# Flexible Waterproofing of Tunnels with Sikaplan Membranes

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Road Tunnels

Rail Tunnels

Metro Tunnels

Water Tunnels

**Islisberg/Switzerland,** TBM construction with Sikaplan® WP 2110-20HL and fixing with hot-meld

**Birmensdorf/Switzerland**
Open cut construction with Sikaplan® WT 1200-30C

**Lötschberg/Switzerland**
Drill and blast construction with Sikaplan® 14.6 NEAT

**NBS Frankfurt – Köln/Germany**
Emergency exit shaft with Sikaplan® WT 2200-31HL2 and Waterstop MP AFI 600/35

**DMRC/India**
Open cut construction with Sikaplan® WP 1100-20HL

# Degree of Watertightness

(According to Pre Norm SIA 272)

**Tunnels are built with a service life of over 100 years, which means that standards for tunnel construction must be high, in particular those involving sealing and waterproofing systems.**

## Class 1

**Completely dry**

**No moist parts on the dry part of the tunnel surface permitted**

## Class 2

**Dry to slightly moist**

**Single failing parts permitted. No dropping water on the dry part of the tunnel surface permitted.**

## Class 3

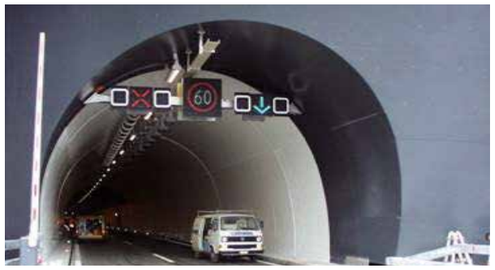
**Moist**

**Partly limited moisty parts and single dropping parts on the dry part of the tunnel surface permitted.**

## Class 4

**Moist to wet**

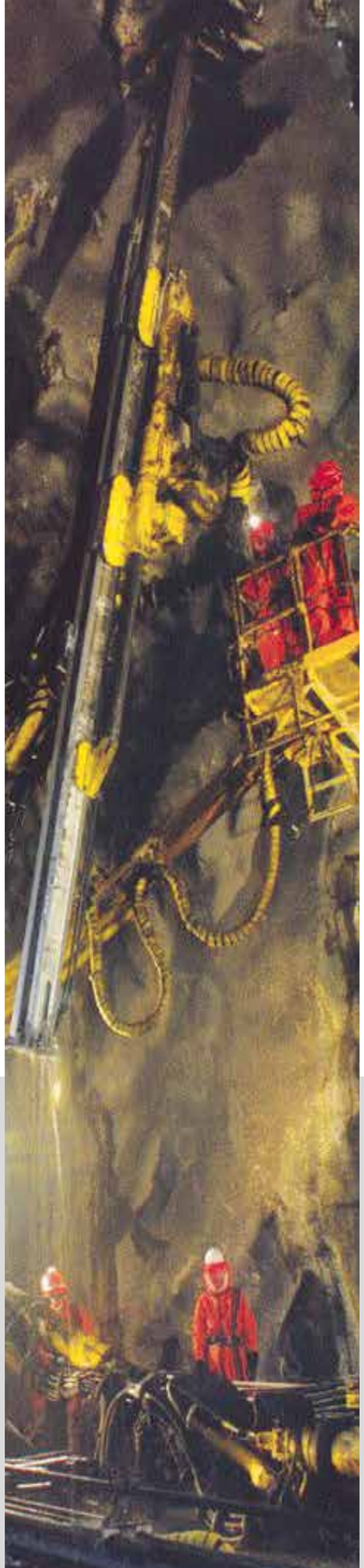
**Moisty parts and dropping parts permitted.**



A tunnel seal has the task of protecting the tunnel construction against damage resulting of moisture or the unintentional entry of water as well as the danger posed by aggressive water or soils and the effects of chemicals.

Thus the reliable functioning of a seal is of particular significance in the case of traffic tunnels, which are not easily accessible for all subsequent repairs after the construction in seepage water and especially when located in a pressure water zone. If groundwater infiltrates, it can cause damage, restrict tunnel service, or create a traffic hazard.

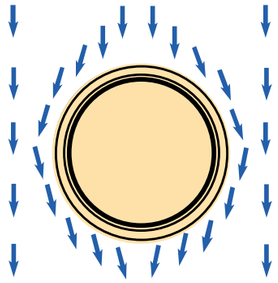
With respect to the overall demands made on sealing tunnels, it is essential to remember that essentially a sealing system has to be selected and planned in order to represent the optimal solution with regard to the given requirements pertaining to its intended use on the one hand, and the technically and economically acceptable possibilities on the other.



# Waterproofing Drainage Concept

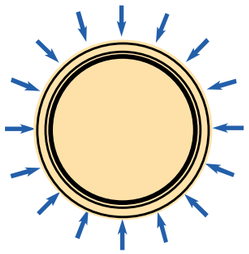
**The tunnel can be built as a non-draining structure with a watertight all-round seal. After the construction is finished there is no need to divert underground water and therefore no permanent negative influence of the water level or water balance.**

The decision not to permanently divert the prevailing underground water into a drain system makes it necessary, for the construction and the seal, to be designed to cope with water pressure. Permanently drained tunnels carry off the prevailing underground water, usually collected at the edges of the floor or feet of the vault, so that the tunnel shell is relieved.



**Draining**
**Evacuation of Mountain Water**

- Less lining costs
- Reduction of concrete thickness
- Allows tunneling under extreme conditions
- Higher maintenance cost
- Permanent drainage concept
- Traffic interruption during maintenance work



**Holding Water Head**
**Mountain Water Displacement**

- Higher lining cost
- Construction has to consider the water pressure
- Lower maintenance cost
- No influence of water table after construction
- Environmentally friendly
- Higher level of waterproofing system
- Reduction of ground settlements

Sikaplan® WP Drainage angle

Loose- Flange construction in case of water pressure

# Influences on Waterproofing in Tunnels

## During the Construction

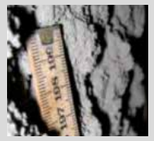
**The waterproofing system in a tunnel is composed of a combination of many factors and influences. Therefore the characteristics of the menbranes are very important.**


**Puncture load**
Reinforcement

**Temperature**
(Portals/Entrance)

**Area load**
Concrete/traffic/ bulk-head

**Water**

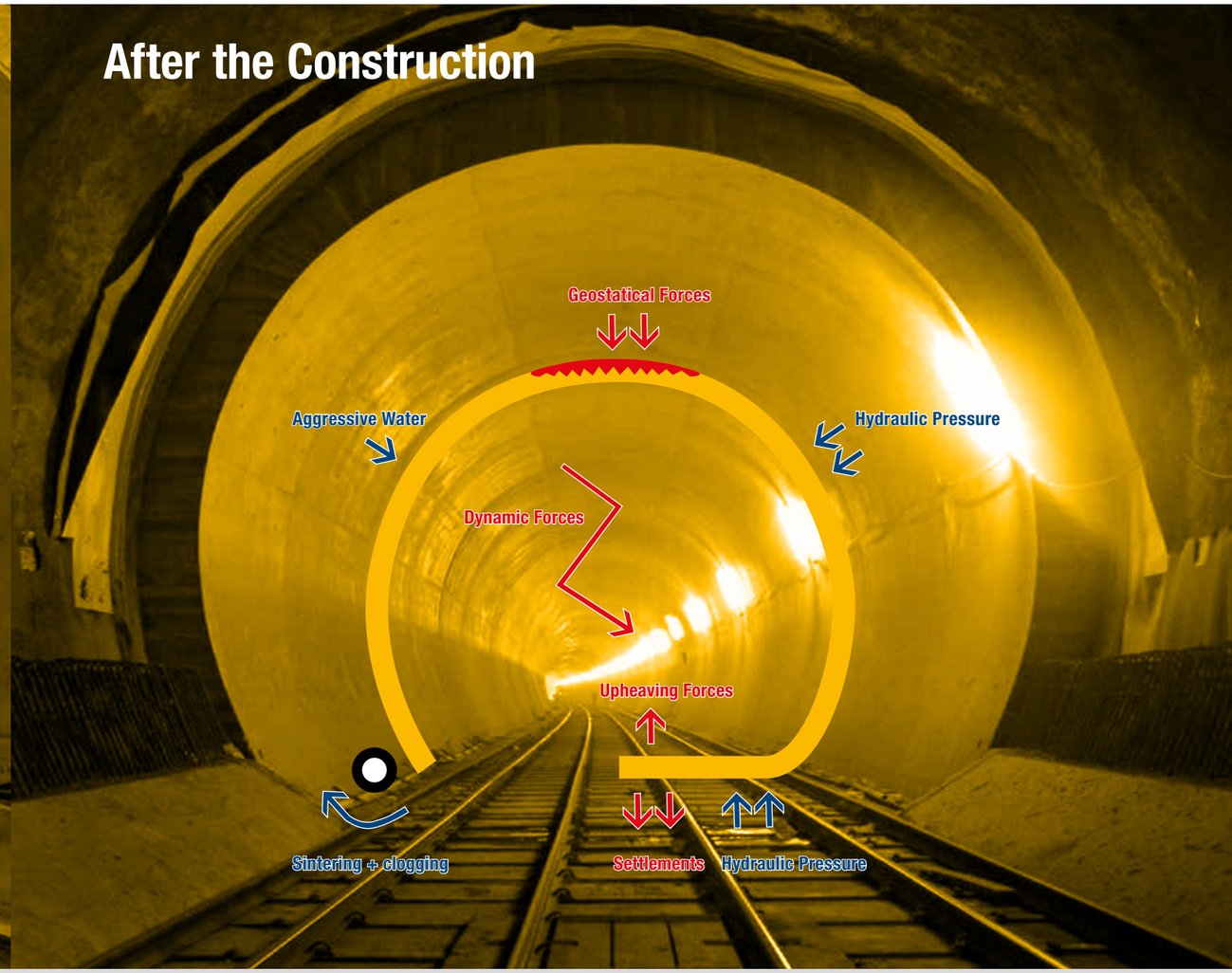


**Puncture load**
Substrate

**Puncture load**
Faulty inner concrete areas

**Fire**

## After the Construction




**Geostatical forces**

**Aggressive water**
- Sulphate water
- Chloride water
- Soft water with low calcium content

**Soluble components + $O_2$**
caused clogging + sintering process of the drainage pipe. High water Flushing

**Settlements**

**Hydraulic pressure**

**Temperature**
(Portals)

# Systems for Waterproofing

**Systems for waterproofing structures built with open cut construction techniques, exposed to hydrostatic pressure and ground water that is chemically aggressive to concrete.**

| Nr. | Water concept | Hydrostatic pressure above invert | Sealing system | | Concrete aggressive water | | Additional measures | | | Sika Membrane System |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | low | strong | Water barriers/tapes | | Integrated injection system | |
| | | | | | | | internal | external (segmentation) | | |
| 1 | Draining<br>Evacuation of mountain water | without<br>(no pressure allowed) | Umbrella seal | flexible | Waterproofing membrane 3 mm | | no | no | no | |
| 2 | | | | rigid | Watertight concrete | | yes | no | no | |
| 3 | | | Full round seal | flexible | | Waterproofing membrane 3 mm | no | no | no | |
| 4 | Holding water head<br>Mountain water displace-ment | 30 mWs | | flexible | Waterproof concrete + Waterproofing membrane 3 mm | | no | yes | yes | |
| 5 | | | | rigid | Watertight concrete | | yes | no | no | |

**Systems for waterproofing structures built with tunnelling techniques, exposed to hydrostatic pressure and groundwater that is chemically aggressive to concrete.**

| Nr. | Water concept | Hydrostatic pressure above invert | Sealing system | | Concrete aggressive water | | Additional measures | | | Sika Membrane System |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | low | strong | Water barriers | | Integrated injection system | |
| | | | | | | | internal | external (segmentation) | | |
| 1 | Draining<br>Evacuation of mountain water | without<br>(no pressure allowed) | Umbrella seal | flexible | Waterproofing membrane 2 mm | | no | no | no | |
| 2 | | | | rigid | Shotcrete | | no | no | no | |
| | | | | | Watertight concrete | | systematically | no | no | |
| 3 | | | Full round seal | flexible | | Waterproofing membranes 2 mm | no | no | no | |
| 4 | Holding water head<br>Mountain water displace-ment | < 30 m Ws | | flexible | Waterproofing membrane 3 mm | | no | yes | yes | |
| 5 | | | | rigid | Watertight concrete | | systematically | no | no | |
| 6 | | 30–60 m Ws | | flexible | Waterproof concrete + Waterproofing membrane 3 mm | | no | yes | yes | |
| 7 | | > 60 m Ws | | flexible | Waterproof concrete + double layer Waterproofing membrane (3+2) mm | | no | yes | yes | |

# Membrane Laying Systems

**According to the required degrees of watertightness- a tunnel structure has to be waterproofed. There are a number of possible solutions depending on the ground and substrate conditions, the water pressure and the water and design concept.**

## Drained
Evacuation of water (seepage water)

## Holding the Head of Water (un-drained)
Water displacement (pressurized water)

### 1. Drainage System

**Loose laid, with lateral drainage, without compartments**

- For waterproofing against ground water, humidity and percolating water
- Requires drainage pipes on the bottom to prevent build-up of water pressure

**Suitable products**
- **Sika® FlexoDrain**
- **Sikaplan® WT Tundrain PE**
- **Sikaplan® WP Disc**
- **Sikaplan® WT Disc**
- **Sikaplan® WP Drainage angle**
- **Sikaplan® WP 1100**
- **Sikaplan® WP 2110**
- **Sikaplan® WP 2160**
- **Sikaplan® WT 2200**
- **Sikaplan® WP 1110 translucent**
- **Sikaplan® WT 2250 translucent**
- **Sikaplan® WP/WT Fleeceback**
- **Sikaplan® WP Protection sheet**
- **Sikaplan® WT Protection sheet**
- **Sika® Dilatec®, type E/ER sealing strips**
- **Sikadur®-Combiflex® sealing system**

Minimum recommendation of shotcrete evenness in connection to the membrane laying system

≈ 1 : 5

### 2. Waterstop System

**Loose laid, with compartments made of waterbars**

- For waterproofing against water under hydrostatic pressure
- Compartments injectable in case of leaks in the waterproofing membranes

**Suitable products**
- **Sika® FlexoDrain**
- **Sikaplan® W Felt 500 g/m²**
- **Sikaplan® W Felt 1000 g/m²**
- **Sikaplan® WP Disc**
- **Sikaplan® WT Disc**
- **Sikaplan® WP 1100**
- **Sikaplan® WP 2110**
- **Sikaplan® WP 2160**
- **Sikaplan® WT 2200**
- **Sikaplan® WP/WT Fleeceback**
- **Sikaplan® WP Protection sheet**
- **Sikaplan® WT Protection sheet**
- **Sika® Waterbar: WT AF-40/6 MP WP AR-40/6 PVC Inject WT AF-50/6 MP WP AR-50/6 PVC Inject WT AF-60/6 MP Inject**
- **Sika® Dilatec®, type E/ER sealing strips**
- **Sikadur®-Combiflex® sealing system**

Minimum recommendation of shotcrete evenness in connection to the membrane laying system

≈ 1 : 10

### 3. Active Control System

**Loose laid, with two membrane layers installed in watertight sectors**

- For waterproofing against water under hydrostatic pressure
- High security of watertightness by vacuum control
- Compartments injectable in case of leaks in the waterproofing membrane

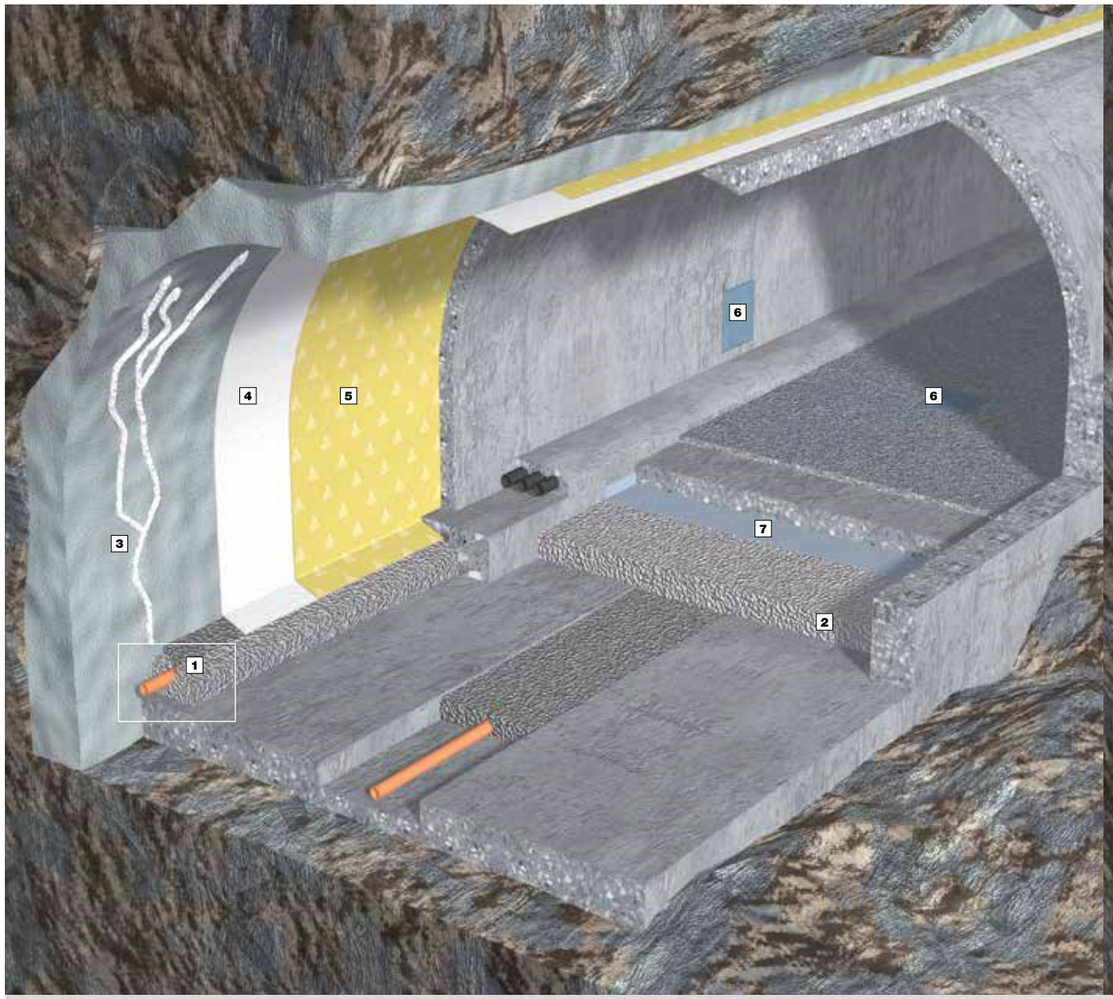
**Suitable products**
- **Sika® FlexoDrain**
- **Sikaplan® W Felt 500 g/m²**
- **Sikaplan® W Felt 1000 g/m²**
- **Sikaplan® WP Disc**
- **Sikaplan® WT Disc**
- **Sikaplan® WP 1100**
- **Sikaplan® WP 2110**
- **Sikaplan® WT 2200**
- **Sikaplan® WP/WT Fleeceback**
- **Sikaplan® WP Protection sheet**
- **Sikaplan® WT Protection sheet**
- **Sika® Waterbar: WT AF-40/6 MP WP AR-40/6 PVC Inject WT AF-50/6 MP WP AR-50/6 PVC Inject WT AF-60/6 MP Inject**
- **Sika® Dilatec®, type E/ER sealing strips**
- **Sikadur®-Combiflex® sealing system**

Minimum recommendation of shotcrete evenness in connection to the membrane laying system

≈ 1 : 10 – 1 : 15

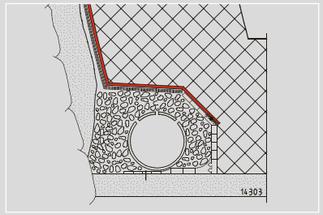
# Flexible Waterproofing with Sikaplan® Membrane Systems

## Drill-and-blast Excavation with Drainage



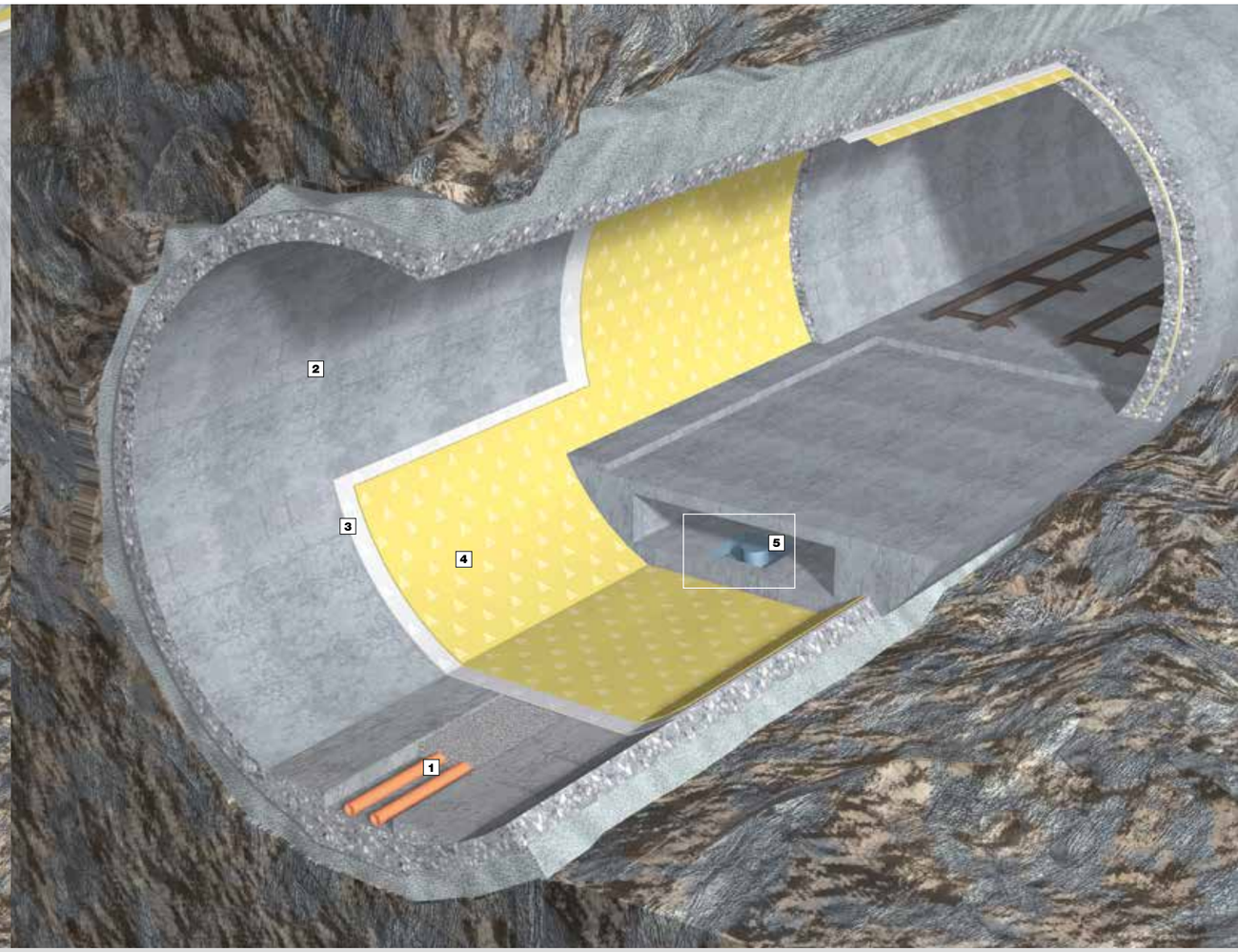

### Drainage of Mountain Water / Not holding a Head of Water / Drill-and-blast Excavation

1 Drainage pipe with gravel package
2 Invert drainage with gravel
3 Sika® FlexoDrain for preliminary waterproofing
4 Geotextile or drainage mats for draining and levelling out
5 Polymer waterproofing membranes Sikaplan®
6 Manholes for inspection and cleaning
7 Separation layer



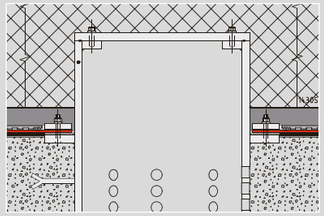

- Mountain water flows without head of pressure into the drainage
- No accumulation of water
- Sikaplan® WP drainage angle

## TBM driving with Drainage




### Mountain Water Displacement / Holding the Head of Water / Drill-and-blast / TBM Excavation

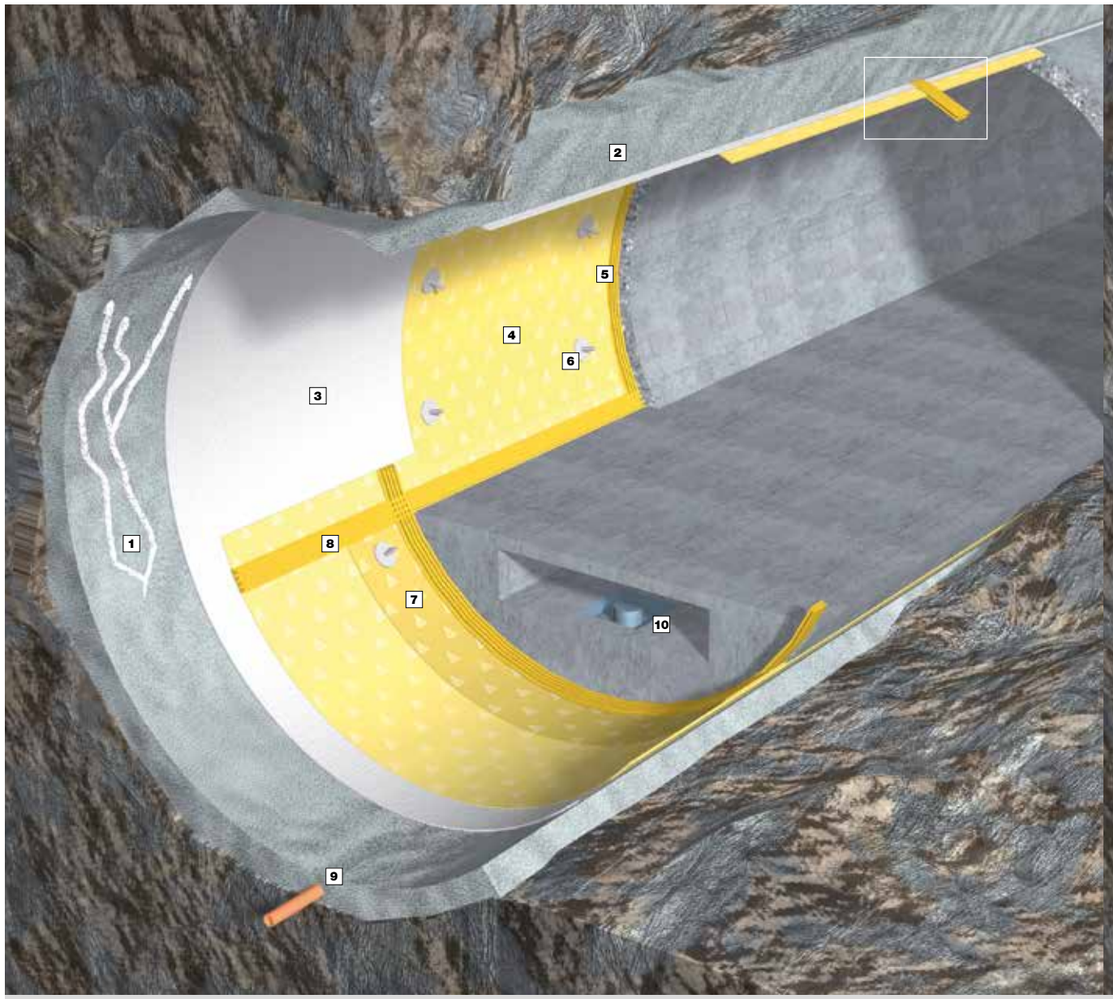
1 Drainage pipe with gravel package
2 Tubbing segments ring gap and segment joints (hollow space for drainage)
3 Protective geotextile as levelling layer
4 Polymer waterproofing membrane Sikaplan®, protective membrane in the invert and shuttering zone
5 Manholes for inspection and cleaning




- Mountain water flows without head of pressure into the drainage
- No accumulation of water
- Loose-Flange construction

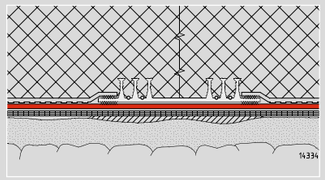
# Flexible Waterproofing with Sikaplan® Membrane Systems

## Drill-and-blast / TBM Excavation



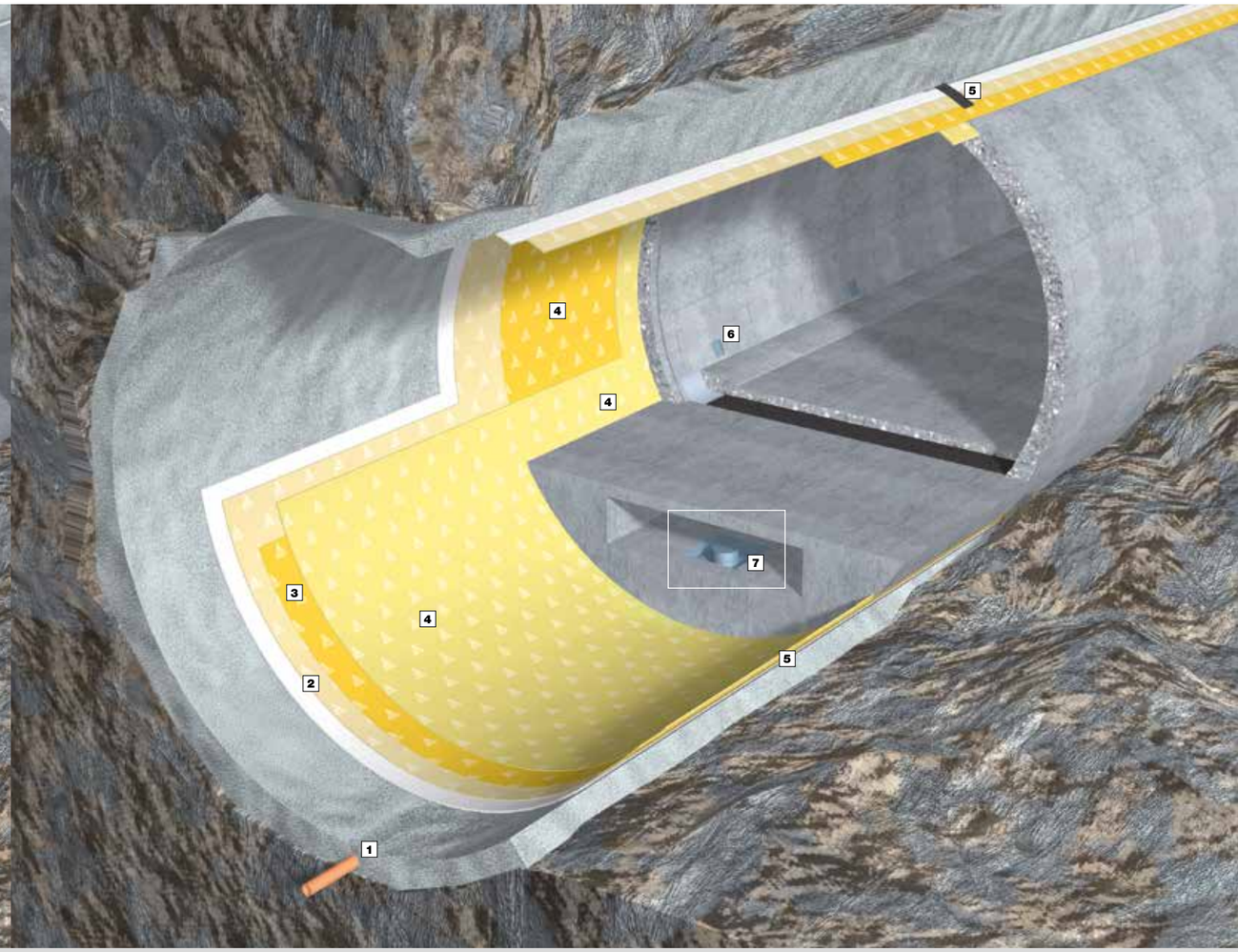

### Mountain Water Displacement / Holding the Head of Water / Drill-and-blast / TBM Excavation

1 Sika® FlexoDrain for preliminary waterproofing
2 Substrate
3 Levelling layer
4 Sikaplan® membrane
5 Partitioning with Sikaplan® Waterbars, injectable
6 Sikaplan® control socket
7 Sikaplan® protection sheet
8 Injection barrier/compartment
9 Drainage during construction
10 Groundwater relief socket



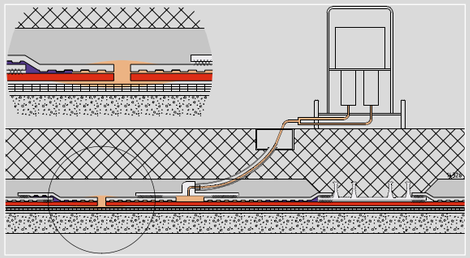
Waterstop, 6 anchors, 4 integrated injection canals

## Drill-and-blast / TBM Excavation




### Mountain Water Displacement / Holding the Head of Water / Drill-and-blast / TBM Excavation

1 Construction phase drainage, possibly with groundwater relief drains filled by cement grout after structural completion
2 Polymer waterproofing membrane Sikaplan® with geotextile
3 Waterproofing membranes Sikaplan® with knops-embossed surface (knops height: 0.3 mm, knops area: < 30% of membrane surface)
4 Polymer waterproofing membrane Sikaplan®, protective membranes in invert, shuttering and reinforcement steel zones
5 Segmental weld of double layer membranes
6 Connection point for vacuum test and injection
7 Groundwater relief drain

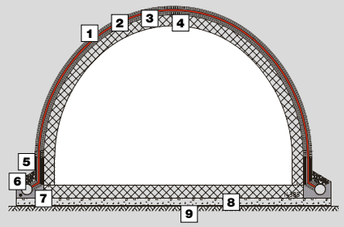


Active control system

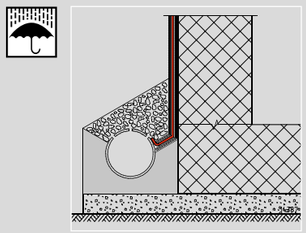
# Flexible Waterproofing with Sikaplan® Membrane Systems

## Open Cut Tunnel

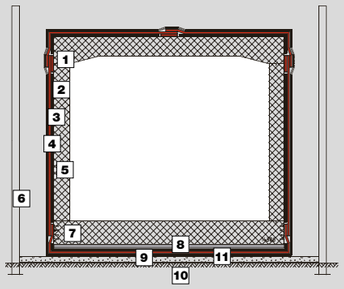
### Drainage of Mountain Water / Not holding a Head of Water / Drill-and-blast / TBM Excavation



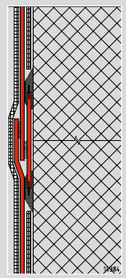

1 Sikaplan® protection sheet
2 Sikaplan® membrane
3 Levelling layer/Geotextile
4 Levelling grout
5 Filter (gravel)
6 Drainage pipe
7 Concrete foundation
8 Substrate
9 Excavated surface



### Mountain Water Displacement / Holding the Head of Water / Open Cut Tunnel



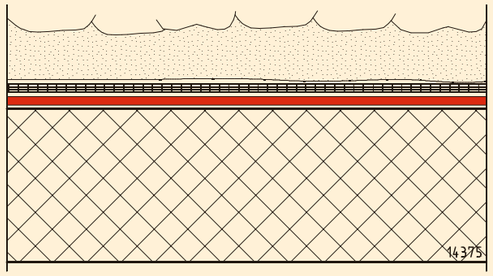

1 Sika® Dilatec®, joint sealing system or Sikadur® Combiflex®
2 Levelling layer/Geotextile
3 Sikaplan® membrane
4 Sikaplan® protection sheet
5 Levelling grout
6 Steel sheet piling
7 Partitioning with Sikaplan® waterbars, injectable
8 Protective concrete layer
9 Substrate
10 Excavated surface
11 Levelling layer/Geotextile



# Flexible Waterproofing

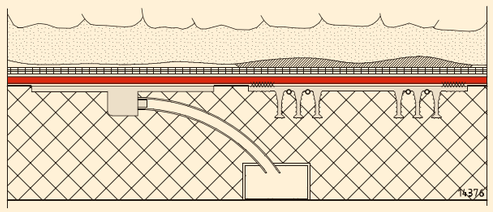
**Sika offers a wide range of diferent waterproofing systems according to the required degrees of watertightness and to the individual project conditions. A tunnel structure has to be waterproofed either by drainage system by waaterstop system or by active control system for highest demands with double layer waterproofing, controlled by vacuum.**

## Drainage of water, not holding a head of water

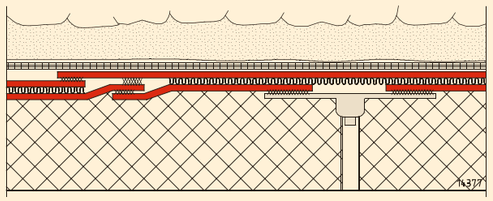



**Drainage system**
Single-layer polymer waterproofing membrane with geotextile or drainage mats or open tubbing segment joints

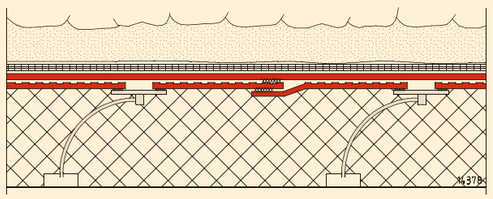
## Displacement of water, holding the head of water




**Waterstop system**
Single-layer polymer waterproofing membrane with partitioning




**Evacuation of leak-water system**
Double-layer polymer waterproofing membrane with knobs or with an intermediate drainage layer and partitioning




**Active control system**
Double-layer polymer waterproofing membrane with injection space and partitioning with compartments; ability to actively test the waterproofing seal

# Rigid Waterproofing

## Waterproof Concrete and Joint Sealing

**Sika® ViscoCrete®** SCC technology and **Sika®-1** capillary pore blocking technology.
**Sika® Waterbars, Sika® Injectoflex, SikaSwell®, Sikadur®-Combiflex®, Sika® Dilatec®** and **Sikaflex®** sealants are used for watertight joints.

# Thin-shell Waterproofing

## Tunnel rehabilitation

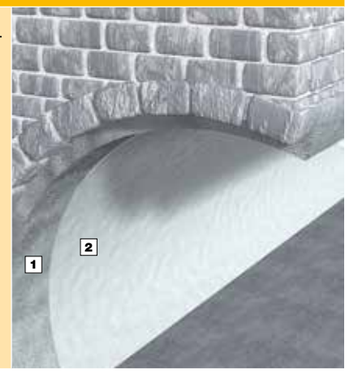
Sika waterproofing gunites are high-performance waterproofing systems requiring only little space. They are used for restoration and waterproofing work in the field of rehabilitation of existing tunnels.

1 Clean masonry linig and joints
2 **Sikacrete®-Gunit® 113** for joint sealing and preliminary mansory waterproofing
3 **SikaCem®-Gunit® 143** for the main thin-shell waterproofing lining


## New Tunnels

The outstanding waterproofing capacity of **SikaCem®-Gunit® 143** allows using high-durability thin-shell waterproofing linings also for new tunnels. The quick-setting gunite can be applied onto wet substrates. The polymer content of **SikaCem®-Gunit® 143** maximizes durability-relevant qualities such as freeze-thaw-deicing salt resistance and sulphate resistance while reducing the E-modulus. For special applications, fibre-reinforced types of the waterproofing gunites can be supplied on request.

1 Shotcrete applicaton for immediate support upon excavation
2 Waterproofing shell with **SikaCem®-Gunit® 143**



# Raw Material

**Considering the application of waterproofing membranes in tunnels, the long time experience of sealing, the practical welding behaviour, the economics and the technical characteristics of the wide plastic range, in general two of them have convinced: Advanced plasticized PVC and high flexible TPO (FPO) with an $E_{1\text{-}2}$-Modul < 65 N/mm². Important for the material specification and test procedures: PVC-P and TPO are completely different materials, with different material characteristics and behaviour.**

**Material-related properties of tunnel sealing materials made of thermoplastics (PVC-P) and thermoplastics elastomers (polyolefine elastomers/TPO) for permanent waterproofing.**

## PVC-P

- ++ Easy and reliable joint technology (hot air/adhesive)
- \+ Long experience (more than 50 years)
- \+ Optimal stiffness and material behaviour (elastic behaviour)
- \+ Self exstinguishing (approx. 21 MJ/kg)
- \+ High resistance to mechanical impact in relation to flexibility
- o Thermal extension
- – Ageing through plasticiser loss
- – Affected by cold (depending on the plasticiser)

## FPO

- ++ Thermal and chemical resistance
- \+ Sevice life
- \+ Low smoke behaviour
- \+ High resistance to permanent pressure
- o Good welding properties due to advanced FPO-recipes
- o Environmental stress corrosion cracking (depending on the flexibility/crystallization)
- o Fire behaviour (approx. 40–45 MJ/kg)
- – Ageing through thermal oxidation process
- – Less flexibility

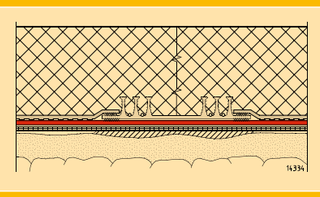
| Properties | Sikaplan® WP 1100 | Sikaplan® WP 2110 (WP 2160) | Sikaplan® WT 2200 (WT 2220) | Sikaplan® WP 1110 | Sikaplan® WT 2250 | Sikaplan® Neat | |
|---|---|---|---|---|---|---|---|
| Former product name | e.g. Sikaplan-14.6 | e.g. Sikaplan-14.6 V (Sarnafil F 635-20) | Sarnafil MP 915 Sarnafil MP 910 | Trocal T | Sarnafil MP 915-T | Sikaplan-14.6 Neat | Sarnafil MP 916-20 Neat |
| Material base | PVC-P | PVC-P | PE/TPO/FPO | PVC-P | PE/TPO/FPO | PVC-P | PE/TPO/FPO |
| Signal layer | Yes (yellow) ≤ 0.2 mm availible | Yes (yellow/grey) ≤ 0.2 mm availible | Yes (beige) ≤ 0.2 mm availible | No (translucent) | No (translucent) | Yes (yellow) | Yes (beige) < 0.2 mm |
| Roll width (m) | 2.00/2.20 | 2.00/2.20 | 2.00 | 2.00 | 2.00 | 2.00/2.20 | 2.00 |
| Special standards | EN 13491/13967 ZTV-ING (2003) SIA V 280/272 | EN 13967/ 13491 Heft 365/ RVS 8T External Quality Control ZTV-ING (2003) SIA V 280/272 | EN 13967/13491 ZTV-ING/ Rili 853 External Quality Control SIA V280/ SIA 272 | EN 13491/13967 Fascule 67° | EN 13491/13967 Fascule 67° | NEAT and SIA V280 | |
| Fire resistance class | E/EN 11925 B2/DIN 4102 | E/EN 11925 B2/DIN 4102 B1/Ö-Norm 3800 5.1 SIA V 280 | E/EN 11925 B2/DIN 4102 4.2 SIA V 280 | E/EN 11925 B2/ DIN 4102 | E/EN 11925 B2/DIN 4102 | 5.2 SIA V 280 | 4.3 SIA V 280 |
| Section elasticity module $E_{1\text{-}2}$ according to DIN EN ISO 527 | < 20 N/mm² | < 20 N/mm² | < 70 N/mm² | < 20 N/mm² | < 70 N/mm² | < 20 N/mm² | < 70 N/mm² |

# Ancillary Products

### Sika® Waterbar, PVC and FPO based types

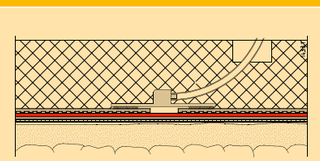
- Sika® Waterbar type AR (PVC)
- Sika® Waterbar type DR (PVC)
- Sika® Waterstop type MP AF (FPO)
- Sika® Waterstop type MP DF (FPO)

Compartments in invert and arch of tunnels, raw material compatible with the water-proofing membrane



### Sikaplan® WP/WT protection sheets

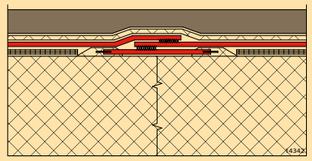
- Sikaplan® WP Protection sheet (PVC)
- Sikaplan® WP Protection sheet HE (PVC)
- Sikaplan® WT Protection sheet (TPO)
- Sikaplan® WT Protection sheet HE (TPO)

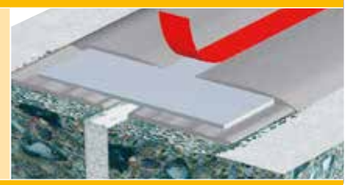


### Sikadur®-Combiflex® joint sealing system

- Sikadur®-Combiflex tape
- Sikadur®-31 (EP adhesive)

for compartments and terminations with FPO membranes

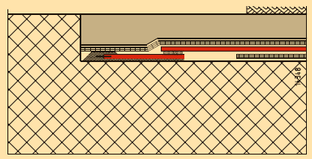




### Sika® Dilatec®, type E / ER joint sealing strips

- Sika® Dilatec E-220 for expansion joints
- Sika® Dilatec ER -350 for waterproofing terminations
- Sikadur®-31 (EP adhesive)

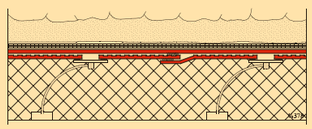
for compartments and terminations with FPO membranes

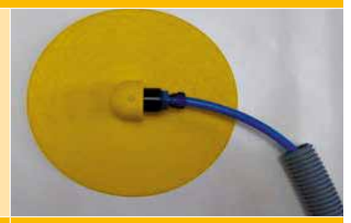


### Sika® Control and injection flange

- Sikaplan® WP/WT Injection Flange
- Sikaplan® WP/WT Control socket
- Sikaplan® W Flexible PP protection pipe
- Sikaplan® W PU-control tube

For an integrated prophylactically injection system for possible repair work, for injec-tion of fine cement and chemicals and for vacuum control.





### Sikaplan® WP/WT laminated metal

### Sikaplan® WP/WT disc fixing element

### Sikaplan® WP/WT Trumpet Flange

# 100 Years Service Life?!
## Long Term Testing according to the NEAT -standard

**During the last decade, different waterproofing materials have been studied and tested in tunnel applications, mainly in Switzerland and Germany.**

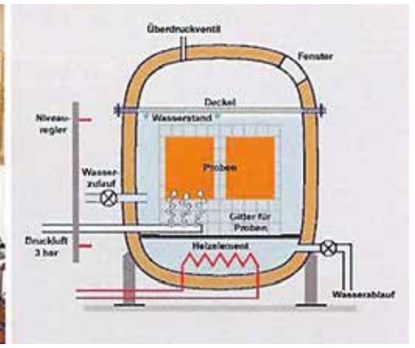
**The materials are based on polyolefines compounds (PE and PP) or polyvinylchloride (PVC-P). A comprehensive evaluation procedure was performed for two particularly long tunnels through the Swiss Alps based on requirements established by Alp Transit Gotthard AG and BLS Alp Transit AG.**

Special influences such as high geothermal heat (45 °C), high water pressure (40–160 bar), high pressure of mountain mass, construction, and high expectations for the service lifetime of 100 years had to be considered.

Polymeric products combined to waterproofing systems (membranes PE, PE-copolymer, PVC-P; drainage materials PE, PP, PA, PES) were tested in a 24-month programme. Existing test methods were complemented, e.g. by ageing at elevated temperatures and in oxygen-enriched water at elevated temperatures, respectively, compression creep tests, behaviour under combined lateral compression and horizontal shear, seam and installation tests.

As many systems and products did not meet all of the stringent requirements, the most promising systems were then optimized and re-evaluated.

The result of this evaluation and these test procedures clearly showed that Sika products based on PVC-P and polyolefine compounds could fully meet the defined requirements for the waterproofing systems (EMPA-Report).




Schematic of the pressure vessel with test specimens vertically arranged in oxygen-enriched water.

### Ageing Behaviour

In this part of the evaluation, the components of the waterproofing systems were exposed for 24 months without mechanical loading to the following media: water circulated at temperatures of 23 °C, 45 °C and 70 °C, alkaline and acidic water at 50 °C, oxygen-enriched water at 70 °C and 3 bar pressure (Roxi-test) and by burying specimens in an environment with both aerobic and anaerobic micro-organisms.

At 5 intervals during the storage, the waterproofing membranes were tested for mass changes, changes in dimension and mechanical puncture strength. An additional series of tests including tensile, thermo-mechanical and thermo-analytical assessment after 3, 6, 12 and 24 months were used to determine the most appropriate properties for a sufficiently complete description of the ageing process (EMPA-Report).




Schematic cross-section of the compression shear set-up with heating and drainage capability, the top plate (fixed) corresponds to the shotcrete surface of the outer tunnel shell.

### Sikaplan® approved Systems

System 212, Sikaplan 14.6 Neat and PP drainage ("Wirrgelege").

System 620, Sikaplan-14.6 Neat Felt 500, Sikaplan PVC-P backed with a PP geotextile and a drainage made of gravel.

System 121, Sarnafil MP 916 Neat and a PE drainage inclusive studs.

### Test Application Field – NEAT

The system was installed on a shotcrete surface with variable surface roughness between 3–7 mm and a waviness of 4:1, 7:1 and 15:1. With additional heating during the setting of concrete the temperature in the waterproofing system rose to 55 °C. After completition of the construction the drainage capability was determined. The concrete support shell was then removed and the waterproofing system exposed.

The first installation tests showed that the waterproofing membranes develop regular folds with small radius of curvature during construction. Development of folds in the plane of the waterproofing membrane produces potential failure lines and has thus to avoided in long-term service.

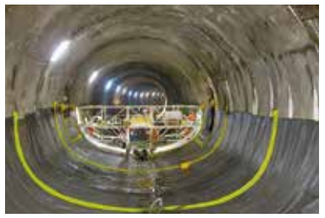
To avoid such folds in the waterproofing membrane and to guarantee a close fit to the shotcrete profile, the Neat committee set strict requirements concerning the quantity and location of fixing points, the jointing procedure and the friction between waterproofing membrane and drainage material.

To achieve such a close fit to the shotrecte profile, the flexibility of the waterproofing membrane – described with the section elasticity module between 1 % and 2 % elongation according to DIN EN ISO 527 – is recommended below 70 N/mm$^2$.

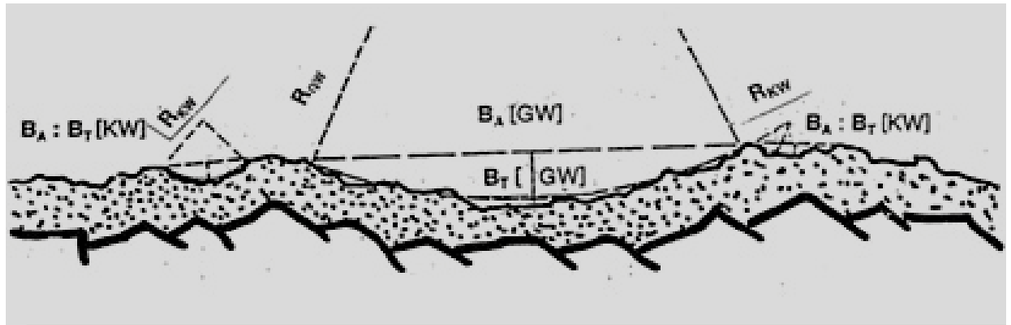
# Substrate Roughness/Evenness

**To support the excavated space and if necessary also the tunnel front during the excavation of a new tunnel, shotcrete has to be used. In case of a double shell tunnel lining, incorporating a geomembrane, the final shotcrete layer shall be sprayed in a way that no re-profiling with additional shotcrete is necessary to be able to properly fix the geotextile and the membrane respectively. Arch ribs, wire mesh, lattice girder and shotcrete are used for primary support.**

**All initial shotcrete surfaces are prepared so as to achieve the smoothness and regularity required to preserve the membrane integrity. Additional shotcrete has to be used where required to smooth surface irregularities and meet the criteria below.**



In the application field of tunnels, the problem has mainly involved the stiffness of the material and the difficulties of hand welding, particularly in wet and uncomfortable conditions or e.g. in niches, in cross sections, welding of waterstops, welding of patches, etc. Arguably, the most important aspect of the waterproofing operation is the welding of the membranes, which has to be carried out very carefully to maintain the continuity of the waterproofing sheet; any failure in the welding will cause leakage in the tunnel, with fatal results if water under pressure is present. The flexibility of a material will be described with the section elasticity module $E_{1\text{-}2}$ according to DIN EN ISO527.




| Requirement of membrane flexibility in connection with shotcrete evenness | | | |
|---|---|---|---|
| **Evenness of shotcrete** | ≈ 1 : 5 | ≈ 1 : 10 | ≈ 1 : 15 |
| **Section elasticity module $E_{1\text{-}2}$ according to DIN ISO 527 1-3** | < 20 N/mm² | < 70 N/mm² | < 100 N/mm² |

| Roughness of shotcrete (recommendation according to NEAT/SIA 272) | | | |
|---|---|---|---|
| | **Definition** | **Requirement** | **Method of measurement** |
| **Roughness** | Depth | Max. value 4–16 mm | Sandfill as per ZTV-SIB measured at Ø 250 mm |
| **Evenness** | Small waves (R ≤200 mm) | | |
| | $R_{KW}$ Radius (mm)<br>$B_A : B_T$ Ratio | Min. value<br>$B_A$ at $B_T$ =1<br>=10 : 1 | Manual measurement of substrate at negative form |
| | Large Waves (R ≥ 200 mm) | | |
| | $R_{KW}$ Radius (mm)<br>$B_A : B_T$ Ratio (GW) | Min. value<br>$B_A$ at $B_T$ =1<br>=10 : 1 | Measurement of substrate with profilometer |

## Waterproofing Sections, with the Membrane Installation on Shotcrete (initial lining)

The surface of the shotcrete should be smooth and even. The shotcrete aggregate shall have a diameter of 4–8 mm. Minimum radius of any unevenness shall be not less than 20 cm. Loose and protruding stones must be removed. The shotcrete shall be cured for at least 24 hours. Steel elements, such as reinforcement bars, steel girders and the heads of rock bolts – as far as not used to hold inner lining structures – shall be covered with at least 5 cm of shotcrete. Running water ingress can be plugged with waterproof mortars (i.e. **Sika®-4A** admixture) mixed with brand new Portland cement, prior to the initial lining. Heavy water ingress can be collected into PVC half-pipes (i.e. **FlexoDrain**), mounted by nailing and led into the permanent drainage system. The mounted half-pipe should be covered with at least 5 cm of shotcrete prior to the initial lining installation.

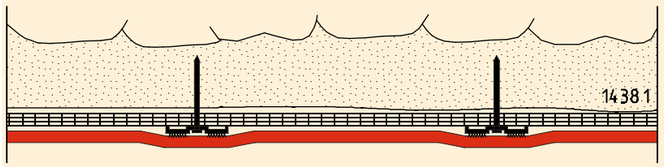
Difficult substrate conditions

Substrate conditions in Uetliberg/Switzerland

# Fixing Technique

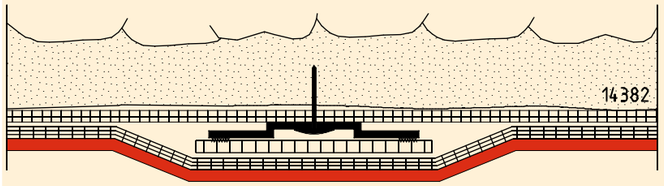
**The possibility to bridge joints, cracks, fissures and gravel pockets is the big advantage of loose laid (spot-fixed) plastic sealing membranes. Fixing discs (roundels) are installed on the shotcrete surface to provide adequate support and a close fit over the entire shotcrete surface. The waterproofing membrane is laid with the signal layer inside the tunnel and with sufficient slack to prevent overstressing during concreting. New fixing methods come up, e.g. the hook and loop fastener system and the hot-melt system, which allows an automatic installation.**

## Spotwise welding



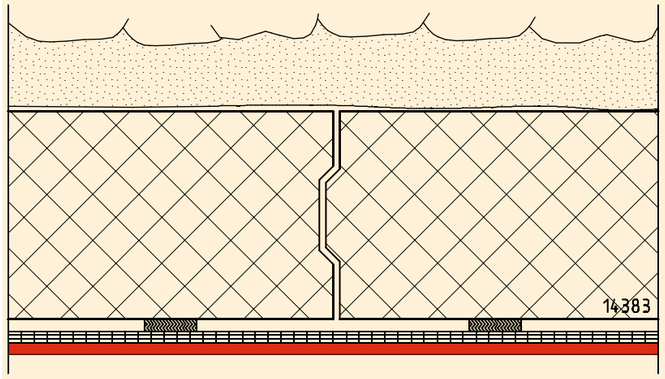

- Shotcrete, >5 cm
- Geotextile / Drainage mat
- Fixing discs
- Hot air weld
- Waterproofing membrane Sikaplan

## Spotwise hook and loop




- Shotcrete, >5 cm
- Geotextile / Drainage mat
- Fixing disc with hook and loop
- Hot air weld
- Waterproofing membrane Sikaplan fleece-backed

## Stripwise adhesive-bonded (e.g. hot melt)




- Tubbing segment concrete (shotcrete)
- Adhesive bead (liquid adhesive)
- Waterproofing membrane Sikaplan fleece-backed

# Welding Technique of Membranes

**Sikaplan membranes are heat-welded using various methods. The main difference is between welding by hand and welding using an automatic welding machine. The welding method must be adapted to the site conditions and must be suited to the Sikaplan membrane type. Before the membrane is welded, a trial weld and peel test must be carried out. The trial weld serves to check the welder settings and adjust these to suit the site conditions if necessary.**

## Hand-Welding

- **Sika seam surfaces to be welded must be clean and dry (cleaning / seam preparation).**
- **Adjoining sheets should overlap at least 80 mm.**

**Leister PID**
Proper hand welding involves three steps:

**1. Tack welding**
Hold the sheets in position.

**2. Pre-welding**
Continuous weld joins the sheets to form a heat pocket. The weld is placed along the back of the overlap, leaving 35 to 40 mm of free material to weld with a 40 mm wide welding nozzle (or 15 to 20 mm for a 20 mm nozzle).

**3. Final welding**
The final weld produces an airtight and watertight seam 10 to 30 mm wide (depending on nozzle width). A Sika pressure roller is applied at a distance of 30 mm in front of the nozzle and parallel to it. The travel of the roller should always extend beyond the welded seam.

## Automatic Welding

- **Heated wedge automatic welding machines are predominantly used on civil engineering projects.**
- **The machines are used to weld both the longitudinal and transverse seams.**

**Leister COMET / Leister TWINNY T / S**
This heated wedge automatic welding machine is used in tunnels, below-ground structures, and hydraulic / water-retaining structures. For membranes 1.5 mm to 3 mm thick, dependent on the material.

Double seams (widths: 15 mm each plus 10 mm air testing channel) only with automatic welding machines.

Heat is transferred to the material to be welded by a temperature-controlled heated wedge, heated electrically or by hot air. The machines can be used over any substrate. The use of each machine is described in detail in the relevant user manual.

**Heat welding of Sika Waterbars onto the installed Sikaplan® membrane with heated blades**

Butt joints between **Sika® Waterbars** type AR/AF are made with hot copper blades whilst the waterbar's ends are fixed into special clamps.

# Seam Inspection after Welding

## Testing with compressed Air

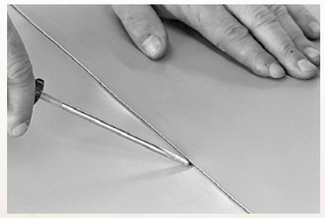
The double-wedge machines produce two welded seams at once. At both ends of the double seam the channel between the two welds to be tested is clamped shut and a manometer and needle is installed. A foot-pump or air compressor is then connected to the valve and the appropriate test pressure developed. (The pressure depends on the material and the temperature; see DVS 2225 Part 2 / Test pressure chart.)

The standard test parameters are as follows:
Test duration: 10 minutes; test pressure: 1.5–2 bars, depending on the temperature and membrane thickness. The seam is considered watertight if the initial pressure in the test channel drops by not more than 10 % during the test period. The pressure values are recorded, specifically the initial pressure and the final pressure.

## Visual Inspection of Seams

After welding, all seams should be visually inspected for good workmanship. Special attention should be paid to T-joints, penetrations, and flashings.

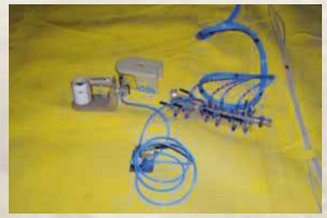
## Mechanical Testing of Seams



All hand-welded seams should be mechanically tested once they have completely cooled. For this purpose use a screwdriver (about 5 mm wide, with blunted edges). Apply light pressure to the seam, and do not scratch the membrane. Mechanical testing is not a test for watertightness; it helps detect seams that are not fully welded.

## Testing with Vacuum

Vacuum bell over seam area to be tested, build up vacuum with electric pump.



Testing of watertightness for the double-layer system, which is the only waterproofing system which can be tested during any of the construction phases.

# Checklist for Waterproofing

**Acceptance of substrate**
- Make sure the substrate is even, smooth and clean as specified.

**Levelling and protective layer**
- Are the type, weight, and quality correct?
- Are the lapped seams correct?
- Is the number of fixing points correct?

**Sikaplan® membrane**
- Are the type, thickness, and quality correct?
- Are lapped seams correct? Field cuts?
- Is the membrane laid without wrinkles?

**Welding of the membrane**
- Is the welding machine clean (heating wedges)?
- Are temperature, speed, and pressure correctly set?

**Checking welds**
- Check double-wedge seams with compressed air in accordance with the Installation Manual.
- Check finished hand-welded seams with a screwdriver as recommended.

**Transition at invert / vault**
- Cut the overlap correctly.
- Bevel edges at T-joints.
- Weld transverse seams with a welding machine.
- Test welded seams with compressed air.

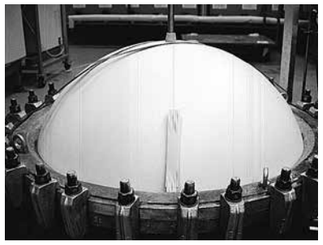
**Waterstops**
- Check position of the waterstops.
- Check welds with a screwdriver.

**Membrane Protective layer**
- Are the type, thickness, and quality correct?
- Are welded seams and welds to the waterstops complete?

**Acceptance of each section**
- Visually inspect the waterproofing surface for damage or faults.
- Make sure waterstops are clean and free of residue.
- Ensure acceptance by construction supervising officer.

# Quality

**The success of a construction project is determined by the quality of every aspect. Thus quality assurance is especially important. That's why we are focussed to deliver the following demonstrable characteristics:**



## Quality Assurance of the Product

Sika is innovative, uses advanced raw materials, researches intensively, uses modern production methods, ensures the internal monitoring of processes and external monitoring of products. – These are the principles we follow as we provide our customers with high-quality products. Yet that's just the start of the long chain of processes a **Sikaplan**® membrane goes through to ultimately become a customer-tailor-made waterproofing system that protects a tunnel against water.

## Material Qualitiy

- Specified and cost-optimized Sika products and systems
- Certified Sika Systems according to NEAT-standard
- High quality and advanced raw material technology for PVC-P and FPO products
- Experienced material know how based on different application fields in tunnels, basements, roofing, pit and ponds, groundwater protection, tank sealing and swimming pools
- Complete- material compatible-systems including design and accessories

## Quality of the Installation

- **Welded seams**
  Flawless seams can be welded by hand and/or with automatic welding machines. Seam quality is tested and evaluated according to DVS 2225 Part 2.
- **Checklist**
  This tool is adapted to the specific conditions of each job. It is one part of quality management on the construction site and serves to reduce sources of errors.
- **Field Test Report**
  The Field Test Report helps ensure that all tests and inspections are carried out for each tunnel section. The report form also documents readiness for the subsequent concreting.
- For more information on working with Sika membranes: The Sika Membrane Installation Manuals describe and illustrate each step of detail work. Sika Installation Manuals for Sikaplan PVC and for TPO membranes are available on request.

- **Quality in terms of substantially meeting the expectations of customers**
- **Professional competence in line with current knowledge and technology**
- **Punctual delivery of goods and services**
- **Effective problem-solving with verifiable actions**

Responsible Care

Certified Quality System ISO 9001/EN 29001 since 1986

Certified Management System ISO 14001 since 1997

**Inadequate workmanship or incorrect installation of membrane waterproofing could mean that the structure is not watertight, thus allowing future water ingress. Sika® trained professional contractors and QC on site are always recommended to prevent such defects.**

Non-professional welding

Incorrect welding

Ignoring substrate requirements and omitting protective backing materials

# Global Case Studies
## Flexible Waterproofing of Tunnels with Sikaplan® Membranes

**Project**
- Railway -Gotthard-Tunnel/ Switzerland, year 1910
- Protection of Electricity against water

**Sika solution**
- Drainage System
- Improvement of concrete structure with mortar sealing compound

**Products**
- **Sika-1** waterproofing adhesive for mortars



**Project**
- NBS-Köln-Rhein Main/ Germany
- 60 m waterpressure

**Sika solution**
- Active Control System with double membrane layer (3+2 mm) & vacuum control
- Using of high flexible TPO membranes (FPO), which allow to weld difficult sections of tunnels without cutting (e.g. cross sections) and therefore to reduce hand-welded seams and vacuum tests
- Installation of flexible – membrane compatible – polyolefine waterstops with integrated injection canals and external grouting hoses

**Products**
- **Sikaplan® WT** 2200-32 HL2
- **Sikaplan® WT** 2220-25 HLE
- **Sikaplan® WT** Protection sheet-30H
- **Sarnafil® Waterstop** MP 6-STEGIG AFI 600/35
- **Sikaplan® W** FELT PP RIL 850
- **Sikaplan® WT** Control socket 6 mm PE
- **Sikaplan® W** Flexible PP protection pipe
- **Sikaplan® W** PU-control tube
- **Sikaplan® WT** Disc grey PE

High flexible FPO membranes allow to weld difficult sections of tunnels without cutting.

**Project**
- N4.1.5 Ueltlibergtunnel- Birmsdorf/ Switzerland, 4200 m, 360 000 m²
- NATM/ TBM, shotcrete surface, waterhead 50 m (partly)

**Sika solution**
- Waterstop System with double layer membrane and Drainage System (full round seal)
- Using an innovative injection barrier/compartment system in the area of the horizontal construction joints
- At the interfaces between the different waterproofing drainage concepts (drained/undrained) it was necessary to install a tight sealing ring system “Dammring” between the rock and waterproofing membrane. This detail was solved with a Sikadur Combiflex System

**Products**
- **Sikaplan®** 30 PECO
- **Sikaplan®** 20/30 PECO DIA
- **Sika® Waterstop** AR 60-6 inject PECO
- **Sika® Waterstop** AR 40-6 inject PECO
- **Sika® Waterstop** AR-10/1 PECO
- **Sikadur® Combiflex®** 2502

**Project**
- Road tunnel Bad Ems/ Germany, 1.600 m, 36 500 m²
- Thermal water up to 55°C incl. lime corrosive carbonic acid, under pressure

**Sika solution**
- Waterstop System
- Full round sealing with a 3 mm flexible polyolefine membrane – **Sikaplan® WT** 1200-30 C – including contraction preventing with glass fleece
- Installation of flexible – membrane compatible – polyolefine waterstops including pre-fabricated cross-joints

**Additional products:**
- **Sikaplan® W** FELT PP ZTV 950
- **Sikaplan® WT** Protection sheet-30H
- **Sika® Waterstop** MP AF 240/30 (4 anchors)
- **Sika® Waterstop** MP AF 400/30 (6 anchors)
- **Sika® Waterstop** MP DF 400/30 (6 anchors)
- **Sikaplan® WT** Disc grey PE

# Global Case Studies

## Flexible Waterproofing of Tunnels with Sikaplan® Membranes

**Project**
- Katzenbergtunnel / Germany, cross section, 90 mWS
- Main tunnel with pre-cast-concrete elements/ tubbings (TBM)

**Sika Solution**
- Waterstop System
- Using of high flexible TPO membranes (FPO) to guarantee a close fit to the surface profile and to improve the workability/ patch-work
- Installation of flexible – membrane compatible – polyolefine waterstops with four integrated injection canals

**Products**
- **Sikaplan® W** FELT PP RIL 850
- **Sikaplan® WT** 2200-32HL2
- **Sikaplan® WT** 2200-42HL2
- **Sarnafil® Waterstop** AF-600/34 MP Inject
- **Sikaplan® WT** Disc grey PE

**Project**
- Islisbergtunnel/ Switzerland
- Full automatically installation with hot-melt on pre-cast concrete elements/ tubbings

**Sika Solution**
- Drainage System
- Using a PVC-P-fleece backed (500 g/m², PP) waterproofing membrane
- To avoid critical peeling process between membrane and fleece caused by water and weight, the lamination between both has to be more than 80 % of the surface
- Fire behaviour of the membrane 5.1 acc. to SIA V 280, self exstinguishing, caused by high continuously membrane installation without final concrete lining

**Products**
- **Sikaplan® WP** 2110-20 HL Felt 500
- **Sikaplan® WP** 2160-20 HL Felt 500

**Project**
- Road tunnel N 20.1.4- Birmsdorf-Hafnerberg/ Switzerland, 130 000 m²
- pressure water

**Sika Solution**
- Waterstop System
- Using a PVC-Anchor to fix the reinforcement of inner lining to the outer shell without losing the watertightness in case of membrane penetration

**Products**
- **Sikaplan® WP** 2110-30HL
- **Sikaplan® WP** Protection sheet-40HE
- **Sikaplan® WP** Anchor 16/200
- **Sikaplan® WP** Disc 80/10mm yellow

**Project**
- AlpTransit/NEAT-Gotthard-section Bodio/ Switzerland, year 2007, 16.5 km, 1.8 Mio m²

**Sika Solution**
- Drainage System
- Full automatically installation with hook and loop fixing discs
- Spot-wise fixing technology in combination with a fleece backed PVC-P membrane (200 g/m², PP)
- Guarantee of a close fit to the shotcrete surface (machiened) and therefore improvement of the system quality
- Waterproofing membrane according to NEAT-Alp Transit requirements

**Products**
- **Sikaplan®-14.6** Neat F 200 Klett (System 216)

# Global Case Studies

**Project**
- Tunnel Mrazovka, CZ
- 40 m waterpressure

**Sika Solution**
- Waterstop System with 3 mm FPO membrane
- Using of high flexible TPO membranes (FPO), which allow to weld difficult sections of tunnels
- Installation of flexible – membrane compatible polyolefine waterstops with integrated injection canals
- Injection of cement based material from bottom to top, approx. 8.6 l/m² (average)
- Injection of PU based material

**Products**
- **Sarnafil**® G 476-20
- **Sarnafil**® GN 479-25, including glas fleece and knops
- **Sikaplan**® **WP** Protection sheet -30 H
- **Sikaplan**® **WP** discs

**Project**
- Tunnel Gernsbach, D
- First tunnel project used an Active Control System, 1995
- 40 m waterpressure

**Sika Solution**
- Active Control System
- PVC-membranes with signal layer (2 + 2 mm)

**Products**
- **Sikaplan**® **WT** 2200-30HL2
- **Sikaplan**® **WT** Protection sheet-30H (Sarnafil Schutzbahn N8-30)
- **Sarnafil**® **Waterstop** MP 6-STEGIG AFI 600/35
- **Sikaplan**® **W** FELT PP 500 (SARNAFELT PP 500 )
- **Sikaplan**® **WT** Control socket 14 mm PE
- **Sikaplan**® **W** Flexible PP protection pipe
- **Sikaplan**® **WT** Disc grey PE
- **Sikaplan**® **WP** anchor 16/120

# Sika Experience in Waterproofing for nearly 100 Years

**As early as 1920, when the electrification of the railways began, the importance of tunnel waterproofing was recognized. Nowadays, the waterproofing of underground traffic structures is required as a matter of course by specialists. With its quick-setting mortar, Sika not only provided the first lead in the tunnel waterproofing epoch, but was consequently involved most influentially to the present day in the development of new technologies, as the following brief history shows.**

**1910** Gotthard railway tunnel (CH), waterproofing with pointing mortar Sika®-4, surface waterproofing with Sika®-1

**1930** Paris metro, Chalifert-station (F), waterproofing with Sika® mortars

**1940** Oberhasli power station (CH), preliminary waterproofing with Sika®-4a

**1950** Walensee road, Kerenzer tunnel (CH), isolation of interior tunnel vault with Sika® bitumen felts

**1960** Loibl tunnel, Carinthia (A), tunnel waterproofing with Sika® Colmasyn polyester coating

**1960** Felber-Tauern tunnel (A), preliminary waterproofing with Sika®-4a and application of shotcrete layer with Sigunit® and Sikalite®

**1968** Belchentunnel, highway (CH), installation of 1 mm thick PVC-P waterproofing membrane fastened spot-wise with press-studs

**1968/69** Bärenburgtunnel (A13/CH), waterproofing membrane (Sarnafil) with hot-melt technology

**1968** Arisdorftunnel (A2/CH), PVC-P membrane made at Düdingen (CH)

**1969** Viamala, Roflatunnel (CH), waterproofing with Sikaplan® bitumen membranes, fully glued to inner concrete ring with hot-seal adhesive

**1971** Furka railway tunnel (CH), preliminary surface waterproofing by machine with SikaShot® (ready-mix concrete/ sprayable membrane).

**1972** Gotthard road tunnel (CH), application of frost-resistant concrete with the admixture Plastocrete®

**1976** Schönbuchtunnel (D), Herrenberg, water pressure resistant sealing with Sikaplan® (Sarnafil) mod. TPO membranes, double welding seam with test canal

**1977** Seelisbergtunnel (CH), use of setting accelerator Sigunit® and waterproofing by the Bituflex-Sika Norm Hypalon

**1978** Belmont tunnel (CH), waterproofing with Sikaplan® PVC-P tunnel membranes, spot-fastened by the "suspender method"

**1978** Ventilation shaft for Gotthard road tunnel (CH), waterproofing with Sikaplan® PVC-P tunnel membrane, in hardly combustible version and with incorporate signal layer

**1984** Gubrist tunnel (CH), fully glued Sikaplan® PVC-P, with signal layer and fleece backing

Trancheé couverte de Sévaz, A1 (CH), waterproofing with Sikaplan® PVC-P membrane fully glued

**1990** Tunnel Planzetta Sierre, A9 (CH), waterproofing with Sikaplan® FPO membrane

**1995** Gernsbachtunnel (D), first Active Control System with a PVC-P membrane

Girsberg tunnel A7 Kreuzlingen (CH), PVC-P waterproofing against pressurized water (25 m WS) with spot-wise fixing based on Sika hook and loop technology

Önsbergtunnel (CH), adhesive fixing technology wih fully automatic installation, Sikaplan® PECO fleece-backed, on tubbings
NBS Köln-Rhein/Main (D), tunnel under water pressure (60 m WS), Active Control system with Sikaplan® (Sarnafil) FPO

Lötschberg base tunnel (CH), waterproofing with Sikaplan® PVC-P

**2006** Metro São Paulo (BR), waterproofing with PVC-P membrane according to SIA V 280 standard

Hallandsås Tunnel (S), 120 m WS, cross section, Sikaplan® (Sarnafil) FPO membranes

Islisbergtunnel (CH), adhesive fixing technology with fully automatic installation, Sikaplan® PVC-P fleece-backed on tubbings

**2007** Tunnel Grouft (LUX), waterproofing with PVC-P, fire resistance of 5.1 according to SIA V 280

**2007** Katzenbergtunnel (D), 90 m WS, cross section, Sikaplan® (Sarnafil) FPO and new generation of Sika waterstops

Tunnel chain Perschling and tunnel Wienerwald (AT), adhesive fixing technology with fully automatic installation, Sikaplan® PVC-P fleece-backed on tubbings

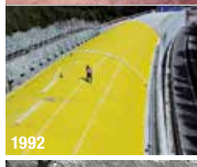
**2008** AlpTransit/ Tunnel San Gottardo, spot-wise fixing based on Sika® hook and loop technology, Sikaplan® PVC-P Neat fleece-backed and Sikaplan® (Sarnafil) FPO Neat





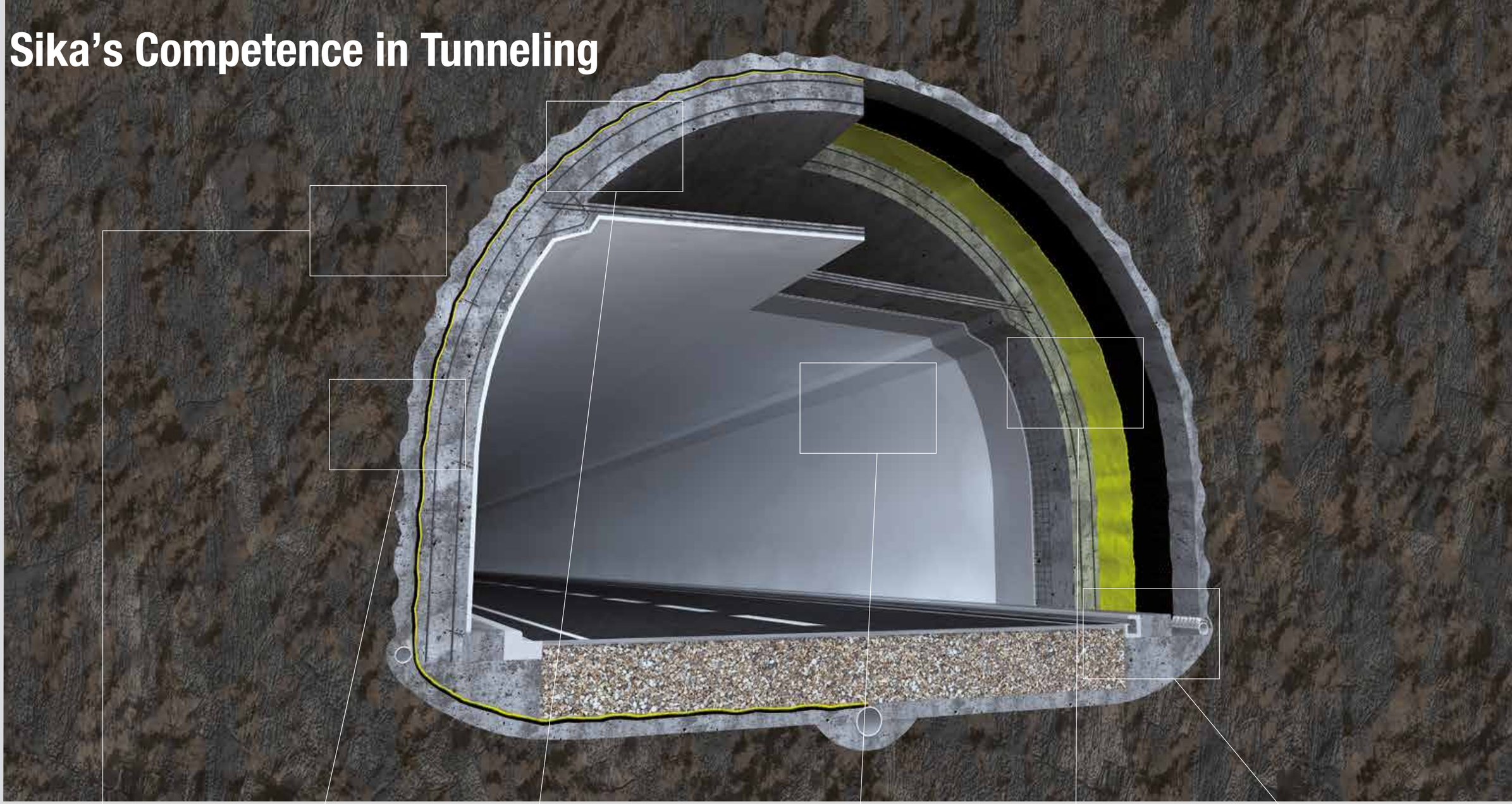






# Sika’s Competence in Tunneling

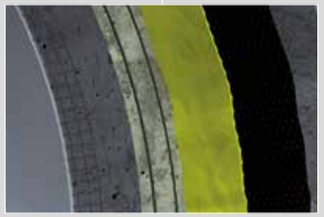


Rock stabilization with
**Sika® Injection** resins

Sprayed concrete
**SikaCem®-Gunite®**

Tubbing/Pre-cast-concrete elements
**Sika® ViscoCrete® SCC**
Concrete admixture technology

Wall protection
**Sikagard®-Wallcoat**



Flexible waterproofing
**Sikaplan®** membrane

Specialities
**SikaGrout®** mortars
**Sikadur®** epoxy adhesives

Joint sealing, crack sealing
**Sikadur®-Combiflex® System**
**Sika® Waterbar**
**Sikaplan® WP** drainage angle

# Sika® Injection Technology for Waterpr oofing Construction Joints or Remedial Works

## Solutions for Leaks and Construction Damage

### Concrete Damage

Damage can occur to the concrete in many ways but primarily through difficulties in interpreting design aspects, inadequate or untimely compaction, or by accident. Sika produces a full range of concrete repair systems, which are compatible with all Sika waterproofing systems.

### Cracks/Honeycombing

The terms “watertight” and “vapour-tight” do not mean “crack-free”. Cracking can always occur in concrete in its plastic or in its hardened state, due to the stresses imposed. These include the internal forces caused by temperature and water content changes. Sika has a complete range of products and systems for the repair of “cracks” and “honeycombing” in watertight concrete structures.

### Sealing and Waterproofing of Cracks

**Closing, sealing and flexible bridging of leaking cracks and honeycombing or voids in new and existing structures:**

**Sika® Injection-101**
Fast-foaming, low-viscous polyurethane injection foam for temporary water-stopping

**Sika® Injection-201**
Low-viscous, flexible polyurethane injection resin for permanent waterproof sealing

**Sika® InjectoCem-190**
Two-component injection grout based on microfine cement

### Waterproofing of Construction Joints

**For sealing construction joints in a watertight structure, Sika provides a full range of products and systems:**

**Sika® Injection-29**
Low-viscous, flexible polyacrylate injection resin with a high solids content

**Sika® Injection-201**
Low-viscous, flexible polyurethane injection resin for permanent watertight sealing even in wet conditions

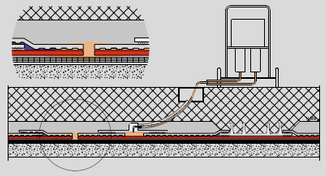
**Sika® InjectoCem-190**
Two-component injection grout based on microfine cement for waterproof sealing of voids and non-moving cracks in the structure

### Surface Sealing and Waterproofing of Concrete Structures

**Remedial surface sealing by curtain injection of surface defects in below ground concrete structures:**

**Sika® Injection-304**
Flexible, very low-viscous and very quick-gelling polyacrylate injection gel for permanent watertight sealing. The material reacts to form a waterproof, flexible but solid gel with good adhesion to both dry and wet substrates.

### Waterproofing of damaged Membranes



Repair by injection of damaged waterproofing membranes (single and double layer systems)

**Sika® Injection-305**
Flexible, very low viscous and quick-gelling polyacrylic injection gel for permanent watertight sealing of damaged membranes (single and double layer systems). The material reacts to form a waterproof, flexible but solid gel with good adhesion to both dry and wet substrates.

### Compartmentalization Waterbars

To ensure watertight embedding of the anchors, the waterstop system uses injectable waterstops. Potential air pockets or minor imperfections in the concrete can be injected with this system, but it is not possible to use the system to fill large voids left by inadequate or incomplete concreting.

**Sika® Injection-201**
Low-viscous, flexible and solvent-free polyurethane injection resin for permanent waterproof sealing of cracks and construction joints. In contact with water, it forms a uniform, closed and therefore watertight pore structure.

## Sika® Injection Pumps and Packers

### Single-component Pumps for Polyurethane, Epoxy and Polyacrylate Resins

**Sika®** single-component injection pumps are universal injection devices suitable for a wide range of applications.
They are designed for professional use in crack injection and for the **Sika® Injectoflex System.** The **Sika® Injection Pump EL-1, EL-2, Hand-1** and **Hand-2** are suitable for Sika polyurethane, epoxy and polyacrylate injection resins.

Type EL-1

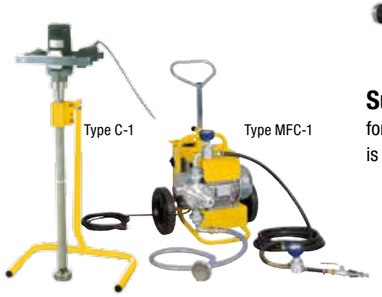
### Two-component Pumps for Polyacrylate Gels

**Sika® Injection Pump PN-2C** is specially designed for curtain injection. A two-component pump is required for these fast-reacting polyacrylate gels. The individual resin components are introduced to the mixing head separately. The actual mixing process takes place in a static mixer located in the mixing head.

Type PN-2C

### Mixing and Pumping Equipment for Microfine Cement Suspension

The colloidal mixer **Sika® Injection Mixer C-1** is designed for the complete and thorough mixing of **Sika®** microfine cement suspensions. **Sika® Injection Pump MFC-1** is used for the pumping of **Sika®** microfine cement suspensions. It provides continuous pumping without separation of the suspension.



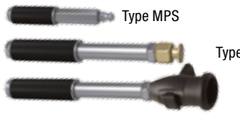
Type C-1

Type MFC-1

### Sika® Injection Packers are used as Connection Pieces between the Injection Pump and the Structure. Sika® provides a full Range of Packers for different Applications.

#### Mechanical Packers

for high and low pressure injection where injection hole drilling is possible



Type MPS

Type MPR

Type MPC

#### Surface Packers

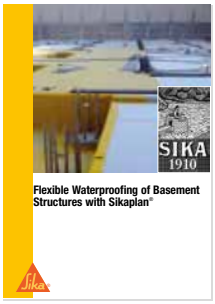
for low pressure injection, where drilling is not possible

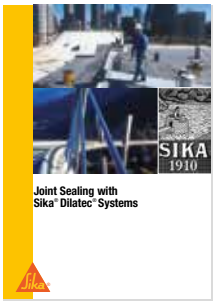
Type SP

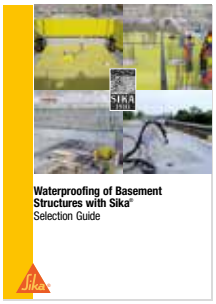
# Flexible Waterproofing of Tunnels with Sikaplan® Membranes

**Sika is a globally active company in the speciality and construction chemicals business. It has subsidiary manufacturing, sales and technical support facilities in over 70 countries around the world. Sika is THE global market and technology leader in waterproofing, sealing, bonding, dampening, strengthening and the protection of buildings and civil engineering structures. Sika has approx. 12'000 employees worldwide and is therefore ideally positioned to support the success of its customers.**

**Also available from Sika**



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Responsible Care

Certified Quality System ISO 9001/EN 29001 since 1986

Certified Management System ISO 14001 since 1997