Slab
Without working space



Compartment system

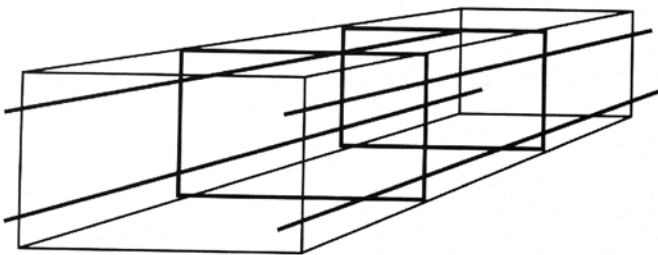
This system helps to limit the repair works in case of damage. The water stop, welded to the geomembrane, divides the lining system into compartments which limit the spreading of the infiltrating water. The surface of one compartment should not overcome 100 m².

The anchors of the water stop have to be well embedded into the concrete in order to stop any spreading from one compartment to the other.

The PVC water stops are welded to the geomembrane (with welding automate for horizontal surfaces).

Through these compartments the area of leakage can be determined precisely to a certain limited surface. In combination with an injection system, a repair of a leaking compartment can be carried out without damaging the geomembrane, which also keeps the cost at a reasonable level.

Depending on the joints (working joints or dilatation joints) an external water stop or an expansion water stop has to be used.



Scheme of compartments in cut and cover tunnel



Water stop installed

Materials

Geomembrane

The choice of the geomembrane should be done following the task the geomembrane should fulfil (PVC, PP or PE).

PVC Geomembranes are the most suitable material for the waterproofing of tunnels and foundations due to their excellent mechanical performance and their good chemical resistance.

During the past 40 years all kind of PVC geomembranes have been made, and in view of the existing standards in Europe two types have finally conquered this difficult market.

In the German spoken countries the "signal layer" geomembrane (bicolour) entered all important standards.

In France and other Mediterranean countries the translucent geomembrane was the convincing one as the suitable material for this important sector as a waterproofing material.

System with signal layer

The target of the "signal layer" geomembrane is to detect failures and leakages through a very thin signal layer. The signal layer should be a bright coloured thin upper-layer (less than 0,2 mm in DS 853) so that the dark colour of the geomembrane underneath can be seen in case of any mechanical impact to the material. The signal layer geomembrane can be produced in two ways :

- by calendaring a 0.2mm thin signal layer to be laminated with the geomembrane;
- by printing.



Double seam welding with translucent geomembrane

Translucent system

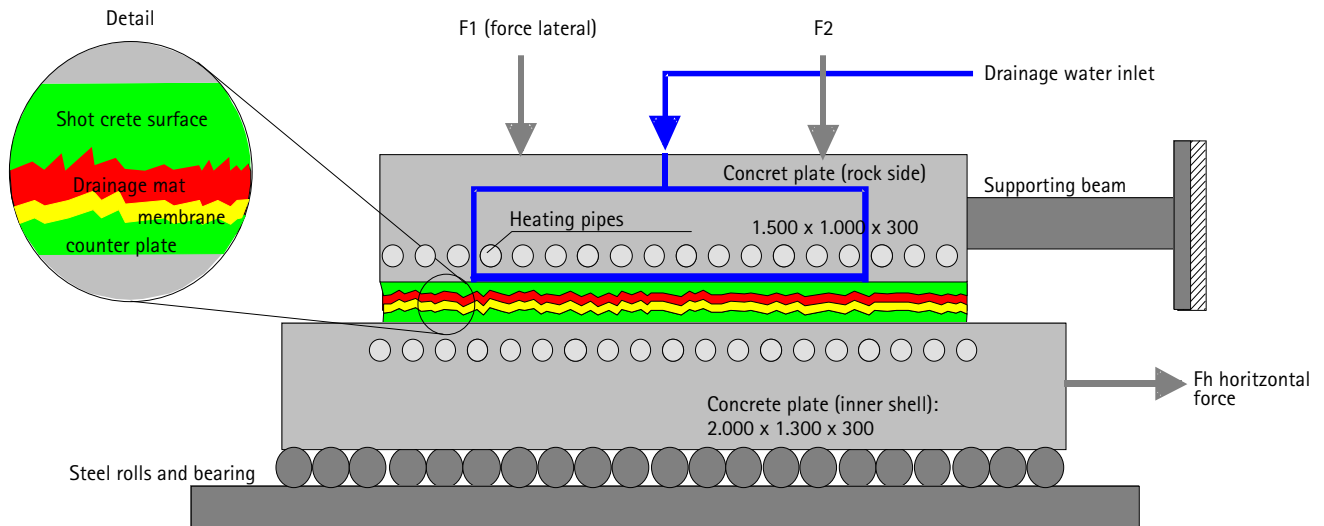
The use of a translucent geomembrane allows a very good visual control of the welding (continuity + burning).

This picture shows visually that the welding is of good quality as the welding is more translucent than the area of the testing canal, but the black traces at the beginning of the welding show that the temperature was either very high, or the hot wedge not properly cleaned. In such a case a special investigation of the quality of welding in this area can be done immediately. With an opaque geomembrane such defaults never would appear.

The double welding can be controlled with air pressure as well as with coloured liquids. The advantage of this method is to detect immediately the place of failure of the welding.

Resistance of RENOLIT ALKORPLAN PVC geomembrane under pressure:

- Intense tests for the St. Gotthard tunnel in Switzerland (Project of NEAT) showed the high shear/compression resistance of translucent PVC membrane RENOLIT ALKORPLAN (type 35036 2mm thick), even under high pressure:
- Load of 2Mpa
- Horizontal movement of 3mm
- INTENSE TEST FOT THE ST GOTTTHARD
- SZZ
- CETE



Source : The Sealing of Deep-seated Swiss Alpine Railway Tunnels – New Evaluation
Procedure for Waterproofing Systems – NEAT AlpTransit

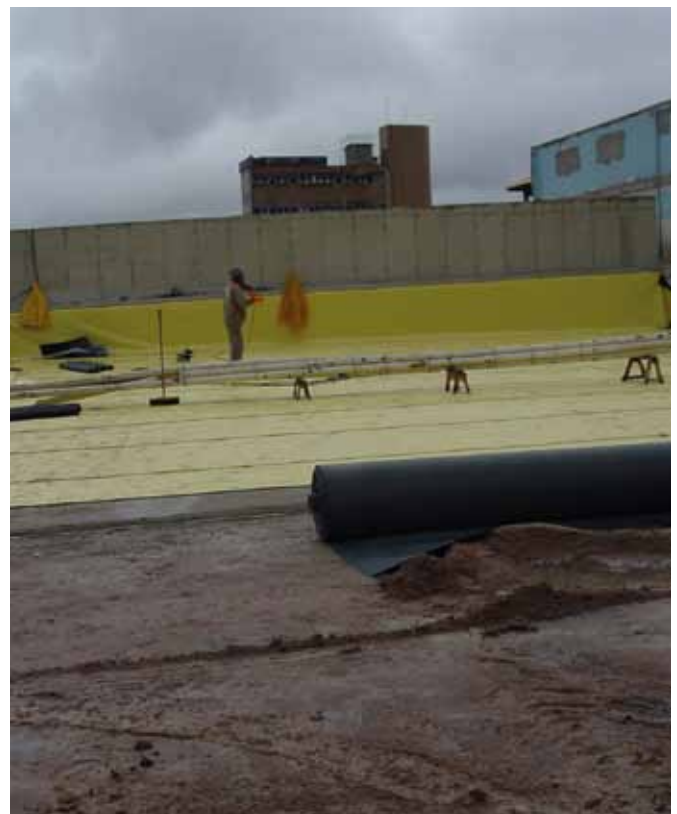
Figure7: Schematic cross-section of the compression/shear set-up with heating and drainage capability, the top plate (fixed) corresponds to the shotcrete surface of the outer tunnel shell

- The German laboratory SKZ showed that the translucent PVC geomembrane RENOLIT ALKORPLAN 35041 2mm thick had an excellent behavior under pressure (EN ISO 604):
- Compressive stress, at 20% compression, is 13.3 MPa, when a minimum of 2.5 MPa is required;
- Compression, at 2.5 MPa compressive stress, is 7.5%, when a maximum of 20% is required.
- The French Institute CETE showed that the waterproofing system composed by a geotextile 700g/m² + geomembrane RENOLIT ALKORPLAN 35036 2mm + protection layer RENOLIT ALKORPLAN 35020 1.9mm offers a dynamic puncture resistance higher than 8.5J (fascicule 67 titre III of C.C.T.G.)

Geotextile

Product

The geotextile has to be of Polypropylene fibers, short fibers mechanically fixed or long fibers. Polyester geotextile has to be avoided because of hydrolysis of polyester due to the alkalinity of concrete. The freshly applied concrete attacks the Polyester geotextile and after a certain time the geotextile dissolves completely.



Normal water stop

Water stops

It is recommendable to use water stops with integrated injection tube as it is important to assure the water tightness in the joints. They are used between concrete sections.

Water stop for Expansion joint

This water stop is placed in all dilatations of the construction. In case of important movements of the construction the middle bulb is able to break in the thin part on the bottom to follow the movements without losing water tightness.

Injection devices

In addition to the water stops, injection devices are welded at specific spots to the geomembrane. The task of the injection devices is to provide the possibility of injecting liquid waterproofing materials in order to close the leakage of the geomembrane. These liquids or resins are based mainly on two components acrylate or polyurethane. The injection devices go through the concrete shell and are always reachable in case of a failure of the waterproofing system.

The injection work is a difficult task and has to be carried out by experts. The injection resin has to be pressed through the injection pipes between geomembrane and inside concrete. The mixuter of the two resin components is very important as on the one hand it has to stay liquid long enough to be able to spread over the whole surface of the compartment and on the other hand it has to harden quickly so it does not leak out by the infiltrating water.

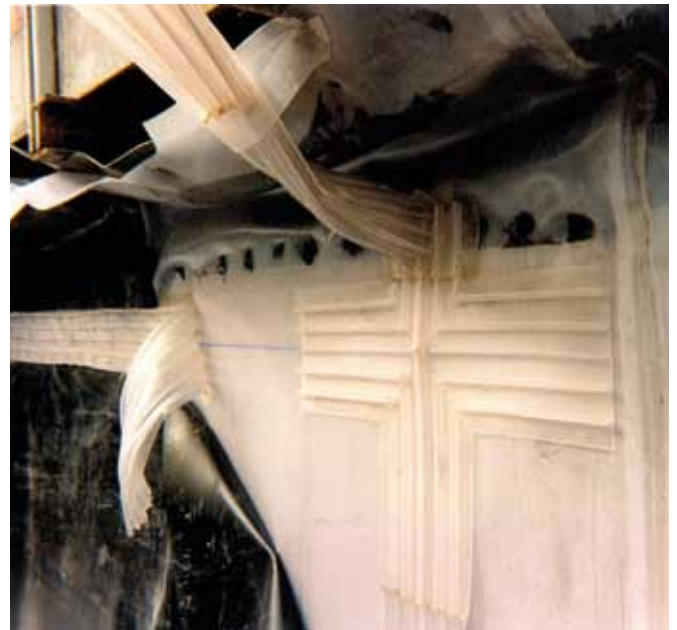
Two different injection systems are available:

- injection pipe
- injection tube

Injection pipe

The injection pipe is a hose on which a PVC tube will be welded through THF. One has to ensure that the tube can resist a pressure of at least 6 to 8 bars. No metallic device will be used to avoid the danger of perforating the geomembranes.

The exit piece of the injection pipe has to be integrated into a safe device of the surface of the concrete



Protected inlet of Injection Pipe

Injection tube

Alternative injection device: injection tubes spot welded to the geomembrane that open when the resin is injected under pressure.



Injection tube welded to geomembrane





Welding tools

Automatic hot wedge welding machine

This kind of machine works with an electric heated wedge. Above and underneath the wedge there are two pressure rolls which are both independently motorized. The hot wedge is guided between the overlapped geomembranes; the two pressure rolls advance the machine at a determined speed. Temperature, pressure and speed are adjusted before executing the final welding.

The machine is completely electronically guided. By changing In case the outside temperature is changing the electronic guidance adjusts to the temperature following the conditions. Tests have shown that welding executed with a hot wedge machine deliver nearly 100 % good result.



Automatic hot wedge welding machine



Automatic hot air welding machine

Automatic hot air welding machine

The machine is a combination of hot wedge / hot air automatic welding machine.

The hot air temperature, the pressure, and the speed of welding are adjustable in step less way and are electronically controlled.

Hand welder

The hand welder works with hot air and is indispensable for underground projects. All details have to be done with this well known device.



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