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RENOLIT

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1. INTRODUCTION

1.1. Scope of the Work

The estimated reserve of water is 1.500 billion m², but only 0,3 % is usable fresh water. 97,3 % of the water is salty, 2,15 % appears as polar or glacier bound water, 0,65 % is in the ground water table or shows up as surface water. Around 12 million people die yearly due to lack of potable water.
These numbers tell us it is time to act: too much water is wasted and polluted without reason, water which could save human lives.
A very effective method to conserve water is to build water basins for multiple uses. Besides being a reserve of water and other liquids, it can also be used to gain electric energy. The water can be used as drinking water or for irrigation, all purposes which save lives.
These kinds of constructions are frequently built in areas with porous underground. Water can disappear through the ground, through the side walls and in case of Storage Lakes through the dam as well.
There are technical solutions to avoid this negative phenomenon. One very effective method is the installation of water proofing membranes. There are different possibilities to use such membranes. One of the most convenient membranes is the thermoplastic membrane. The best known thermoplastic membranes are PVC-P, PP and PE in different densities.

1.2. Products of RENOLIT

RENOLIT offers a large range of suitable plastic sheeting to carry out the waterproofing of dams, basins, and similar projects:

- RENOLIT ALKORPLAN PVC-P geomembranes
- RENOLIT ALKORTENE PE geomembranes
- RENOLIT ALKORTENE PP geomembranes

The following type of projects can be built with the above mentioned products:

- Irrigation basins
- Artificial lakes
- Fire fighting ponds
- Drinking water basins
- Waste disposals for different waste (basic waterproofing as well as cover)
- Canals
- Retention basins for all kinds of liquids (rainwater, chemical products and similar)
- Floating covers
- Dams

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1.3. Requirements on the waterproofing materials

The quality of the waterproofing depends on:

- choice of geomembrane
- waterproofing system including the preparation of the underground
- method of carrying out the work (underground, drainage, waterproofing system, protection).

1.3.1. Water tightness

Depends on the definition of geomembrane (product group, thickness) in order to withstand all influences (pressure, condition of underground).

1.3.2. Flexibility

This factor has to be taken into consideration when drafting the project. The type of membrane has to be chosen according to the form, angles and settlements of the construction site.

1.3.3. Chemical resistance

The waterproofing has to be resist against the chemical influence of:
- stocked material
- pollution rising from the underground due to changing water levels in the water table.

1.3.4. Compatibility to drinking water

In case the waterproofing has to serve in connection with drinking water the geomembrane has to correspond to the national standards.

1.3.5. Geography

The described waterproofing systems are suitable for all geographical regions and climatic zones. In any case it is recommended to ask for technical advice from the technical team of RENOLIT concerning questions of choice of material, situation concerning UV radiation or cold temperatures.

2. GEOMEMBRANES OF RENOLIT

2.1. Geomembranes RENOLIT ALKORPLAN

The type RENOLIT ALKORPLAN represents all geomembrane of soft, homogeneous and reinforced PVC-P.

2.1.1. References of Geomembranes RENOLIT ALKORPLAN

- 35052, drinking water geomembrane. Light grey or dark grey. Homogeneous and reinforced with protection against UV radiation.

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- 35254 PES, reinforced geomembrane for dams, floating cover and hydraulic works. Light grey or dark grey with protection against UV radiation.
- 35053, geomembrane for hydraulic works. Light grey or dark grey. Homogeneous without protection against UV radiation.
- 35054 / 35254, geomembrane for hydraulic works. Light grey or dark grey. Homogeneous with protection against UV radiation.
- 02339 geomembrane for hydraulic works, homogeneous with protection against UV. Dark grey or black.
- 35038, geomembrane resistant against temporary influences of hydro carbonates and can be applied directly in contact with bitumen (non UV resistant). Black.

All mentioned geomembranes can also be produced:

- With reinforcement (polyester grid or reinforcement with glass fibres).
- Fleece backed with a PES (polyester) or PP (polypropylene) geotextile.

The mechanical characteristics are changing due to the reinforcement and/or the fleece backing.

2.1.2. Properties

RENOLIT ALKORPLAN geomembranes are PVC-P soft membranes, calendared or extruded, enrolled in a hard box with a width of 2,05m.

- No point of yield will be reached before break: after elongation under stress, PVC-P is able to relax and to adapt to the underground.
- High performance concerning bi-directional deformation due to their elasticity (>170%).
- Very high resistance against hydrostatic puncture (>950 kPa/mm).
- Good resistance against chemicals like acid bases and salts, against aging, against roots and against environmental influences.
- PVC-P Geomembranes resists permanent contact of pH levels between 2 and 10.
- Geomembrane without UV protection can resist 1 month to direct exposition to UV radiation without loosing mechanical characteristics.
- UV protected geomembranes may be used for permanent exposition to sunlight.
- Very good weld ability with hot air hand welder (type Triac) and automatic machine (hot wedge and/or hot air), even after many years of use, with a large range in temperature and speed.
- Limited thermal dilatation : 1.5 10-4 cm/cm/°C
- Very good angle of friction (+- 28°).

2.1.3. Characteristics

See technical data sheets.

2.2. Geomembranes RENOLIT ALKORTENE

This type of geomembrane is made of Polypropylene, flexible

2.2.1. References of RENOLIT ALKORTENE geomembranes

- 03550, homogeneous geomembrane, black, extruded, 5.80 m and
- 6.00 m width.
- 35080, homogeneous geomembrane, grey, calendared, 2.10 m width.
- 35086, reinforced geomembrane with Polyester grid, grey, calendared, 2,10 m with, UV resistant.
- 35087, reinforced geomembrane with glass fiber, grey, calendared, 2,10 m width, non UV resistant.

2.2.2. Properties

Geomembranes made of flexible PP, homogeneous or reinforced.

- FPP is less flexible than PVC-P.
- A pseudo yield point can be observed after a certain elongation of the material (+-40%).
- Homogeneous geomembranes show good performance concerning bi-directional deformation due to their relative flexibility, especially in cold temperatures.
- Good chemical resistance.
- Medium hydraulic puncture resistance (600 kPa/mm).
- FPP can be welded with hot air and hot wedge automatic machines and with hot air hand welder, with a narrow range in temperature.

2.2.3. Characteristics

See technical data sheet.

2.3. Geomembranes RENOLIT ALKORTENE

This type of geomembrane is made of Polyethylene (PE)

2.3.1. References of RENOLIT ALKORTENE geomembranes

- 00251, geomembrane HDPE, black
- 00274, geomembrane LDPE black

2.3.2. Properties

Geomembranes made of PE, extruded, black.

- High resistance against chemical influence, especially hydro carbonates acids and bases.
- Poor resistance against active oxygen.
- Capability of deformation is reduced due to their low flexibility, especially on uneven and rough underground.
  To initiate an elongation of the material, important power has to be

applied due to its stiffness. After an elongation of around 8% (one-direction) the point of yield is reached and the material starts to flow. The elongation happens on the weakest point of the material until it breaks. In the flowing state HDPE is very sensitive to any mechanical influence.

- Medium hydraulic puncture resistance (675 kPa/mm).
- Poor friction angle (+- 18°)
- High thermal dilatation (+- 2.6 10-4 cm/cm/°C)
- PE-HD has to be welded by hot air or hot wedge welding machines with high pressure. Details have to be welded by extrusion. It is not possible to weld this material by hand with hot air.

2.3.3. Characteristics

See data sheets

2.4. Accessories

Geomembranes are the most important part of a waterproofing system. To make it function correctly different accessories are needed, depending on the type of construction to be water proofed, to complete the whole system. All accessories have to be compatible with the geomembrane being used.
The following accessories are part of such a system:

- Protection layer (geotextile, plastic sheeting made of regenerates and similar)
- Drainage layer (all kind of geo-grids)
- Fixation elements (laminated metal sheet, water stop, stainless metal plates, anchor and more)

2.5. RENOLIT Production

The whole production procedure including management and the purchase of raw materials has to conform to the demands of ISO 9001.
The control of production starts with the supply of raw material before proceeding to the laboratory, which is responsible for the mixing of the compound, from there it goes to production, then the logistic department and finally ends up at the management department.
After passing through the mixing and melting unit, the compound is transported to the calendaring or extrusion unit. After passing though numerous calendaring drums the final membrane, controlled by many electronic devices for thickness, heat and speed, is extracted and rolled up.
A reinforced geomembrane is produced on laminating machinery where the Polyester grid (or Glass fibre) is introduced between two layers of geomembrane. Exact heat and pressure are important to achieve a perfect lamination between the 2 layers of geomembrane and the reinforcement.

2.6. Geomembrane recommended

RENOLIT group manufactures and markets a complete range of PVC-P, PE or PP geomembranes in response to a wide variety of applications. Experience has shown that the PVC-P geomembrane is the most suitable for waterproofing of hydraulic structures due to its excellent mechanical properties, weld ability, resistance to UV and durability.
Specifically for dams, RENOLIT developed geocomposites consisting of a thick PVC-P geomembrane (up to 5.0 mm) laminated with a geotextile (up to 700 g/m²) which can be made of polyester or polypropylene: RENOLIT ALKORPLAN 00418 & 00518.
In addition, this geocomposite can be reinforced with a polyester or a glass grid: RENOLIT ALKORPLAN 00416 & 00516.
If necessary, the geocomposite is also available with a special formulation for storage of potable water: RENOLIT ALKORPLAN 00426.

3. 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

4. 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.

5. INSTALLATION OF THE WATERPROOFING SYSTEM

5.1. Conception of the waterproofing layer

- Protection layer:
  Geotextile of min. 500 g/m² made of Polypropylene or Polyester. It has to be of Polypropylene especially when the basin 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-P, 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).

5.2. 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

5.3. Installation of the geomembrane

5.3.1. Prefabrication of panels

For large surfaces it is recommended to use large panels. This especially concerns PVC-P 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.

5.3.2. 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.

5.3.3. Installation on site

5.3.3.1. 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: +- 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)
Reference: Congdon 1998


Unrolling and placing of geomembrane

5.3.3.2. 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-P, 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-P and PP. Extrusion welding is the common technique for the execution of details for PE geomembranes

Welding with hot air and double seam

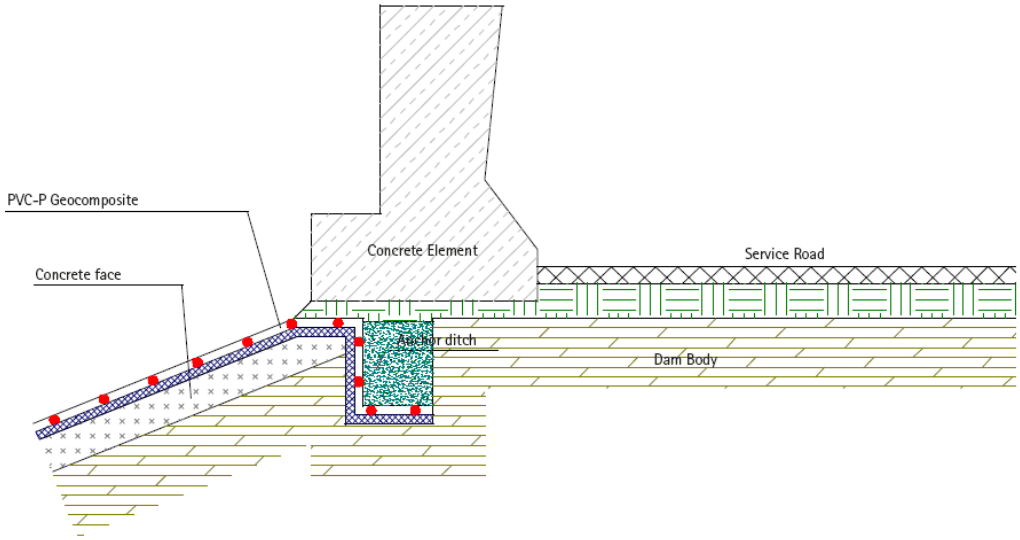
5.3.3.3. Action of wind

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.

5.4. 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:



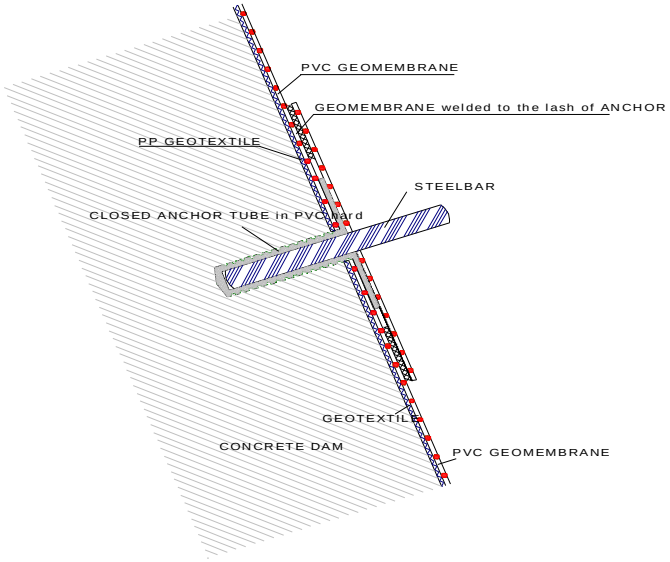
Crest Fixation of Waterproofing System

5.5. 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 a shotcrete protection, the reinforcement can be fixed to the steel bar of the

anchor.

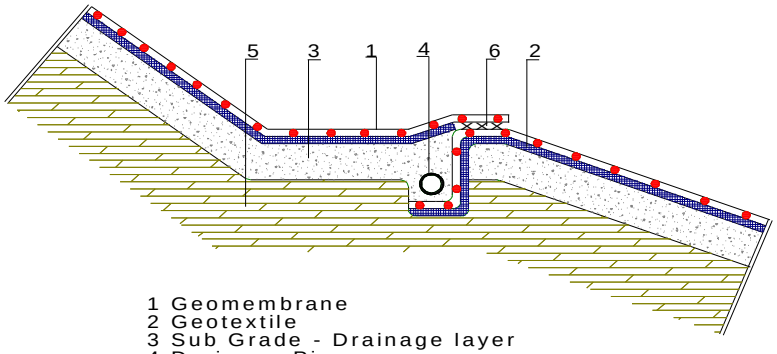
INTERMEDIATE FIXATION OF GEOMEMBRANE TO THE DAM



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-P 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 digs.

Intermediate Fixation



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

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

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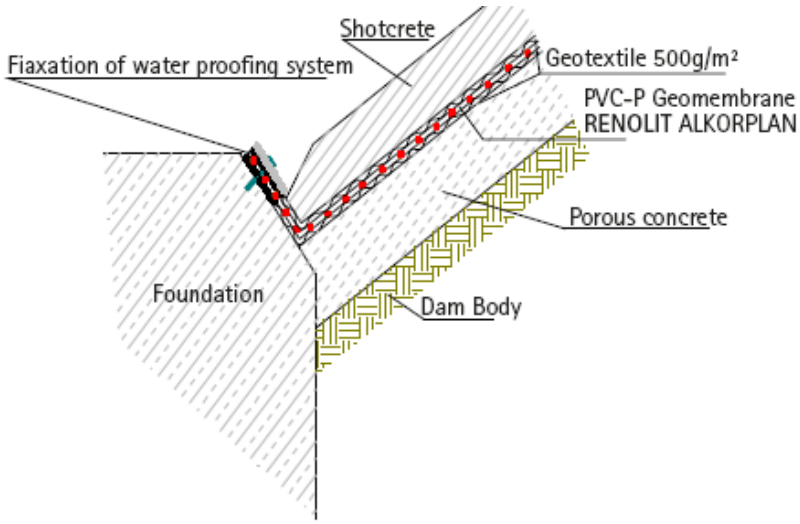
5.6. Fixation of the waterproofing system on the sides and on the bottom of the dam

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

Principle of a flange construction to fix the lining system

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

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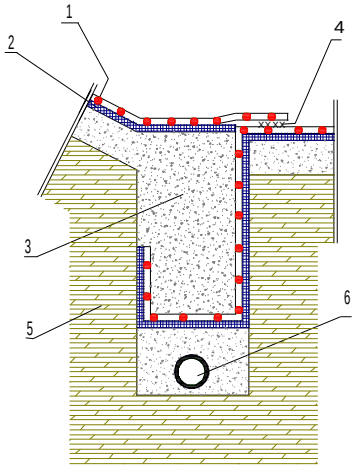
Fixation on the Bottom



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

5.7. 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 professionally.
With the use of PVC-P as a water proofing material the details are fixed with a hot air hand welding device.
PP of good quality also allows hand welding of details with hot air.
With PE, details must be welded with a manual extruder, having previously carefully prepared the surface of the geomembrane.

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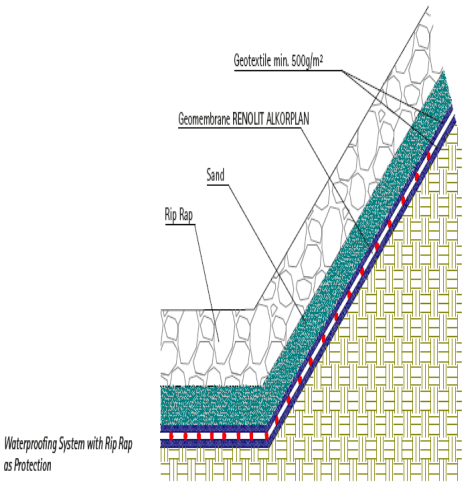
5.8. Testing and control

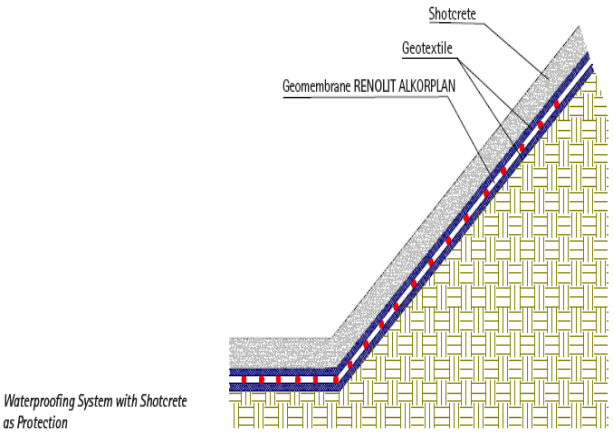
The installer has the duty to control every seam on the site. For that purpose it is necessary to establish a protocol which has to be filled out every day with the following parameters:

- 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

6. 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.





Protection with RIP RAP

Protection with concrete

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

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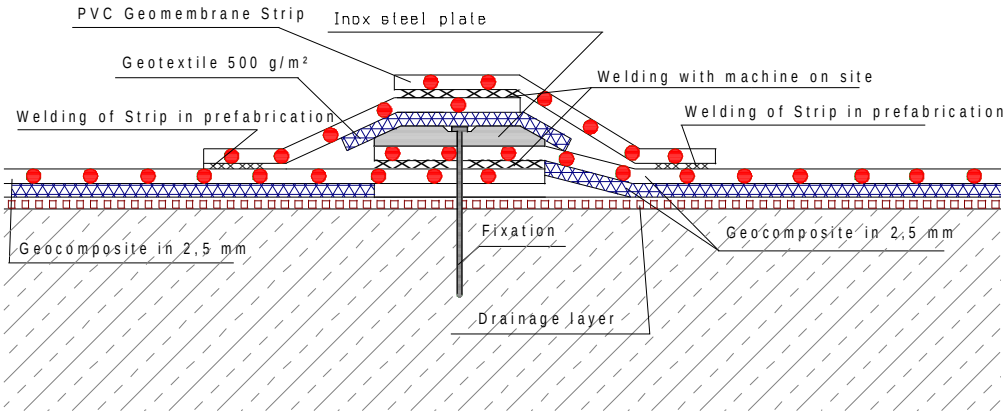
7. INSTALLATION OF A GEOCOMPOSITE

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.

Vertical Fixation of Geocomposite
With inox metal plate



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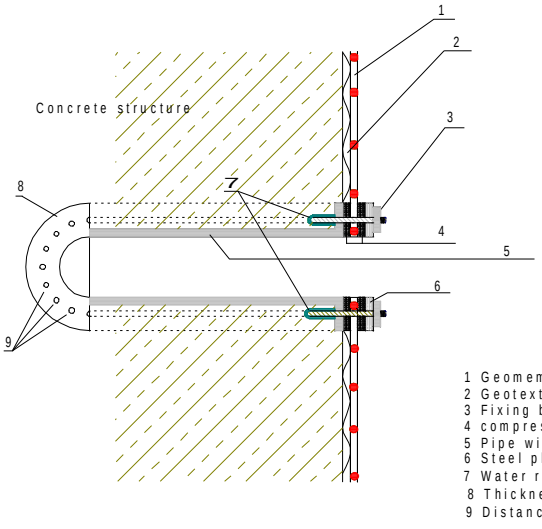
8. SPECIAL CONSTRUCTION

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.

Passage of Pipe



1 Geomembrane
2 Geotextile
3 Fixing bolt
4 compressible band
5 Pipe with fixed flange
6 Steel plate as loose flange
7 Water resisting Cement or Resin
8 Thickness of Flange min. 10 mm
9 Distance of Fixation Bolts > 20 mm

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

9. CONCLUSION

The waterproofing of dams and lagoons is a highly technical work. Only experts are allowed to carry out the installation and welding works.
The technical support from the side of RENOLIT Ibérica S.A, starting already at the design of the project till the end of the waterproofing works is a guarantee of delivering a successful work. The experience is high and is an advantage for the client. Many projects have been successfully carried out in the past as shown from our long list of references.

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