WATERPROOFING
SIKA SOLUTIONS FOR WATERTIGHT TUNNEL STRUCTURES
In 1882, the first tunnel through the Gotthard was opened, providing a new railway corridor through the Alps. The tunnel was 15 km long and located at an altitude of 1150 m above sea level. More than 100 years ago, Sika’s success story also began in tunneling on the Gotthard. With the waterproofing for the tunnel electrification in 1918, Sika created the conditions for the success of the railway and also the basis for the company’s global success. Kaspar Winkler introduced Sika-1, an additive for post-applied waterproofing mortars onto the existing tunnel lining. To date, Sika-1 is sold with the same formulation and for the same use in over 90 countries worldwide.
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WATERPROOFING SOLUTIONS

WATERPROOFING SYSTEMS for tunnel structures are faced with very stringent requirements regarding durability, exposure and stress conditions, demanding construction methods and sequences, ease of application and total cost management. In addition, sustainable system solutions are becoming more important in order to save natural resources such as energy and water, reduction of CO₂, etc.

As the global leader in providing structural waterproofing solutions, Sika has a complete and comprehensive range of solutions and designed systems to meet the specific needs and requirements of owners, architects, engineers and contractors on site, consisting of highly flexible membrane systems, liquid applied polymeric membranes, waterproofing concrete admixtures, joint waterproofing systems, waterproofing mortars and coatings as well as injection grouts.

Today, operators request a service life for underground structures of 100+ years, but a lack of watertightness severely reduces the long-term durability of a tunnel structure and badly affects its planned use, as water ingress results in physical attack and deterioration of the concrete. Expensive repair works, damage and operational downtime are the results. The selection of the appropriate waterproofing solution, the project specific design of the chosen waterproofing system and its safe application at site are the key elements to minimize the operation costs.

A waterproofing system typically amounts to a fraction of the total constructions costs. The selection of a high quality waterproofing solution may easily save an amount of its initial investment or more on future maintenance and repair costs during the entire service life of the structure.

ROAD TUNNELS
Waterproofing of cut-and-cover structures and mined tunnels for roads and express ways.

RAILWAY TUNNELS
Waterproofing of cut-and-cover structures and mined tunnels for railways

METRO TUNNELS
Waterproofing of cut-and-cover structures, mined tunnels and shafts for subways tubes and metro stations.

PRESSURE GALLERIES
Waterproofing of high-pressure galleries, surge chambers and caverns to resist against hydraulic pressure.
EXPOSURE IMPACT ON BELOW GROUND STRUCTURES

The following types of exposure may adversely influence the use, watertightness and durability of a tunnel structure, resulting in a reduced service life of the entire structure.

<table>
<thead>
<tr>
<th>Exposure</th>
<th>Impact on structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water ingress</td>
<td>Damage to structure, wiring and electrical installations. Corrosion of steel reinforcement.</td>
</tr>
<tr>
<td>Aggressive chemicals</td>
<td>Concrete damage (due to sulphate attack), corrosion of steel reinforcement (due to chloride attack)</td>
</tr>
<tr>
<td>Unequal static forces</td>
<td>Structural cracking</td>
</tr>
<tr>
<td>Dynamic forces</td>
<td>Structural cracking</td>
</tr>
<tr>
<td>Temperature variations</td>
<td>Condensation, scaling or cracking of concrete</td>
</tr>
<tr>
<td>Gas penetration</td>
<td>Gas penetration and exposure for users</td>
</tr>
<tr>
<td>Fungal/bacterial attack</td>
<td>Damage to the waterproofing system, finishes or contents</td>
</tr>
</tbody>
</table>

Geostatitical forces

Water pressure

Uplift forces

Vibrations

Settlements

Gas

Clogging of drainage pipe

Aggressive groundwater
OWNER’S PROJECT REQUIREMENTS

TO DEFINE THE APPROPRIATE WATERPROOFING STRATEGY AND TYPE OF SYSTEM for a specific project, it is important to consider not only the ground conditions but also the project requirements of the owner: Functionality and future use, the service life and the total cost of ownership.

Owners requirements

1 FUNCTIONALITY (USE, GRADE OF WATERTIGHTNESS)

The future use defines the degree of watertightness and protection of a structure. The German tunnel standard Ril 853 describes different levels of watertightness which can be combined with additional protection requirements.

<table>
<thead>
<tr>
<th>Class 1</th>
<th>Class 2</th>
<th>Class 3</th>
<th>Class 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Completely dry</td>
<td>Dry to slightly moist</td>
<td>Moist</td>
<td>Moist to wet</td>
</tr>
<tr>
<td>No moist parts on the dry part of the tunnel surface permitted</td>
<td>Single failing parts permitted. No dropping water on the dry part of the tunnel surface permitted</td>
<td>Partly limited moisty parts and single dropping parts on the dry part of the tunnel surface permitted</td>
<td>Moisty parts and dropping parts permitted</td>
</tr>
<tr>
<td>Clean air rooms</td>
<td>Road tunnels highway</td>
<td>Regional railways</td>
<td>Sewage tunnels</td>
</tr>
<tr>
<td>Dry rooms</td>
<td>Road tunnels in frosty zones</td>
<td>Metro lines</td>
<td></td>
</tr>
<tr>
<td>Energy supply rooms</td>
<td>High speed train tunnels</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metro stations (presence of people)</td>
<td>Parking areas</td>
<td>Escape tunnels</td>
<td></td>
</tr>
</tbody>
</table>

Water infiltration in l/sqm within 24 h acc. STUVA report

<table>
<thead>
<tr>
<th></th>
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<th>0.1</th>
<th>0.5</th>
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</table>
2 SERVICE LIFE / DURABILITY

100+ years durability are common requirements nowadays for tunnels and underground structures. The following guidelines and standards used internationally describe material and system properties to be considered to achieve a service life of 100+ years:

- Austria: ÖBV Guideline ‘Richtline Tunnelabdichtung’
- Germany: ZTV-ING, Ril 853
- Switzerland: SIA 272

The requirements defined in those standards are not limited to initial physical properties, but include stringent long-term tests as well, such as exposure to hot water and specific chemicals, to simulate the ageing process of the waterproofing products.

3 TOTAL COST OF OWNERSHIP

The total cost of ownership (TCO) for the owner and investor includes all of the building costs for the entire service life of the structure, including the initial investment, the cost of any repair and maintenance, plus the cost of any downtime during any such works. The graphic below illustrates the total cost of ownership for a specific project (e.g. tunnelling structure) with a required service life of 100+ years.
MINED TUNNELS include all structures excavated underground by conventional methods or tunnel boring machines. Depending on the excavation method and the required watertightness, single or double linings are chosen. In case of single-shell tunnels, the primary lining is the waterproofing barrier in itself. In case of double-shell constructions, the waterproofing layer is provided between the first and the secondary lining.

CONVENTIONAL EXCAVATION

BY DRILL AND BLAST

Description:
By default, mined tunnels limit the selection of the waterproofing system to pre-installed membrane systems or integral waterproofing only. Externally or post-applied bonded waterproofing systems can not therefore be used.

Waterproofing systems:
Integral waterproofing systems:
- Sika White Box / Watertight Concrete System

Pre-installed waterproofing systems:
- Loose-laid prefabricated membrane systems, drained and pressurized

MECHANISED EXCAVATION

BY TBM

Description:
Single-shell tunnels with pre-fabricated segments or double linings are common. The type of TBM (shield or hard rock) defines the waterproofing system.

Waterproofing systems:
Integral waterproofing systems:
- Sika White Box / Watertight Concrete System

Pre-installed waterproofing systems:
- Loose-laid prefabricated membrane systems, as drainage or barrier system (double shell)
CUT-AND-COVER STRUCTURES describe buildings constructed in an open pit and then covered by soil again. The type of temporary pit support and excavation method defines the possible waterproofing systems to be used.

OPEN CUT EXCAVATION

WITH SLOPING SIDES

Description:
This basic excavation method using sloping sides allows an easy bottom-up construction method and has no impact on the selection or installation of the waterproofing system.

Waterproofing systems:
Integral waterproofing systems:
- Sika White Box / Watertight Concrete System

Externally applied waterproofing systems:
- Loose laid compartmentalized membrane systems
- Pre- and post-applied fully bonded sheet membranes
- Liquid applied membranes
- Waterproofing mortars and coatings (in combination with drainage systems)

CONSTRUCTION WITH PILED / DIAPHRAGM WALLS

CONSTRUCTION INSIDE PILED WALLS

Description:
The structure is normally built directly against the temporary pit support. Post-applied waterproofing systems can therefore not be used for these structures (except for podium and roof sections).

Waterproofing systems:
Integral waterproofing systems:
- Sika White Box / Watertight Concrete System

Externally applied waterproofing systems (base slab):
- Loose laid compartmentalized membrane systems
- Pre-applied fully bonded sheet membranes
GENERAL WATERPROOFING CONCEPTS

THERE ARE TWO BASIC WATERPROOFING CONCEPTS for the sealing of underground structures. Different factors such as location, groundwater conditions, overburden etc define the appropriate approach, which has to be selected by the designer prior to any definition of the construction layout and the waterproofing materials and systems.

DRAINAGE SYSTEM

Description:
Permanent drainage of water keeps the ground water table below the raft. The concrete structure is not under water pressure. The waterproofing lining protects the concrete in the arch and conveys water to the drainage pipes. The drainage pipes are the main element and must be checked and maintained regularly to avoid blocking (sintering) of the drainage system.

Pros & Cons:
- Reduction of concrete thickness possible
- Less waterproofing lining cost
- Allows tunneling under extreme conditions
- Higher maintenance cost (cleaning of drainage pipes)
- Traffic interruption during maintenance work
- Ground settlements above the tunnel area possible due to drainage
**Description:**
The entire tunnel is under full water pressure which must be considered in the structural design. The waterproofing lining protects the complete concrete structure against water ingress and chemical attacks. Depending on the waterproofing technology, an in-built control and injection system can be established in order to have a redundant system.

**Pros & Cons:**
- No influence of water table after construction, no negative impact on environment.
- Strongly reduced risk for ground settlements
- Higher level of waterproofing system
- Allows easy control and repair of waterproofing function
- No maintenance cost
- Higher cost (concrete structure and waterproofing lining)
SIKA PROVIDES A WIDE RANGE of different waterproofing systems and solutions. The selection of the best system for a specific project depends on many factors, incl. the local ground conditions. Waterproofing is closely connected with the structural design and construction of tunnels, therefore it is important for the designer to integrate the selected waterproofing system into the structural design at an early stage.

Due to the high cost but more in view of uninterrupted availability to traffic, tunnels are expected to have long service life expectations of 100 years and more without significant renovation work. All of the components in the multilayer tunnel construction must fulfill these expectations. Among these components the waterproofing layer is an important element. Leaks could reduce the tunnel service life, cause damage to electrical installations or lead to dangerous situations for the road traffic. The waterproofing layer is in the middle of the tunnel construction, therefore access to this layer for repair or replacement purposes is not feasible in most cases.

Each technology of waterproofing system has a specific durability, degree of security, of watertightness and reliability. For some technologies – such as synthetic sheet membranes – specific test methods for > 100 y durability are described in leading standards (ÖBV). For other technologies no standards exist (e.g. bitumen membrane) or tests are not applicable (e.g. watertight concrete and waterproofing mortars). A differentiation of the following technologies are shown on page 14/15.

1. SYNTHETIC SHEET MEMBRANE SYSTEMS

For nearly half a century polymeric membranes based on PVC have been used for the waterproofing of tunnels. The service life of the membranes is determined by the most comprehensive and standardized material testings, including accelerated aging procedures, therefore, they provide the highest security regarding durability.

2. LIQUID APPLIED, REACTIVE MEMBRANES (PUR/PUA)

These materials provide the highest chemical resistance. Regarding durability, no comprehensive tests and regulations are available so far.
3. FULLY BONDED SHEET MEMBRANES

The latest evolution of polymeric sheet membranes are advanced systems with a full bond to the structural concrete. The base material fulfills the highest durability tests, which have been used for loose-laid polymeric sheet waterproofing membranes, nevertheless, the bond itself and the overlaps are neither standardized nor investigated extensively regarding durability.

5. WATERPROOFING MORTARS

Manually or spray applied mortars provide a reasonable durability in fresh water. With increasing sulfate and magnesium contents, the durability is reduced drastically.

4. SIKA WHITE BOX CONCEPT/WATERTIGHT CONCRETE

The in-built waterproofing of the concrete structure makes this technology a very convenient approach for contractors but the durability highly depends on the groundwater quality, especially as salt water leads to corrosion and substantially reduces the durability.

6. BITUMINOUS MEMBRANES

Bituminous membranes are one of the oldest waterproofing technologies, with limited durability even in non-aggressive ground-water conditions.
TECHNOLOGY SELECTION

MINED TUNNELS

Durability / Reliability
- Very high: High redundancy system / water completely under control / proven high durability.
- High: Redundant system / low risk for water ingress / high durability.
- Medium: No redundant system / limited risk for water ingress.
- Low: No redundant system / increased risk for water ingress / limited durability

Exposure / Aggressive conditions
- Very high: Water pressure > 60 m / high temperature > 35°C / very aggressive water.
- High: Water pressure 30 - 60 m / aggressive water, cracks > 0.2 mm.
- Moderate: Water pressure 5 - 30 m / cracks < 0.2 mm / no aggressive water.
- Low: Water pressure < 5 m / no cracks / no aggressive water.

Waterproofing
WATERTIGHT TUNNEL STRUCTURES
CUT-AND-COVER STRUCTURES

Durability / Reliability

Very high: High redundancy system / water completely under control / proven high durability.
High: Redundant system / low risk for water ingress / high durability.
Medium: No redundant system / limited risk for water ingress.
Low: No redundant system / increased risk for water ingress / limited durability.

Exposure / Aggressive conditions

Very high: Water pressure > 30 m / high temperature > 35°C / very aggressive water.
High: Water pressure 15 – 30 m / aggressive water, cracks > 0.2 mm.
Moderate: Water pressure 5 – 15 m / cracks < 0.2 mm / no aggressive water.
Low: Water pressure < 5 m / no cracks / no aggressive water.
COMPARTMENTALIZED MEMBRANE SYSTEMS WITH INTEGRATED CONTROL AND INJECTION BACK-UP

1. Sika Dilatec E Tape or Sikaplan® WP Tape or Sikaplan® WT Tape
2. Sika® Waterbar WP/WT
3. Sikaplan® WP/WT
4. Sikaplan® W Felt or Sikaplan® W Tundrain or Sika® Drain
5. Sika Dilatec E Tape or Sikaplan® WP Tape or Sikaplan® WT Tape
6. Sikaplan® WP/WT
WATERPROOFING WATERTIGHT TUNNEL STRUCTURES

Sikaplan® WP 1100 and 2100 series
Homogeneous and plastisiced PVC sheet waterproofing membranes, for waterproofing of tunnels and cut-and-cover structures, membrane overlaps sealed by heat welding.

Sikaplan® WT 1200 series
Fleece stabilized FPO sheet waterproofing membranes, for waterproofing of cut-and-cover tunnels, membrane overlaps sealed by heat welding.

Sikaplan® WT 2200 series
Homogeneous FPO sheet waterproofing membranes, for waterproofing of mined tunnels, membrane overlaps sealed by heat welding.

Sika® Waterbar WP/WT
External waterstops, heat welded on installed Sikaplan® sheet waterproofing membrane to form a compartment network for pressurized systems.

Sika® Waterbar WP/WT Control Socket
Preformed flange welded on installed Sikaplan sheet waterproofing membrane as control and injection ports, connected with flexible pipes for leak detection access and injection.

Sika® W Tundrain
Drainage and protection boards for mined tunnels and open cut structures.

USE
- As waterproofing solutions to ensure completely dry conditions
- For high demands and harsh ground conditions
- For structures in aggressive groundwater like coastal areas
- For tunnels, portals, metro stations, cross passages etc.

MAIN ADVANTAGES
- Watertightness is controlled and secured at any time during service.
- All membranes and system components fulfil leading tunneling standards to achieve a service life of 100+ years

TYPICAL PROJECTS
- Road tunnels
- Railway tunnels
- Metro tunnels
- Cross passages
- Shafts
- Pressure water galleries

SIKA PRODUCTS AND SYSTEM SOLUTIONS

HIGH PERFORMANCE, CRACK-BRIDGING, WITH IN-BUILT REDUNDANCY FOR FUTURE REPAIR WORKS

Highly flexible state-of-the-art waterproofing systems using Sikaplan® PVC-based or FPO-based sheet waterproofing membranes are installed in mined tunnel structures or post applied on cut-and-cover tunnel structures to ensure completely dry tunnels and to fully protect the concrete lining against drained or pressurized water.

USE

MAIN ADVANTAGES

TYPICAL PROJECTS

SIKA PRODUCTS AND SYSTEM SOLUTIONS
REACTIVE LIQUID APPLIED WATERPROOFING MEMBRANES

1. SikaProof® A-12
2. SikaSwell®
3. Sikafloor® Primer or Sika® Concrete Primer
FAST SETTING AND CRACK-BRIDGING

Reactive liquid applied membranes (LAM) are highly elastic and flexible polymeric systems based on polyurea or hybrids, with excellent technical properties for high performance applications. These materials are spray applied onto prepared / primed external concrete surfaces to provide excellent solutions particularly for complicated geometries. Liquid applied membranes will also prevent underflow of any lateral water in the event of local damage.

USE
- As post-applied waterproofing of retaining walls and roof sections to ensure dry conditions
- For high demands and harsh groundwater conditions

MAIN ADVANTAGES
- Fully-bonded solution
- Crack bridging
- Fast reacting
- High chemical and abrasion resistance
- Easy application at complex details

TYPICAL PROJECTS
- Cut- and cover tunnels for roads and railways
- Metro station boxes

SIKA PRODUCTS AND SYSTEM SOLUTIONS

Sikalastic®-851
Highly flexible, fast curing, two-component resin based on polyurea / polyurethane, spray-applied onto structural concrete for waterproofing of retaining walls and roof sections.

Sikalastic®-8800
Highly flexible, fast curing, two-component resin based on pure polyurea, spray-applied onto structural concrete for waterproofing of retaining walls and roof sections.

Sikafloor®-156 and -161
Epoxy primer

Sika® Concrete Primer
Two component fast reacting hybrid primer

Complementary products for joint sealing
- SikaSwell®
  Ready to use gaskets for various purposes of concrete joint sealing, with hydrophilic properties.
- SikaFuko®
  Re-injectable injection hose for the waterproofing of construction joints.
- Sika® Drain
  Drainage and protection board

Raft waterproofing
Please note that it is not recommended to apply a liquid membrane onto blinding concrete, therefore, a prefabricated membrane system is to be selected under the structural slab:

Option 1
SikaProof® A-12
Fully bonded membrane system, see page 20

Option 2
Sikaplan® WP/WT
Compartmentalized membrane system, see page 16
HIGH PERFORMANCE, CRACK-BRIDGING, FAST AND EASY TO INSTALL

Sika’s pre- and post-applied fully bonded sheet waterproofing membrane systems can permanently prevent any lateral water underflow between the waterproofing and the structural concrete in the event of local damage, even when this has occurred below the base slab.

The SikaProof® and SikaBit® fully bonded sheet waterproofing membrane systems are simple and easy to use, making them fast and secure to install on site. The overlaps, butt joints and details are all connected and sealed very simply by bonding them together with sealing tapes or self-adhered overlaps. There are no welding procedures and no special equipment is required on site.

USE
- As pre- or post-applied waterproofing solution to ensure dry conditions
- For high demands and harsh ground conditions
- For structures in aggressive groundwater like coastal areas

MAIN ADVANTAGES
- Cost effective solution (Material + Application)
- High durability
- No lateral water underflow
- High flexibility and crack-bridging ability
- Approved detailings

TYPICAL PROJECTS
- Metro stations
- Cut-and-cover tunnels

SIKA PRODUCTS AND SYSTEM SOLUTIONS

Pre-applied waterproofing (raft and walls)

SikaProof® A-12
Pre-applied FPO sheet waterproofing membrane system for application below base slabs, plus on single faced formwork cast walls.

Post-applied waterproofing (walls and top)

Option 1
SikaProof® P-1201 System
SikaProof® P-1200: Post-applied in-situ adhered FPO sheet waterproofing membrane, specially designed for roof slabs and double-faced formwork cast walls.

Option 2
SikaBit® S-515 System
Self-adhesive prefabricated bituminous membrane (including primer) against percolating water.

Complementary products

SikaSwell®
Ready to use gasket for various purposes of joint sealing, with hydrophilic properties.

SikaFuko®
Re-injectable injection hose for the waterproofing of construction joints.

Sika® Drain
Drainage and protection boards
WATERTIGHT CONCRETE, WHITE BOX SYSTEM
INTEGRAL WATERPROOFING SYSTEM

The Sika® White Box Concept involves optimum structural design and reinforcement together with an integral waterproofing solution. It consists of a waterproof concrete, combined with appropriate joint sealing systems for all construction and movement joints. The production of watertight concrete uses admixtures including superplasticisers and pore-blocking or active crystallization agents, to ensure optimum consistency, flow and easy compaction in a dense matrix with minimal voids. In addition, Sika can offer a wide range of joint sealing products such as PVC waterstops, hydrophilic gaskets and sealants, as well as injection hoses and adhesive tapes.

USE
- As a waterproofing solution to ensure dry conditions
- For high demands in soft groundwater conditions

MAIN ADVANTAGES
- Cost effective solution concerning material and construction works
- Reduced working procedures on site

TYPICAL PROJECTS
- Road tunnels
- Railway tunnels
- Metro tunnels
- Service tunnels

SIKA PRODUCTS AND SYSTEM SOLUTIONS

<table>
<thead>
<tr>
<th>Product</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sika® ViscoCrete®</td>
<td>High Range Water Reducing admixtures for reducing pore volumes and improving rheology for self compacting concrete.</td>
</tr>
<tr>
<td>Sika® WT 100</td>
<td>Pore-blocking and active crystalline admixtures to block pores against water penetration.</td>
</tr>
<tr>
<td>Sika® WT 200</td>
<td></td>
</tr>
<tr>
<td>Sika® Waterbar</td>
<td>Cast in place external and internal waterstops based on PVC or rubber, cast into concrete for the waterproofing of joints.</td>
</tr>
<tr>
<td>Sikadur-Combiflex®</td>
<td>Adhesive sealing tape based on FPO, bonded with Sikadur®-31 CF adhesive for post applied joint sealing system.</td>
</tr>
<tr>
<td>SikaFuko®</td>
<td>Re-injectable injection hose for the waterproofing of construction joints.</td>
</tr>
<tr>
<td>SikaSwell®</td>
<td>Ready to use gaskets for various purposes of joint sealing, with hydroswelling properties.</td>
</tr>
<tr>
<td>Sika® Drain</td>
<td>Drainage boards</td>
</tr>
</tbody>
</table>

Sika® ViscoCrete®
Sika® WT 100/WT 200
Sika® Waterbar
WATERPROOFING MORTARS AND SPRAYED TUNNELING MEMBRANES

1. SikaCem®-711 Elastic
2. Sikalastic® 1K or SikaTop® Seal-107
3. SikaSwell®
Sika® waterproofing mortars and cement-based membranes in mined tunnels and cut-and-cover structures with good technical properties to seal against damp soil, seepage and percolating water. These materials are applied on prepared external concrete or shotcrete surfaces by manual application or by spraying. These waterproofing mortars are used in combination with joint sealing products.

**USE**
- As pre- or post-applied waterproofing of structures with low requirements regarding watertightness and reliability

**MAIN ADVANTAGES**
- Easy application
- Can be combined with Sika joint sealing systems

**TYPICAL PROJECTS**
- Escape tunnels with a maximum water pressure of 5 m

**SIKA PRODUCTS AND SYSTEM SOLUTIONS**

<table>
<thead>
<tr>
<th>Product</th>
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</tr>
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<tbody>
<tr>
<td>Sikalastic®-1K</td>
<td>One component, polymer modified cementitious waterproofing mortar with medium flexibility for application on concrete surface of cut-and-cover structures.</td>
</tr>
<tr>
<td>SikaTop® Seal-107</td>
<td>Two component, polymer modified cementitious waterproofing mortar with slight flexibility for application on concrete surface of cut-and-cover structures.</td>
</tr>
<tr>
<td>SikaCem®-711 Elastic</td>
<td>Spray applied cementitious, polymer modified, flexible waterproofing gunite, delivered in powder bags, to be applied by Shotcrete robot (Aliva 237) onto shotcrete linings underground.</td>
</tr>
<tr>
<td>Sika® FlexoDrain</td>
<td>Channels for the free flowing drainage of groundwater penetrating through the shotcrete lining.</td>
</tr>
<tr>
<td>Sika® Shot-3</td>
<td>Highly accelerated ready-to-use gunite for the overspraying of damp and wet areas of shotcrete linings, or as surface preparation for liquid membranes.</td>
</tr>
<tr>
<td>Sikadur-Combiflex®</td>
<td>Adhesive sealing tape based on FPO, bonded with Sikadur®-31 CF adhesive for post applied joint sealing of construction and expansion joints.</td>
</tr>
<tr>
<td>SikaSwell®</td>
<td>Ready to use gaskets for various purposes of joint sealing, with hydrophilic properties.</td>
</tr>
<tr>
<td>Sika® Drain</td>
<td>Drainage and protection boards for cut-and-cover structures</td>
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</tbody>
</table>
WATERPROOFING SOLUTIONS FOR SINGLE SHELL TUNNELS WITH PRECAST SEGMENTS

Sikagard® 65 WN application
Sikagard® 65 WN
Sika® ViscoCrete® Admixture
Prefabricated tunnel segments (tubbings) for use in shield TBM-tunnels. The system consists of a waterproof concrete segment combined with EPDM gaskets for the segmental joint sealing. The production of watertight concrete uses admixtures including superplasticisers in order to ensure optimum consistence, flow and easy compaction in a dense matrix with minimal voids, plus slump retention. The quality and durability of the segments are further improved by the use of a protective epoxy coating and curing compound.

**INTEGRAL, RIGID AND COST EFFICIENT SYSTEM**

- Waterproofing and concrete protection for single linings made of tubbings (precast segments)
- Cost effective solution concerning material and construction works
- Reduced working procedures on site
- Road tunnels
- Railway tunnels
- Metro tunnels
- Service tunnels

**SIKA PRODUCTS AND SYSTEM SOLUTIONS**

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<td>High Range Water Reducing admixtures for reducing pore volumes and improving rheology for self compacting concrete.</td>
</tr>
<tr>
<td>Sikagard® 65 WN</td>
<td>Curing agent and protective epoxy coating to be applied onto the fresh (green) concrete on the outside of the segments. Improves the concrete quality and increases the durability of single shell constructions permanently exposed to groundwater.</td>
</tr>
</tbody>
</table>

**Additional solutions for all cross passages**

<table>
<thead>
<tr>
<th>Product</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sikaplan® WP/ WT Sheet membranes</td>
<td>Waterproofing membranes for the sealing of all cross-passages.</td>
</tr>
<tr>
<td>Sikaplan® WT Tapes Sikaplan® WP Tapes</td>
<td>Adhesive sealing tapes based on PVC or FPO, bonded with Sikadur®-31 CF adhesive for a watertight termination of cross passages at segmental linings.</td>
</tr>
</tbody>
</table>
# SYSTEM SELECTION GUIDE FOR MINED TUNNELS

## DRAINED SYSTEMS

### UMBRELLA SHEET MEMBRANE SYSTEM

- **Sika solution:** Sikaplan®
- **Excavation method:**
  - Conventional excavation
  - Hard Rock TBM
  - Shield TBM
- **Lining(s):** Double-shell tunnel:
  - Primary lining: Shotcrete or segments
  - Secondary lining: Concrete or shotcrete
- **Waterproofing technology:** Drainage layer plus loose-laid synthetic membrane (umbrella) made of PVC or FPO
- **Degree of water tightness:** Class 1 (Completely dry)
- **Concrete protection:** High
- **Durability/Reliability:** High
- **Performance characteristic:** Crack-bridging: +++
- Water vapour tightness: n.a.
- Chemical resistance: ++
- Gas barrier: n.a.
- **Repair in the event of leaks:** Local injection
- **Conditions of application:** Defined evenness of shotcrete lining
- **Advantages:** Cost effective solution, full proof arch, drainage reduces criticality of application
- **Typical application fields:** Road and railway tunnels in mountainous areas with high overburden

### CHANNELED SYSTEM

- **Sika solution:** FlexoDrain® / SikaCem®
- **Excavation method:**
  - Conventional excavation
  - Hard Rock TBM
- **Lining(s):** Single-shell tunnel with shotcrete or double shotcrete lining with liquid applied membrane in between
- **Waterproofing technology:** FlexoDrain drainage channel system:
  - Catching spot-wise ingress of water.
  - Optional sprayed waterproofing membrane on top
- **Degree of water tightness:** Class 4 (Moist to wet)
- **Concrete protection:** None or limited to secondary lining
- **Durability/Reliability:** Low
- **Performance characteristic:** Crack-bridging: +
- Water vapour tightness: +
- Chemical resistance: +
- Gas barrier: n.a.
- **Repair in the event of leaks:** Crack injection
- **Conditions of application:** Crack injection
- **Advantages:** In-built waterproofing through industrialized process at segments factory
- **Typical application fields:** Metro tunnels, road tunnels and railway tunnels with limited water pressure
## BARRIER SYSTEMS

### HYDROSTATIC MEMBRANE BARRIER

- Silicone - Conventional excavation
- Hard Rock TBM
- Shield TBM

Double-shell tunnel:
- Primary lining: Shotcrete or segments
- Secondary lining: Concrete

Loose laid membrane system made of PVC or FPO with compartments and integrated injection back-up. Membrane application in one or two layers

<table>
<thead>
<tr>
<th>Class</th>
<th>High</th>
<th>Med</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water tightness</td>
<td>Class 1 (Completely dry)</td>
<td>Class 2 (Dry to slightly moist)</td>
<td>Class 3 (Wet to very wet)</td>
</tr>
<tr>
<td>Durability</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
</tr>
<tr>
<td>Crack bridging</td>
<td>+++</td>
<td>+</td>
<td>n.a.</td>
</tr>
<tr>
<td>Water vapour tightness</td>
<td>+++</td>
<td>+</td>
<td>n.a.</td>
</tr>
<tr>
<td>Chemical resistance</td>
<td>+++</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Ductility</td>
<td>+</td>
<td>+</td>
<td>n.a.</td>
</tr>
<tr>
<td>Crack injection</td>
<td>+</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
<td>Injection ports inside of structure</td>
<td>defined evenness of shotcrete lining</td>
<td>injection ports defined</td>
<td>injection ports defined</td>
</tr>
</tbody>
</table>

### WATERTIGHT CONCRETE SYSTEM

- Sika® White Box

Double-shell tunnel:
- Primary lining: Shotcrete
- Secondary lining: Concrete

Sika White Box system: Watertight concrete plus joint sealing and structural design

<table>
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<td>+</td>
<td>n.a.</td>
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<td>Chemical resistance</td>
<td>+++</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Ductility</td>
<td>+</td>
<td>+</td>
<td>n.a.</td>
</tr>
<tr>
<td>Crack injection</td>
<td>+</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
<td>Joint injection</td>
<td>+</td>
<td>+</td>
<td>n.a.</td>
</tr>
</tbody>
</table>

### SEGMENTAL LINING

- Sikaplan®
- Sika® White Box
- Sikagard®

- Conventional excavation
- Hard Rock TBM
- Shield TBM

Double-shell tunnel:
- Primary lining: Tubbing segments
- Secondary lining: Concrete

Sika White Box system: Watertight concrete plus joint sealing and structural design

<table>
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<th>High</th>
<th>Med</th>
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<td>Crack injection</td>
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<td>n.a.</td>
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<td>Joint injection</td>
<td>+</td>
<td>+</td>
<td>n.a.</td>
</tr>
</tbody>
</table>

### Typical Application Fields

- Road and railway tunnels in mountainous areas with high overburden
- Road and railway tunnels in urban areas with no permission to change the groundwater conditions
- Metro tunnels, road tunnels and railway tunnels with limited water pressure
- Metro tunnels, railway tunnels, road tunnels

### Advantages

- Cost effective solution, full proof arch, drainage reduces criticality of application
- Simple to install
- High waterproofing security, in-built redundancy by compartment injection
- Integrated waterproofing, limited waterproofing works at all joints
- In-built waterproofing through industrialized process at segments factory
WATERPROOFING
WATERTIGHT TUNNEL STRUCTURES

Sika solution
Time of application
Groundwater conditions
Waterproofing technology
Degree of watertightness
Concrete protection
Durability/Reliability
Performance characteristic
Repair in the event of leaks
Conditions of application
Advantages
Typical application fields

COMPARTMENTALIZED SHEET MEMBRANE SYSTEM

- Injection of leaking compartments through injection ports inside the structure
- Substrate preparation (priming) required before membrane spraying.
- Easy detailing, seamless application, super fast setting time, fully bonded
- Station boxes, metro tunnels, road tunnels, railway tunnels

FLEXIBLE SYSTEMS

Sika solution
Sikakomp®
Sikalastic®

Time of application
Pre-applied onto blinding concrete or temporary pit support
Post-applied onto structural concrete
Post-applied onto structural concrete

Groundwater conditions
Percolating water or hydrostatic groundwater
Percolating water or hydrostatic groundwater
Percolating water

Waterproofing technology
Loose laid membrane system based on PVC or FPO, with compartments and integrated injection back-up. Membrane application in one or two layers.
Reactive 2K sprayed membranes based on Polyurethane and Polyurea

Degree of watertightness
Completely dry
Dry to slightly moist

Concrete protection
Very high
High

Durability/Reliability
Very high
High

Performance characteristic
Crack-bridging: +++
Water vapour tightness: +++
Chemical resistance: +++
Gas barrier: +++
Crack-bridging: +++
Water vapour tightness: ++
Chemical resistance: +++
Gas barrier: ++

Repair in the event of leaks
- Injection of leaking compartments through injection ports inside the structure
- Crack injection
- Soil injection

Conditions of application
No special requirements
Substrate preparation and primer required before membrane application
Controlled concreting on site required: casting, compaction, curing

Advantages
High waterproofing security
In-built redundancy
High durability
Easy detailing, seamless application, super fast setting time, fully bonded

Typical application fields
Station boxes, metro tunnels, road tunnels, railway tunnels
Retaining walls, podiums, roof sections of station boxes

SPRAYED MEMBRANES

- Crack injection
- Joint injection
- Crack injection
- Joint injection

- Crack injection
- Soil injection

- Substrate preparation (priming) required before membrane spraying.
- Dew point control on site mandatory.

- Easy detailing, seamless application, super fast setting time, fully bonded
- Retaining walls, podiums, roof sections of station boxes

- High waterproofing security
- In-built redundancy
- High durability

- Simple and fast to apply
- No specialist applicator required
**RIGID SYSTEMS**

### FULLY BONDED SHEET MEMBRANES

- **SikaProof® / SikaBit®**
  - Pre- and post-applied onto structural concrete

### WATERTIGHT CONCRETE

- **Sika White Box**
  - Integral waterproofing
  - Percolating water or hydrostatic groundwater
  - Pre-fabricated bituminous membrane sheets, torch-on or self-adhesive, applied in single or multiple layers. Or bituminous emulsions.
  - Dry to slightly moist
  - High

### WATERPROOFING MORTARS

- **SikaTop® / SikaCem®**
  - Post-applied onto structural concrete

<table>
<thead>
<tr>
<th>SikaProof® / SikaBit®</th>
<th>Sika White Box</th>
<th>SikaTop® / SikaCem®</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre- and post-applied onto structural concrete</td>
<td>Integral waterproofing</td>
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</tr>
<tr>
<td>Percolating water or hydrostatic groundwater</td>
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<td>Percolating water</td>
</tr>
<tr>
<td>Pre-fabricated bituminous membrane sheets, torch-on or self-adhesive, applied in single or multiple layers. Or bituminous emulsions.</td>
<td>Sika White Box system: Watertight concrete plus joint sealing and structural design</td>
<td>Cementitious coating</td>
</tr>
<tr>
<td>Dry to slightly moist</td>
<td>Moist</td>
<td>Moist to wet</td>
</tr>
<tr>
<td>High</td>
<td>Limited, depending on concrete quality</td>
<td>Limited</td>
</tr>
<tr>
<td>Limited (for polymeric based sheets) Medium (for bitumen based sheets)</td>
<td>Medium</td>
<td>Low</td>
</tr>
<tr>
<td>- Crack injection - Joint injection</td>
<td>- Crack injection - Joint injection</td>
<td>- Crack injection - Joint injection</td>
</tr>
<tr>
<td>Controlled concreting on site required: casting, compaction, curing</td>
<td>Cost effective. Integrated waterproofing Limited waterproofing works at all joints</td>
<td>Very cost effective Simple and fast to apply No specialist applicator required</td>
</tr>
<tr>
<td>Station boxes, escape tunnels, pedestrian ways, structures with limited requirements regarding water tightness and durability</td>
<td>Station boxes, metro tunnels, road tunnels, railway tunnels</td>
<td>Escape tunnels, pedestrian ways, structures with no or very limited requirements regarding water tightness</td>
</tr>
</tbody>
</table>

### Conditions of application

- No special requirements Substrate preparation (priming) required before membrane spraying.
  - Dew point control on site mandatory.
- Substrate preparation and primer required before membrane application
  - Controlled concreting on site required: casting, compaction, curing

### Advantages

- High waterproofing security
- In-built redundancy
- High durability
- Easy detailing, seamless application, super fast setting time, fully bonded
- Fast and easy to apply
- No specialist applicator required

### Typical application fields

- Station boxes, metro tunnels, road tunnels, railway tunnels
- Retaining walls, podiums, roof sections of station boxes
- Station boxes, escape tunnels, pedestrian ways, structures with no or very limited requirements regarding water tightness
REMEDIAL WORKS BY INJECTIONS

WATERTIGHT CONCRETE SYSTEM

Sika® Injection-101 RC
Sika® Injection-201 CE
Sika® Injection-307

COMPARTMENTALIZED MEMBRANE SYSTEM

Sikaplan® WP/WT control sockets
In situations with water ingress due to localized damage of the waterproofing system, appropriate repair works have to be undertaken. This can only be done by injection to seal leaking areas, due to inadequate access to the waterproofing system itself in most underground structures. According to the type of leakage and if it is through joints or cracks in the structural concrete, the most suitable material has to be injected. The success factor for durable and tight injection work is a combination of Sika’s materials and equipment selection, as well as application experience.

**SIKA INJECTION SOLUTIONS FOR REPAIR AND REFURBISHMENT WORKS**

**USE**
- Sealing and repairing of:
  - Cracks
  - All types of joints
  - Sikaplan compartments
  - Leaking sections by areal or curtain injections

**MAIN ADVANTAGES**
- No excavation required
- Localized repair works
- Durable repair

**TYPICAL PROJECTS**
- Suitable for all types of tunnels and underground structures

**SIKA PRODUCTS AND SYSTEM SOLUTIONS**

**Packer Injection**

**Sika® Injection-101 RC**
- Flexible, solvent-free, fast foaming polyurethane (PUR) foam for temporary water-stopping of high water intrusions through cracks, joints and cavities in concrete.

**Sika® Injection-201 CE**
- Elastic, solvent-free PUR-Injection resin for permanent sealing of dry, damp or water-bearing cracks and joints in concrete.

**Sika® Injection-307**
- Elastic, very low viscous polyacrylic injection resin with active passivation of steel reinforcement.

**Compartment and Fuko® Injection**

**Sika® Injection-306**
- Elastic, very low viscosity polyacrylic injection resin for the repair of damaged waterproofing membrane compartments and injection of SikaFuko® injection hoses. It is also used for the permanent sealing of water-bearing cracks, voids and joints in the concrete.

**Sika® Injection-701**
- Low viscosity cementitous/polyacrylic hybrid injection resin for the repair of damaged waterproofing membrane compartments and injection of SikaFuko® injection hoses. It is also used for the permanent sealing of water-bearing cracks, voids and joints in the concrete.
SIKA PROVIDES A WIDE RANGE of alternative waterproofing solutions for different requirements in new tunnel structures, or refurbishment of tunnels. With more than 100 years of experience in Structural Waterproofing, Sika is the reliable partner for all the parties involved on every project. Innovative Sika waterproofing solutions that include both, rigid and flexible systems, create added value for customers every day, and are the key driver for our global success and one of the key reasons why Sika is the clear number one in Structural Waterproofing. With a local presence all around the world, now in more than 90 countries, Sika is ideally positioned to support our customers everywhere, right from the initial project design and detailing, through to successful installation and completion on site.

**DESIGN SUPPORT**

- Selection of appropriate concept and system solutions
- Concrete mix design and control
- Engineering details, custom solutions
- Cost/Performance

**SPECIFICATION SUPPORT**

- Specifications, Method Statements, Bills of quantities
- Detail drawings (CAD + BIM)

**ON SITE SUPPORT**

- Application training on site
- Troubleshooting
- Quality control procedures
- Concrete quality control

**MAINTENANCE SUPPORT**

- Maintenance Manuals
- Refurbishment systems
- Repair and refurbishment documentations
- Site visits and refurbishment proposals
125 years after the completion of the first railway tunnel through the alps, the new Gotthard Base Tunnel was constructed, at an altitude of only 550 m above sea level, allowing a flat connection from North to South, without ramps, reducing the travel time and increasing the transportation capacity. The construction of the 57 km long double-tube tunnel had started in the year 2000 and took 15 years. Sika, with an experience of 100+ years in tunnel waterproofing, provided the entire waterproofing system with synthetic sheet membranes Sikaplan® WP based on PVC-p and Sikaplan® WT based on FPO.

... AND NOW
GLOBAL BUT LOCAL PARTNERSHIP

WE ARE SIKA
Sika is a specialty chemicals company with a leading position in the development and production of systems and products for bonding, sealing, damping, reinforcing and protecting in the building sector and the motor vehicle industry. Sika’s product lines feature concrete admixtures, mortars, sealants and adhesives, structural strengthening systems, flooring as well as roofing and waterproofing systems.

FOR MORE INFORMATION:

Our most current General Sales Conditions shall apply.
Please consult the Data Sheet prior to any use and processing.

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Switzerland
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Fax +41 58 436 41 50
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