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Waterproofing of **reservoirs and similar**

RENOLIT ALKORGEO

Hydraulic structures

RENOLIT ALKORGEO

Hydraulic 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 hydraulic structures due to its excellent deformability, which allows it to adapt to all forms of support, its puncture resistance, weld ability, resistance to UV and durability: RENOLIT ALKORPLAN 35054 & 35254.
If necessary, the geomembrane is also available with a special formulation for storage of potable water: RENOLIT ALKORPLAN 35052.
In addition, this geomembrane can be laminated with a geotextile in polyester or polypropylene (up to 700 g/m²) and receive a reinforcement grid made of polyester or glass.

Installation of lining

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.

In general the waterproofing system consists of:

→ **Support**
Drainage layer
Protection layer
Filter layer

→ **Waterproofing layer**

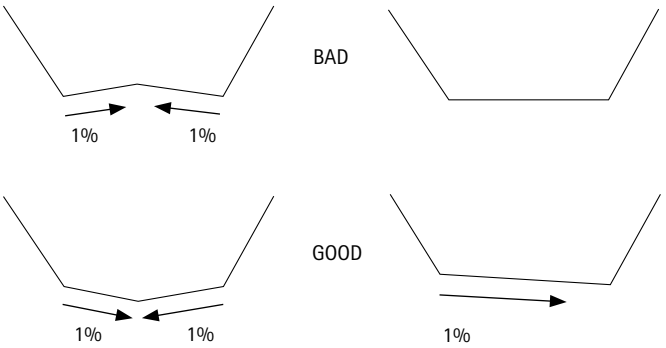
→ **Protection**
Synthetic protection
Mineral protection
Combination

Preparation of the Support

Quality of soil
The quality of soil is of importance. Investigation should be made concerning the existence of gas and organic material in the soil.
It could be possible that drainages to evacuate developing gas underneath the waterproofing system have to be installed. There are multiple reasons for sub-pressure under the waterproofing system which can cause a failure of the waterproofing system:

Geometry

Bottom
In order to have a good functioning of the drainage and to simplify the cleaning of the basin after emptying a minimum inclination of 1 % should be built.



Slopes
The slopes have to be built in such a way in order to be stable on their own. The waterproofing system may not have any stabilising function. In most cases the inclination of the slope has to be below 45° (1/1) for the following reasons:
→ Elongation of the geomembrane due to its weight could lead to flowing and gliding.
→ Instability of the drainage layer and/or the protection layer consisting of gravel, concrete slabs.
→ Quick emptying of the basin can lead to instability of the slope.
→ Work on the steep slopes.

Top area
The dimension of the top area has to be large enough to allow:
→ correct fixation of the waterproofing system
→ circulation of traffic during and after installation of waterproofing system.
→ Special rules for application of PEHD geomembranes.
→ Radius between slope and bottom has to be large enough to avoid local stress of the geomembrane
(German standard DVS 2225 prescribes a radius of 1m with the use of a geomembrane of 2,5 mm).

Drainage

The drainage has to ensure the release of liquids and gas under the geomembrane.
It is recommended to create a slight inclination (1% min.) towards the slope in order to evacuate enclosed air and gas at the first filling of the basin.
A study before starting the project should be done concerning the drainage, as any mistakes during the work can lead to important failures of the waterproofing system.
Drainage of the water/gas should be taken into account under the following circumstances:

→ when the liquids or solids stored are pollutants or toxic
→ when the liquid stored contains organic matters
→ when the soil under the waterproofing system contains organic matters
→ when the soil is karstic or susceptible to internal erosion
→ when the lagoon is subject to rapid tidal rises
→ when temporary groundwater can develop under the geomembrane
→ to avoid the lifting of the geomembrane through wind action.

Gas drainage (in case it is necessary)

In general, perforated pipes of 60 to 80 mm diameter will be used, placed approximately every 20 m (reduced to 10 m if the underlying soil is relatively impermeable and in the event of an expected significant emission of gas). The drainage pipes are not in direct contact with the geomembrane, they are placed in a gas permeable layer (drainage layer or drainage trench), which consists either of granulates with sand (at least 60 %) or a transmissive geotextile. These pipes can be replaced by strips of geo-spacers placed directly on the support.
The outlets of the gas drains are installed at the highest points and equipped with protected chimneys. The output section must be horizontal, and never facing the wind.
In each case, it is necessary to design the gas drainage in such a way that these drains never get filled with water: it must therefore be associated with liquid drainage.
In addition, the form of bottom of the basin should allow evacuation of the air imprisoned under the geomembrane during installation (slope allowing venting to the outside).

Drainage of water

The drainage of water can be carried out as follows:

→ Layer of granulates in a thickness of 10 cm with minimum of 60 % sand, 0,5 < D < 5 mm. A synthetic separation layer (filter) has to be placed between the ground and the drainage layer.
→ A net of drainage ditches has to be installed in order to collect the upcoming liquids. The drainage pipes are covered with a transmissive geotextile to avoid a collimating of the pipes due to fine granulates.
→ Geosynthetic drainage in combination with drainage pipes.

Collectors and outlets

All liquids are guided into the collectors, leading to outlets where they are evacuated through gravity. If an evacuation with gravity is not possible it has to be done with the help of a pump. In this case a well has to be constructed at the lowest point, containing an automatic pump. This well has to be controlled frequently. It also serves as a control for the functioning of the water proofing system. It is recommended to construct such a control well in case the stocked liquids have polluting effects.
For large projects, it is recommended to compartmentalize the drainage system with separate outlets for each area to help locate leaks.

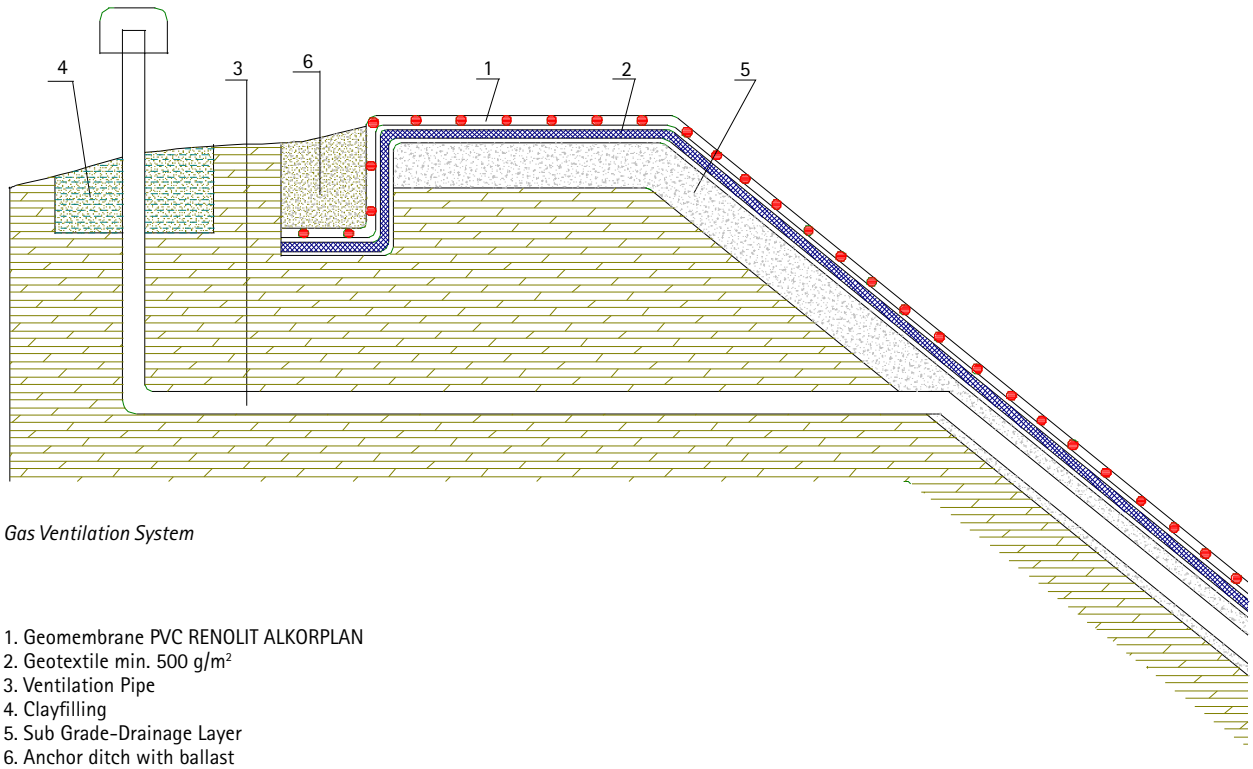
Dimensioning of drainage

To measure the dimension of the drainage the following has to be taken into consideration:

→ quantity of liquids rising behind the geomembrane
→ quantity of liquid in case of a failure of the geomembrane
→ the maximal negative pressure in case of a quick emptying of the basin or a failure of the waterproofing system.

Depending on the hydrogeological context, an additional drainage system outside the work may be indispensable.

In small projects half perforated pipes with a diameter of 125 mm in combination with bands of geospacer in 0,2 m to 0,5 m width are used in general. For big projects the drainage system has to be measured following the actual situation.



Gas Ventilation System

1. Geomembrane PVC RENOLIT ALKORPLAN
2. Geotextile min. 500 g/m²
3. Ventilation Pipe
4. Clayfilling
5. Sub Grade-Drainage Layer
6. Anchor ditch with ballast

Drainage pipes under waterproofing

Sub grade
The surface has to be smooth, without sharp stones, vegetation and well compacted to avoid relative settlements. It should be able to provide a drainage under the water proofing system to avoid negative pressure. This can also be effectively achieved with the help of drainage pipes which are embedded into the sub grade.

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.

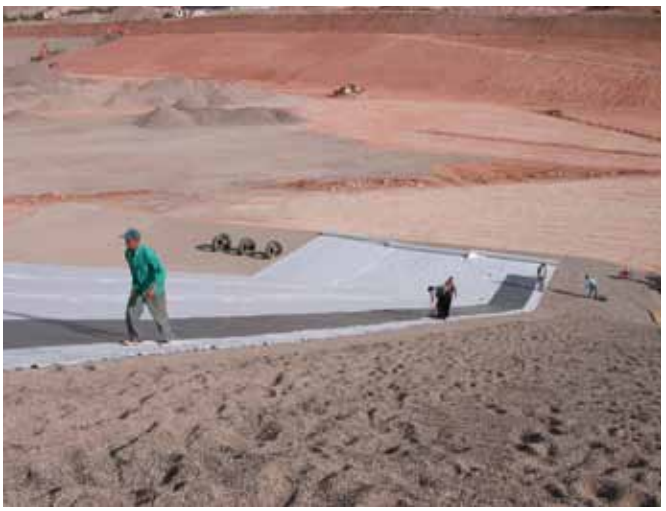
Installation of the waterproofing layer

The waterproofing system
After exactly determining the parameters of the soil and the sub grade the waterproofing system can be chosen.
In general the waterproofing system consists of:

→ Separation or/and protection layer:
Geotextile of min 500 g/m² will be placed on the prepared sub grade (drainage layers). Its task is to protect and to separate the geomembrane from the sub grade. In case the last layer under the geomembrane consists of sand, precautions have to be taken during the welding of the geomembrane to avoid pollution of the welding zone (Strip of geomembrane placed under the actual welding zone and pulled in direction of the welding process following the progress of the welding).

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

→ Protection layer:
It is recommended to protect the waterproofing system. There are different influences possibly damaging the system like waves, rapid emptying of the water, UV-radiation on the exposed part, vandalism. 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 more (sometimes there is no exterior protection, in this case the geomembrane has to be specially made to safely withstand the existing influences).



Placing of geotextile

Installation of the geomembrane

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

The advantages of prefabrication are as follows:
→ Quality of welding is very high as the conditions in prefabrication do not change.
→ Reduction of cost compared with 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 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
→ design an exact assembling plan following the condition of the site.

The welding has to be carried out with an automatic welding machine. It is recommended to use a machine with double welding in order to be able to control the welding with air pressure. In case of a simple welding seam it is recommended to control with an iron pipe (opening about 3,0 mm) with air pressure.
The panels are folded in case of minor thickness of geomembrane or rolled onto a large mandrin for more important thickness. To avoid destruction of the panels they have to be packed for the transport to the site.

Assembling of panels
The assembling is carried out following the installation plan. 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 geomembrane
→ Means of manipulation in the prefabrication as well as on site
→ Accessibility and configuration of site
→ Way of folding 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
a. Placing of geomembrane
→ The installation of the geomembrane of the prefabricated panels can only be executed if all works concerning the sub grade (layers of granulates, separation layer, drainage) are completely finished and approved by the responsible site engineer.
→ The geomembranes are unrolled without tension and have to be overlapped. 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 carry out the welding operation early in the morning when the geomembrane has cooled down from the previous night.

Thermal dilatation of different materials:

PVC-P: 1.0 10-4 cm/cm/°C
(Displacement: 48 cm for 100 m and 50°C change)

HDPE: 2.4 10-4 cm/cm/°C
(Displacement: 120 cm for 100 m and 50°C change)

Source: Congdon, 1998

b. Welding on site
The quality of welding depends on 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 personnel.

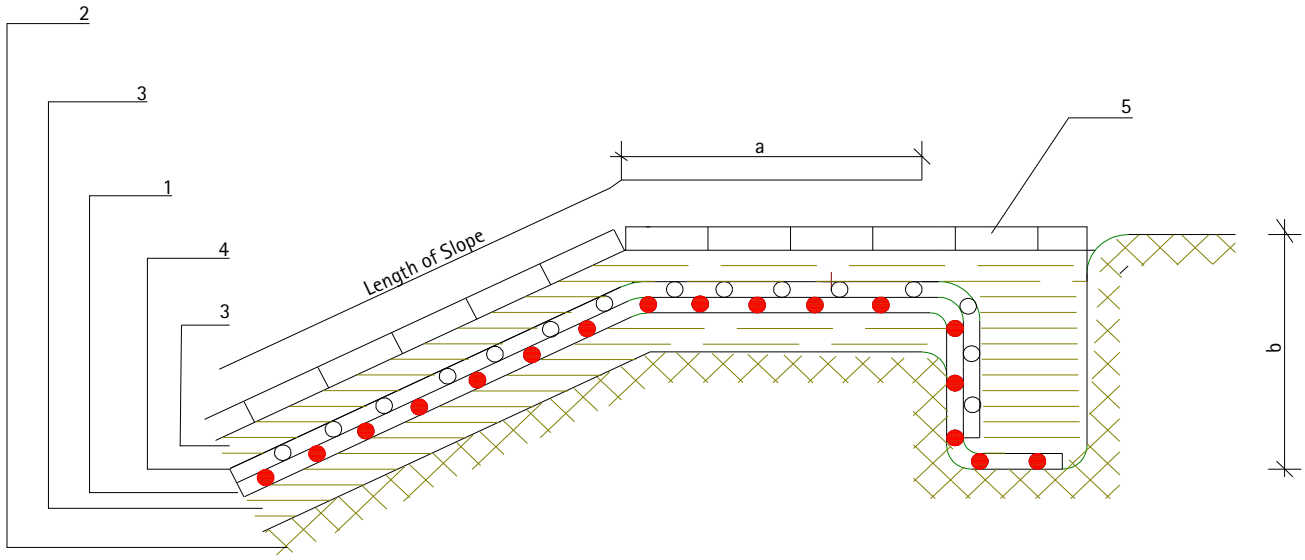
The used machines are hot wedge or hot air machines. This type of machine is suitable for all kinds of materials (PVC, PP, PE). Hand welding for the execution of details, connections at the end of panels, based on hot air can only be applied with PVC and PP. Extrusion welding is the common technique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

c. 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.

Anchorage of the waterproofing system on the crest of the construction

In general the waterproofing system will be anchored in a ditch. The ditch should be immediately refilled as the lining system is introduced into the ditch. The dimension of the ditch depends on the length of the slope.
Other fixations are possible (Stainless steel plates in connection with concrete structures).

Welding with hot air and double seam



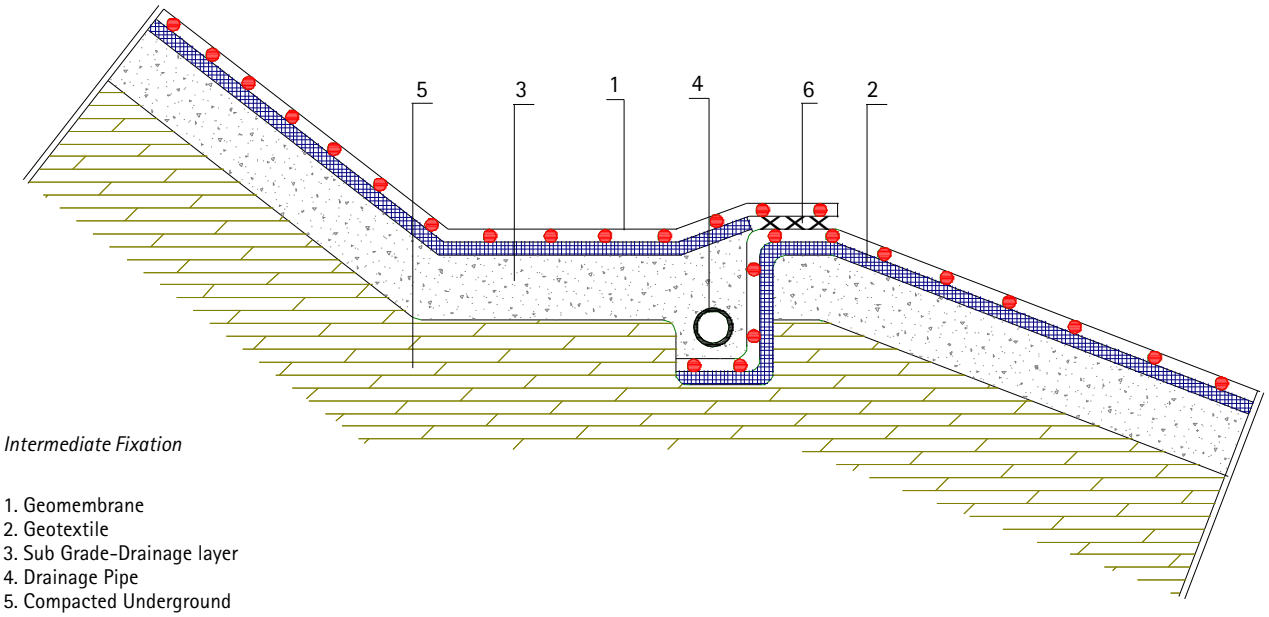
Dimension of Anchor Ditch (Principal Drawing)

1. Geomembrane RENOLIT ALKORPLAN
2. Compacted Subsoil
3. Sand as Protection Layer
4. Geotextile
5. Concrete Slabs

Length of Slope	a	b
< 10 m	> 0,5 m	> 0,5 m
10 - 40 m	> 0,8 m	> 0,6 m
> 40 m	> 1,0 m	> 0,8 m

Intermediate fixation of the lining system

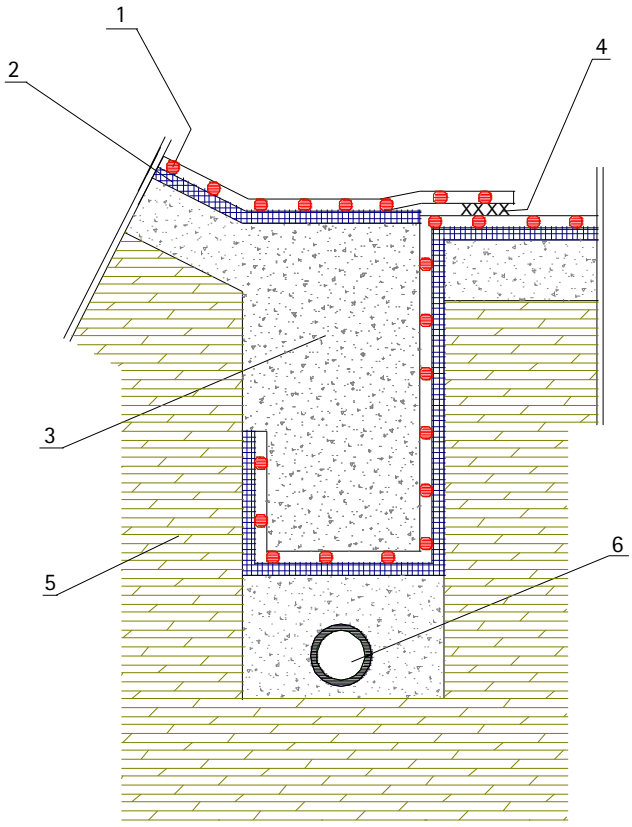
Depending on the construction intermediate fixations could be necessary. In case of very long slopes it is recommended to foresee such a fixation in order to reduce the stress on the membrane due to wind forces.



Intermediate Fixation

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

Anchorage of the water proofing system on the bottom of the construction

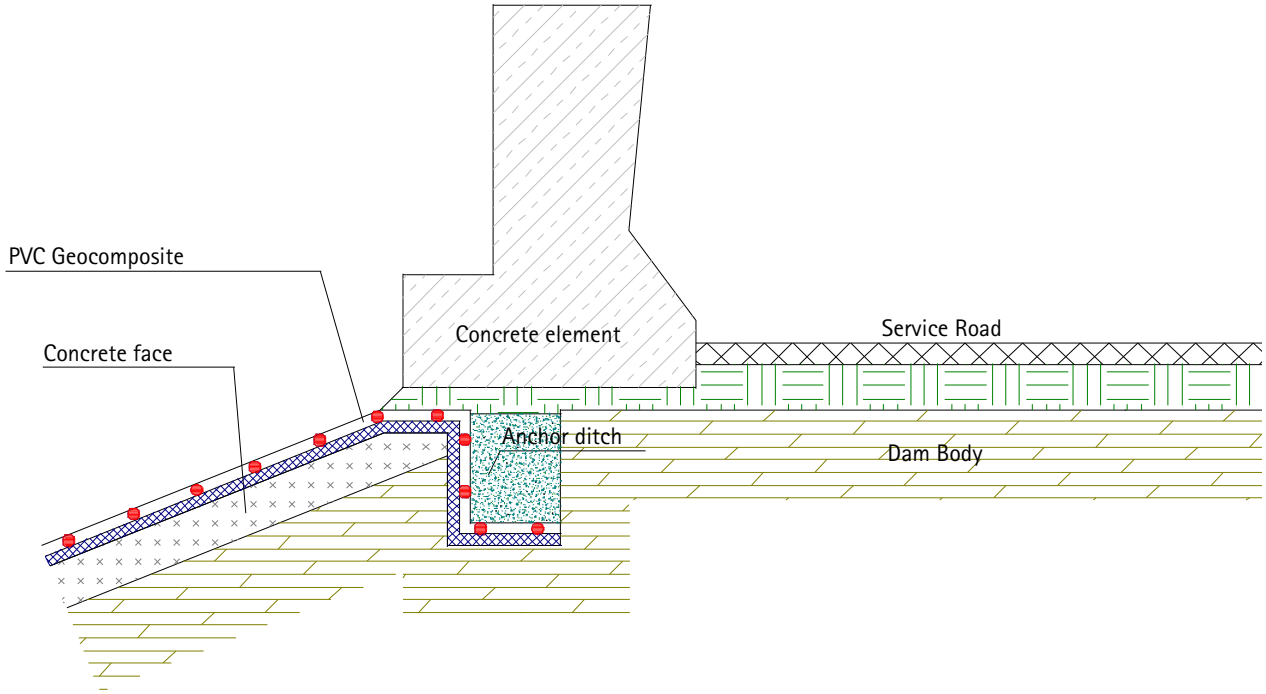


Fixation on the Bottom

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

Anchorage in combination with a concrete structure

It is not always possible to find adequate anchorage in a ditch. If there is a service road these concrete structures are often used. In such a case a possible termination of the lining system could be done as shown in the following drawing:

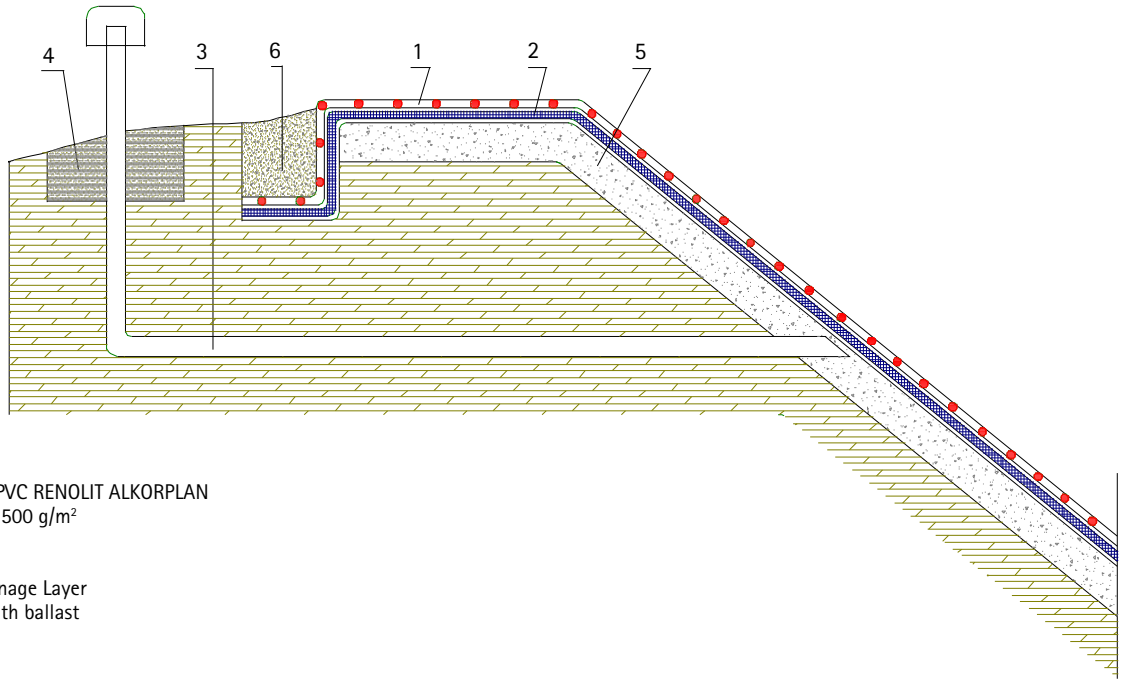


Crest Fixation of Waterproofing System

Ventilation system

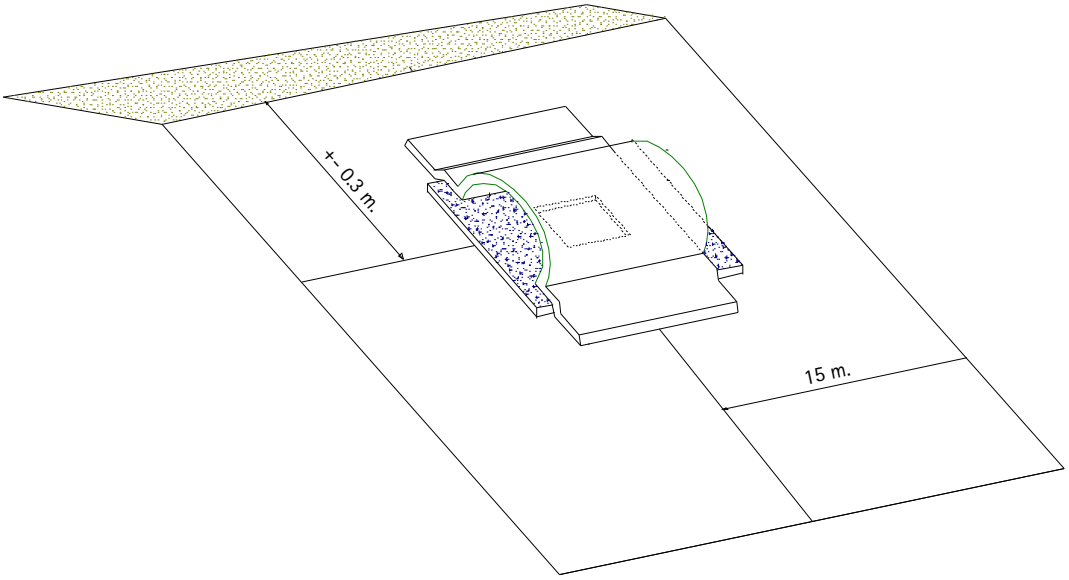
Wind has an important influence on a loosely laid waterproofing system. Especially in basins with high changing water levels (irrigation basin) the exposed part of the membrane could suffer under the wind. Therefore it is recommended to install a ventilation system:

A ventilation system is not necessary if protection of the waterproofing system is provided.



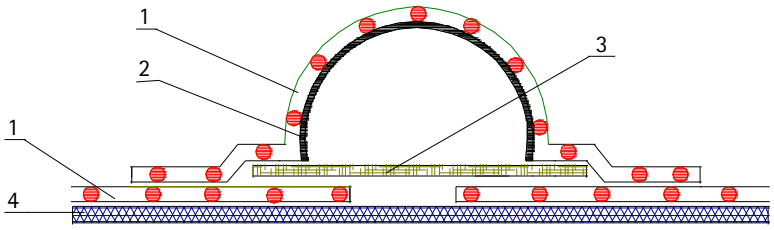
1. Geomembrane PVC RENOLIT ALKORPLAN
2. Geotextile min. 500 g/m²
3. Ventilation Pipe
4. Clayfilling
5. Sub Grade-Drainage Layer
6. Anchor ditch with ballast

Another type of ventilation system is shown in the following drawing:



Ventilation System with Half Pipe of PVC

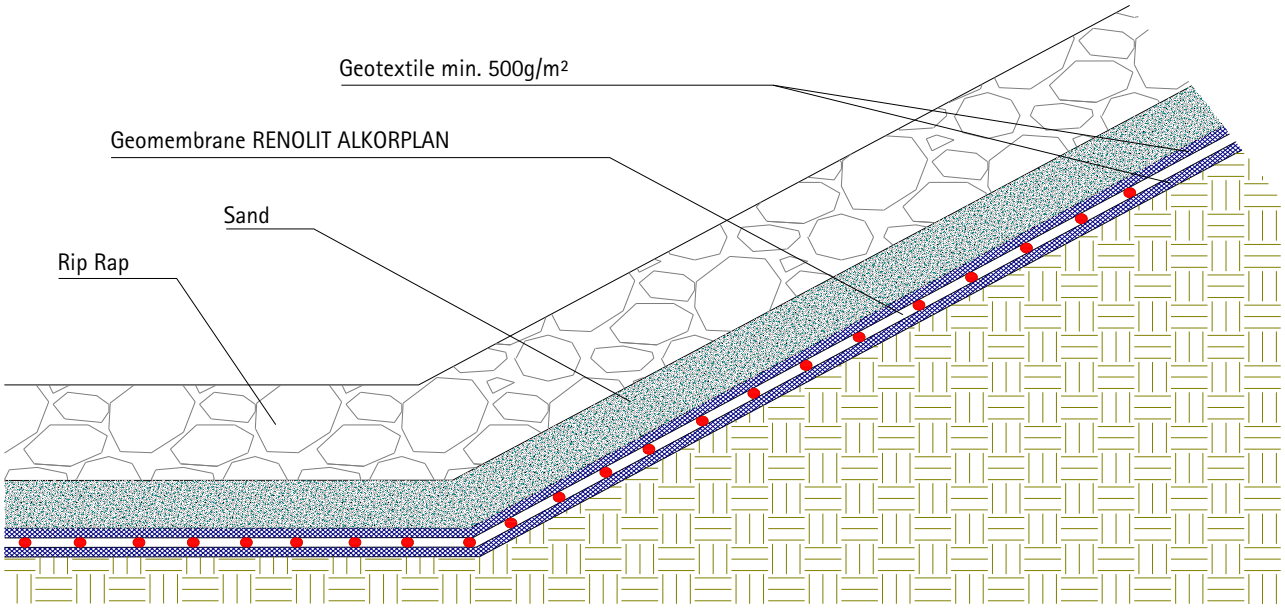
1. Geomembrane PVC RENOLIT ALKORPLAN
2. Half pipe of PVC
3. GEOGRID as protection
4. Geotextile PP



Protection of the waterproofing system

Protection against mechanical influences is a warranty for a long-lasting waterproofing system. Therefore for the following reasons a protection of the waterproofing system should be installed:
→ in canals with a speed of water > 1 m/sec
→ in areas of the project with speed of water > 1 m/sec
→ against floating objects
→ in areas with an access ramp
→ on lakesides of artificial bathing lakes
→ against wind, ice, waves.
→ on the bottom if cleaning with engines is intended
→ against vandalism.
→ against the influence of UV radiation in exposed zones

Protection with granulates
The study of the stability of the protection depends on the complete knowledge of the characteristics of all used materials, granulates or synthetic, that are going to be used. Especially the friction angle between the different faces may change in an important way with the type of geomembrane, the geotextile and the granulation..
Therefore it is recommended to carry out trials on site to find out the best combination.
The thickness of the geomembrane and the weight of the geotextile depend on:
→ type of geomembrane
→ granulation and angle of the ground
→ granulation and angle of the sub grade
→ created forces during the execution of protection layer
These forces depend on:
- thickness of protection layer placed directly onto the waterproofing system
- type of engine used for the placement of the protection layer.



Protection with Rip Rap

Unloading of protection material with truck

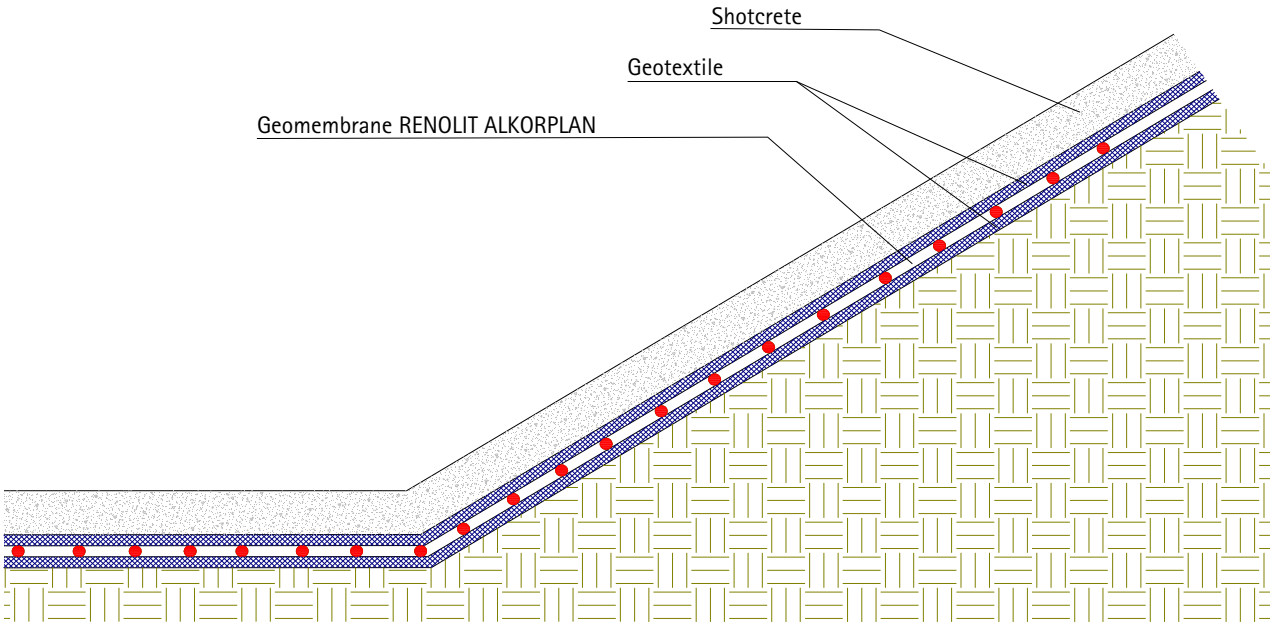
Distribution of material with bulldozer

Distribution with loader

Distribution with excavator

Protection with concrete:

For slopes where no stability with granulates can be achieved (angle of friction too low) a protection with concrete has to be realised.



Waterproofing System with Shotcrete as Protection

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