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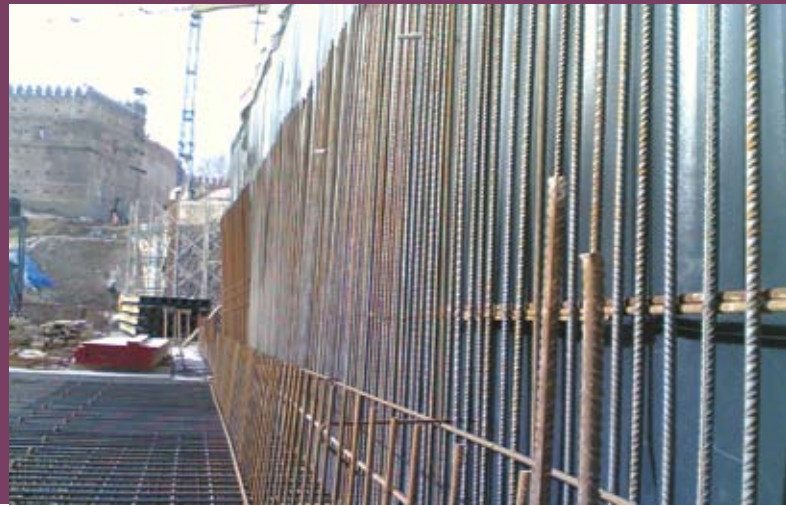
Waterproofing of foundation

RENOLIT ALKORGEO

Underground
structures

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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 foundations 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 35020.

Concept 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/ RENOLIT ALKORPLAN 35020 in 1,7 mm
- PE sheet of 0,25 mm as gliding layer
- Protective concrete

As a control and repair system water stops and injection pipes are installed.

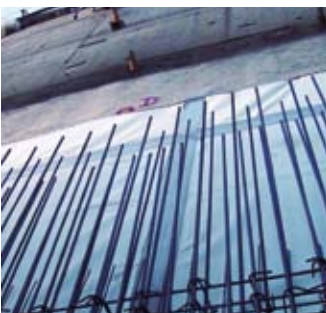
The surface of the control areas should not be larger than 100 m² of the foundation slab.

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 of slab and wall. The surface of the control areas has to be determined following the situation on site.

Installation of the waterproofing system

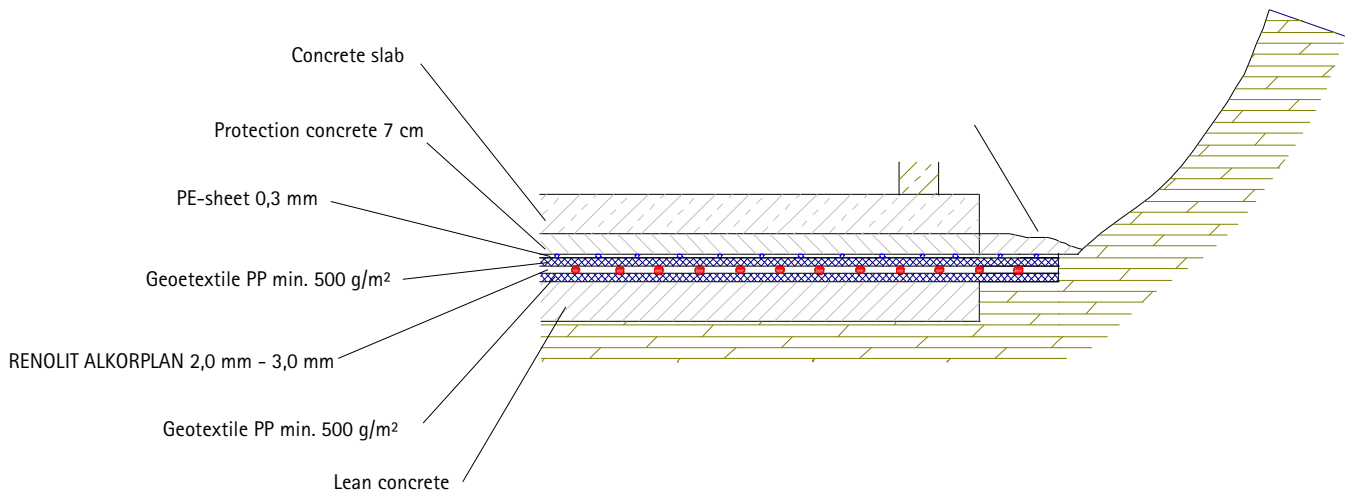
Waterproofing with working space

Lining of the bottom slab

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

- Geotextile PP minimum 500 g/m²,
 - Geomembrane of PVC of a thickness, of at least 1.5 mm
 - 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.





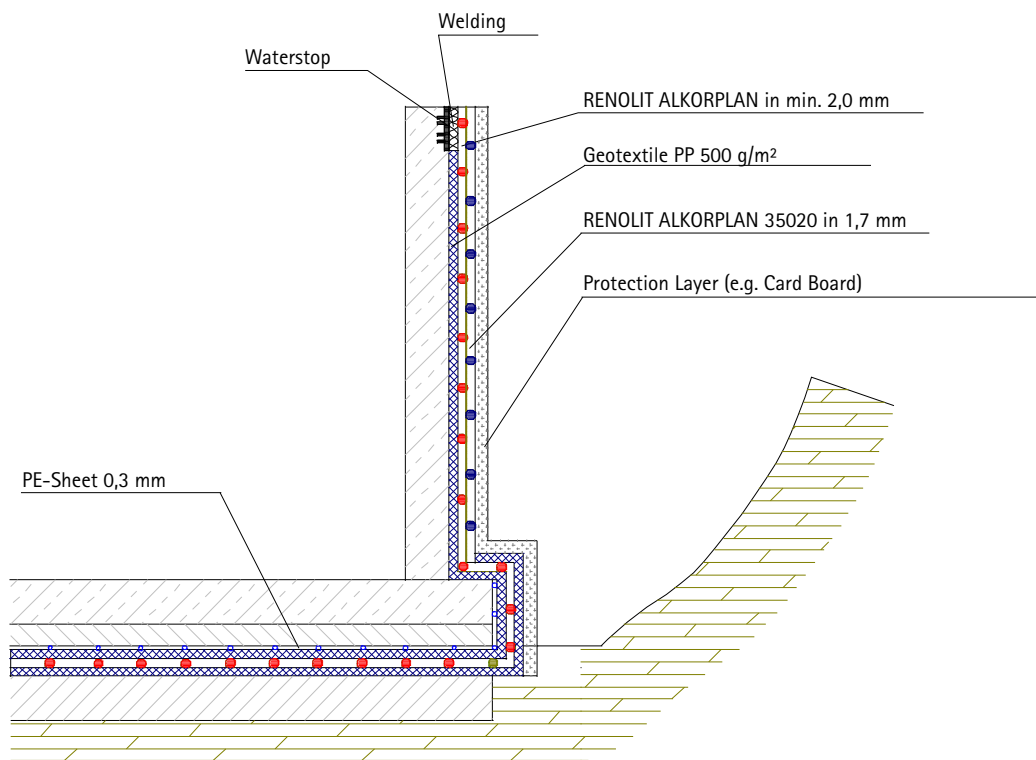
Waterproofing of bottom slab with working space

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 its height, the vertical wall will be constructed in stages.

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 the 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 place the lining with great care.



Lining between Slab and Wall with working space

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 without working space

Lining of the Bottom Slab

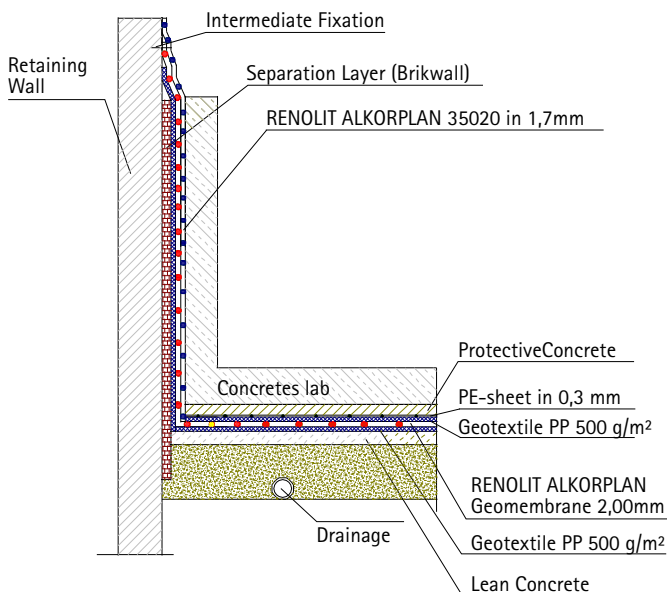
The execution of the waterproofing of the bottom slab without working space is similar to the one with working space, besides the connection point for the wall lining. The waterproofing has to be fixed temporary to the retaining wall at a specific height (minimum 30 cm) to guarantee a safe connection 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 of the next concrete section of the walls and fixed intermediate 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 (Sketch without water stops).



Intermediat Fixation of the Lining System



Protected Slab with exposed Water Stops

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 limits the spreading of the infiltrating water. The surface of one compartment should not be greater than 100 m².

The anchors of the water stop have to be well embedded into the concrete in order to stop the water from 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 leakage area can be precisely determined to a certain limited surface.

In combination with an injection system, the repair of a leaking compartment can be carried out without damaging the geomembrane as well as keeping 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.



Execution of lining system with water stops

Double Layer System for special Applications

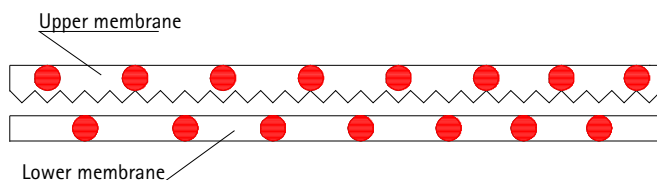
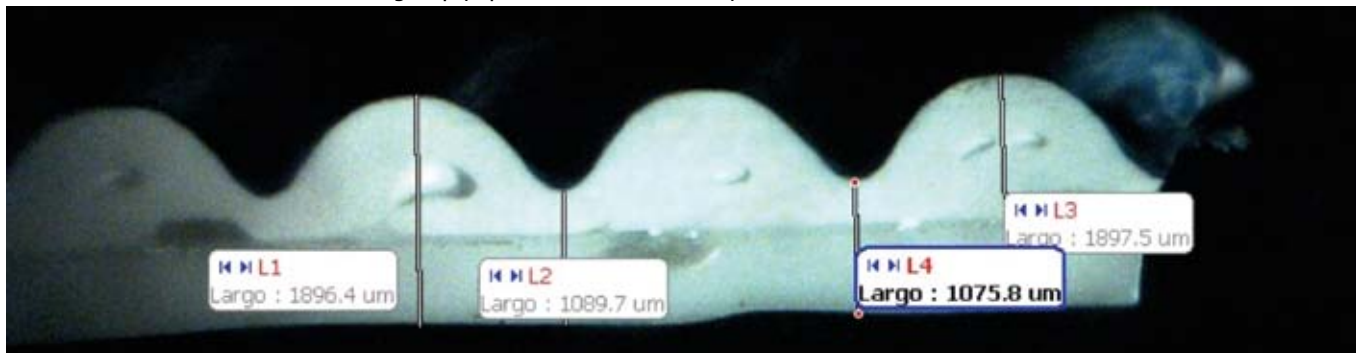
Constructions in high pressure ground water need very secure waterproofing. Such buildings can be nuclear power stations, hospitals, storing isotope materials, banks with safes, park decks and also tunnels at important depths.

For such buildings a single layer waterproofing might not be sufficient as it has to be taken into consideration that the waterproofing membrane could be damaged during the reinforcement and concrete works.

Therefore a controllable and repairable waterproofing system should be applied in such cases.

A possible controllable and repairable waterproofing system is the double layer system. A common and a structured geomembrane are placed one over the other, and they are welded together on all sides to create a closed compartment. Vacuum of each compartment controls its waterproofing. A structured geomembrane allows having space between the two layers. In case of a failure in one of the geomembranes the vacuum will break down. Due to the structured geomembrane the injection material for repair can distribute easily over the whole surface between the 2 layers.

Picture of structured membrane allowing empty space between the two layers



System of Double Layer with structured geomembrane

Advantages:

- By using two layers of geomembrane the risk of damage is highly reduced. In case of damage, in most cases only one layer will be affected which means that there is still one remaining layer left which is fully functioning.
- In the worst case where both geomembranes are damaged there is still the possibility of repair through the injection system with liquid waterproofing material (PU, Acrylic).
- The injection pipes allow in one hand to control the waterproofing of the double layer system (vacuum), and, in the other hand, to repair it without destroying the concrete (injection).



Control and Injection system:

This system helps to control the quality of welding and to detect leakages. At the same time it can be used as a repair system.

The injection pipe can have different forms depending on the product. A small hole is cut into the upper geomembrane and the injection pipe welded onto. Injection pipes can be welded to the elements already during prefabrication but also on site – depending on the structure that will be lined.

When such systems are applied in tunnels it is recommended to install the injection pipes during prefabrication, then the vacuum test has to be executed to control all weldings. In case one welding is not correct it will not be possible to create the vacuum.

Due to the vacuum, both geomembranes stick together and the elements can be installed to the vault as a single layer system. On site the injection tubes are welded to the injection pipe by THF.

Connection of the prefabricated elements on site.

The prefabricated elements are placed into the correct position on site and welded together. All weldings on site, apart from the details should be welded with a welding automate.

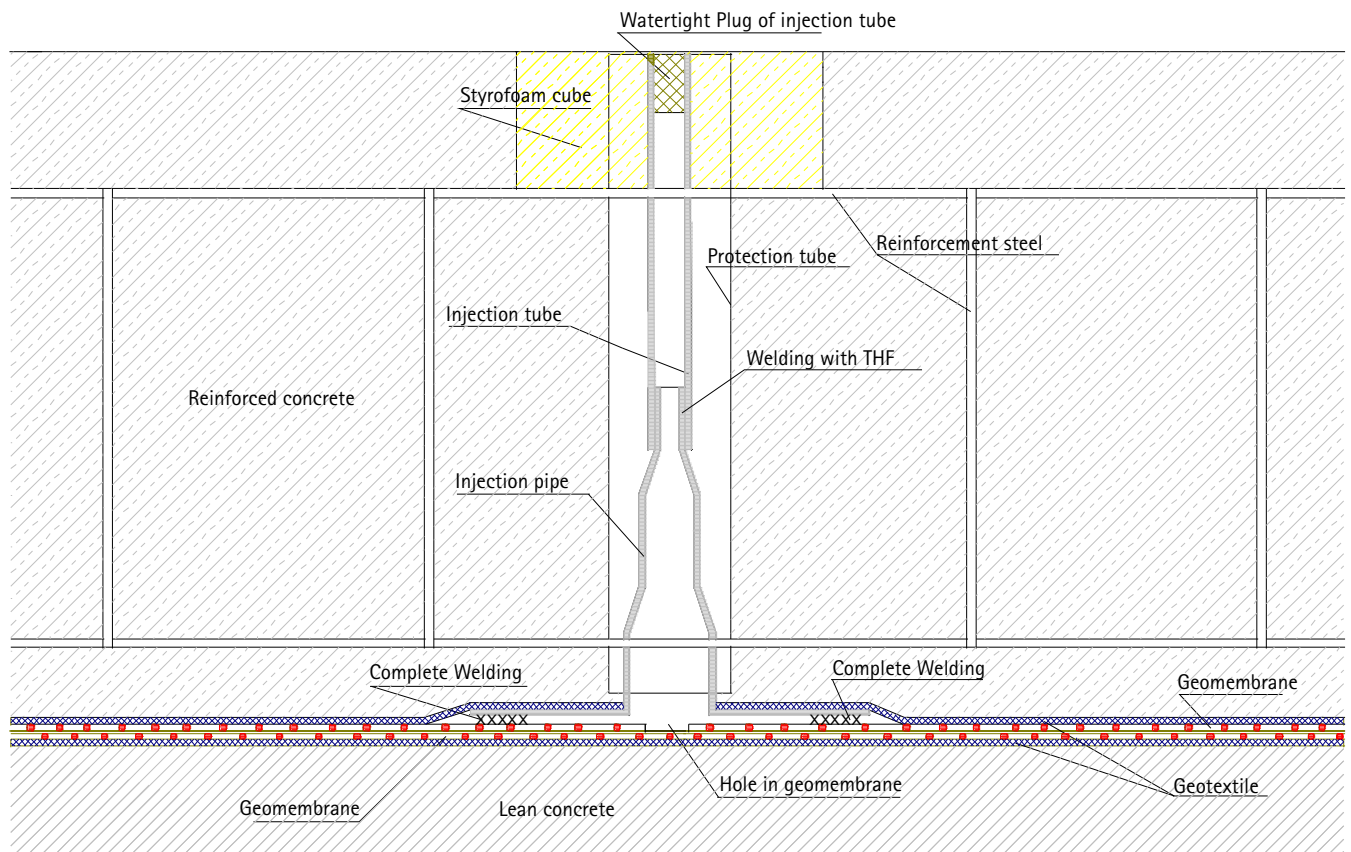
Repair

In case of a fault the vacuum of the prefabricated element will break down. It can happen when only one layer of the 2 geomembranes is damaged or if a welding is incorrect. With the injection pipes it can be controlled which of the 2 layers is damaged as water will appear through the injection tubes.

In case of leakage in the upperlayer, no water will enter but the vacuum will break down. That means the waterproofing is still working but only with one layer of geomembrane and therefore there is no reason to make any repairs.

If both layers are damaged the space between the two layers of geomembrane has to be injected. The repair in general is done by injecting acrylic, PU or water tightening cement.

The injection work has to be carried out by a specialist as it is a very sensitive work. The ideal mixture (viscosity), the force of pressure and the speed of the injection has to be coordinated carefully. On the one hand the injection material has to flow easily through the whole space between the 2 layers of membrane to fill the damage, and on the other hand it should not be too liquid in order to be washed out by incoming water. The viscosity of the injection material has to be determined with great precision.



Injection system for double laid Waterproofing

Materials

Geomembrane

The choice of the geomembrane depends on the task the geomembrane needs to 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 kinds of PVC geomembranes have been created and seen the existing standards in Europe two types 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 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 :

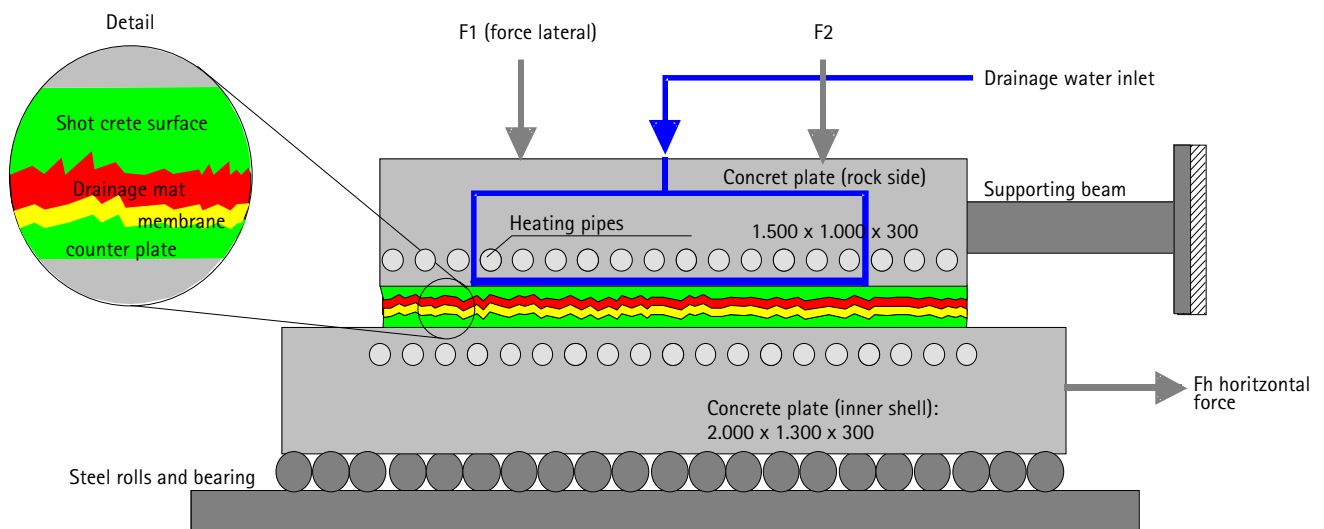
- by calendaring a 0.2mm thin signal layer to be laminated with the geomembrane;
- by printing.

Translucent system

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

This picture shows 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 very high, or the hot wedge not properly cleaned. In such case a special investigation of the welding quality in this area can be done immediately. With an opaque geomembrane such defaults would never 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 the welding failure.



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

ref : The Sealing of Deep-seated Swiss Alpine Railway Tunnels
New Evaluation Procedure for Waterproofing Systems
P. Flüeler, Ch. Löwe, M. Farshad, P. Zwicky, H. Böhni

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
- The German laboratory SKZ showed that the PVC signal layer geomembrane RENOLIT ALKORPLAN (type 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 of a geotextile 700g/m² + geomembrane 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 dissolved completely.

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.



Injection devices

In addition to the water stops, injection devices are welded at specific points to the geomembrane. The task of the injection devices is to provide the possibility to inject liquid waterproofing materials in order to close an eventual leakage of the geomembrane. These liquids or resins are based mostly on two components acrylic or polyurethane. The injection devices go through the concrete shell and are always reachable in case the waterproofing system fails.

Injection pipe

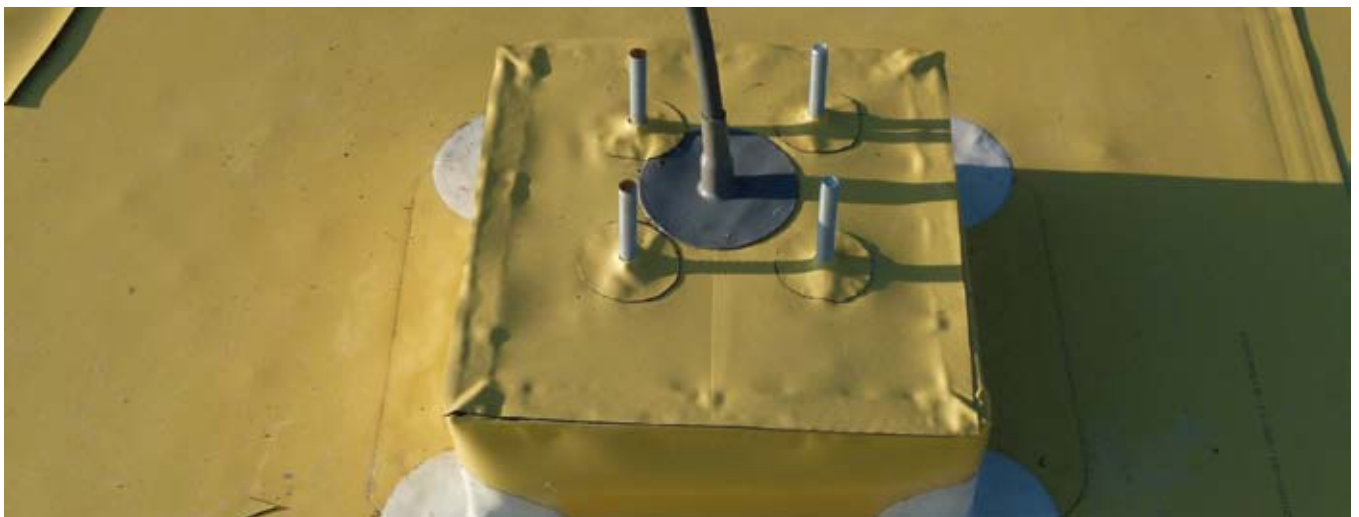
The injection pipe is a hose on which a PVC tube will be welded through THF. One has to ensure that the tube can resist a pressure of at least 6 to 8 bars. No metallic device will be used to avoid the danger of perforating the geomembranes. The exit piece of the injection pipe has to be integrated into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

Injection tube

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



Protected inlet of Injection Pipe



Welding tools

Automatic hot wedge welding machine

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

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



Automatic hot air welding machine

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

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

Hand welder

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

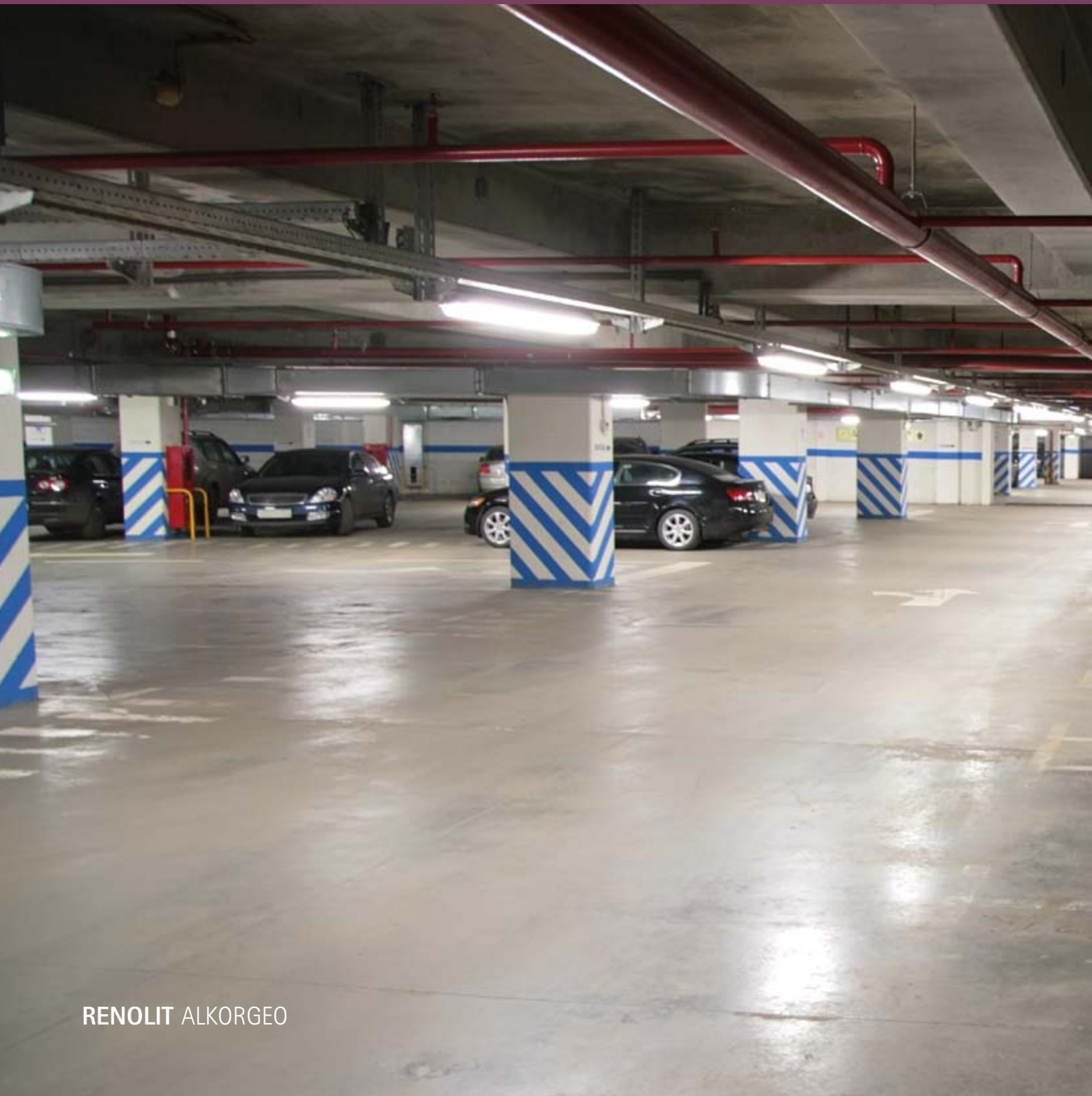




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