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#### 1. INTRODUCTION

#### 1.1. Scope of the Work

The estimated reserve of water is 1.500 billion m<sup>2</sup>, 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 water on the surface. Around 12 millions of people die yearly due to lack of potable water.

These numbers are a clear sign that it is time to act: too much water is wasted and polluted without reason, water which could save human lives.

One way to make reserves of drinking water is by storing it in concrete basins. Concrete is not watertight therefore the basin has to have waterproofing. A very efficient way to achieve water tightness in a concrete basin is with the help of synthetic geomembranes.

## 1.2. Products of RENOLIT

RENOLIT presents a large offer of suitable plastic sheeting to carry out the waterproofing of water reservoirs, concrete basins and similar projects:

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

- o choice of geomembrane
- o waterproofing system including the preparation of the underground
- way the work is carried out (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 question has to be taken into consideration during projecting. Depending on the form, angles and settlements of the construction the type of membrane has to be chosen.

#### 1.3.3. Chemical resistance

The waterproofing has to resist against chemical influence of:

- stocked material
- pollution rising from the underground due to the changing water levels of 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 climate 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.
- 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:

- With reinforcement (polyester grid or 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 hard box, 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, aging, roots and environmental influences.
- PVC-P Geomembranes resist 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 large window 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 ALKORTOP

This type of geomembrane is made of flexible Polypropylene

## **2.2.1.** References 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.



- 6
- 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 bidirectional 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 window 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 till they break. 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 in a correct way different accessories are required, depending what kind of construction will be water proofed, in order to complete the whole system. All accessories have to be compatible with the geomembrane that will be used. In case of the storage of drinking water all used materials have to be compatible with drinking water regulations.

The following accessories are part of such a system:

- Protection layer (geotextile should be treated against development of Microorganism)
- Drainage layer (all kinds of geo-grids)
- Fixation elements (laminated metal sheet, water stop, stainless metal plates, anchor and more)
- Bond: in case bonding material will be used, one has to ensure that it is compatible with drinking water and free of influences that could damage the geomembrane.

## 2.5. RENOLIT Production

The whole production procedure 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 before passing through the laboratory, responsible for the mixing of the compound, then passes onto production, the logistic department and also the management department. After going through the mixing and melting unit the compound is transported to the calendaring or extrusion unit. After passing through numerous calendaring drums, the final membrane, controlled by many electronic devices for thickness, heat and speed, is extracted and rolled up.

The production of geomembranes suitable for drinking water requires a very careful procedure. The mixing unit has to be completely emptied and cleaned 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 concrete reservoirs due to its excellent weld ability, its puncture resistance, deformability, 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.

#### 3. INSTALLATION OF LINING

#### 3.1. Conception 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. After exactly determined the parameters of the sub grade the waterproofing system can be decided.

In general the waterproofing system consists of:

- Support :
  - The ground has to be free of stones, grains and other materials that can damage the geomembrane.
- Protection layer :
  - Geotextile of min. 500 g/m² of Polypropylene. 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 Geomembrane :
  - The choice of the geomembrane should be done according to the task the geomembrane needs to fulfil (PVC-P, PP or PE).
- Inlets and Outlets:
  - Compatible with the geomembrane.

#### 3.2. <u>Installation of the waterproofing system</u>

Good ventilation is required during the installation works, especially during the welding process of the geomembrane.



#### **3.2.1.** Preparation of the ground slab

The ground slab of the reservoir has to be repaired and cleaned with great care. The supporting structure must be disinfected, in case of renovation. The corner between the horizontal and vertical face has to be adjusted with a triangle of concrete to smoothen the change between the horizontal and vertical direction. This is done with a mortar.

### 3.2.2. Protection layer

If the geomembrane is to be installed on top of a rough surface, an antipuncturing geotextile or a composite protective product must be installed first. If this protection has to be provided with a PVC-P protective layer, geomembrane RENOLIT ALKORPLAN 35020 can be used. Geotextile is placed with a minimum overlap of 10 cm.

#### **3.2.3.** Installation of the Geomembrane

The membrane is placed with an overlap of 5 cm to 8 cm depending on the welding device (machine or hand welder). The geomembrane has to be clean and free of dust in order to carry out a perfect welding. It is not allowed to execute welding with the help of welding liquids, type THF (Tetra-Hydro-Furan).

#### 3.2.4. Fixation of the Geomembrane

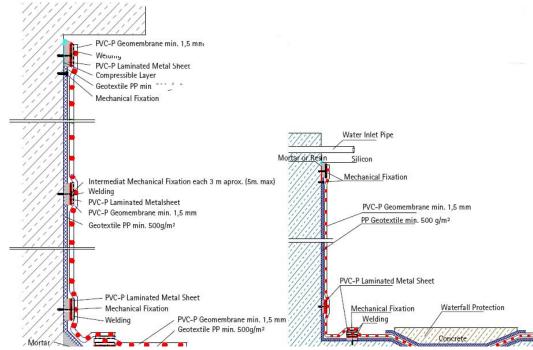
The system is loose laid.

- The geomembrane must be fastened linearly along the perimeter and around all details, in order to resist a pull-out value of at least 2700 N/ml.
- In the corners of the ground slab, the geomembrane can be fixed on PVC-P laminated metal sheets.
- In the vertical faces the geotextile and the geomembrane have to be hanged from the top to the bottom. In case the height of the basin overcomes 4 m it is recommended to execute an intermediate fixation of the waterproofing. Again the fixation can be done with a PVC-P laminated metal sheet. Also the use of a reinforced geomembrane is recommended in case of important heights.
- Fixation on top of the wall: the fixation has to be placed over the highest water line. It is executed with the help on stainless steel metal plates and compressible bands. The surface of the concrete in this zone has to be smooth and absolutely flat. This can be achieved with fine mortar or resins.

#### 3.2.5. Water dropping zone

In most cases the basin is filled from the top and the water falls onto the bottom with high forces. Therefore it is crucial to protect the area of water impact in order not to damage the waterproofing system. This can be done with a slab of concrete.

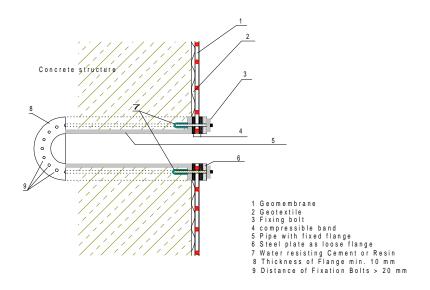




## 3.2.6. Outlet and inlets

Especially the outlet of the basin has to be waterproofed very carefully (loose flange and fix flange). The geomembrane is fixed between 2 compressible layers in the flange construction.

# Passage of Pipe







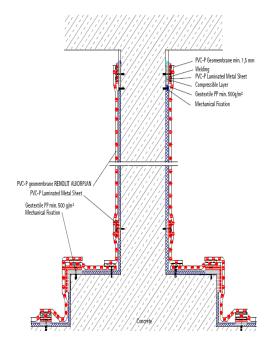
# 3.2.7. Stairs and Columns

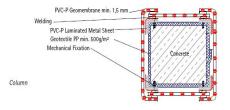
The work carried out with the waterproofing geomembrane on stairs and columns requires very careful work. All the details are done by hand and therefore only the best men should execute these details.







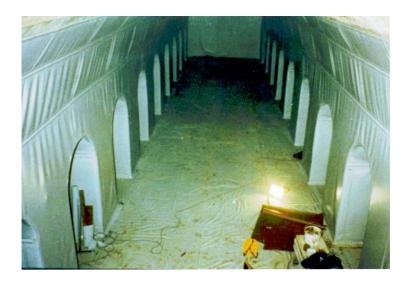




#### 3.2.8. Prefabrication

Depending on the size, form and details of the basin it is recommended to prefabricate panels of geomembrane (parts of the bottom and the wall, details like colons). The advantage is a shorter time of installation, less welding in the closed basin therefore a safer execution of the works.

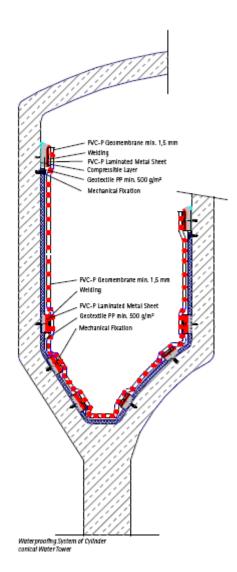






Waterproofing of Water castle





Waterproofing System of Cylinder conical Water Tower



#### 4. CONSTRUCTION QUALITY CONTROL MANUAL

This manual addresses the quality Control Program to assure 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 material delivery and unloading on site. The representative has to note any material that arrived damaged, as well as removing any necessary conformance samples. Upon transfer to site, a representative shall:

- Verify the equipment used on site is adequate and does not risk damage to the geocomposite or other materials.
- o Mark rolls or portions of rolls which appear damaged.
- Verify that storage of materials ensures 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, roll size and log any damage on 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 the 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 shall be noted on the panel placement form, which will be used when required. The contractor then provides a plan, showing the straight sections of the canal, 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 generally is not done during rainfall, in the presence of excessive moisture, in an area of standing water, or



during high winds.

#### 4.2.3.2. Location

The installer will attempt to install field panels as indicated on the layout drawing. If the panels are places at 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 seriously damaged area of a panel 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, 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 prefabricated panels.

#### c) Hand Welding

T-joints, transversal strips, connection of geomembrane to the slopes with bottom elements in areas with curves, and details have to be executed by hand welding. The recommended device is a hot air hand welder from the company Leister. Hand welding with hot air only can 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 to ensure safe welding with the machine, as well as ensuring the welding of 30 mm for simple welding, and 40 mm for double welding.

Clean the seam area prior to seaming to assure 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

Every working day - before starting seaming works - the machinery has to be checked and adapted following the daily circumstances (temperature, air humidity). This is done through daily trials to determine the speed and temperature of the welding equipment. These parameters should not change during the day unless the weather conditions change in drastically.



Trial Welding

# 4.2.7. Samples Procedure

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



Testing device and testing specimen

#### **4.2.8.** Seaming Documentation

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

o outside temperature in the morning, at noon an in the evening;



# RENOLIT ALKORGEO

# Waterproofing of concrete Basins (Reservoirs)

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

## 4.3. <u>Seam Testing – Geomembrane</u>

#### **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 executed one hour after welding. The applied pressure may not 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 though the developing air bubble due to the applied air pressure.

#### 4.3.2. Control of double seam 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 easy 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.** <u>Destructive testing (Pealing test)</u>

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.

- o Depending on the size of the project it will be determined after how many meters of welding a pealing test has to be executed. A 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 reservoirs is a highly technical work. Only experts are allowed to execute the installation and welding works.

The technical support from the side of Renolit Ibérica, 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, as shown from our long list of references.





Amusement Park - Berlin

