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# 1. INTRODUCTION

## 1.1. Scope of the Work

The estimated water reserve 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 on the surface. Around 12 million people die yearly due to lack of potable water.
These numbers are clear sign that it is time to act; too much water is wasted and polluted without reason, water which could save human lives.
The transport of water over long distances is a big danger for loss of water. In the past many concrete canals were built for irrigation, drinking water, electrical power plants amongst others which lose water due to failures in the concrete, which means an important amount of water does not reach its destination.
There are technical solutions to avoid this negative phenomenon. One very effective method is the installation of water proofing membranes. There are different possibilities for the use of 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 presents a large offer of suitable plastic sheeting for the waterproofing of canals, water reservoirs, floating covers and similar projects:

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

The following type of projects can be carried out 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 kind of liquids (rainwater, chemical products and similar)
- Floating covers
- Dams

## 1.3. Requirements on the waterproofing materials

The quality of the waterproofing depends on:

- the choice of geomembrane
- waterproofing system including the preparation of the underground
- the way the project is carried you (underground, drainage, waterproofing system, protection).

#### 1.3.1. Water tightness

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

#### 1.3.2. Flexibility

This question has to be taken into consideration during projecting. The choice of type of membrane to be used depends on the form, angles and settlements of the construction.

#### 1.3.3. Chemical resistance

The waterproofing has to be resistant 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. It is highly 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 RENOLIT ALKORPLAN type represents all geomembranes 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.

- 35254 PES, reinforced geomembrane for 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.

The above mentioned geomembranes can also be produced as described below :

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

The mechanical characteristics can change 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 breakage : after elongation under stress, PVC-P is able to relax and to adapt to the ground.
- High performance concerning bi-directional deformation due to its elasticity (>170%).
- Very high resistance against hydrostatic puncture (>950 kPa/mm).
- High puncture resistance.
- Good resistance against chemicals like acids and salts, as well as aging and environmental influences.
- PVC-P Geomembranes are resistant to permanent contact of pH levels between 2 and 10.
- Geomembranes 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 welding ability with hot air hand welder (type Triac) and automatic machine (hot wedge and/or hot air), even after many years of usage, with a large window of 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. RENOLIT ALKORTOP Geomembranes

This type of geomembrane is made of Polypropylene, very flexible

### 2.2.1. Références of RENOLIT ALKORTOP 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-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 margin in temperature.

### 2.2.3. Characteristics

See technical data sheet.

## 2.3. RENOLIT ALKORTENE Geomembranes

This type of geomembrane is made of Polyethylene (PE)

### 2.3.1. References of AKLORTENE 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.
- Deformation is reduced due to its low flexibility, especially on uneven and rough ground.
  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. In order for it to function properly different accessories are used depending on the construction that needs water proofing.

All accessories have to be compatible with the geomembrane used.
The following accessories are part of such a system:

- o Protection layer (geotextile, plastic sheeting made of regenerates and similar)
- o Drainage layer (all kind of geogrids)
- o Fixation elements (laminated metal sheet, water stoppages, rustproof metal plates, anchors amongst others)

## 2.5. RENOLIT Production

The whole procedure of production including the 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 materials, through to the laboratory responsible for the mixing of the compound, production, logistic department as well as the management.
After the mixing and melting unit the compound is transported to the calendaring or extrusion unit. Over numerous calendaring drums the final membrane, controlled by many electronic devices for thickness, heat and speed, is extracted and rolled.

The production of geomembranes suitable for drinking water requires a very careful procedure. The mixing unit has to be completely emptied and clean of rests of recent production, in order not to influence the quality of the geomembrane.
A PES reinforced geomembrane is produced on laminating machinery where the Polyester grid is introduced between two layers of geomembrane. Exact heat and pressure are important to receive a perfect lamination between the 2 layers of geomembrane and the Polyester grid.

### 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 the waterproofing of canals, RENOLIT developed a PVC-P geomembrane for hydraulic works with a reinforced resistance to microorganisms and UV, thanks to the addition of a top layer of PMMA : RENOLIT ALKORPLAN 35554.
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.

## 3. INSTALLATION OF CANAL LINING

### 3.1. Conception of the Waterproofing System

In general 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:

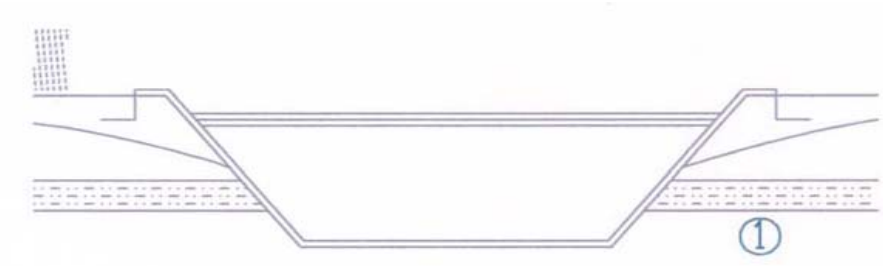
- Support
  - Drainage layer
  - Protection layer
  - Filter layer
- Waterproofing layer
- Protection
  - Synthetic protection

- o Mineral protection
- o Combination

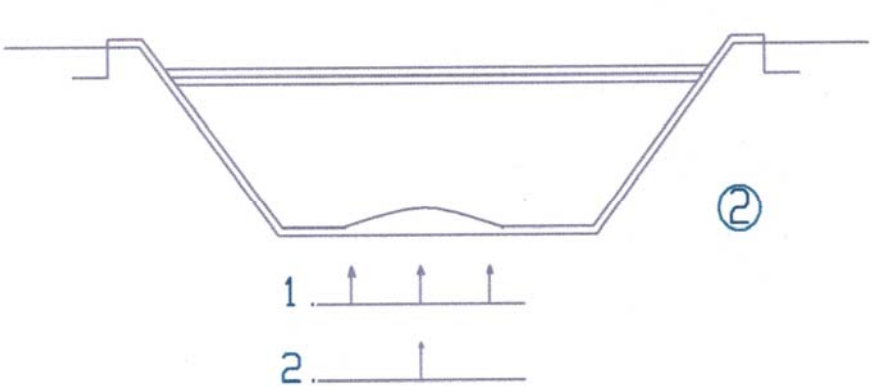
## 3.2. Preparation of the Support

### 3.2.1. Quality of soil

The quality of soil is of importance. Research needs to be done to check for the existence of gas and organic material in the soil. As this could mean that a drainage system has to be fitted underneath the waterproofing system to evacuate developing gas.
There are multiple reasons for sub-pressure under the waterproofing system causing it to fail:




*An impermeable layer and a raising water table due to heavy rainfall can lead to negative pressure.*




*Pressure due to gas and a permeable layer with raising water from the water table can lead to damages.*

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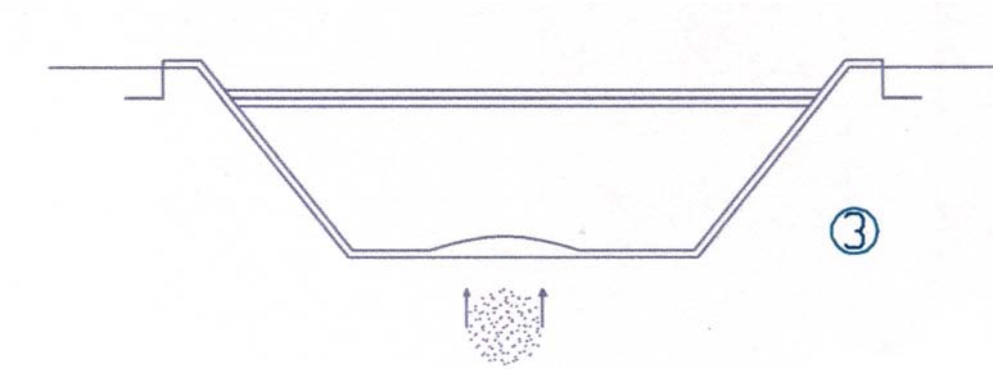
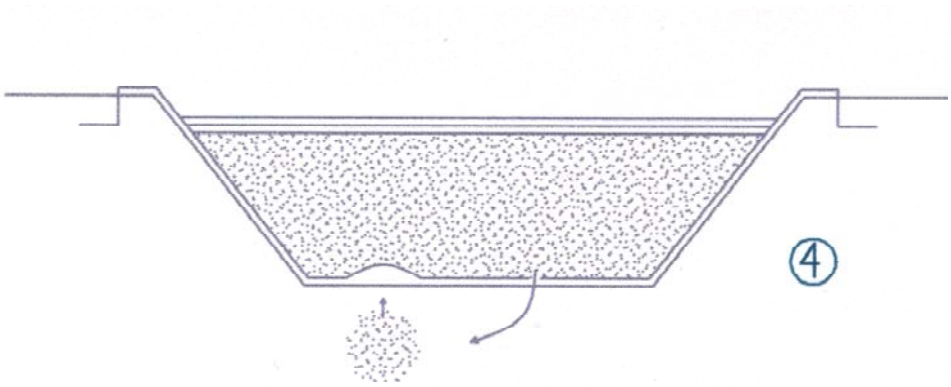
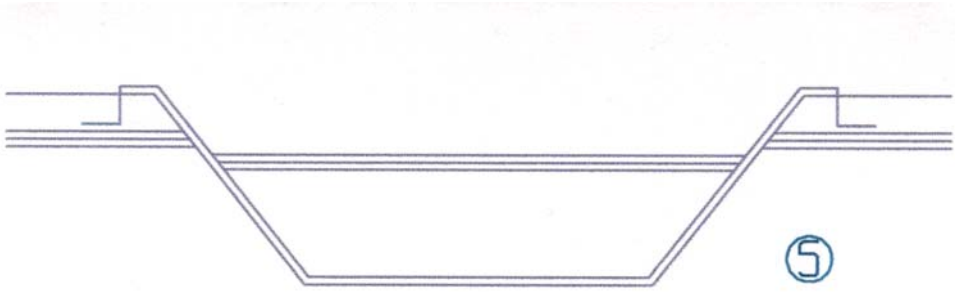



*Dissolution of organic material below the waterproofing system can lead to sub-pressure underneath the water proofing system*




*Leak under a canal of a liquid laden with Organic Material*




*A higher water table than the water level in the canal provoking a sub-pressure.*

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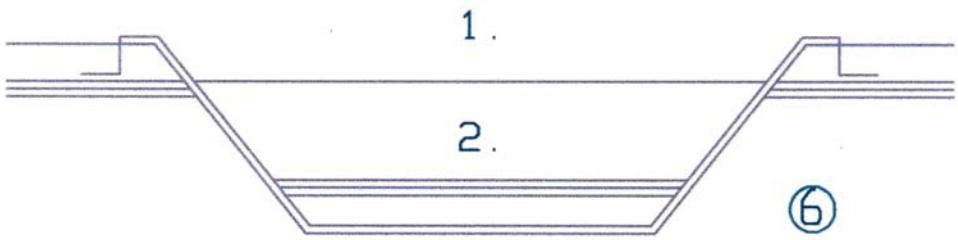
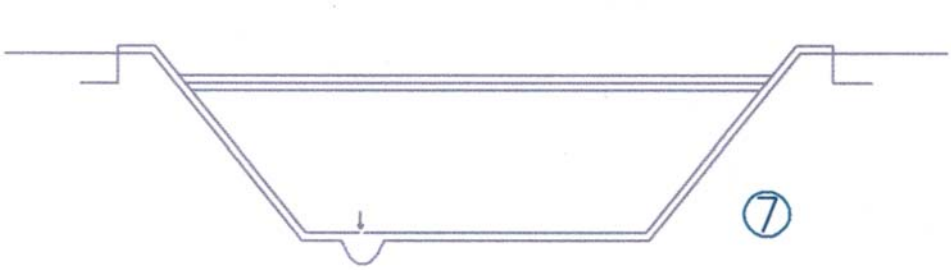



*Rapid emptying of the canal in equilibrium with the outside in the period of service.*




*Localized subsidence as a result of a leak.*

### 3.2.2. Drainage

The drainage has to ensure the evacuation of liquids and gas under the geomembrane.
For new projected canals a study before their execution should be carried out concerning the drainage, as wrong execution can lead to important failures of the waterproofing system.
Drainage for water/gas should be foreseen under the following circumstances:

- when the ground beneath the geomembrane contains organic matter
- when the soil is karstic or susceptible to internal erosion
- when the canal is subjected to rapid tidal rises
- when temporary groundwater can develop under the geomembrane

#### 3.2.2.1. Drainage for water

Drainage for water can be done 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 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 collimating of the pipes due to fine granulates.
- Geo-synthetic drainage in combination with drainage pipes.

#### 3.2.2.2. 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 via pumping. 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 control for the functioning of the water proofing system.

#### 3.2.2.3. Dimensioning of drainage

To dimension the drainage the following has to be taken into account:

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

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

*Geo-grid as drainage under waterproofing*

### 3.2.3. Sub Grade

The surface has to be smooth, without sharp stones, vegetation and well compacted to avoid relative settlements. In case of renovation of old concrete canals the concrete has to be repaired.

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*Repair of old canal bed and cleaning of sub-grade*

## 3.3. Installation of waterproofing system

### 3.3.1. The waterproofing system

After determine exactly the parameters of the soil and the sub grade the waterproofing system can be decided.
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 polluting of the welding zone (Strips of geomembrane placed under the actual welding zone and pulled in the direction of the welding process following the progress of welding).
- Geomembrane :
  The choice of the geomembrane should be done following the task the geomembrane has to fulfil (PVC-P, PP or PE).

### 3.3.2. Installation of geotextile

The geotextile can be produced in different widths. Depending on the construction the width is very 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 roles can lighten the works.

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*Placing of geotextile*

### 3.3.3. Installation of the Geomembrane

#### 3.3.3.1. Prefabrication of panels

For large surfaces it is recommended to prepare large panels. This especially concerns PVC-P geomembranes which are produced in widths of 2,05 m. In the prefabrication phase 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 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 assembly 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 this 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 on a large mandrill for more important thickness. To avoid destruction of the panels they have to be carefully packed packed for safe transportation to the site.

### 3.3.3.2. 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:

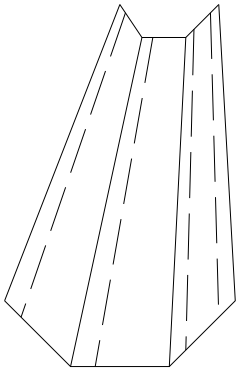
- Thickness of the geomembrane
- Means of manipulation in the prefabrication as well as on site
- Accessibility and configuration of site
- Way of folding of panels
- Size of canal

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

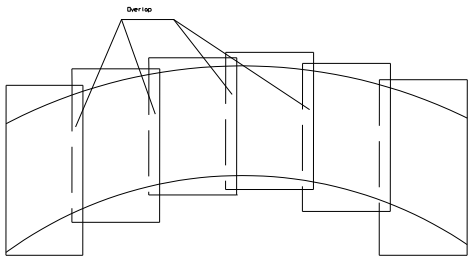
### 3.3.3.3. Installation on site

a) Geometry and size of Canal
The geometry and the size of the canal are important to determine the installation method.
Long and straight sections should be installed longitudinally, curves in a transversal way. Therefore it is recommended to establish an installation plan.

Installation Scheme



Straight Section




Section in Curve

b) Placing the 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 overlap. The overlapping depends on the used welding machine (4cm to 10 cm). Machines creating a control channel require an overlap between 8 cm to 10 cm. For extrusion welding an overlap of 4 cm is the limit.
- The 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-P: Displacement of 48 cm for 100 m length with 50°C Temperature change (from 20°C to 70°C)
HDPE: Displacement of 120 cm for 100 m length with 50°C Temperature change (from 20°C to 70°C)
Ref : Congdon, 1998


*Unrolling and placing of geomembrane*

c) Welding on Site
The quality of welding depends on the following parameters:
- Cleanness of the welding area (cleaning with a dry, clean cloth)
- Good adjusting of the machine (temperature, speed and pressure)
- Qualification of the workers.

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*Welding with hot air and double seam*

The machines used are hot wedge or hot air machines. These types of machine are suitable for all kinds of materials (PVC-P, PP, PE)
Hand welding for the execution of details, connections at the ends 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

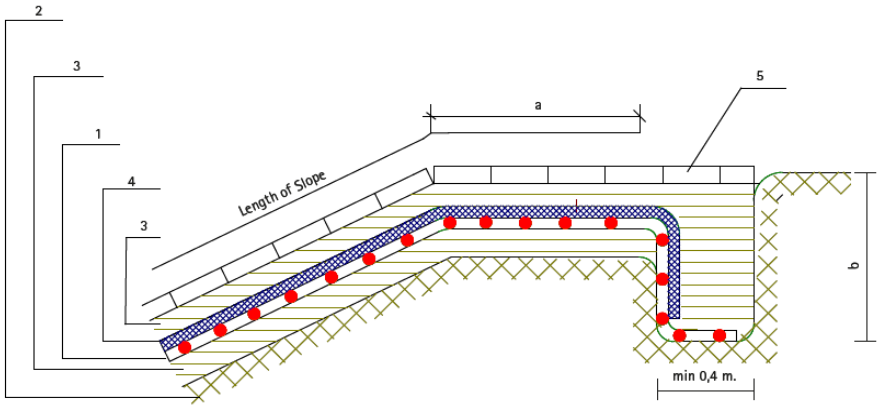
d) Action of the Wind
The geomembrane has to be ballasted after installation. Wind can displace and lift the panels. In general sand bags or old tires are used as ballasting material.
In case of a protected system it is recommended to execute the protection works after the complete control of the executed section.

### 3.3.4. Fixation of the Waterproofing System

The number of fixations depends mainly on the size of the canal and on the speed of water-flow.

#### 3.3.4.1. Anchorage of waterproofing system on the crest

In general the waterproofing system is 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.




*Dimension of Anchor Ditch (Principal Drawing)*

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

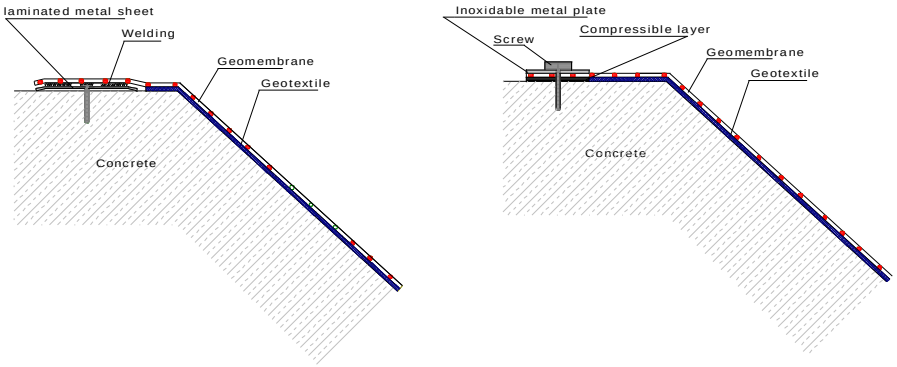
| Length of Slope | a | b |
|---|---|---|
| < 10 m | > 0,5 m | > 0,5 m |
| 10 - 40 m | > 0,8 m | > 0,6 m |
| > 40 m | > 1,0 m | > 0,8 m |

In the past many concrete canals were constructed and often only a mechanical fixation to the waterproofing system is possible. This can be achieved

• or through a colaminated metal sheet (steel sheet coated with a PVC-P membrane) that is cut into strips of 5 cm wide, screwed to the concrete, on which the geomembrane is welded;

• or with a stainless steel plate screwed into the concrete.

Fixation of Waterproofing system on Crest of the Canal




*Fixation of waterproofing to concrete structure*

### 3.3.4.2. Intermediate Fixation of Lining System

Depending on the size of the canal an 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.

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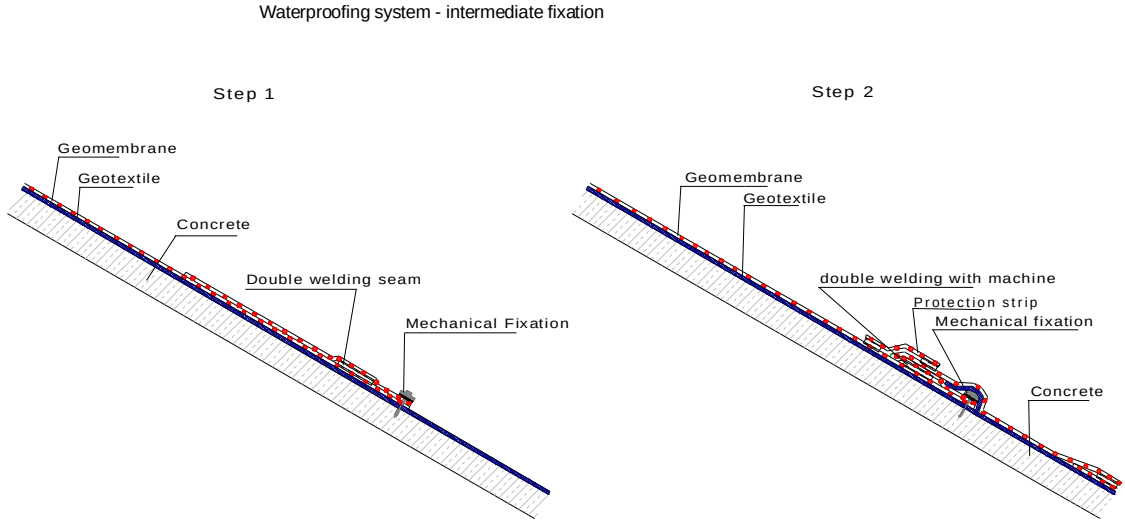
Installation Method to achieve automatic weldings :
Two layers (strips) of geomembrane are placed over each other and welded together on one end with a welding machine producing a double weld. The double seam is around 6 cm inside from the board of the geomembranes. This panel is brought into position and fixed to the concrete at the loose end of the 2 geomembranes directly on the side of the seam. The mechanical fixation will be covered with a geotextile, the upper geomembrane folded downwards and connected with the next layer of geomembrane. In this way only machine welding which can be tested are produced.
This type of fixation can also be carried out with strips of laminated metal sheets which are screwed to the concrete in a longitudinal way. The geomembrane is then welded by hand on the metal sheet (no drawing) without interruption.



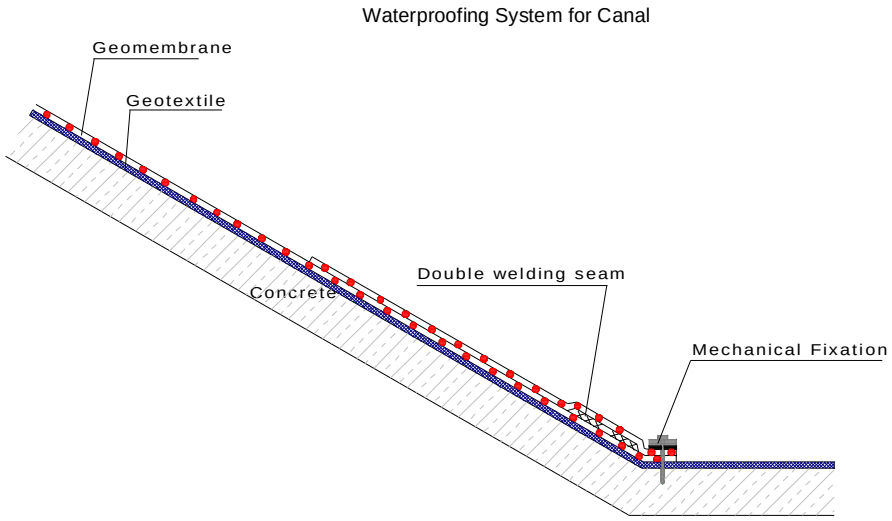

*Welding and fixation of panels*

*Down foldinf of upper membrane*

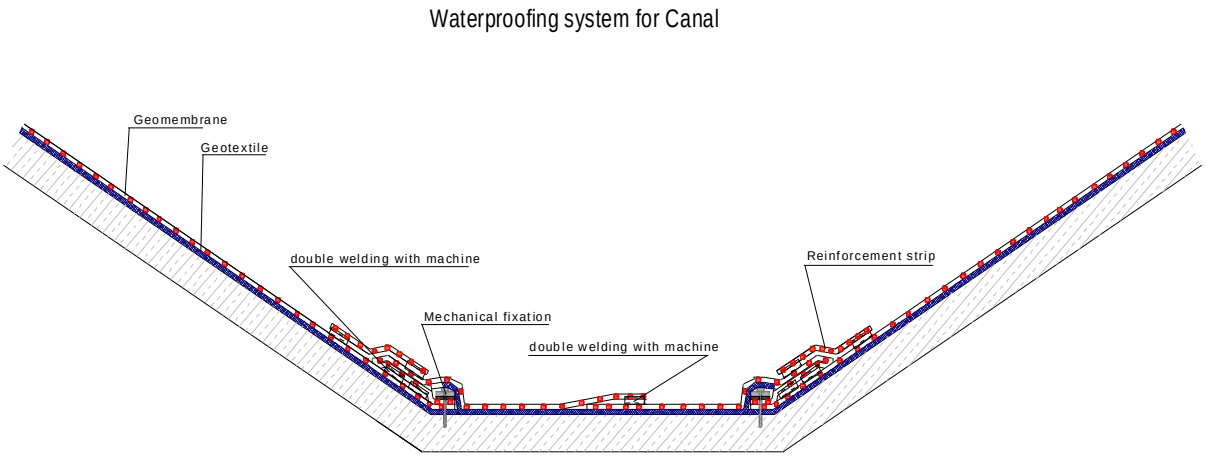
### 3.3.4.3. Anchorage of Waterproofing System on Bottom of Construction

The fixation of the waterproofing system at the junction between the slope and the bottom of the canal, maintains the waterproofing system in place on its support on the whole profile of the canal.

Installation method described in the previous paragraph allows to realise this fixation, connecting the layers only with an automatic welding machine.

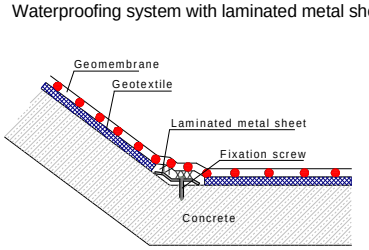


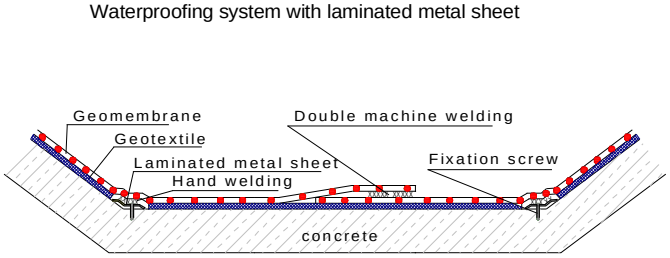

*Step 1: welding and fixation of membranes*




*Step 2: down fold of upper membranes and connection through welding in bottom area*

Alternative fixation is done again with laminated metal sheets.

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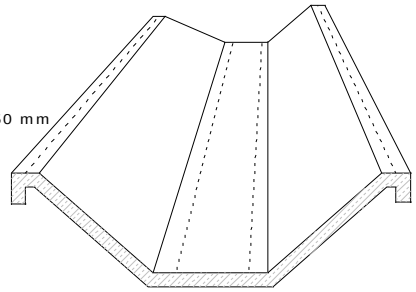
#### 3.3.4.4. Anchorage at the Beginning and at the End of the Waterproofing Section

The concrete of the canal bed is not always in a bad condition and therefore only the worst parts of the canal receive layer of waterproofing. Here it is important to avoid running water flowing underneath the waterproofing system, especially if no drainage layer is installed.

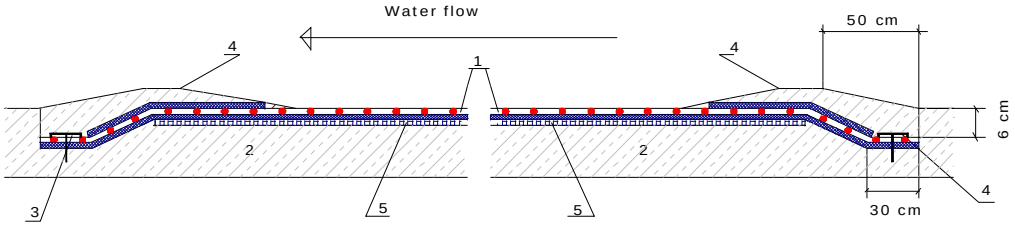
SYSTEM OF FIXATION

1 RENOLIT Geomembrane
2 Existing concrete construction
3 Fixation of geomembrane with metalsheet or PVC hard plate 1,5 mm x 50 mm
4 Protection concrete for fixation
5 Drainage layer

System of Fixation



Fixation of the lining system in the beginning and end of canal




## 3.4. Protection of waterproofing system

Protection against mechanical influences is a warranty for a long-lasting waterproofing system. For the following cases listed below 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 the bottom if cleaning with engines is foreseen
- against vandalism
- against the influence of UV radiation in exposed zones

### 3.4.1. Protection with Granulates

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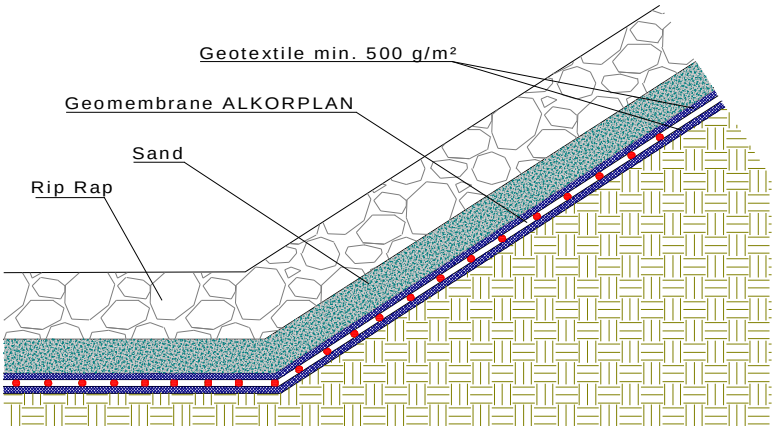
In order to carry out a study on the stability of the protection factor a complete knowledge is required about the characteristics of all the materials used, either granulates or synthetic, that will be used. Especially the angle of friction between the different faces may change in an important way 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 speed of water flow has to be taken into account to avoid any erosion of the protection layer.

Waterproofing System with Rip Rap as Protection




*Possible system of protection with granulates*

To determine the thickness of geomembrane and the weight of geotextile the following needs to be taken into account:

- type of geomembrane
- granulation and angle of the underground
- granulation and angle of the sub grade
- forces created during the fitting of the of the protection layer
  These forces depend on:
  - thickness of the protection layer placed directly onto the waterproofing system
  - type of engine used for the placement of the protection layer.

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*Unloading of protection material with truck*

*Distribution of material with bulldozer*


*Distribution with loader*

*Distribution with excavator*

### 3.4.2. Protection with concrete or shot-crete

For slopes where no stability with granulates can be achieved (angle of friction too low) a protection with concrete is the alternative.

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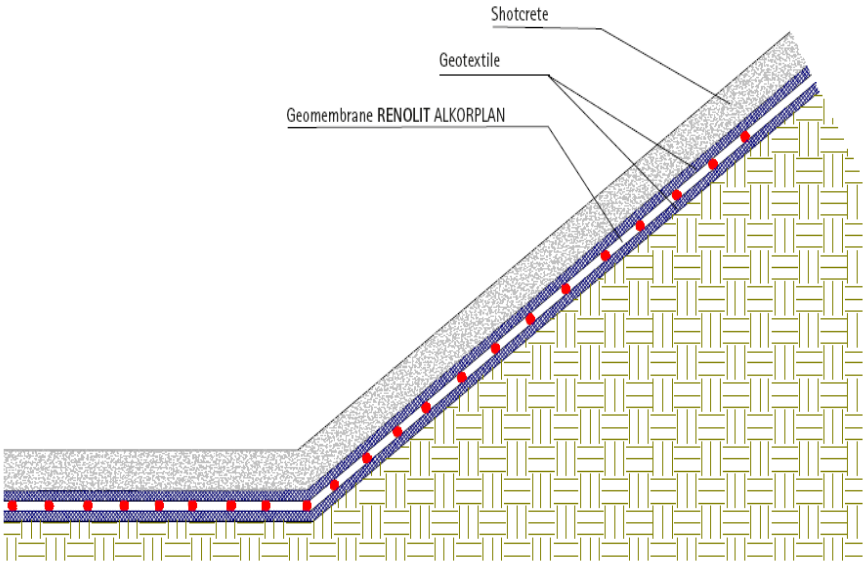


*Waterproofing System with Shotcrete as Protection*
*Possible system of protection with concrete*

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# 4. CONSTRUCTION QUALITY CONTROL MANUAL

This manual addresses the quality Control Program to ensure the quality of workmanship and the installation integrity of geomembranes and other geo-synthetic products.

## 4.1. Material Delivery

A representative should be present, whenever possible, to observe and assist in the delivery and unloading of the material on site. The representative should note any material received in a damaged state and remove any necessary conformance samples. Upon mobilisation to the site a representative shall:

- Verify the equipment used on site is adequate and does not risk damage to the geocomposite or other materials.
- Mark rolls or portions of rolls which appear damaged.
- Verify that storage of materials provides adequate protection against dirt, theft, vandalism, and passage of vehicles.
- Ensure that rolls are properly labelled and that labelling corresponds with QC documents.
- Complete roll numbers, date of production, roll size and any damage due to transport will be noted in the Material Delivery Checklist.

## 4.2. Geomembrane Installation

The general contractor shall be responsible for preparing the concrete surface suitable for installation of the liner unless specifically agreed otherwise.

### 4.2.1. Panel Layout

Prior to commencement of liner deployment, layout drawings shall be produced to indicate the panel configuration and general location of field seams for the project.

### 4.2.2. Identification

Each panel used for the installation will be given a number which correlates with a batch or roll number. This panel identification number should be registered on the panel placement form, which will be used when required. Following a plan, given by the contractor, showing the straight sections of the canal to be in condition to identify these specific rolls for controlling, identifying and deliberating for the prefabrication works.

### 4.2.3. Field Panel Placement

#### 4.2.3.1. Weather conditions

Geomembrane deployment will generally not be done during rainfall, in the presence of excessive moisture, in an area of standing water, or during high wind.

#### 4.2.3.2. Location

The installer will attempt to install field panels as indicated on the layout drawing. If the panels are deployed in a location other than that indicated on the layout drawings, the revised location will be noted in the field.

#### 4.2.3.3. Damage repairs

Any area of a panel seriously damaged will be marked and repaired in accordance with Paragraph 2.4 of this document.

### 4.2.4. Geomembrane Field Seaming

#### 4.2.4.1. Personnel

All personnel performing seaming operations shall be trained in the operation of the specific seaming equipment being used and will qualify by successfully welding a test seam as described in Paragraph 2.6

#### 4.2.4.2. Equipment

a) Welding in Prefabrication
Before starting the daily welding work a trial has to be carried out in order to regulate the welding equipment concerning the important parameters such as temperature and welding speed. The used welding machine is a device applied for lining works on flat roofs (Type Leister Variant or X 10). The welding machine produces simple seams.

b) Welding on site with hot wedge welding machine
This type of machine delivers welding with testing canal. It will be employed for the assembling of geomembrane and the prefabricated panels.

c) Hand Welding
T-joints, transversal strips, connection of geomembrane of the slopes with bottom elements in areas of curves, and details have to be done by hand welding. Recommended device is a hot air hand welder from the company Leister. Hand welding with hot air can only be used in connection with PVC-P and PP geomembranes. PE geomembranes will be welded with the help of an extrusion welder.

### 4.2.5. Seam preparation

The overlapping of the geomembrane has to be done in such a way that a safe welding with the machine is guaranteed and to ensure a welding of 30 mm for simple welding, and 40 mm for the double welding.
Clean the seam area prior to seaming to ensure that the area is clean and free of moisture, dust, dirt, and debris of any kind.
Adjust the geomembrane (panels) so the seams are aligned with the fewest possible number of creases.

### 4.2.6. Trial welding

At the start of each working day – before seaming starts – the machinery has to be checked and adapted to the current environmental parameters (temperature and air humidity). This is done through daily test to determine the speed and temperature of the welding equipment, and regarding the hot wedge machine also the pressure that need to be applied to the seam. These parameters should not be changed during the day unless the weather conditions change drastically.


*Trial Welding*

### 4.2.7. Samples Procedure

Cut 2 x 2,5 cm wide specimen and proceed to carry out a peeling test with a field traction device. The welding must not separate; the specimen must show the break of the material.


*Testing device and testing specimen*

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#### 4.2.8. Seaming Documentation

The welding technicians have to fill out all important parameters into the form for seam control:

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

## 4.3. Seam Testing – Geomembrane

#### 4.3.1. Control of seams executed in prefabrication

##### 4.3.1.1. Double seams

Double seams are controlled through air pressure. The air canal has to be closed on both sides of the testing distance. A testing needle (e.g. type Leister) is introduced into the testing channel. The needle has a conical form to avoid the evacuation of the air under pressure. During the testing time the needle may not be removed or manipulated. The applied testing pressure depends on the thickness of the geomembrane and the outside temperature. The testing has to be carried out one hour after execution of the welding. The applied pressure may decrease more than 20 % for PVC-P geomembranes.

##### 4.3.1.2. Simple seams

In case of a single seam, a steel pipe connected to a compressor with a diameter of 3 to 4 mm is drawn along the seam under an air pressure of 5 bars. This kind of testing is only suitable for flexible geomembranes not for PE. Leakages are immediately detected through the developing air bubble due to the applied air pressure.

#### 4.3.2. Control of double seams on site through air pressure

See point **4.3.1.** Control of seams executed in prefabrication.
After successful testing, a patch of geomembrane has to be welded over the penetration hole of the testing needle. The testing data will be noted

again in the testing document.

**4.3.3.** Control of hand welding

Follow the procedure of control of seams described under Paragraph **4.3.1.2.** Simple seams. Repair patches and short hand seams are easily controlled with a vacuum bell.

**4.3.4.** Repair of detected leakage

The detected leakages have to be repaired with homogeneous geomembrane patches. This welding has to be tested following the procedure mentioned under **4.3.3.** Control of hand welding.

**4.3.5.** Destructive testing (Pealing test)

The purpose of destructive testing is to determine and evaluate seam strength. These tests require direct sampling and thus subsequent patching. Therefore destructive testing should be held to a minimum to reduce the amount of repairs to the geomembrane.

- The size of the project will determine after how many meters of welding a pealing test has to be executed. Test samples will be extracted by noting date, time and location.
- Destructive samples should be taken and tested as soon as possible after the seams are welded but not before one hour in order to receive test results in a timely manner.
- All destructive test locations with pass/fail designation will be marked on the geomembrane with permanent mean streak markers.

Testing method:
The material has to break outside of the welding area. Following values are recommended:

- PVC-P and PP geomembranes: > 4 N/mm for machine welding
  > 3,5 N/mm for hand welding
- PE geomembranes > 15 N/mm

## 5. CONCLUSION

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

*Drinking Water Supply for the City of Athens – Canal of Mornos*

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