METHOD STATEMENT

Sikaplan® WP sheet membrane system for waterproofing of tunnels

10/2021 / VERSION 02

BUILDING TRUST
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1 SCOPE

This method statement describes the installation procedure of the Sikaplan® WP 1100 and 2100-series Sheet Waterproofing Membranes and the Sika® AR/DR waterbars made of plasticized PVC for waterproofing of tunnels.

2 SYSTEM DESCRIPTION

Underground structures, especially tunnels in most of the cases need to be watertight. A waterproofing system is required to prevent leaks into or out of the structure and to protect the structure against the harmful influences of aggressive ground- or seawater. Highly flexible Sikaplan® WP waterproofing membranes protect a structure against water from damp soil contact, percolating water groundwater and mountain water under hydrostatic pressure.

There are three different waterproofing concepts which can be chosen using the Sikaplan® WP waterproofing system regardless of the excavation and construction method:

- Drained system
- Waterstop system
- Active control system

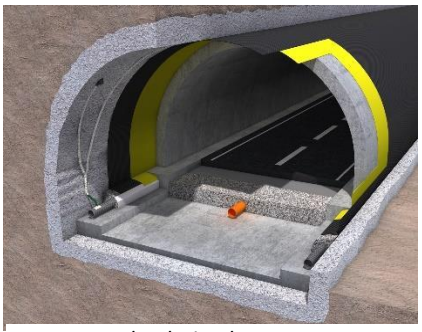
However the installation sequence differs significantly between the waterproofing membrane installation on a cut and cover tunnel and a mined tunnel.

2.1 DRAINED WATERPROOFING SYSTEM

A **drained waterproofing system** is a partial waterproofing against damp soil contact and percolating water using single layer membranes without compartment. Drainage waters is collected with a drainage pipe system and removed from the tunnel.

This system is not resistant against water under hydrostatic pressure.

The system needs a continuous maintenance as floods related to blocked drainage channels might affect the functionality of the tunnel.



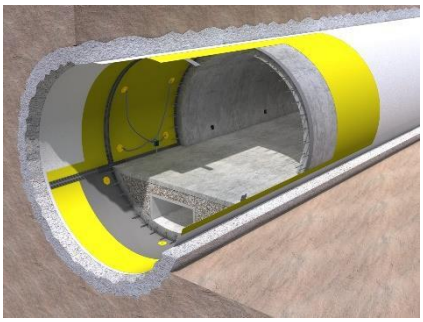
The drained system

2.2 WATERSTOP OR BARRIER SYSTEM

A **waterstop or barrier system** is a fully enclosed waterproofing system against water under hydrostatic pressure. The system is a combination of a single layer membrane and waterbars, which are forming compartments.

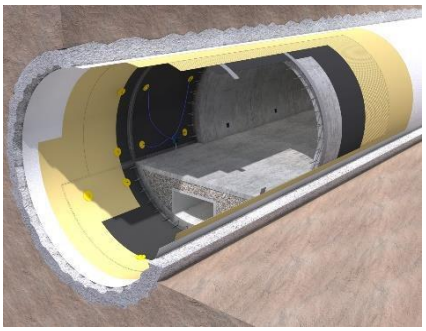
Using compartments, the damaged membrane can be localised and repaired as the waterbars will prevent the lateral water migration between the membrane and the concrete.

In case of a damaged waterproofing, these compartments between the membrane and the structural concrete will be injected using acrylates, reins, foams or cementitious grouting materials.



The waterstop or barrier system

2.3 ACTIVE CONTROL SYSTEM



The active control system

An **active control system** is a high end fully enclosed waterproofing system against water under hydrostatic pressure. The system is a combination of double layer membranes and waterbars forming injectable compartments. This system not only allows the highest security against water inflow, but also a surveillance of the waterproofing by vacuum testing the system.

In situations with leaking waterproofing membranes caused by mechanical damage to the membranes, either loose laid and single layer-, or double layer systems, infiltrating water might underflow and spread uncontrolled between the installed membrane and the structure. A compartment system made of waterbars and specially welded membranes, combined with injectable hoses provides the possibility of controlling the water inflow and repairing of the leaks by injecting the damaged areas with acrylates, resins, foams or cementitious grouting materials.

Additional advantages of the loose laid waterproofing systems are fast installation procedures, the high crack bridging ability of the installed membranes, and minimal requirements for substrate preparation.

2.4 DESIGN REQUIREMENTS

A successful waterproofing system requires detailed design and specification prior to the membrane installation works being carried out on site. It is suggested to involve a waterproofing specialist in the beginning phase of the project to ensure a buildable, reliable and repairable waterproofing system and to minimise the risk during the installation process.

The main criteria for the correct design of the Sikaplan® WP flexible sheet membrane waterproofing system against ingress of water into mined tunnel structures are:

- specification of waterproofing against drainage waters and/or waterproofing against pressure waters based on the function of the tunnel
- definition of the excavation method:
  tunnel excavation by Tunnel boring Machines
  drill and blast method
  partial excavation and lining
  full face excavation and lining
- definition of the geotechnical, geo-mechanical and hydro-geological conditions
- dimensions of the structures, including construction phases, construction schedule
- design of construction joints and movement joints

All elements protruding from or through the waterproofing membrane and cast into the concrete is a critical detail when designing waterproofing. Therefore all elements protruding from or through the waterproofing membrane and cast into the concrete, i.e. well shafts, service pipes, anchors, etc. should be designed and made of corrosion-free steel (i.e. stainless V2A or V4A steel) or other non-corroding materials. The elements should be designed with flanges in order to allow watertight connection to the membranes or must be designed with casted waterproofing around them.

In order to avoid any kind of damage to the installed membranes and to ensure their proper function the following design requirements must be met:

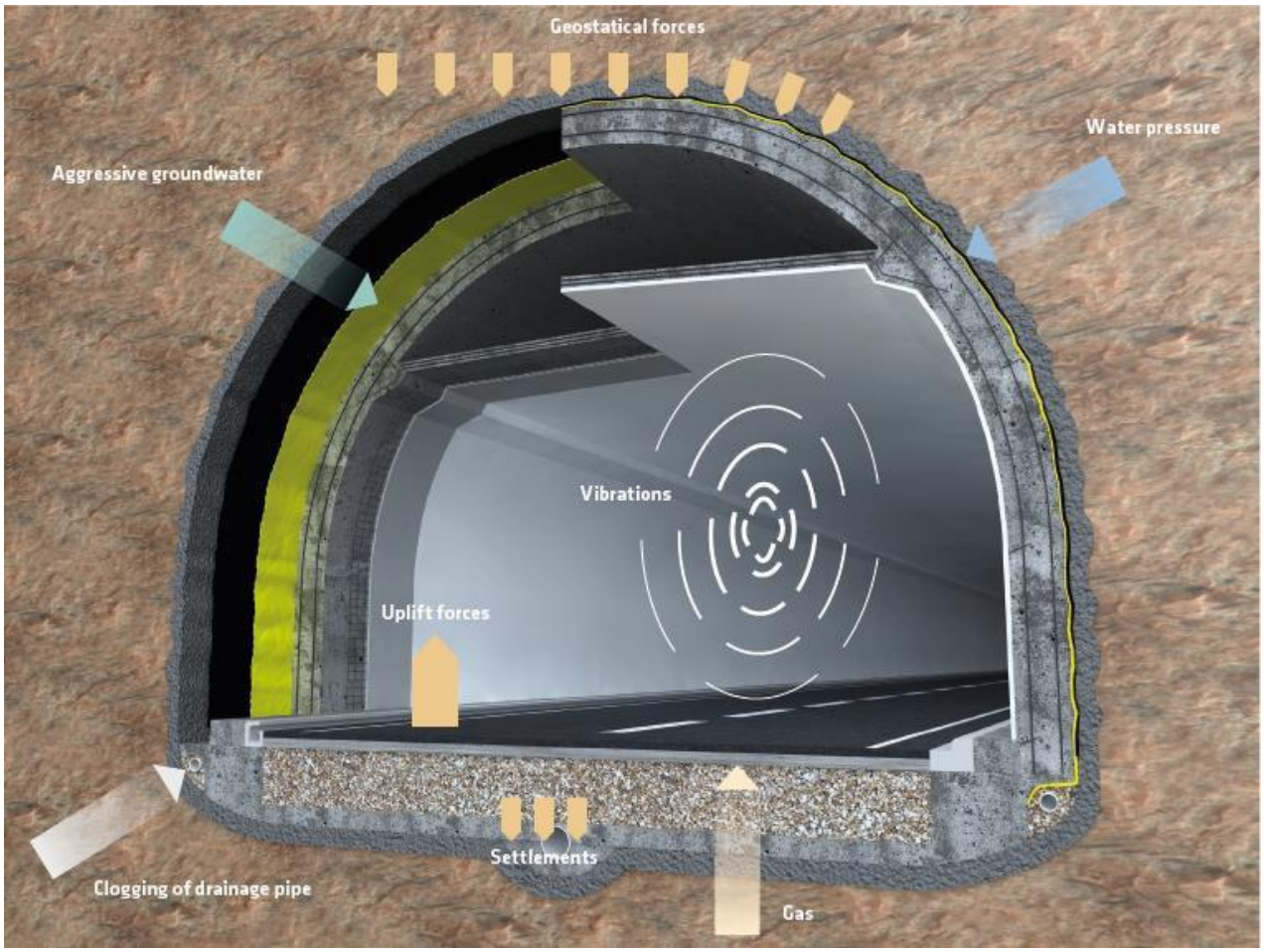
- structures must be designed to minimise movement/displacement (i.e. temperature, settlement and concrete shrinkage, contraction etc.)
- reinforcement bars should have a min. of 30mm concrete cover if not regulated otherwise
- protruding elements of the waterproofing should be stainless steel or other non-corrosive materials (i.e. cast iron, V2A, V4A steel quality, aluminium, plastic, fibreglass, etc.)

The waterproofing must be designed based on the hydrostatic pressure of the surrounding water. If local requirements or standards do not specify otherwise, the membrane thickness should be specified according to estimated immersion depth and consequent potential water pressure:

		membrane thickness
Moisture and water ingress, no hydrostatic pressure due to a drainage system		≥ 1.5 mm
Hydrostatic pressure	less than 10 m	≥ 1.5 mm
Hydrostatic pressure	10 m - 20 m	≥ 2.0 mm
Hydrostatic pressure	higher than 20 m	≥ 3.0 mm

2.5 CONSTRUCTION REQUIREMENTS

The structure should be built in such a way that the Sikaplan® WP waterproofing membrane system can adequately fulfil its function during its service life. Therefore the installation of the Sikaplan® waterproofing systems must only be carried out by skilled and experienced waterproofing contractors. The personnel must be trained in correctly installing and welding of the Sikaplan® WP sheet membranes and related products and ideally should hold a certification issued by Sika stating his skills and expertise.



Exposure of the tunnel waterproofing

The construction requirements for a successful Sikaplan® WP flexible sheet membrane waterproofing system against water ingress into mined tunnel structures are:

- actual geological, geo-mechanical and hydro-geological conditions during construction period
- conditions of the drain-off mountain waters during construction period
- actual groundwater levels (max., min., average, immersion depth of structure)
- condition of groundwater and mountain water (aggressive water, salt water)
- temperature condition, including the ground, rock and water
- condition of the substrate to be waterproofed

- dimensions of the structure (length, width, depth)
- construction phases, construction schedule
- construction and movement joint details
- installation of the waterproofing system by trained and experienced personnel
- proper supervision during all stages of the construction, including storage, transportation, substrate preparation, installation, quality control and protection of the installed waterproofing system

In order to avoid any kind of damage to the installed membranes and to ensure their proper function the following requirements must be met:

The surface of the substrate being waterproofed should be smooth (see page 14). Unevenness of a shotcrete surface must not exceed the ratio of length to depth unevenness of 5:1 and its min. radius must be 200 mm. The shotcrete surface must not contain broken aggregates.

Local water infiltration, shall be sealed either with waterproof plugging mortar, or channelled to the invert using half pipes.

It is recommended to apply a fine gunite layer on fibre reinforced shotcrete surfaces with a min. thickness of 500 mm and its aggregate dia. not exceeding 4 mm (if the above mentioned shotcrete requirements cannot be fulfilled). Steel elements (girders, reinforcement mesh, anchors etc.) must be covered with a min. of 300 mm of shotcrete/gunite.

The surface of shotcrete, resp. gunite must be clean and free of loose debris (no loose stones, nails, wires, etc.).

- to avoid puncturing the membrane under the future influence of hydrostatic pressure
- the surface of the substrate being waterproofed should be cleaned from all loose items before installing the waterproofing
- the surface of the substrate being waterproofed should be fenced off and only the personnel involved in the waterproofing should be allowed on the area during the installation of the waterproofing
- after installing the waterproofing membrane, all welded seams should be tested and documented if not regulated otherwise
- all elements protruding the waterproofing should be stainless, or anticorrosive materials (i.e. cast iron, V2A, V4A steel quality, aluminium, plastic, fibreglass, etc.)
- all elements protruding the waterproofing should be controlled and documented before proceeding for the further construction steps
- the installed waterproofing must be as soon as possible protected with an adequate protection layer, geotextile or screed concrete according to the waterproofing design
- construction and movement joints should be clean, smooth and made according to the waterproofing design

After the concrete covering the waterproofing is casted it is extremely costly and time consuming to repair the waterproofing membrane. Therefore site access control, QC control during the construction, proper documentation and a properly installed protection layer is necessary to reduce the risks posed by a damaged membrane or an inadequately installed detain.

2.6 SYSTEM COMPONENTS

The loosely laid Sikaplan® WP Sheet Waterproofing Membrane System components are designed based on the following basic criteria:

- partial- or full enclosed waterproofing system to seal against drainage water or pressure water
- project design of bottom, arch, niches, alcoves and cross passages
- project design of termination with cross passages, shafts, stations and other structures
- damp soil contact, percolating water, or water under hydraulic pressure
- immersion depth below groundwater level
- temperature conditions
- chosen membrane type and its fixing methods
- chosen waterproofing system, i.e. drainage system, waterstop system, or active control system for highest demands
- experience of the applicator

Generally the following system components are necessary based on the waterproofing concept, however this must be adjusted to the project specific criteria:

System component	Drained system	Waterstop system	Active control system
drainage system	x	o	o
geotextile	x	x	x
fixation system made of discs, fixation plates and fixation bars	x	x	x
connection system between watertight concrete elements and waterproofed areas	x	x	x
waterproofing membrane	x	x	x
geomat/embossed waterproofing membrane			x
Waterbars, construction joint sealing and movement joint sealing including tapes and adhesives	x	x	x
anchor waterproofing/ flanges	optional	optional	optional
control sockets/ trumpet flanges		x	x
protection sheets	x	x	x

o: might be necessary during the construction process, but not part of the final waterproofing system

Equipment and items necessary for installation:

membrane cleaner	x	x	x
welding tools	x	x	x

3 PRODUCTS

3.1 SIKAPLAN® WP SHEET WATERPROOFING MEMBRANES

Specials (with signal layer 0.6 mm) other thicknesses available on inquiry	**Sikaplan® WP 1181 -15 HL**	**Sikaplan® WP 1181 -15 HL**
Material	Homogeneous PVC-p membrane, partly made of recycled PVC-p material	

Standard product (with signal layer 0.6 mm) other thicknesses available on inquiry	**Sikaplan® WP 1100-15 HL**	**Sikaplan® WP 1100-20 HL**	**Sikaplan® WP1100 -30 HL**
Material	Homogeneous PVC-p membrane		

Standard product (with signal layer 0.2 mm) other thicknesses available on inquiry	**Sikaplan® WP 1100-15 HL2**	**Sikaplan® WP 1100-20 HL2**	**Sikaplan® WP 1100-30 HL2**
Material	Homogeneous PVC-p membrane		

Special membranes	**Sikaplan® WP 1110-15 H translucent**	**Sikaplan® WP 1110-20 H translucent**
Material	Homogeneous translucent PVC-p membrane	

Specials (certified according to ÖBV 4.7)	**Sikaplan® WP 2101– 21 HL2**	**Sikaplan® WP 2101– 31 HL2**
Material	Homogeneous PVC-p membrane	

Specials (high fire resistant liner material)	**Sikaplan® WP 2110– 21 HL**	**Sikaplan® WP 2110– 31 HL**
Material	Homogeneous PVC-p membrane, fire resistance class 5 (according to Swiss regulations VKF)	

Specials membranes (black, oil and bitumen resistant on request)	**Sikaplan® WP 6110 -15H black**	**Sikaplan® WP 6110 -20H black**
Material	Homogeneous PVC-p membrane, oil and bitumen resistant	

Use	waterproofing of all types of structures, situated below ground against groundwater ingress

3.2 SIKA® FLEXODRAIN HALF PIPES AND ACCESSORIES

Material	PVC based half pipes and connection elements
Use	For spotwise fixing on shotcrete to collect local water inflows and to channel water to main drainage system or tunnel invert prior to fixing geotextile and waterproofing membrane

3.3 SIKADRAIN

Material	PE based drainage sheets with or without fleece backing
Use	For using as a separation, protection and drainage layer on tunnelling jobs

3.4 SIKAPLAN® W TUNDRAIN TYPE C, TYPE D

Product	Sikaplan W Tundrain Type C	Sikaplan W Tundrain Type D
Material	low-density polyethylene drainage and protection mesh Tundrain Type C must be always used with a min 100 g/m2 geotextile separation layer between the PVC membrane and the Tundrain Type C drainage layer	a three-dimensional, high void ratio monofilaments core heat bonded with one filter geotextiles
Use	As a drainage layer for underground structures	

3.5 SIKAPLAN® WP FIXATION PLATE PVC

Material	Fixation plate on base of rigid PVC
Use	For linear fixing of Sikaplan® WP 1100 and 2100 waterproofing sheets. Strip to be cut to the required length with suitable tools. Fixing with screws or metal spikes into reinforced concrete substrates. Sikaplan WP 1100 and 2100 membrane to be heat welded on fixed plates.

3.6 SIKAPLAN® WP DISC 80/10MM

Material	Fixation disc on base of plasticised PVC
Use	For spotwise fixing of Sikaplan® WP 1100 and 2100 waterproofing sheets. Fixing of disc with screws or metal spikes into reinforced concrete, or shotcrete substrates. Sikaplan WP 1100 and 2100 membrane to be heat welded on fixed discs.

3.7 SIKA® WATERSBARS, TYPE AF/DF

Material	Preformed profiles on base of plasticised PVC with/without integrated injection pipes
Use	Cast in concrete waterbars for compartments and linear fixings of Sikaplan® WP 1100 and 2100 waterproofing sheets exposed to groundwater under hydrostatic pressure

3.8 CONNECTION STRIPS AND SEALING STRIPS

	Sika® Dilatec, type E/ER joint sealing strips
Material	Joint sealing tapes on base of plasticised PVC with integrated fleece edges

Use	Surface applied joint sealing strips, bonded with Sikadur® -31 epoxy adhesive on concrete for compartments and linear fixings of Sikaplan® WP 1100 and 2100 waterproofing sheets exposed to groundwater under hydrostatic pressure

	Sika® WP Tape
Material	The Sikaplan® WP Tape-200 is a waterproofing tape based on modified PVC
Use	Creation of sealed compartments for compartment waterproofing systems, termination of the Sikplan WP Membrane System, Connecting Sikaplan WP Membrane System to existing structures or prefabricated concrete elements

3.9 PRODUCTS FOR MEMBRANE PENETRATION

	Sikaplan® WP Trumpet Flange
Material	Preformed piece of injection flange in trumpet shape on base of plasticised PVC
Use	Single spot-access pipe flange to be connected with metal nipple and metal pipe for control of water-tightness and injection of compartment waterproofing system

	Sika Anchor 300
Material	a hard PVC shell with flange welded on a Sikaplan PVC waterproofing membrane
Use	temporary fixing the reinforcement of inner lining or fixing the reinforcement mat for shotcrete inner lining to reduce rebound off the waterproofing membrane

3.10 PRODUCTS FOR COMPARTMENT INJECTION

	Sikaplan® WP control socket
Material	Preformed piece of injection flange on base of plasticised PVC
Use	The control sockets are connected to an injection hose to control the water-tightness and injection of compartment waterproofing system

3.11 PROTECTION CHEETS

	Sikaplan® WP Protection sheet-21H, -31H
Material	PVC-p membrane, homogeneous, not bitumen resistant with smooth surface
Use	Protection of installed waterproofing membranes against mechanical damage

	Sikaplan® WP Protection sheet-15HE, 20HE, 30HE
Material	PVC-p membrane, homogeneous, not bitumen resistant with embossed surface
Use	Protection of installed waterproofing membranes against mechanical damage. Embossed surface faced to waterproofing membrane allow free space for pressure control and injections

	Sikaplan® WP Protection sheet-32HL2
Material	PVC-p membrane, homogeneous with a signal layer of 0.2 mm, not bitumen resistant with smooth surface
Use	Protection of installed waterproofing membranes against mechanical damage according to the specification of ÖBV

3.12 EPOXY BASED ADHESIVE

	Sikadur® - 31 CF normal	**Sikadur® - 31 CF rapid**	**Sikadur® - 31 CF slow**
Material	moisture tolerant, thixotropic, structural, two part adhesive based of Epoxy resin to glue Sika Dilatec E/ER type joint tapes and Sika® WP Tape		
Use	at ambient temperature of +10 °C until +30 °C	at ambient temperature under +15 °C	at ambient temperature above +25 °C

3.13 MEMBRANE CLEANER

	Sarna Seam Cleaner	**Sika-Trocal Cleaner**
Material	solvent containing cleaner to clean welding area and WP tape	solvent-free cleaner to clean membrane surface
Use	cleaning of contaminated surface	

3.14 POLYETHYLENE FOIL AS SEPARATION-/GLIDING LAYER

	PE foil
Material	Min 0.3 mm thick PE foil
Use	gliding and separation layer between geotextile membrane protection and concrete

4 INSTALLATION PROCEDURE

The installation procedure of the waterproofing system is depending on the chosen waterproofing concept and the site conditions.

Installation of Sikaplan® WP waterproofing sheets must only be performed by skilled and experienced waterproofing contractors, trained in Sikaplan® WP membrane welding and installation.

In finalising their tender submissions the waterproofing contractor must have the possibility to inspect the site conditions beforehand.

- installation works can be performed in ambient temperature at least min +5 °C
- membrane rolls, geotextile rolls, etc. must be stored in horizontal positions in dry areas and protected against exposure to weathering on site, if stored outside of tunnel
- in order to prevent damage of the installed waterproofing membranes, unauthorised individuals must be prevented from having access to the installation site during and following the waterproofing works
- waterproofing contractor's personnel shall only wear suitable shoes with rubber soles, when walking on installed membranes
- smoking and open fires must not be permitted on site
- heat welding machine operators must be trained and instructed on the safety of electrical equipment for site welding procedures
- in order to prevent mechanical damage by third parties, the installed membranes must be temporarily protected and/or must be kept under surveillance until their final covering with protective layers

4.1 INSTALLATION PODIUM AND OTHER EQUIPMENT NEEDED FOR INSTALLATION

In large tunnels movable scaffoldings are required for membrane installations, i.e.:

- prefabricated membrane installation machine with moveable working platform, designed for actual tunnel-radius
- prefabricated membrane installation platform (mobile and manual driven) for linings in narrow cross passages
- mobile hydro-pneumatic movable working platform (alternative to installation machine, available from local)

In smaller tunnels, i.e. cross passages fixed scaffoldings might be sufficient to install the waterproofing, however in this case the full area should be waterproofed in one step to reduce the downtime related to removing and erecting the scaffolding in n a new position.

Other necessary equipment are:

- illumination equipment, to be mounted at installation scaffolding
- power supply with 380V/220V or 110V at the installation area to drive welding equipment
- equipment to lift membrane and geotextile rolls on working platforms, i.e. light hydraulic cranes, forklifts or telehandlers

The installation scaffolding equipment for mining tunnels shall be constructed in portal form in order not to block the construction traffic.

4.2 MATERIAL STOCKYARD ON SITE, SITE LOGISTICS

A secured area (i.e. storage hall, or open ground) is required to store rolls of membranes, geotextiles, waterbars and all its required auxiliary products. The area must be accessible to lifting and carrying equipment to move the waterproofing material from stockyard to tunnel portals and to installation site in the tunnels.

Membranes shall be stored weathering protected, not exposed to direct sunlight and water.

The minimal quantities of waterproofing membranes and geotextiles in stockyards must be defined prior the beginning of the waterproofing works and shall at no time be less than the defined quantity.

4.3 INSTALLATION SEQUENCE

The following installation sequence is recommended based on the used waterproofing system, however it must be adapted to the site conditions, construction sequence, and/or client's requirements:

Drainage system (detail see page 23)

- install the drainage system in the tunnel including the loose filling around the drainage pipes
- prepare substrate prior to installation of the waterproofing according to design criteria
- install geotextile cushion and drainage layer
- install of Sikaplan WP sheet membranes by spotwise fixing with fixing discs
- heat weld of seam with overlaps according to application manual
- connect the waterproofing to the drainage system
- concrete the tunnel invert
- concrete the walls and the crown

Waterstop system (detail see page 24)

- prepare the substrate prior to installation of the waterproofing according to design criteria
- install the geotextile cushion and drainage layer in the tunnel invert
- install the Sikaplan WP sheet membranes by spotwise fixing with fixing discs in the tunnel invert
- install the control sockets and waterbars according to the design
- install the protection layer
- concrete the tunnel invert
- install the Sikaplan WP sheet membranes by spotwise fixing with fixing discs on the walls and in the tunnel crown
- install the control sockets and waterbars according to the design
- install the protection layer if necessary
- cast the tunnel walls and crown

Active control system (detail see page 27)

- prepare the substrate prior to installation of the waterproofing according to design criteria
- install the geotextile cushion and/or drainage layer in the tunnel invert
- install two layer of Sikaplan WP sheet membranes
  loosely lay the first layer in the tunnel invert
  lay and spotwise fix the geomat on the first layer according to waterproofing design, if necessary
  use spotwise fixing of the of the second layer
  weld the compartment edges with continuous seams according to the waterproofing design
- install the control sockets and waterbars according to the design
- install the protection sheet, if necessary
- test the compartments with vacuum
- concrete the tunnel invert
- install two layer of Sikaplan WP sheet membranes
  spotwise fixing of the first layer with fixing discs on the tunnel walls and crown
  install and spotwise fix the geomat on the first layer according to waterproofing design, if necessary
  use spotwise fixing of the of the second layer
  weld the compartment edges with continuous seams according to the waterproofing design
- install the control sockets and waterbars according to the design
- install the protection sheet, if necessary
- test the compartments with vacuum
- Casting tunnel walls and crown

4.4 SUBSTRATE PREPARATIONS

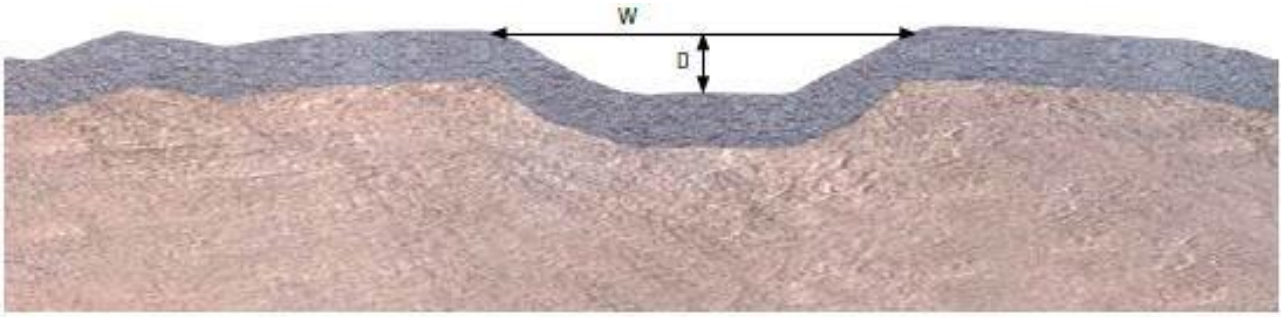
Conditions of substrate surfaces of shotcrete/gunite:

Unevenness of a shotcrete surface must not exceed the ratio of length to depth unevenness of 5:1 and its min. radius must be 200 mm. The shotcrete surface must not contain broken aggregates.

Local water infiltration, shall be sealed either with waterproof plugging mortar, or channelled to the invert using half pipes.

It is recommended to apply a fine gunite layer on fibre reinforced shotcrete surfaces with a min. thickness of 50 mm and its aggregate dia. not exceeding 4 mm (if the above mentioned shotcrete requirements cannot be fulfilled). Steel elements (girders, reinforcement mesh, anchors etc.) must be covered with a min. of 30 mm of shotcrete/gunite.

The surface of shotcrete, resp. gunite must be clean and free of loose debris (no loose stones, nails, wires, etc.).



Requirement of membrane flexibility in connection with shotcrete evenness			
Material type	PVC-P	FPO	LLDPE
Section elasticity module $E_{s,s}$ according to ISO 527	< 20 N/mm²	< 65 N/mm²	< 100 N/mm²
Eveness of shotcrete W:D	≥ 5:1	≥ 10:1	≥ 15:1

Substrates of blinding, or concrete surfaces below bottom slabs:

The surface of the concrete or mortar shall be smooth (steel trowel finish) and edges/corners should be rounded with a min. radius of 30 mm. Any projections in the cementitious substrate shall be removed by chiselling or grinding; nails, wires or loose stones should be removed. Any protective mortar layer thickness shall be min. 50 mm, if necessary light reinforced with a concrete cover of min. 30 mm. The maximum aggregate diameter of mortar screeds shall not exceed 4 mm. The whole surface shall be thoroughly cleaned using high pressure water. Ponding water must be removed and the whole surface shall be dried using compressed air if possible.

Substrate preparation procedure prior to application of Sikadur®-31 CF adhesives must be according to its product data sheet and application manual.

Substrate surfaces for refurbished concrete structures:

Old linings, as well as any de-bonded rendering and screeds must be removed. Larger cracks and honeycombing must be broken out and re-profiled with adequate repair mortars.

Water infiltration must be sealed, either with waterproofing mortars, or by injection with acrylic resin or micro-fine cement grout.

The new renderings and screeds shall be applied on blast clean substrates, its maximum aggregate diameter shall not exceed 4 mm and its surface shall be steel-trowel finished. Edges must be chamfered/rounded with a min. radius of 30 mm. The whole surface should be free of loose debris. Ponding water must be removed and the whole surface shall be dried using compressed air if possible.

Substrate preparation procedure prior to application of Sikadur® -31 CF adhesives must be according to its product data sheet and application manual.

Substrate surfaces for new concrete structures:

The surface of the concrete must be smooth (steel trowel finish, resp. first class formwork quality) and edges must be chamfered/rounded with a min. radius of 30 mm. Reinforcement steel bars shall be covered min. 30 mm. Any projections in the cementitious substrate must be removed by chiselling and grinding; nails and wires must be removed. Honeycombed concrete shall be broken out and re-profiled with repair mortar.

Water infiltration through cracks of concrete structures, or along steel elements shall be sealed, either with waterproofing mortar or by injection of acrylic resin, or micro-fine cement grout.

The maximum aggregate diameter of rendering and mortar screeds shall not exceed 4mm. The whole surface shall be thoroughly cleaned using high pressure water. Ponding water must be removed and the whole surface must be dried using compressed air.

Substrate preparation procedure prior to application of Sikadur® -31 CF adhesives must be according to its product data sheet and application manual.

Sealing of local water infiltrations and ingresses:

Even the membranes and the accessories are waterproof, local inflows, dropping and ponding water should be avoided. It is difficult to weld the membranes in wet areas, as water can damage the welding equipment and can influence the welding temperature.

Running water ingress should be plugged with plugging mortars (i.e. Sika® 4A admixture) mixed with Portland cement or can be injected with the SikaFix products prior to the waterproofing works.

Waters of heavy ingress shall be collected into PVC half-pipe (i.e. Sika® FlexoDrain half pipe) mounted on the concrete surface to channel the water into permanent drainage system. Prior to initial installation of cushion layer, the mounted half pipe shall at least be covered with min. 5cm thick shotcrete layer.

4.5 CUSHION AND DRAINAGE LAYERS

The waterproofing membrane to be installed must be protected against hard and rough substrates. Based on the chosen waterproofing concept and site condition, either a drainage layer or a geotextile cushion layer must be placed under the waterproofing membrane, according to the design specification. This cushion layer must be based on of Polypropylene (PP) non-woven fabric, needle punched, or thermally cured, or endless fibre mat made of open structured polyamide.

The geotextile cushion layer must have a min. unit weight of 500 g/m^2 and a geomat must have min. thickness of 10mm for use on shotcrete substrates. Cushion layers shall be loose laid and must be overlapped min. 100 mm and it must be spotwise fixed with fasteners at walls and crowns of tunnel.

The physical properties of geotextiles must fulfil the requirements of the relevant local standards as well as the permeability required to drain off water behind membrane if not defined otherwise by the client

5 WELDING OF THE WATERPROOFING MEMBRANES

The Sikaplan® WP 1100-series and 2100-series Sheet Waterproofing Membranes and Sika® AR/DR waterbars are installed using manual, semi-automatic and automatic thermoplastic welding methods. The two layers are heated up and fused together using pressure.

5.1 OPERATIONAL STEPS, RECOMMENDATIONS AND CRITERIA OF THE THERMOPLASTIC WELDING:

- seam overlaps of membranes must in all cases be min. 80 mm
- the width of the finished welded seam (single or double seam) must be at least > 30 mm
- prior to the welding procedure, membrane surfaces shall be dry, clean, and free of dust, oil and grease etc.
- in case of polluted surface, Sikaplan® WP membrane surfaces must be cleaned preliminary to welding procedure with Sarna Seam Cleaner
- prior to any heat welding work conduct a welding test with membrane specimen (mandatory in order to adjust welding temperature and speed of the machine)
- for continuous welding quality, it is recommended to run welding equipment connected with own circuit, or using its own generating set (automatic welding machine: 360V, hand held welding gun: 220V, resp. 110V according to regulations)
- welding machine operators must be trained and experienced in heat welding technology and to operate electrical devices in wet, or humid conditions according to the local regulations

Sikaplan® WP waterproofing membranes may be welded by using suitable heat welding machines of any type.

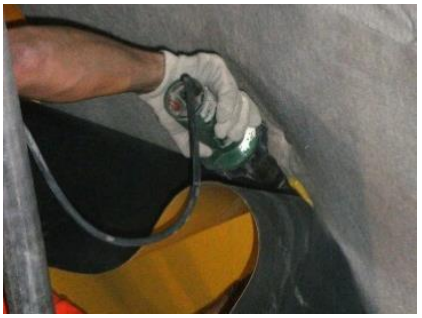
5.2 HEAT WELDING PROCEDURE OF INSTALLED SHEET MEMBRANE

The membrane surfaces to be welded shall be clean, dry and free of fat, grease and oil. Fat, grease and oil shall be cleaned with dry and white cotton rags and Sika Trocal Cleaner (solvent-free cleaner for PVC membranes).

Prior to any welding works, the welding parameters (speed, temperature and pressure of rollers) shall be adjusted at the automatic welding machine and tested at separate membrane specimen according to the application manual.

5.3 MANUAL WELDINGS

Details (i.e. membrane intersection to waterproofing of cross passage, jet fan niches, station boxes, penetrations of anchors, etc.) shall be performed by hand held welding machine and pressure roller (i.e. type Leister Triac) as single seam welding. Membrane overlaps shall be min. 50 mm. Stitch weld the membranes to prevent movement of the material. Then use handheld welding machine to produce a continuous welding seam along the membrane edge.



Manual welding

All welded seams must be checked and approved before continuing the works.

Equipment:

- hand held welding gun i.e. type Leister Triac S, Triac PID, 220 V, resp. 110 V (*www.leister.com*)
- hand held welding gun i.e. type BAK Rion, 230 V (*www.bak-ag.com*)
- heat nozzles 40 mm and 20 mm, or 30 mm all purpose-nozzle
- hand held pressure (Silicone) roller with ball bearing (usually available from same supplier as of welding machine), width 20 mm and 40 mm
- reserve heating element

5.4 SEMI-AUTOMATIC WELDING FOR HORIZONTAL, VERTICAL AND OVERHEAD WATERPROOFING

Semi-automatic welding

Reset working platform parallel to tunnel axis at one lateral edge of installed waterproofing membrane. Clamp membrane overlaps at membrane end into welding machine, insert welding nozzle into overlap and start machine self-traction. Lead the machine at hand held along overlap, and follow movement with working platform at the same speed than welding machine. This welding procedure shall be performed without interruption until other the end of the seam.

All overlaps within the tunnel profiles (excl. details) shall be performed with double seam welding, two seams with air testing channel between them.

All welded seams must be checked and approved before continuing the works.

Equipment:

- hand held semi-automatic, self-propelled welding machine, i.e. type Leister Triac Drive, 220V, resp. 110V with adjustable temperature and speed control of pressure roller (*www.leister.com*)

5.5 AUTOMATIC WELDING FOR HORIZONTAL, VERTICAL AND OVERHEAD WATERPROOFING

Automatic welding

Reset working platform parallel to tunnel axis at one lateral edge of installed waterproofing membrane. Clamp membrane overlaps at membrane end into welding machine, insert welding nozzle into overlap and start machine self-traction. Lead the machine at hand held along overlap, and follow movement with working platform at the same speed than welding machine. This welding procedure shall be performed without interruption until other the end of the seam.

All overlaps within the tunnel profiles (excl. details) shall be performed with double seam welding, two seams with air testing channel between them.

All welded seams must be checked and approved before continuing the works.

Equipment:

- automatic, self-propelled, i.e. types Leister Twinny S, Twinny T, Comet (adjustable temperature, speed and pressure), 220/380V (*www.leister.com*)
- automatic, self-propelled, i.e. types BAK Mion, Comon (adjustable temperature, speed and pressure), 230 V (*www.bak-ag.com*)

5.6 AUTOMATIC WELDING FOR HORIZONTAL, VERTICAL AND OVERHEAD WATERPROOFING

Welding the membranes and waterbars is a temperature sensitive activity. Therefore at each work start or work – re-start after a pause, a welding test must be made to ensure that the machine settings are still valid for the situation. This includes:

testing the machine on a membrane surface to see that it does not burn the membrane and to check how much time is needed to melt the surface,

welding together two strips of membranes and then tearing them apart to see the seam quality

Generally the following work-site conditions are recommended:

Ambient temperature range for membrane installation works: above 0 °C

Membrane temperature range for welding the membrane: between +5 °C and +35 °C

6 QUALITY CONTROL

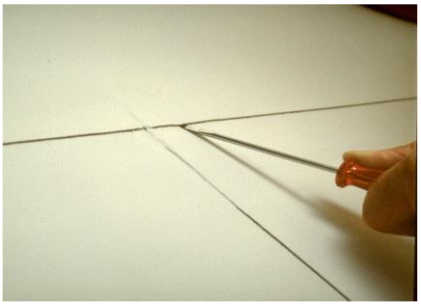
After the membrane is installed, it is crucial to perform a proper quality control. When the membranes are covered with concrete, they are not accessible anymore and the repair is costly and time consuming.

6.1 QUALITY CONTROL OF THE WELDED MEMBRANES

All welded seams must be tested for water-tightness. Several testing methods are available depending on the available testing equipment and/or client's specification. The most common test methods are mechanical testing with a needle/hook/screwdriver, test using air pressure for double seems and compartments, and testing with vacuum bells.

Visual test:

- correctly heat welded single seams show continuous welding 'rope' at seam edge
  irregular, or interrupted rope can be the sign of voids or capillaries in the seam
- glide the point of the needle/hook or the head of screw driver/ (approx. size 2) with slight pressure along seam edge and check visually
- any voids or capillaries must be marked, rectified with hand held welding gun and 20 mm Silicone roller
  correction welding must be re-checked after welding is done

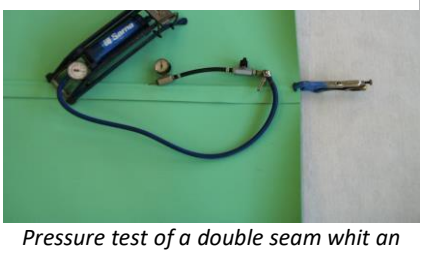


Gliding a No5 flat screwdriver along the seam

Pressure testing of the double seams:

- double seams must be tested with compressed air testing kit
  - the testing kit contains:
    containing testing needle
    reverse flow valve
    manometer gauge
    air pressure pump (manual, or electric)
- air channels must be sealed with clamp at both ends of welded seam
- insert testing needle, connected with reverse flow valve and manometer at one membrane overlap end and connect testing needle with hose of manual, or electric compressed air pump
- inflate air channel until pressure of 2.0 bar is achieved
  close reverse flow valve
  disconnect hose from testing needle
  check air pressure 20 minutes after inflation procedure
- the welded seam should be regarded as tight, if the pressure decrease is less than 20%
  - if the welding pass the air pressure test, release clamp from membrane ends
    Heat weld membrane patch over the membrane penetration, caused by insertion of testing needle with hand held welding machine
    sign approved and tight seam with marking pen
    record the test in paper sheet form
    repeat this procedure at all double seams.
  - if the test of double seam welding fails, inflate double seam again and search for leaks

Pressure test of a double seam whit an electronic pump



Pressure test of a double seam whit an electronic pump

Pressure testing needle with manometer

mark the leaks and repair with membrane patch to be heat welded with hand held welding machine over defective area
re-check after patching is finished

- any voids or capillaries must be marked and rectified with hand held welding gun and 20 mm Silicone roller
  rectifying works must be rechecked after welding is done

Local pressure tests using vacuum bell:

Vacuum bell test

- vacuum bell testing is suitable to approve tightness of welded seams at cross- and T-junctions of membrane overlaps and other details
  - The vacuum bell testing kit contains:
    vacuum bell (Plexiglas, metal frame with rubber-pressure lips, reverse flow valve, manometer gauge, hose connection)
    vacuum pump
    soap solution
    marking pen (chalk pen only)
- apply soap solution over seam edge within the range of vacuum bell
- press vacuum bell over area treated with soap solution and build-up vacuum
- visual check of seam under vacuum
  bubbling soap solution shows leak
- remove vacuum bell and clean seam with rag
- any leaks should be marked and rectified with hand held welding gun and 20 mm silicone roller at welding temperature, or if required, closed with welded membrane patch
  rectifying works must be rechecked after welding is done

7 CLEANING, INSPECTION AND PROTECTION OF THE INSTALLED WATERPROOFING SYSTEM

The membrane surface must be cleaned and inspected before installation of waterbars, control and injection pipes and protection layers over membrane.

Inspection of the waterproofing system can be performed when one section of the waterproofing is completed, or after completion of the whole area according to the contractor's or client's requirements.

Representatives from the waterproofing contractor and from the client must inspect the completed works.

In drainage system and waterstop system, membrane surface must be visually inspected before continuing works.

In active control systems, compartments must be inspected using vacuum before continuing works.

The inspection must be recorded in a written report and to be signed by all interested parties. The waterproofing contractor must keep original labels (incl. batch No.) of delivered and installed membrane rolls, incl. inspection report in his files.

After inspection, the membrane surface must kept clean (free from loose stones, sand, construction waste, etc.). The installation of waterbars and control- and injection hoses and pipes (if compartment system is specified) must be protected as well.

Recommended protection methods:
In tunnel invert:

- loosely laid 500 g/m² geotextile with min. 100 mm overlapping
  - waterbars for compartments shall be kept unprotected
  - provisional ballast for geotextile with sandbags
- alternative, loose layout of Sikaplan® WP protection sheets with min. 80 mm overlapping
  - waterbars for compartments shall be kept unprotected
  - use provisional ballast on protection sheets with sandbags
- loose layout of Polyethylene foil 0.30 mm as separation-/gliding layer on geotextile with overlap 100 mm
  - joints to be sealed with adhesive tapes
  - if necessary, application of protective mortar layer (cement min. 300 kg/m³, thickness min. 50 mm, reinforced with wire mesh if required)
  - The waterbars of compartments must be left unprotected and exposed.

On tunnel walls:

- geotextile 500 g/m², 100 mm overlapped, suspended on top and free hanging
- as alternative, Sikaplan® WP protection sheets 80 mm overlapped, suspended on top and free hanging
- alternatively shotcrete/gunite, thickness min. 50 mm, with light reinforcement mesh, faced with glass fleece, to be fixed with anchors

In tunnel crown:

- Sikaplan® WP protection sheets, min. 80 mm overlapped, spotwise welded to the waterproofing membrane at the membrane fixing points
- mounting of suspended reinforcement according to specification using Sika® Anchor 300
- application of shotcrete or gunite layers according to specification

Shafts:

- loose layout of geotextile 500 g/m², min. 100 mm overlapped
  waterbars for compartments must be kept unprotected
  use provisional ballast to prevent movement of the protection sheets
- as alternative, loose layout of Sikaplan® WP protection sheets min. 80mm overlapped
  waterbars for compartments must be kept unprotected
  use provisional ballast to prevent movement of the protection sheets
- use loosely laid Polyethylene (PE) foil 0.30 mm as separation-/gliding layer on geotextile with an overlap of 100mm
  loose edges of the PE foil to be sealed with adhesive tape
  PE foil should be not in direct contact with the PVC membrane

- if required, a protective mortar layer (cement min. 300 kg/m³, thickness min. 50 mm, use reinforced wire mesh if required) might be necessary to protect the waterproofing system
  the waterbars of compartment must be kept unprotected/exposed

At retaining walls:

- direct placing of concrete on the waterproofing membrane
- formwork for construction-/expansion joints require a soft medium on membrane surface (i.e. plastic hose, cut-off in longitudinal direction and capped over the formwork edge)
- reinforcement bars must be held with spacers (material compatible to plasticised PVC) min. 50 mm from the membrane surface
- provisional layout of non-combustible mineral wool insulation boards needs to be used to protect the membrane against sparks from steel welding works
- for special cases or on request, gunite protective layer with a thickness min. 50 mm, reinforced with suspended light mesh and glass fleece (waterbars for compartments must be kept free) might be necessary according to clients requirements or local regulations

On cut and cover tunnel roof slabs below ground:

- loose layout of geotextile 500 g/m², min. 100 mm overlapped
  use provisional ballast to prevent movement of the protection sheets
- as alternative, loose layout of Sikaplan® WP protection sheets min. 80mm overlapped
  use provisional ballast to prevent movement of the protection sheets
- use loosely laid Polyethylene (PE) foil 0.30 mm as separation-/gliding layer on geotextile with an overlap of 100 mm
  loose edges of the PE foil to be sealed with adhesive tape
  PE foil should be not in direct contact with the PVC membrane
- application of protective mortar layer (cement dosage min. 300 kg/m³, thickness min. 50 mm, use reinforced wire mesh if required).

Control- and injection hoses

- control and injection hoses must be kept secured during the installation of the reinforcement
- after reinforcement is installed, control and injection hoses must be clamped to the reinforcement, must be connected to the injection and control boxes fixed on the formwork and must be sealed to prevent any material to plug the hoses
- after the injection and control boxes are connected, the hoses are sealed, additionally the boxes should be sealed and documented

8 MEMBRANE INSTALLATION INSTRUCTIONS

The tunnel can be excavated with mechanized or drill&blast method in full face excavation or partial profile excavation with traditional methods. The membrane installation procedure can be performed in one phase in case of full face excavation and more phases in case of partial excavations or if the construction sequence and schedule require partial waterproofing installation during the excavation. This is certainly possible, but it is not recommended, as excavation involves heavy machinery, which can damage the waterproofing membrane.

The installation procedure for waterproofing membranes depends on the:

- excavation method (partial, blasting, drilling)
- project design and construction sequence
- chosen membrane type and its fixing methods
- chosen waterproofing system (drainage system/waterstop system/active control system)

As an outline guideline, the following work sequences can be considered to be normal practise. These general installation procedures assume the use a movable waterproofing installation platform to assist the unrolling of the geotextile and membrane and the fixing of the waterproofing on the tunnel walls and crown.

8.1 MEMBRANE INSTALLATION PROCEDURE FOR DRAINAGE SYSTEM IN MINED TUNNELS

The tunnel can be excavated with mechanized or drill&blast method in full face excavation or partial profile excavation with traditional methods. The membrane installation procedure can performed in one phase in case of full face excavation and more phases in case of partial excavations or if the construction sequence and schedule require partial waterproofing installation.

Installation of cushion/drainage layer and flexodrain:

Install the drainage angle in the tunnel invert according to the waterproofing design. Install the perforated drainage pipe.

Install the Flexodrain system where necessary to divert the localised water inflow to the drainage system.

Fill the drainage angle with loose gravel according to the design specification.

Supply rolls of geotextile (roll width 2.00 m – 4.00 m, depending to used product) or the drainage layer and suspend roll at unrolling hook on installation platform. Reset the installation platform parallel to tunnel axis at one lateral edge of waterproofing area. Unroll the geotextile or drainage layer (loose laid) by moving of working platform until level of horizontal tunnel axis. Fix geotextile with fixing elements (PVC discs and nailing gun). Layout of the fixing elements should be included on the waterproofing detail drawings. Continue unrolling along excavation line (resp. shotcrete surface) until other lateral edge of waterproofing area and fix according to the design. The unrolling direction should be rectangular to tunnel axis. Once the first geotextile-section completed, move the installation platform to next section and repeat procedure, considering 100 mm overlap to the already installed geotextile. Overlaps of geotextiles shall be stitched by hand and warm-up under aid of hand held heat welder (hot air welder type Leister Triac, heating temperature set at approx. 100 °C). Installed geotextiles to be terminated at lateral drainage pipes.

Theoretical consumption of fixing elements (rondels and nails): 1.5 nos/m2

Installation of sheet waterproofing membrane:

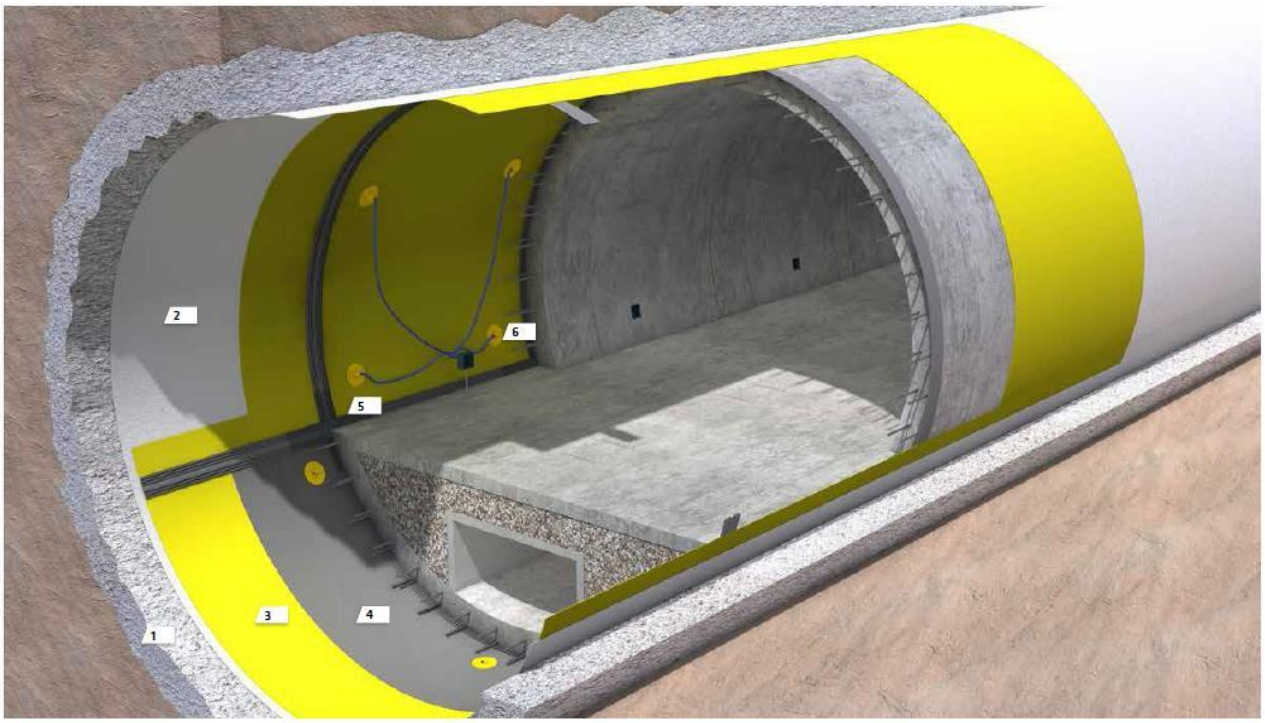
Supply rolls of waterproofing membrane (roll width 2.20 m) and suspend roll at unrolling hook on the installation platform. Reset working platform parallel to tunnel axis at one lateral edge of waterproofing area. Unroll the waterproofing membrane (loose laid) by moving of working platform until level of horizontal tunnel axis. Start fixing waterproofing membrane by heat welding on all fixed PVC discs with the aid of hand held welding gun (i.e. type Leister Triac: welding temperature set according to the data sheet and/or application manual) and press membrane firmly on the PVC disks by hand. The unrolling direction should be rectangular to tunnel axis. Once the first membrane-section completed, move working platform to next section and repeat procedure, considering 80mm overlap to the already installed membrane. Terminate installed membrane at lateral drainage pipes.

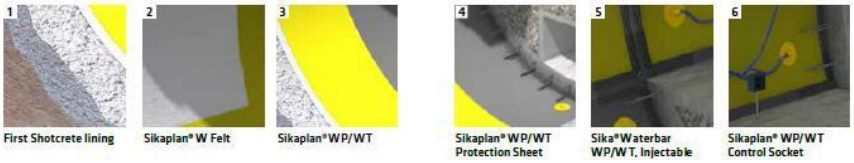
Details of the welded seams should be done according to section 5 of this method statement.

8.2 MEMBRANE INSTALLATION PROCEDURE FOR WATERSTOP SYSTEM IN MINED TUNNELS

The tunnel is excavated by drilling and blasting method in full, or partial profile. The membrane installation procedure is performed in two phases:

- 1st phase: installation by loose layout on bottom
- 2nd phase: installation by spotwise fixings at walls and crown





Installation of cushion/drainage layer on the bottom:

Supply rolls of geotextile (roll width 2.00 m – 4.00 m, depending to used product). Cut them to the adequate length and roll them up. Unroll the geotextile (loose laid) by on bottom from one side to the other, the unrolling should be almost rectangular to tunnel axis. If necessary, fix the geotextile with PVC disks on the tunnel wall. Once first geotextile-section completed, continue the procedure in the next section, considering 100 mm overlap to the already installed geotextile. Overlaps of geotextiles shall be stitched by hand and warm-up under aid of hand held heat welder (i.e. hot air welder type Leister Triac, heating temperature set at approx. 150 °C or according to product data sheet/ application manual).

Terminate the installed cushion/drainage layer temporary min 500 mm above level of the tunnel invert concrete or the wall starter bars.

Installation of sheet waterproofing membrane on bottom:

Supply rolls of waterproofing membrane (roll width 2.20 m). Unrolling of waterproofing membrane (loose laid) by moving of working platform until level of horizontal tunnel axis. Unroll the membrane in a direction almost rectangular to tunnel axis. If necessary, fix the membrane to the PVC disks with the aid of hand held welding gun (i.e. type Leister Triac: welding temperature set according to the data sheet and/or application manual) and press membrane firmly on the PVC disks by hand. Once first membrane-section completed, move to next section and repeat procedure, considering 80 mm overlap to the already installed membrane. Terminate installed membrane temporary min 200 mm above level of the tunnel invert concrete or the wall starter bars.

Membrane termination min 200 mm over starter bars or concrete

After all the membranes are laid out, the membranes should be welded together using and automatic welding machine. The double seams must be checked before installation of the waterbars according to section 6 of this method statement.

Theoretical consumption of fixing elements (roundel and nail): 1.5 nos/m2

Installation of Sika® waterbars on installed waterproofing membranes on bottom:

The surface of installed membrane must be clean and free of oil and grease. The welded seams must be inspected for water tightness and the membrane edge shall be chamfered (i.e. with peeling knives). Projecting welding seams on waterbars must be peeled off with knives. Waterbars may be heat welded directly to membrane, if the side laps of used waterbars type exceeds 50 mm by using of hand held manual welder. Direct welding of waterbars with side laps less than 50 mm requests the use of semi-automatic welding machine (i.e. type Leister Triac Drive). The waterbars shall be welded according to the waterproofing design to form compartments for repair works, if necessary. Each compartment shall not exceed 150 m². Vertical waterbars to be continued into wall, and shall be temporary terminated min 200 mm above level of the tunnel invert concrete or the wall starter bars. Horizontal waterbars are butt-jointed to the vertical waterbars.

Membrane termination min 200 mm over starter bars

Horizontal waterbars should be installed at the level of the tunnel invert concrete.

Mounting of Sikaplan® WP Control Socket or Trumpet–Flange on bottom:

The Sikaplan® WP Control Socket or Trumpet–Flanges are welded on the waterproofing membrane with handheld welding machine. They are connected to injection hoses. The hoses are terminated in sealed junction boxes fixed to the formwork of the inner lining.

These hoses are used to control the water tightness of the membrane and if required, injection of grouts into each compartmentalised waterproofing area. The correct function of these hoses requires min. three hoses in each compartment, one on the lowest, one in the middle and one on the highest point.

The hoses shall be mounted on reinforcement bars. The PVC flange shall be spot welded on the installed waterproofing membrane according to the waterproofing detail drawings. It must be secured during concreting works such a way that no cement slurry can penetrate into the hose.

Installation of cushion/drainage layer at walls and crown:

Supply rolls of geotextile (roll width 2.00 m – 4.00 m, depending to used product) and suspend roll at unrolling hook on the installation platform. Reset working platform parallel to the tunnel axis at one lateral edge of waterproofing area. Unroll the geotextile (loose laid) by moving of working platform until level of horizontal tunnel axis. Fix geotextile with fixing elements (PVC discs and nailing gun) at this level. Continue unrolling along excavation line (resp. shotcrete surface) until other lateral edge of waterproofing area and fix according to the design specification and application manual. The unrolling direction should be rectangular to tunnel axis. Once the first geotextile-section completed, move the working platform to next section and repeat procedure, considering 100mm overlap to the already installed geotextile. The overlaps of the geotextiles shall be stitched using a hand held heat welder (i.e. hot air welder type Leister Triac, heating temperature set at approx. 10+5 °C or according to product data sheet and application manual). Installed geotextiles should be terminated above the invert concrete level.

Theoretical consumption of fixing elements (roundel and nail): 1.5 nos/m2

Installation of waterproofing membrane at walls and crown:

Supply rolls of waterproofing membrane (roll width 2.20 m) and suspend roll at unrolling hook on installation platform. Reset working platform parallel to tunnel axis at one lateral edge of waterproofing area. Unroll the waterproofing membrane (loose laid) by moving the working platform until the level of horizontal tunnel axis. Start fixing waterproofing membrane by heat welding on all fixed PVC discs with hand held welding gun (type Leister Triac: welding temperature set according to the data sheet and/or application manual) and press membrane firmly by hand on roundel. Unrolling direction must be almost rectangular to tunnel axis. Once the first membrane-section completed, move the working platform to the next section and repeat the procedure, considering min. 100 mm overlap to the already installed membrane. The membrane must be connected with the sheet membrane of bottom.

After all the membranes are laid out, the membranes should be welded together using and automatic welding machine. The double seams must be checked before installation of the waterbars according to section 6 of this method statement.

Installation of Sika® waterbars on installed waterproofing membranes at walls and crown:

The surface of installed membrane must be cleaned and free of oil and grease. The welded seams must be inspected for water tightness and the membrane edge shall be chamfered (i.e. with peeling knives). Projecting welding seams on waterbars must be peeled off with knives. Waterbars may be heat welded directly to membrane, if the side laps of used waterbars type exceeds 50 mm by hand held manual welder.

Direct welding of waterbars with side laps less than 50 mm requires the use of semi-automatic welding machine type Leister Triac Drive.

The waterbars shall be welded according to arrangement for the compartment. Each compartment shall not exceed 150 m² The waterbars must be continuously welded to the sheet membrane.

Mounting of Sikaplan® WP Control Socket or Trumpet–Flange

The Sikaplan® WP Control Socket or Trumpet–Flanges are welded on the waterproofing membrane with handheld welding machine. They are connected to injection hoses. The hoses are terminated in sealed junction boxes fixed to the formwork of the inner lining.

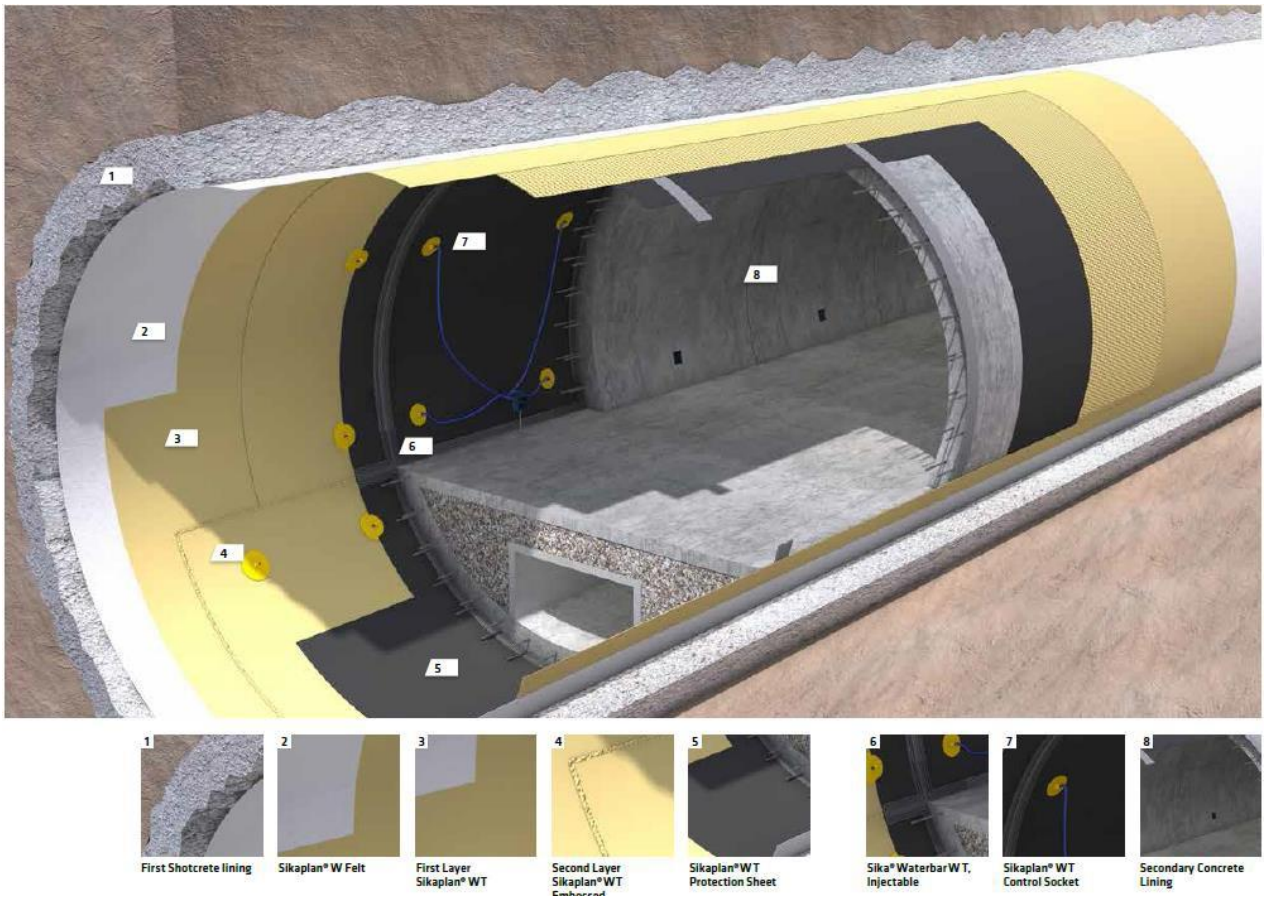
The purpose of the hoses is access for control the water tightness and if required, injection of grouts into each compartmentalised waterproofing area. The correct function of these hoses requires min. three hoses in each compartment, one on the lowest, one in the middle and one on the highest point.

The hoses shall be mounted on reinforcement bars. The PVC flange shall be spot welded on the installed waterproofing membrane according to the waterproofing detail drawings. It must be secured during concreting works such a way that no cement slurry can penetrate into the pipe.

8.3 MEMBRANE INSTALLATION PROCEDURE FOR ACTIVE CONTROL SYSTEM IN MINED TUNNELS

The tunnel is excavated by drilling and/or blasting method in full, or partial profile. The membrane installation procedure is performed in two phases:

- 1st phase: installation by loose layout on bottom
- 2nd phase: installation by spotwise fixings at walls and crown



Installation of cushion/drainage layer:

Supply rolls of geotextile (roll width 2.00 m – 4.00 m, depending to used product) and suspend roll at unrolling hook on installation platform. Reset working platform parallel to tunnel axis at one lateral edge of waterproofing area. Unroll of geotextile (loose laid) by loose laying on bottom. Unrolling and laying direction must be almost rectangular to tunnel axis. Once first geotextile-section completed, move working platform to next section and repeat procedure, considering 100mm overlap to the already installed geotextile. Overlaps of geotextiles shall be stitched by hand and warm-up under aid of hand held heat welder (hot air welder type Leister Triac, heating temperature set at approx. 10+5 °C or according to product data sheet and application manual).

Terminate the installed cushion/drainage layer temporary min 500 mm above level of the tunnel invert concrete or the wall starter bars.

Installation of 1st layer of sheet waterproofing membrane on bottom:

Supply rolls of waterproofing membrane (roll width 2.20 m) and suspend roll at unrolling hook on installation platform. Reset working platform parallel to tunnel axis at one lateral edge of waterproofing area. Unroll the waterproofing membrane (loose laid) by moving of working platform until the level of horizontal tunnel axis. Unrolling direction must be almost rectangular to tunnel axis. Once the first membrane-section completed, move the working platform to the next section and repeat the procedure, considering min. 80 mm overlap to the already installed membrane. Terminate the installed membrane temporary min 200 mm above level of concrete bottom slab or the tunnel wall starter bars.

Installation of separation layer on completed 1st layer of waterproofing – if 2nd layer does not have embossed surface:

The surface of the installed membrane must be cleaned and free of oil and grease. The welded seams must be inspected for water tightness.

Supply rolls of geomat (roll width 2.00 m – 4.00 m, depending to used product) and suspend the geomat roll at unrolling hook on installation platform. Reset the working platform parallel to tunnel axis at one lateral edge of waterproofing area. Unroll the geomats (loose laid) by loose laying on bottom. Unrolling and laying direction should

be almost rectangular to tunnel axis. Once the first geomat-section completed, move the working platform to next section and repeat procedure according to the waterproofing layout.

The edges of geomats shall be butt-jointed.

Installation of 2nd layer of sheet waterproofing membrane on bottom:

Supply the rolls of waterproofing membrane (roll width 2.20m) and suspend the roll at unrolling hook on installation platform. Reset the working platform parallel to tunnel axis at one lateral edge of waterproofing area. Unroll the waterproofing membrane (loose laid) by moving the working platform until the level of the horizontal tunnel axis. The Unrolling direction must be almost rectangular to tunnel axis. Once the first membrane-section completed, move the working platform to the next section and repeat procedure, considering min. 80mm overlap to the already installed membrane. Terminate the installed membrane temporary min. 200 mm above level of concrete bottom slab or the wall starter bars.

Each of 2nd layer forming compartment shall not exceed an area of 100m2.

Mount and weld min. 5 nos. of control sockets within this area of 100m2.

The edges of 2nd layer must be welded on 1st waterproofing layer by using single seam welding machine.

Mounting of Sikaplan® WP Control Socket or Trumpet–Flange

The Sikaplan® WP Control Socket or Trumpet–Flanges are welded on the waterproofing membrane with handheld welding machine. They are connected to injection hoses. The hoses are terminated in sealed junction boxes fixed to the formwork of the inner lining.

The purpose of the hoses is access for control the water tightness and if required, injection of grouts into each compartmentalised waterproofing area. The correct function of these hoses requires five hoses in each compartment, four at the corners of the compartment and one in the centre.

The hoses shall be mounted on reinforcement bars. The PVC flange shall be welded on the installed waterproofing membrane according to the construction method. It must be secured during concreting works such a way that no cement slurry can penetrate into the pipe.

Installation of cushion/drainage layer at walls and crown:

Supply rolls of geotextile (roll width 2.00 m – 4.00 m, depending to used product) and suspend roll at unrolling hook on the installation platform. Reset working platform parallel to the tunnel axis at one lateral edge of waterproofing area. Unroll the geotextile (loose laid) by moving of working platform until level of horizontal tunnel axis. Fix geotextile with fixing elements (PVC discs and nailing gun) at this level. Continue unrolling along excavation line
(resp. shotcrete surface) until other lateral edge of waterproofing area and fix according to the design specification and application manual. The unrolling direction should be rectangular to tunnel axis. Once the first geotextile-section completed, move the working platform to next section and repeat procedure, considering 100 mm overlap to the already installed geotextile. The overlaps of the geotextiles shall be stitched using a hand held heat welder (i.e. hot air welder type Leister Triac, heating temperature set at approx. 150 °C or according to product data sheet and application manual). Installed geotextiles should be terminated above the invert concrete level.

Theoretical consumption of fixing elements (roundel and nail): 1.5 nos/m²

Installation of sheet waterproofing membrane at walls and crown:

Supply the rolls of waterproofing membrane (roll width 2.20 m) and suspend the roll at unrolling hook on installation platform. Reset the working platform parallel to tunnel axis at one lateral edge of waterproofing area. Unroll the waterproofing membrane (loose laid) by moving of working platform until level of horizontal tunnel axis. Start fixing waterproofing membrane by heat welding on all fixed PVC discs with the hand held welding gun (type Leister Triac: welding temperature set at approx. 300-350 °C or according to product data sheet and application manual) and press membrane firmly by hand on roundel. Unrolling direction must be almost rectangular to tunnel axis. Once the first membrane-section completed, move the working platform to next section and repeat the procedure, considering min. 80 mm overlap to the already installed membrane. The membranes must be connected with sheet membrane of bottom.

Installation of separation layer on completed 1st layer of waterproofing if 2nd layer does not have embossed surface:

The surface of installed membrane must be cleaned and free of oil and grease. The welded seams must be inspected for water tightness. Supply the rolls of geomat (roll width 2.00 m – 4.00 m, depending to used product)

and suspend the roll at unrolling hook on installation platform. Reset the working platform parallel to tunnel axis at one lateral edge of waterproofing area. Unroll the geomats by moving the working platform until level of horizontal tunnel axis. Start fixing the geomats to the waterproofing membrane by heat welding on all fixed PVC discs with the hand held welding gun (type Leister Triac: welding temperature set at approx. 300-350 °C or according to product data sheet and application manual) and press the geomat firmly by hand on 1st layer of the waterproofing membrane at the roundels. Once first geomat-section completed, move working platform to next section and repeat procedure. The edges of geomats shall be butt-jointed.

Installation of 2nd layer of sheet waterproofing membrane at walls and crown:

Supply rolls of waterproofing membrane (roll width 2.20 m) and suspend the roll at unrolling hook on installation platform. Reset the working platform parallel to tunnel axis at one lateral edge of the waterproofing area. Unroll the waterproofing membrane (loose laid) by moving of working platform until level of horizontal tunnel axis. Start fixing the 2nd layer of the waterproofing membrane to the geomats by heat welding at all fixed PVC discs location with the hand held welding gun (type Leister Triac: welding temperature set at approx. 300-350 °C or according to product data sheet and application manual) and press the 2nd layer of sheet waterproofing membrane firmly by hand on the 1st layer of the waterproofing membrane/geomats at the roundels. Unrolling direction must be almost rectangular to tunnel axis. Once the first membrane-section completed, move working the platform to next section and repeat the procedure, considering min. 80 mm overlap to the already installed membrane. Terminate the installed membrane temporary above level of concrete bottom slab.

Each of 2nd layer forming compartment shall not exceed an area of 100 m².

Mount and weld min. 5 nos. of control sockets within this area of 100m².

The edges of 2nd layer edges must be welded on 1st waterproofing layer by using single seam welding machine.

Mounting of Sikaplan® WP Control Socket or Trumpet–Flange

The Sikaplan® WP Control Socket or Trumpet–Flanges are welded on the waterproofing membrane with handheld welding machine. They are connected to injection hoses. The hoses are terminated in sealed junction boxes fixed to the formwork of the inner lining.

The purpose of the hoses is access for control the water tightness and if required, injection of grouts into each compartmentalised waterproofing area. The correct function of these hoses requires five hoses in each compartment, four at the corners of the compartment and one in the centre.

The hoses shall be mounted on reinforcement bars. The PVC flange shall be welded on the installed waterproofing membrane according to the construction method. It must be secured during concreting works such a way that no cement slurry can penetrate into the pipe.

8.4 MEMBRANE INSTALLATION PROCEDURE FOR DRAINAGE SYSTEM IN CUT AND COVER TUNNELS

The tunnel is constructed in as cut and cover tunnel. This means that after excavation the construction pit, the base slab is casted. After hardening the concrete of the base slab, tunnel walls and crown is casted. Finally the excavation pit is backfilled and the area is re-cultivated.

Membrane installation is executed in one step, as no waterproofing is necessary under the base slab.

Installation of cushion layer:

Install the drainage angle in the tunnel invert according to the waterproofing design. Place the perforated drainage pipe behind the drainage angle and fill the drainage angle with loose gravel according to the design specification.

Supply rolls of geotextile (roll width 2.00 m – 4.00 m, depending to used product) and cover the reinforced concrete surface. Fix geotextile with fixing elements (PVC discs and nailing gun). Layout of the fixing elements should be included on the waterproofing detail drawings. Continue unrolling along the concrete surface until other lateral edge of waterproofing area and fix according to the design. The unrolling direction should be rectangular to tunnel axis. Once the first geotextile-section completed, move the installation platform to next section and repeat procedure, considering 100 mm overlap to the already installed geotextile. Rolls of geotextiles shall be overlapped and stitched by hand. Installed geotextiles to be terminated at lateral drainage pipes.

Theoretical consumption of fixing elements (rondels and nails): 0.5 nos/m²

Installation of sheet waterproofing membrane:

Reset working platform parallel to tunnel axis at one lateral edge of waterproofing area. Start fixing waterproofing membrane by heat welding on all fixed PVC discs with the aid of hand held welding gun (i.e. type Leister Triac: welding temperature set according to the data sheet and/or application manual) and press membrane firmly on the PVC disks by hand. Unroll the waterproofing membrane (loose laid) by moving of working platform from one drainage angle to the other drainage angle. The unrolling direction should be rectangular to tunnel axis. Once the first membrane-section completed, move working platform to next section and repeat procedure, considering 80 mm overlap to the already installed membrane. Terminate installed membrane at lateral drainage pipes. Membrane should be spotwise welded onto the drainage angle to prevent dislocation at backfilling
Details of the welded seams should be done according to section 5 of this method statement.

Installation of protection/drainage layer:

Supply rolls of geotextile (roll width 2.00 m – 4.00 m, depending to used product) and cover the reinforced concrete surface. Fix geotextile with fixing elements (stitched membrane strips or membrane hooks). Layout of the fixing elements should be included on the waterproofing detail drawings. Continue unrolling along the tunnel surface until other lateral edge of waterproofing area and fix according to the design. The unrolling direction should be rectangular to tunnel axis. Once the first geotextile/drainage-section is completed, move the installation platform to next section and repeat procedure, considering 100 mm overlap to the already installed geotextile. Rolls of geotextiles/ drainage mats shall be overlapped and stitched by hand. Installed geotextiles to be terminated at the drainage angles

8.5 MEMBRANE INSTALLATION PROCEDURE FOR WATERSTOP SYSTEM IN CUT AND COVER TUNNELS

The tunnel is constructed in as cut and cover tunnel. This means that after excavation the construction pit, the base slab is casted. After hardening the concrete of the base slab, tunnel walls and crown is casted. Finally the excavation pit is backfilled and the area is re-cultivated.

Membrane installation is execution in three step:

- Installation of the base slab waterproofing and waterbars
- Installation of the waterbars on the walls and crown formwork, cast the concrete
- Installation of the waterproofing membrane on the walls and crown

Installation of cushion/drainage layer on the bottom:

Supply rolls of geotextile (roll width 2.00 m – 4.00 m, depending to used product). Cut them to the adequate length and roll them up. Unroll the geotextile (loose laid) on bottom from one side to the other. The unrolling should be rectangular to tunnel axis. Once first geotextile-section completed, continue the procedure in the next section, considering 100 mm overlap to the already installed geotextile. Overlaps of geotextiles shall be stitched by hand and warm-up under aid of hand held heat welder (i.e. hot air welder type Leister Triac, heating temperature set at approx. 150 °C or according to product data sheet/ application manual).

Terminate the installed cushion/drainage layer temporary on the side formwork of the base slab.

Installation of sheet waterproofing membrane on bottom:

Supply rolls of waterproofing membrane (roll width 2.20 m). Unrolling of waterproofing membrane (loose laid) by moving of working platform until level of horizontal tunnel axis. Unroll the membrane in a direction almost rectangular to tunnel axis. Once first membrane-section completed, move to next section and repeat procedure, considering 80 mm overlap to the already installed membrane.

Terminate the waterproofing membrane temporary on the side formwork of the base slab.

After all the membranes are laid out, the membranes should be welded together using and automatic welding machine. The double seams must be checked before installation of the waterbars according to section 6 of this method statement.

Installation of Sika® waterbars on installed waterproofing membranes on bottom:

The surface of installed membrane must be clean and free of oil and grease. The welded seams must be inspected for water tightness and the membrane edge shall be chamfered (i.e. with peeling knives). Projecting welding seams on waterbars must be peeled off with knives. Waterbars may be heat welded directly to membrane, if the side laps of used waterbars type exceeds 50 mm by using of hand held manual welder. Direct welding of waterbars with side laps less than 50 mm requests the use of semi-automatic welding machine (i.e. type Leister Triac Drive). The

waterbars shall be welded according to the waterproofing design to form compartments for repair works, if necessary. Each compartment shall not exceed 150 m². Vertical waterbars to be continued into wall, and shall be temporary terminated min 200 mm above level of the tunnel invert concrete or the wall starter bars. Horizontal waterbars are butt-jointed to the vertical waterbars.

Horizontal waterbars should be installed at the level of the tunnel invert concrete.

Mounting of Sikaplan® WP Control Socket or Trumpet–Flange on bottom:

The Sikaplan® WP Control Socket or Trumpet–Flanges are welded on the waterproofing membrane with handheld welding machine. They are connected to injection hoses. The hoses are terminated in sealed junction boxes fixed to the formwork of the base slab.

These hoses are used to control the water tightness of the membrane and if required, injection of grouts into each compartmentalised waterproofing area. The correct function of these hoses requires min. five hoses in each compartment, at the corners and one in the middle.

The hoses shall be fixed on reinforcement bars. The PVC flange shall be spot welded on the installed waterproofing membrane according to the waterproofing detail drawings. It must be secured during concreting works such a way that no cement slurry can penetrate into the hose.

Installation of protection layer on the bottom:

Supply rolls of geotextile (roll width 2.00 m – 4.00 m, depending to used product) and cover the waterproofing membrane.

Unroll the geotextile along the base slab until you reach the other edge of waterproofing area. The unrolling direction should be rectangular to tunnel axis. Consider 100 mm overlap to the already installed geotextile. Rolls of geotextiles mats shall be overlapped and stitched by hand.

Loose lay a min 0.30 mm polyethylene foil as separation-/gliding layer on geotextile. Laz out the polyethylene sheets with 100 mm overlap. Secure the PE sheets with adhesive tapes. Apply a protective mortar/PCC layer with a cement content of min. 300 kg/m³ and a thickness of min. 50 mm over the waterproofing area. Reinforce the protection mortar/PCC layer with a wire mesh if necessary.

Alternatively loose laid Sikaplan WP Protection sheet can be used as a protection layer. Cover the waterproofing area similar to the geotextile. Edges of the protection sheets should be spot welded to the waterproofing membranes.

In neither cases waterbars should be not covered as they must anchored in the structural concrete.

Installation of Sika® waterbars on installed waterproofing membranes on the walls and crown:

In cut and cover tunnels, waterbars must be installed on the formwork prior to concreting.

Fix the waterbars on the wall and crown formworks with nails through the side flaps of the waterbars, then secure the edges of the waterbar to the formwork with adhesive tapes. This will prevent the cement slurry to enter between the waterbar and the formwork.

Remove the formwork when concrete is hardened. Waterbars should be cleaned by hand with wire brush and grinding paper from all cementitious material before installing the waterproofing membrane.

Mounting of Sikaplan® WP Control Socket or Trumpet–Flange

The Sikaplan® WP Control Socket or Trumpet–Flanges are fixed on the wall and crown formworks before concreting using nails. They are connected to injection hoses. The hoses are terminated in sealed junction boxes fixed to the inner formwork of the wall and crown.

The purpose of the hoses is access for control the water tightness and if required, injection of grouts into each compartmentalised waterproofing area. The correct function of these hoses requires five hoses in each compartment, four at the corners of the compartment and one in the centre.

The hoses shall be mounted on reinforcement bars. The control sockets and trumpet flanges must be secured during concreting works such a way that no cement slurry can penetrate into the pipe.

Installation of cushion/drainage layer on the walls and crown:

Supply rolls of geotextile (roll width 2.00 m – 4.00 m, depending to used product). Cut them to the adequate length and roll them up. Unroll the geotextile (loose laid) on bottom from one side to the other. The unrolling should be rectangular to tunnel axis. Fix geotextile with fixing elements (PVC discs and nailing gun) at this level. Once first

geotextile-section completed, continue the procedure in the next section, considering 100 mm overlap to the already installed geotextile. Overlaps of geotextiles shall be stitched by hand and warm-up under aid of hand held heat welder (i.e. hot air welder type Leister Triac, heating temperature set at approx. 150 °C or according to product data sheet/ application manual).

Do not cover the cleaned waterbars and the control sockets/trumpet flanges as the membranes will be welded on these in the next step.

Installation of sheet waterproofing membrane on the walls and crown:

Supply rolls of waterproofing membrane (roll width 2.20 m). Start unrolling of waterproofing membrane (loose laid) by moving of working platform until the first waterbars. Weld the waterproofing membrane continuously to the waterbars. Weld the waterproofing membrane spotwise to the control sockets and trumpet flanges if necessary. Unroll the membrane in a direction almost rectangular to tunnel axis. Once first membrane-section completed, move to next section and repeat procedure, considering 80 mm overlap to the already installed membrane.

After all the membranes are laid out, the membranes should be welded together using and automatic welding machine. Also connect the waterproofing membrane to the membrane of the base slab using and automatic welding machine.

The double seams must be checked before installation of the waterbars according to section 6 of this method statement.

Installation of protection/drainage layer:

Supply rolls of geotextile (roll width 2.00 m – 4.00 m, depending to used product) and cover the reinforced concrete surface. Fix geotextile with fixing elements (stitched membrane strips or membrane hooks). Layout of the fixing elements should be included on the waterproofing detail drawings. Continue unrolling along the tunnel surface until other lateral edge of waterproofing area and fix according to the design. The unrolling direction should be rectangular to tunnel axis. Once the first geotextile/drainage-section is completed, move the installation platform to next section and repeat procedure, considering 100 mm overlap to the already installed geotextile. Rolls of geotextiles/ drainage mats shall be overlapped and stitched by hand.

Installed geotextile should be terminated at the base slab.

9 MEMBRANE INSTALLATION DETAILS

9.1 SPOT FIXING BY WELDING AT NAILED SIKAPLAN® WP DISC IN SHOTCRETE/GUNITE SUBSTRATE

Fixing of Sikaplan® WP Disc discs (ø 80 mm) on geotextile into shotcrete/gunite, or concrete is to provide support for the waterproofing membrane and to fix the geotextile to the tunnel wall as well.

The fixing of discs must be executed with nail gun into the shotcrete, or with dowels into predrilled holes in the concrete (i.e. Hilti DX nail gun system/Hilti type DX nail/washer and compatible cartridges). The grid distance should be min. two fixings each membrane rolls width in the horizontal direction and 2.00 m in the vertical direction.

The waterproofing membrane is heat welded onto the fixed discs.

9.2 SPOT FIXING WITH SUSPENDERS MADE OF SIKAPLAN® WP 1100 AND 2100 MEMBRANE STRAPS

Cut straps of Sikaplan® WP 1100 or 2100 membrane from roll (size approx. 50mm x 200mm). Fix the Sikaplan® WP 1100 or 2100 membrane straps on geotextile into shotcrete/gunite, or concrete, the geotextile is fixed with this operation also.

The fixing of membrane straps must be executed with the aid of nail guns into the shotcrete, or with dowels into predrilled holes in the concrete (i.e. Hilti DX nail gun system/Hilti type DX nail/washer and compatible cartridges). The grid distance shall be min. two fixings each membrane roll width in the horizontal direction and max. 2.00 m in the vertical direction.

The waterproofing membrane is heat welded onto the fixed straps.

9.3 MEMBRANE PENETRATIONS

The pipe-/anchor steel flanges, etc. from third parties must be fixed by others prior to the membrane waterproofing works.

The surface of steel must be smooth, clean and free of oils and grease. A sealing ring (min. one piece each penetration), must be made on site of waterproofing membrane according to the size of flange.

Cut an opening in the waterproofing membrane as per the size of the penetration. Overlapping seams of membrane must be bypassed around penetration by using separate membrane piece.

Do not allow membrane overlaps within flanges. Membrane must be welded outside of flange, when double layer membrane system has to be installed.

The prepared sealing ring must be heat welded on waterproofing membrane within the flange. Holes in equal diameter than bolts must be punched through both the membrane and the sealing ring, exactly at the locations of flange bolts.

The prepared piece of waterproofing membrane, incl. welded sealing ring shall then be slipped over the base flange and be fixed to the pressure flange. The membrane shall not be loose or creased and the membrane sealing rings must not be “fishmouthed”.

9.4 EXPANSION JOINTS

A support steel must be mounted over expansion joints in walls and on roof slabs below ground for waterproofing of structures without compartment system. Stainless steel sheets must be mounted one sided (size 200 mm x max. 2000 mm) with fixing-holes (dia. 5 mm, distance 150 mm). The one-sided fixings shall be made with countersunk screws and dowels (dia. 4.5 mm/20 mm length/stainless steel). Between the ends of metal sheet elements shall be a gap of 2 - 3 mm, which must be covered with 20 mm adhesive tape.

9.5 HEAT WELDING OF SIKA® WATERBARS ON INSTALLED WATERPROOFING MEMBRANES

The surface of installed membrane must be cleaned and free of oil and grease. The welded seams must be inspected for water tightness and the membrane edge shall be chamfered (i.e. with peeling knives). Projecting welding seams on waterbars must be peeled off with knives. waterbars may be h eat welded directly to membrane, if the side laps of used waterbars type exceeds 50 mm by using of hand held manual welder. Direct welding of waterbars with side laps less than 50 mm requests the use of semi-automatic welding machine type Leister Triac Drive. Strips of Sikaplan® WP waterproofing membranes must be preliminary heat welded on flat reverse of waterbars, if such welding tool is not available and the widths of side laps are less than 50 mm.

Connect waterbars with butt joints only. For square connection, taylor-made elements are ready to be ordered. This significantly reduce the risk of on-site detailing, therefore ensure the quality of works.

Waterbar welding onto membrane with Leister Triac Drive semi automatic heat welding device

9.6 CONNECTING SIPALAN WP MEMBRANE TO EXISTING CONCRETE STRUCUTRES AND PREFABRICATED CONCRETE ELEMENTS

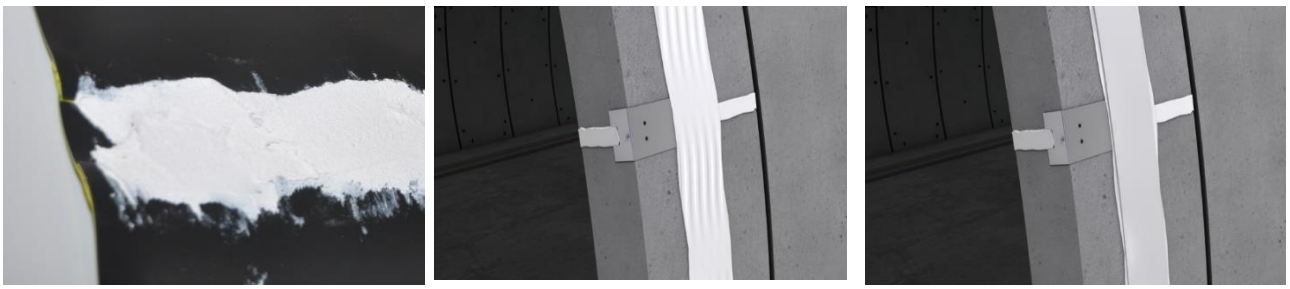
The connection to the existing watertight concrete structure can be made with Dilatec Tape, or Sikaplan WP Tape, according to the waterproofing design.

The surface of the concrete must be levelled, cleaned, dust free and free of oil, grease and any other contaminants. All loose and friable particle must be removed. The surface can be moist, however no ponding or flowing water allowed in the connecting area. Clean the black side of the Sikaplan WP Tape with Sarna Seam Cleaner.

If connection of Sikaplan WP Tape is necessary, abrade lightly the welding area of the two Sikaplan WP Tapes. With a handheld hot air machine (450 °C or according to recommendation) weld together the Sikaplan WP Tapes with a min. 4 cm overlap weld.

Mix the Sikadur®-31 CF according to the mixing instruction in the PDS. Apply a strip of Sikadur®-31 CF at the location of the Sikaplan WP Tape or Dilatec tape. Also cover the welded area of the Sikaplan® WP Tape with Sikadur®-31 CF to prevent any lateral water flow after installation. Press the Sikaplan® WP Tape firmly into the freshly applied Sikadur®-31 CF adhesive using the roller to avoid creating any air-pockets.

Joining two WP Tapes with overlap welding



Preparing cross passage junction to connect the segments to the waterproofing membrane

Before connecting the Sikaplan WP Membrane to the Sikaplan® WP Tape clean the surface of the Sikaplan® WP Tape.

10 HEALTH AND SAFETY ON THE JOBSITE

10.1 PERSONAL PROTECTION EQUIPMENT (PPE)

For the installation of the Sikaplan membrane system there is no specific personal protection and safety equipment required. However due to the heat welding ad fire hazard, no plastic clothing (over-trousers, hi-vis wests, hand shoes are allowed during the works). Any specific local regulations and/or requirements must be fully complied with.

10.2 VENTILLATION

Although the fumes form PVC welding are not a Health and Safety issue, a proper ventilation is necessary on the jobsite to provide cool air. In closed space the temperature can rapidly raise above the allowed level due to the use of hot air welding machines.

10.3 WASTE DISPOSAL

The generation of waste should be avoided or minimized wherever possible.

Any waste from Sikaplan WP membrane sheets and the ancillary tapes that are also produced from synthetic polymers, plus the packaging material (cardboard and liners), can all be recycled and/or disposed of in accordance with local regulations.

Empty containers of Sikadur®31 epoxy adhesive may contain some product residues. This material and its container must be disposed of in a safe way. Disposal of this product and any by-products should at all times comply with the requirements of local environmental protection and waste disposal legislation and any relevant local authority requirements. Avoid dispersal of spilled material and run-off, including contact with soil, waterways, drains and sewers.

10.4 CLEANING OF TOOLS

Tools and equipment must be cleaned immediately after use.

11 LEGAL NOTE

The information contained herein, and any other advice are given in good faith based on Sika's current knowledge and experience of the products when properly stored, handled and applied under normal conditions in accordance with Sika's recommendations. The information only applies to the application(s) and product(s) expressly referred to herein and is based on laboratory tests which do not replace practical tests. In case of changes in the parameters of the application, such as changes in substrates etc., or in case of a different application, consult Sika's Technical Service prior to using Sika products. The information contained herein does not relieve the user of the products from testing them for the intended application and purpose. All orders are accepted subject to our current terms of sale and delivery. Users must always refer to the most recent issue of the local Product Data Sheet for the product concerned, copies of which will be supplied on request or may be downloaded from our website at: www.sika.ca

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