

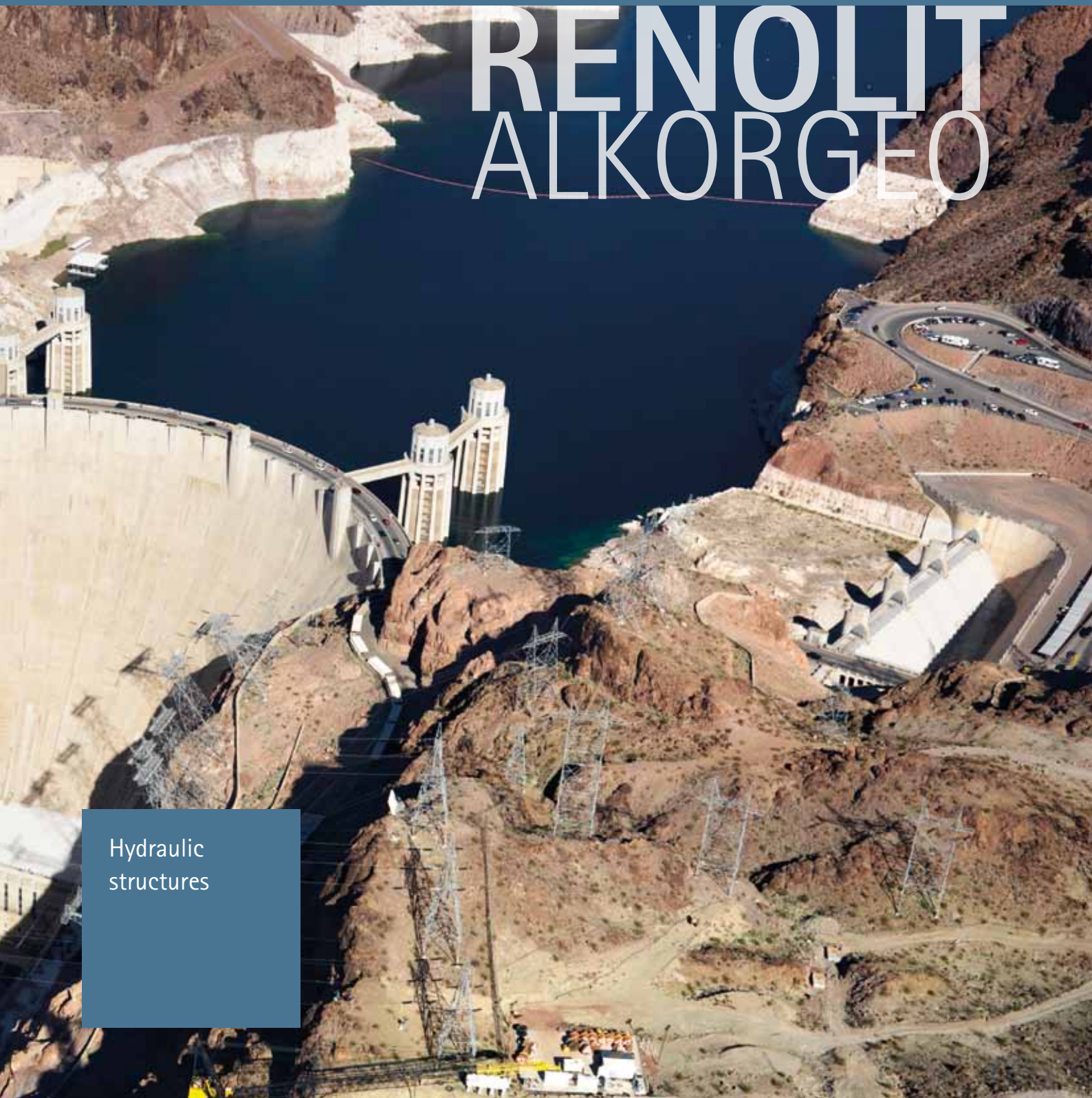


Rely on it.

Waterproofing of dams

RENOLIT ALKORGEO

Hydraulic
structures



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Hydraulic structures



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Geomembrane recommended

The RENOLIT Group has all kinds of different geomembranes, the right product for each application. The experiences of the past have shown that PVC is the most adapted product for the lining of dams, due to its mechanical characteristics, handling, resistance against UV-radiation and durability.

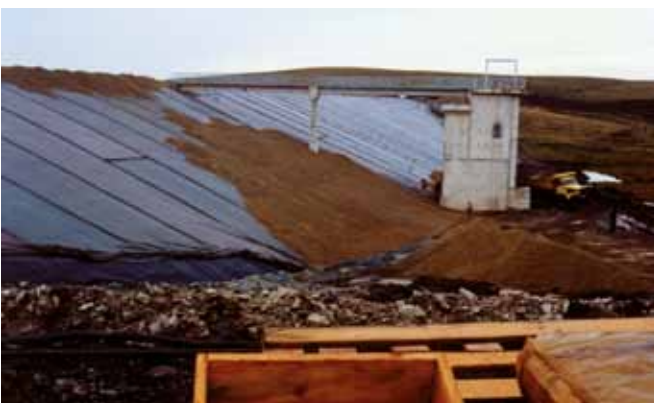
For dams, RENOLIT developed special Geocomposites RENOLIT ALKORPLAN 35254, up to 5mm thick, laminated with geotextile PES or PP (until 700 g/m²), which can be reinforced with Glass or Polyester (technical data sheet available on request).

Concept of the waterproofing system

It is necessary to study the exact conditions under which the waterproofing system has to be installed and has to work. Different parameters can lead to a malfunction of the system. Therefore the geological and geo-technical conditions have to be investigated on site. After exactly determining the parameters of the soil and the sub grade the waterproofing system can be decided.

In general the waterproofing system consists of:

- Support
 - Drainage layer
 - Protection layer
 - Filter layer
- Waterproofing layer
- Protection
 - Synthetic protection
 - Mineral protection
 - Combination



Preparation of the Support

Before starting the installation of the waterproofing system, the subgrade has to be carefully prepared. The surface has to be smooth, without sharp stones, vegetation and well compacted to avoid settlements. The area should have a drainage system under the water proofing system to avoid negative pressure. This can also be effectively done with the help of drainage pipes which are embedded into the sub grade.

Old concrete dams have to be checked carefully and all damages have to be repaired with mortar.



Installation of the waterproofing system

The waterproofing system

Protection layer:

Geotextile of min. 500 g/m² made of Polypropylene or Polyester. It has to be of Polypropylene especially when the dam is new or repaired with mortar. The high pH value of cement destroys geotextiles of other qualities.

Waterproofing membrane:

The choice of the geomembrane should be done according to the task it is meant to fulfil (PVC, PP or PE)

Protection layer:

It is recommended to protect the waterproofing system. There are different influences that can damage the system, like waves, rapid emptying of the water, UV-radiation on the exposed part, vandalism, amongst others. Depending on the steepness of the slope this protective layer can be composed of mostly a combination of geotextile and a solid protective layer as Rip Rap, sand, shotcrete and or other (sometimes there is no exterior protection, in this case the geomembrane has to be specially formulated to safely resist the existing influences).

Installation of geotextile

The geotextile can be produced in different widths. Depending on the construction the width could be important. For large surfaces the maximum width (up to 8 m) should be used. It may be useful to combine 2 different widths in order to cover the whole project. It is difficult to cut the geotextile therefore some smaller rolls can lighten the work.



Placing of geotextile



Installation of the geomembrane

Prefabrication of panels

For large surfaces it is recommended to use large panels. This especially concerns PVC geomembrane which are produced in widths of 2,05 m. At the prefabrication stage any size can be produced.

The advantages of prefabrication are as follows:

- Quality of welding is very high as the conditions during prefabrication do not change.
- Reduction of cost compared to welding on site
- Reduction of working time as prefabrication can start before installation on site.
- Reduction of welding on site, therefore failure of welding on site is reduced.
- Reduction of testing time.

To be able to produce in prefabrication it is necessary that:

- engines on site are available to place the panels without destruction
- deploy an exact assembling plan following the conditions of the site.

The welding has to be executed by automatic welding machine. It is recommended to use a double welding machine in order to be able to control the welding with air pressure. In case of a simple welding seam it is recommended to control this with an iron pipe (opening about 3,0 mm) with air pressure.

The panels are folded in case of minor thickness of the geomembrane or rolled onto a large mandrin for more important thickness. To avoid destruction of the panels they have to be packed for transportation to the site.

Assembling of panels

The assembling is executed following the plan of installation. The prefabricated panels are numbered to help with the installation and also for clear identification of the panels.

In general the size of panels is between 200 m² to 1.000 m² depending on:

- Thickness of the geomembrane
- Means of manipulation in the prefabrication as well as on site
- Accessibility and configuration of site
- Way of folding of panels

For PP and PE in most cases it is not necessary to prefabricate panels as the production width can be superior to 5 m.

Installation on site

Placing of geomembrane

- The installation of the geomembrane of the prefabricated panels can only be executed if all work concerning the sub grade (layers of granulates, separation layers, drainage) are completely finished and approved by the responsible site engineer.
- The geomembranes are unrolled without tension and have to overlap. The overlap depends on the used welding machine (4cm to 10 cm). Machines creating a control channel demand an overlap between 8 cm to 10 cm. For extrusion welding an overlap of 4 cm is the limit.
- Outside temperature has to be taken into consideration. During periods of high temperature the elongation of the geomembrane can be important. In hot climates therefore it is recommended to execute the welding operation early in the morning when the geomembrane has cooled down during the night.

Thermal dilatation of different materials:

PVC-P: $\pm 1.0 \cdot 10^{-4}$ cm/cm/°C

(Displacement: 48 cm for 100 m and 50°C change)

HDPE: $\pm 2.4 \cdot 10^{-4}$ cm/cm/°C

(Displacement: 120 cm for 100 m and 50°C change)

Welding on site

The quality of welding depends on the following parameters:

- Cleanness of the welding area (cleaning with a dry and clean cloth)
- Good adjusting of the machine (temperature, speed and pressure)
- Qualification of personal.

The used machines are hot wedge or hot air machines. This type of machine is suitable for all kind of materials (PVC, PP, PE). Hand welding for the execution of details, connections at the ending of panels, based on hot air can only be applied with PVC and PP. Extrusion welding is the common technique for the execution of details for PE geomembranes

Action of wind

The geomembrane has to be ballasted after installation. Wind can displace and lift the panels. In general sand sacks or old tyres are used as ballasting material.

In case of a protected system it is recommended to execute the protection works after the complete control of the executed section.



Unrolling and placing of geomembrane

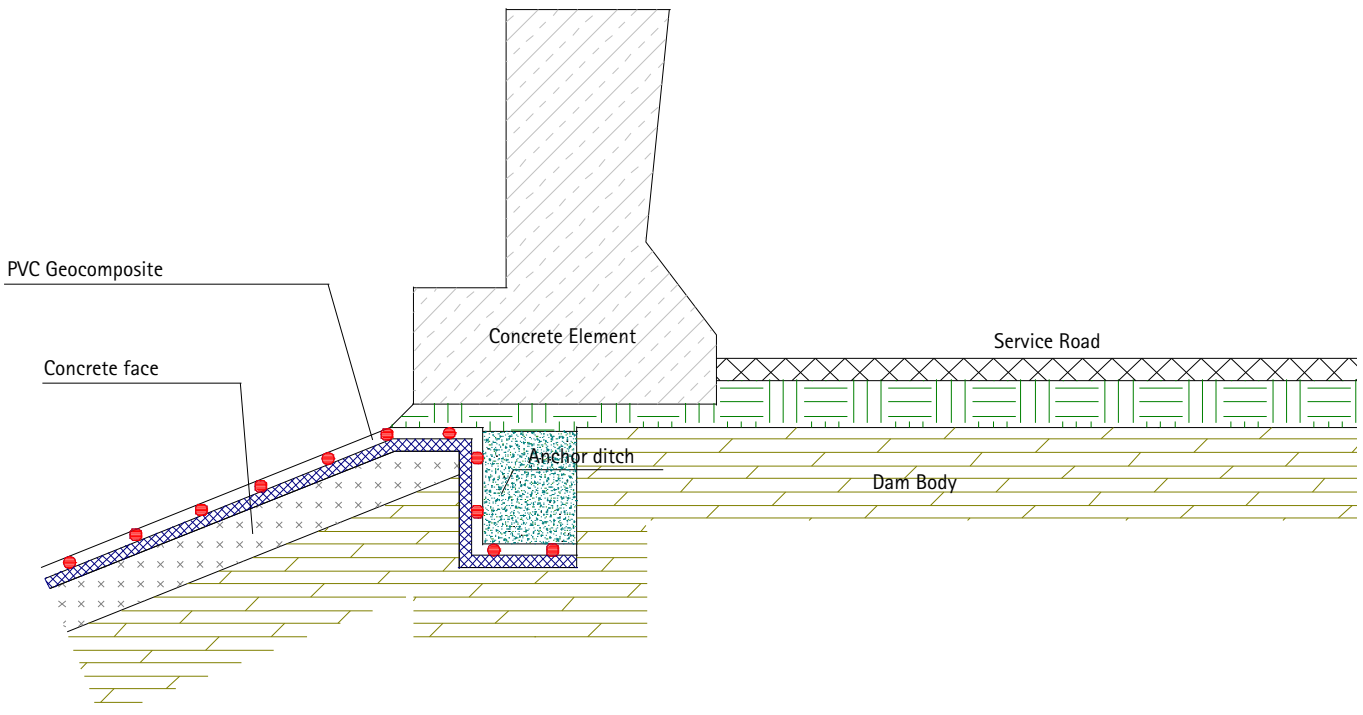


Welding with hot air and double seam

Fixation of the lining system on the crest of the dam

The waterproofing system has to be fixed in a secure way to the crest of the dam. Depending on the kind of system, this fixation carries the weight of the waterproofing system.

It is not always possible to use a ditch as an anchor. In the case of a service road very often concrete structures are used. In such a case a possible termination of the lining system could be executed as shown in the following drawing:



Crest Fixation of Waterproofing System

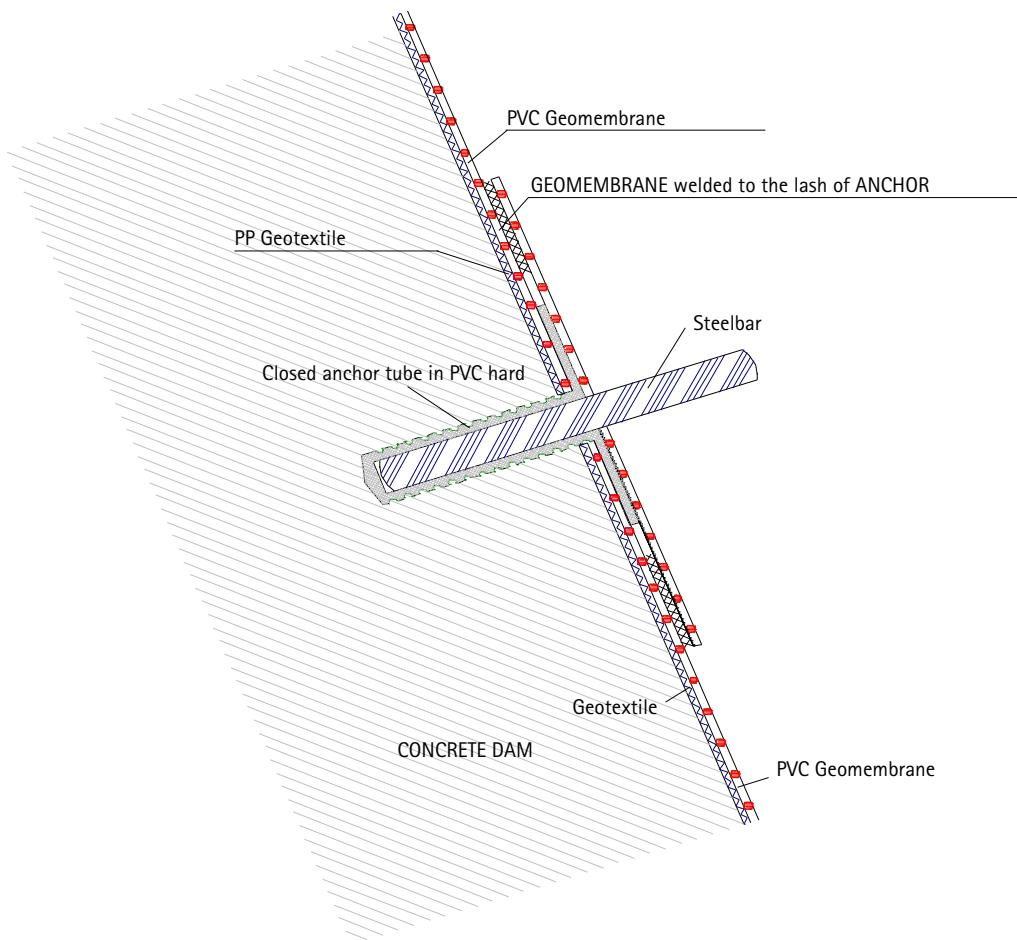
Intermediate fixation of the lining system

Depending on the technical characteristics of the dam (height, inclination of the slope, earth dam or concrete dam, protected or unprotected waterproofing system) it has to be determined if the geomembranes should be fixed intermediately or not.

On very high concrete dams, exposed to heavy influence of wind the geomembrane should be fixed to the underground. Due to the weight of the geomembrane it will elongate without fixation. Influence of high temperatures promotes such a phenomena and the initial thickness of the geomembrane will reduce. With the use of reinforced or fleece backed material this phenomena can be greatly avoided. In case of a homogeneous material an intermediate fixation is recommended.

In case of a protected system the geomembrane should be fixed in such a way to the dam that forces due to the weight of the protection do not have any influence on the geomembrane. This can be done with the help of anchors which are placed into the concrete. The geomembrane is welded to the flange of the anchor. In case of shotcrete protection, the reinforcement can be fixed to the steel bar of the anchor.





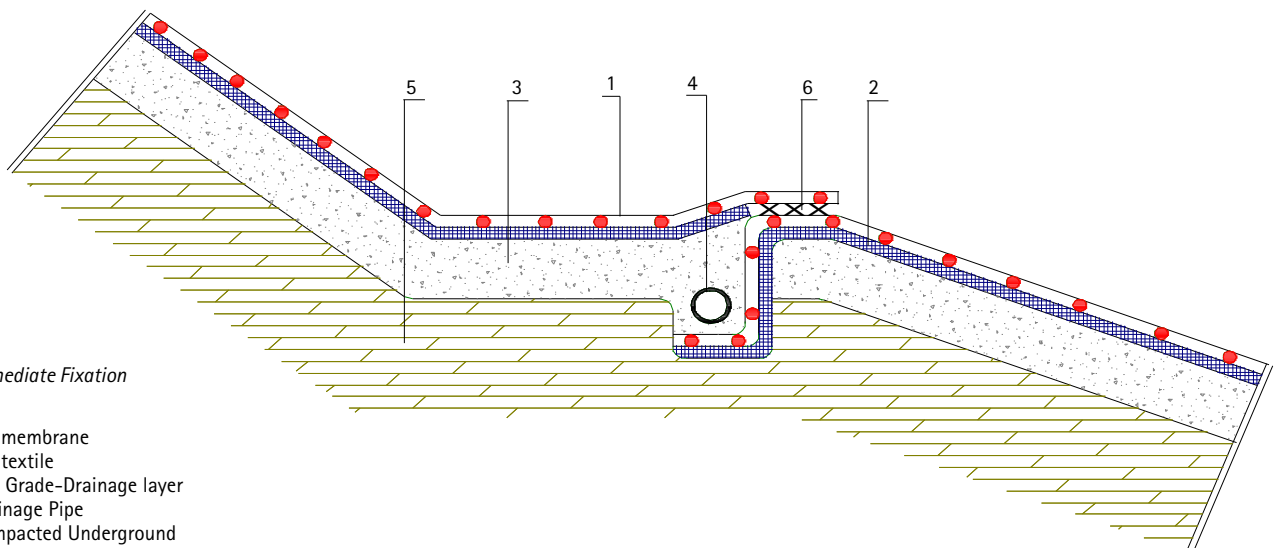
Intermediate fixation of geomembrane to the dam

It is also possible to use other technologies to achieve an intermediate fixation to the concrete dam, such as the use of fixation roundels or strips of laminated PVC metal sheets.

When using such fixations the geomembrane will no longer lay completely flat on the ground. Slight creases, which do not influence the lining system at all, may appear.

For earth dams it is useful to create fixation ditches.

Depending on the level of ground water a drainage pipe can be integrated into the fixation trench.



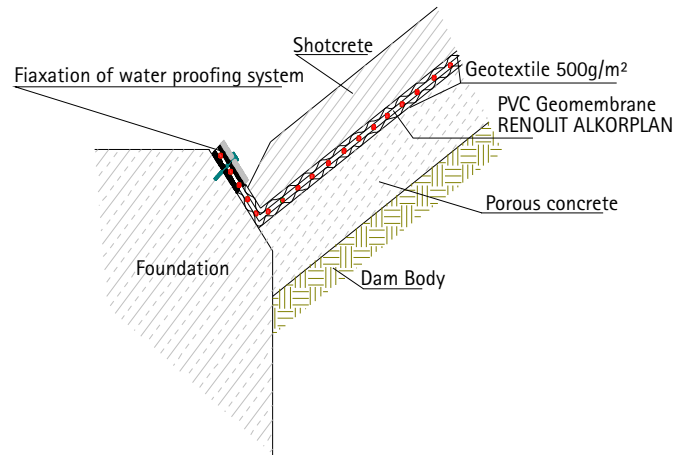
Intermediate Fixation

1. Geomembrane
2. Geotextile
3. Sub Grade-Drainage layer
4. Drainage Pipe
5. Compacted Underground
6. Welding

Fixation of the waterproofing system on the sides and on the bottom of the dam

This part is a sensitive area as the stored water can penetrate the dam, between the passage of the watertight dam and the side slopes if the work is not carried out carefully.

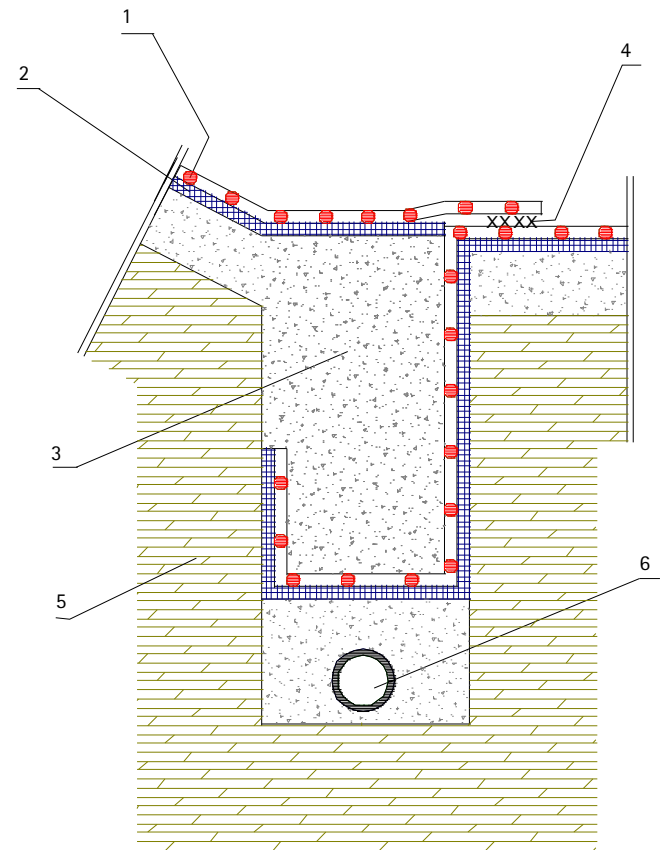
Regarding concrete dams, the fixation is mainly done with the help of a loose-fix flange. This construction is done around the whole dam over the highest waterline. The materials used for the flange construction have to be made out of stainless steel, the loose flange has to be minimum 10 mm thick. The geomembrane has to be embedded between two compressible layers (EPDM or similar) to guarantee a watertight connection between concrete and fixation.



Principle of a flange construction to fix the lining system



The fixation at the bottom for an earth dam can be built as followed:



1. Geomembrane
2. Geotextile
3. Sub Grade-Drainage layer
4. Welding
5. Compacted Underground
6. Drainage Pipe

Welding

The welding in the surfaces has to be carried out with welding machines. It can be based on hot air or on a electrical heated hot wedge. Both devices deliver very satisfying results. Hand welding has to be done very professional.

With the use of PVC as a water proofing material the details are fixed with a hot air hand welding device.

PP of good quality also allows hand welding with hot air.

PE must be welded with extrusion in the details. The surface of the geomembrane has to be prepared in order to carry out safe welding.



Testing and control

The installer has the duty to control every seam on the site. For that purpose it is necessary to establish a protocol which has to be filled out every day with the following parameters:

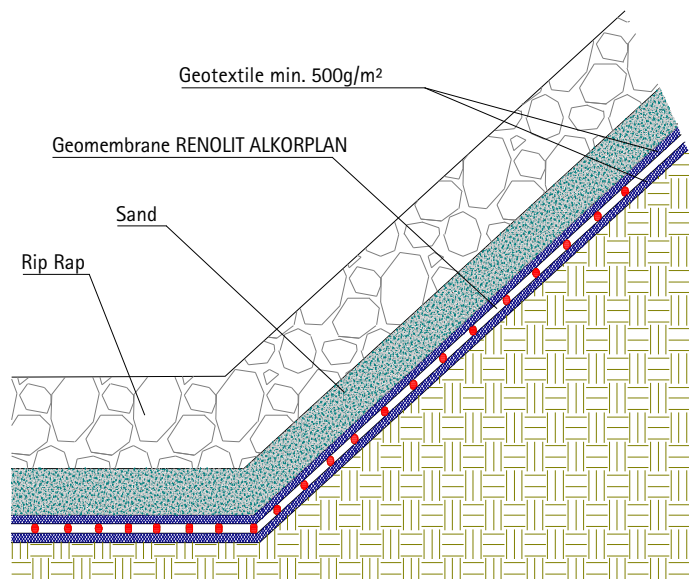
- outside temperature in the morning, at noon and in the evening
- data like welding temperature, pressure and speed of the machine determined through the daily testing procedure (controlled through peeling test and traction resistance)
- time of beginning and ending of welding works
- numbers of the seam
- data of the welding result after testing (reduction of pressure after 15 minutes of testing)
- destructive tests of welding seam (peeling test and traction resistance)
- repair measurements if seams do not pass the test
- signature of representative of the client and the installer



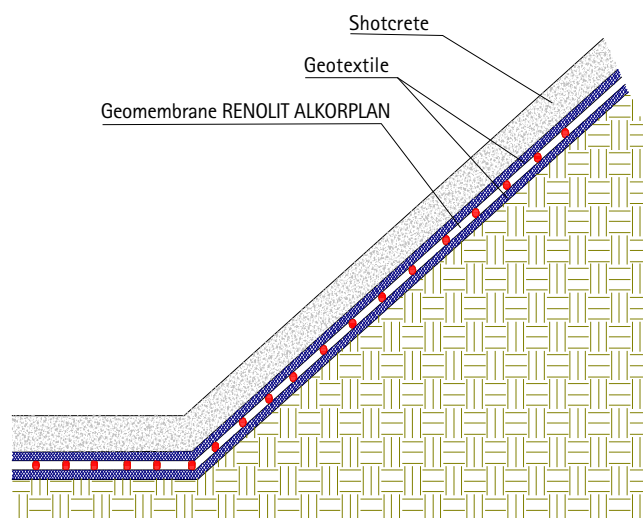
Protection of the waterproofing system

The protection of the waterproofing system can be done in many ways. The angle of the slope is the most important parameter. Slopes up to 25 ° can be protected with rip rap, concrete slabs or similar. When the waterproofing system is protected, there is no need for a ventilation system.

Besides normal concrete, Rip Rap and shotcrete, small slabs of concrete also can be used as a protection.



Waterproofing System with Rip Rap as Protection



Waterproofing System with Shotcrete as Protection

Installation of a geocomposite

The advantage of this system is double :

- installation of the complex geotextile / geomembrane in one pass ;
- increase the tensile strength without reducing the elongation capacity of the geomembrane

The geocomposite has a free welding strip (geomembrane without geotextile) of +- 8 cm, on one side in order to be able to carry out the welding.

This technology is often used for waterproofing of vertical dams. The geocomposite has to be fixed vertically which can be done with stainless steel plates. To avoid hand welding on site it is recommended to weld strips of geomembrane to the waterproofing system in prefabrication in order to produce only machine welding on site. These strips are welded along the geocomposite with an automatic welding machine (as used in roofing) at a distance of 25 cm to 30 cm. After the fixation of the waterproofing system to the dam wall with the stainless steel plates, the strips are welded together with a double welding automatic machine.



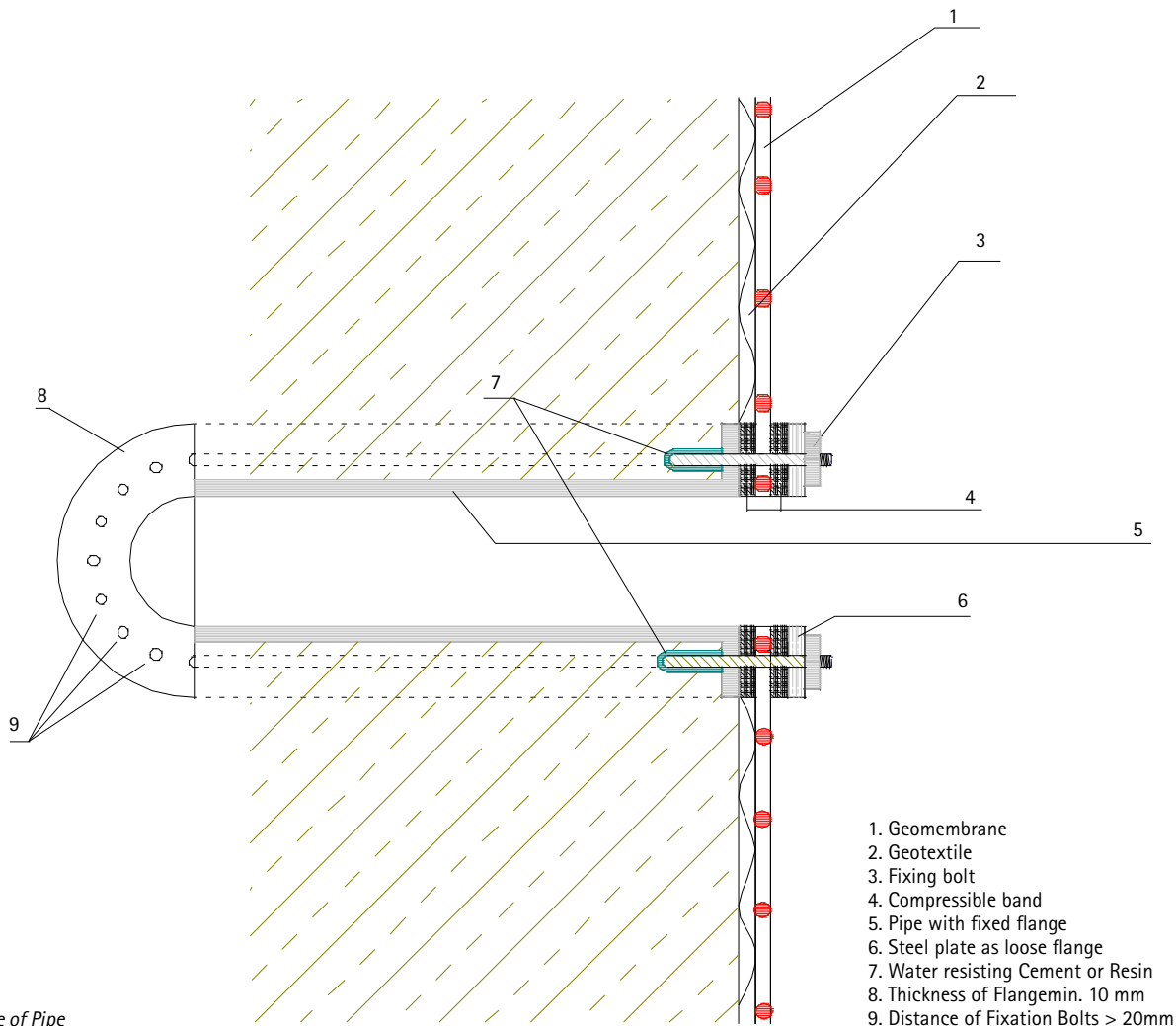
Special construction

Dams are constructed with a system of regulation of the water level, mainly through outlets and inlets.

The connection between the waterproofing system and those outlets and inlets has to be done with a solid loose-fix flange construction.



Connection to the concrete structure with the help of loose-fix flange







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