EXPERTISE IN TUNNEL CONSTRUCTION
EXPERIENCE FOR MORE THAN 100 YEARS
TUNNEL CONSTRUCTION WORK – WE ARE AT HOME

Subterranean transport construction like road tunnels, railways tunnels or metro tunnels are subjected to severe stress from nature. They require constant protection against penetrating water and simultaneously must be able to withstand the requirements of different operating modes.

For all tunnel construction works, Sika offers an extensive range of construction chemical products through tested systems for a permanent sealing including application technology. For all our solutions, we provide a comprehensive object-related technical service.

Detailed technical consultation and suitability tests for sprayed concrete are included in the service portfolio as well as the instruction with injections for rock stabilization or service-support of machines under use.

The individual client support is ensured through experienced Key Account Management. Besides this, a complete overview of the products and services offered by Sika are available in the technical brochures for details on tunnel construction.

Apart from professional services, Sika is obliged to a worldwide environment management system of the chemical industry called 'Responsible Care' and takes into account the fundamentals determined therein with respect to security, health and environment protection.

Know-how, experience and sense of responsibility make Sika a quality-oriented competent partner for owners, consultants and contractors. Sika comprehensively protects tunnel construction works.
COMPREHENSIVE PROTECTION THROUGH MATERIAL AND TECHNOLOGY-KNOW-HOW
The tunnel excavation is influenced by geological conditions, character and composition of the rock/soil as well as the presence of water. According to the environmental conditions, cippings, complete flooding or collapse of the soil can occur. Therefore, initial safety measures are carried out before and/or after the excavation. Stabilization measures include setting up of rock anchors fixed with cementitious/spokey resin capsules and sprayed concrete.

**Anchor Mortar**

It is important that the rock anchors are connected firmly with the substrate. Therefore specific anchoring mortars for respective rock and soil conditions are applied. Sika® Reiken anchor capsules can be placed overhead and take care of a force-fit joining between rock and steel or fiber-glass reinforced synthetic anchor.

**Rock Stabilization/Consolidation**

Inadequately firm or severely hydrous rock mass can be secured and/or sealed through injections with finest binders. Simultaneously these measures contribute in improving the quality of the structure. As fine binders Sika® InjectaCem® with high penetration capability is applied. For better processing Intraplast® and Sikament® is applied as flow promoter. The products of Sika® Flex® series are ideal for immediate sealing in case of rock fall and for bonding of unstable rocks and for sealing of water-seeping through the substrate. Likewise, for sealing and reinforcement, cementitious products, silicates, acrylics or polyurethane foams and resins can be applied. The features of all filling and sealing products can be specifically controlled through appropriate additives. Many products enable injection in flowing water.

As technically advanced system for collecting mountain water in tunnel constructions during excavation, the drainage system FlexIDrain is suitable. It comprises of half-shells and suitable form pieces, which can be fitted on the rock by hand or with the aid of a nail pistol. The reinforcement of the half-shells enables a direct re-coating with wet or dry sprayed concrete up to 8 mm grain diameter. For this, Sika® Shot-3 is best suitable. The FlexIDrain system enables a cross-section of up to 16 cm.
KNOW-HOW AND EXPERIENCE IN PRODUCT DEVELOPMENT AND LOGISTICS

Constant development of construction processes and construction materials require constant update and development of our products. With the usage of our concrete admixtures contractors benefit from specially adjustable characteristics of concrete.

The reaction between different cements and water-reducing admixtures for example, is an important factor. Sika™ViscoCrete™ and SikaKem™, based on the latest polycarboxylates (PCE) technology, enable a precise adjustment of water-reducing plasticizers to different cements. Besides the performance, other factors like commercial feasibility, experience and know-how play an important role. In order to be able to be adjusted to real conditions, shotcrete products are tested in Sika’s own spray lab. Additionally, newly developed products are tested for their practical suitability in field trials besides the lab tests. Through this, the product can be adjusted to the requirements of the construction sites and clients can be advised optimally.

In-situ concrete products:
- Sika™ViscoCrete™ (Superplasticizer)
- Sika™Tact™ (Retarder)
- Sika™Separ® (demolding agent, on emulsion base also)

Ready-mix plant
- Shotcrete
- Pre-cast concrete segments (tubbing)
- In-situ concrete (concrete for inner lining of tunnel)

Pre-cast products (for segments):
- Sika™ViscoCrete™ (Superplasticizer)
- Sika™Separ® (demolding agent, on emulsion base also)
- Sika™Antisap® (Curing agent)
- Sikkagard®65WN (Combined curing and protection coating)
CUSTOM-MADE CONCRETE ADMIXTURES FOR SPRAYED CONCRETE

With the application of shotcrete, the requirements on safety of persons and environment protection mainly stress in minimization of caustic and toxic chemicals as well as in reduction of dust exposure. Sika takes both into account with its shotcrete technology. Besides, commercial viability at the construction site is an essential aspect. For high spray capacities, the optimum must be determined on the sprayed concrete mix design, compressive strength, accelerator type, and accelerator dosage. The concrete must be enabled to be pumped without any impediment. In doing so, special additives like SikaPump®-Start and Sika-Pump® prevent segregation and reduce the pump pressure. The quantity of rebound loss is a decisive cost factor and is to be minimized through material and application technique so the maximum extent possible.

HIGHLY EFFECTIVE WATER-REDUCING ADMIXTURES

The concrete admixtures of Sika have stood the test of time for more than 100 years with numerous tunnel projects. For wet sprayed shotcrete processes, new effective superplasticizers are available with Sika®ViscoCem® technology. These show excellent features with pumping (especially dense stream pumping).

SikaTrail® retarders act as setting retarders as well as mixture stabilizers, cause a strong liquefaction in fresh concrete and thereby cause a possibility for reduction of workability with unchanged workability. With correct dosage, simultaneously the cement hydration is stopped. The retarded shotcrete can be accelerated without loss of quality with Signum® AF setting accelerator. The combination of both materials optimizes early strength development.

Sika® Fume DS: Micro Silica increases the density of the mix, leading to higher compressive strength and durability.

EARLY STRENGTH – SIGNIFICANT REQUIREMENT IN SPRAYED CONCRETE

When it comes to overhead spraying (especially with high spray capacity), with thick layers being applied and sprayed against seeping water, the early adhesion of the applied shotcrete is a compulsory pre-requisite. The course of strength development in the initial minutes has greater influence on the dust formation and rebound loss. The strength development is normally characterized for the period between 6 and 60 minutes. Additionally, the strength is still measured in hourly intervals. "Sika® 1448/2° standard defines appropriate methods to test the early strength development.

In tunnel construction mix-design and processing equally influence the impediment free functionality of the sprayed concrete. Based on the interlocking of these factors, Sika provides efficient sprayed-concrete admixtures as well as machines and equipment relevant for all application.

ALKALI-FREE ACCELERATOR

The non-toxic Signum® AF solidification accelerators do not contain any caustic aerosol in the spray and are applied in the fields of application mentioned below. In dry and wet spray processes, correctly dosage accelerators clearly reduce the rebound and take care of quick setting and accelerated development of adhesion of shotcrete. They offer improved adhesion on rocks and concrete and ease spray concrete works overhead. Even thick layers can be applied just one work process. Shotcrete accelerators cause an increased water tightness. Additionally, the material is free of chloride and do not attack the reinforcement steel. Sika® P10 AF is a special accelerator delivered in powder form to the site for low temperature terrains.

FIBERS

With our Sika®Fiber product line, Sika can provide the full range of steel and polypropylene fibers for shotcrete and concrete linings. The performance of the fibers shall be tested and defined in accordance with EN 14484-5.

<table>
<thead>
<tr>
<th>Energy absorption class</th>
<th>Energy absorption in joules [J] for deflection up to 25 mm</th>
<th>Application for following ground / rock conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>E500</td>
<td>500</td>
<td>&quot;hard&quot;</td>
</tr>
<tr>
<td>E900</td>
<td>750</td>
<td>&quot;medium&quot;</td>
</tr>
<tr>
<td>E1000</td>
<td>1000</td>
<td>&quot;difficult&quot;</td>
</tr>
</tbody>
</table>

Energy absorption classes according to EN 14484-1.
SIKA ALIVA SHOTCRETE ROBOTS

FLEXIBLE SHOTCRETE APPLICATION WITH CONCRETE SPRAYING MACHINES

The spray-concrete systems Aliva® manufactured by Sika Schweiz AG are robustly built and flexibly usable construction machines, which convey through nozzles. The conveyed material is transported with pressurized air in the thin stream process to the spraying nozzle, where mixing water and admixtures (accelerators) are added. New sealing plates made of special steel and an automatic plate lubrication reduce wear and tear and operational costs. All Aliva® machines of new generation are in conformity with the EU-Machines Guidelines 168.

The AL-237 is a compact concrete spraying machine for processing small quantities of dry and wet spray shotcrete. The integrated frequency transformer enables a continuous adjustment of the rotor speed. With 0-14 m³/h (as per rotor size) the machine is also suitable for the application of liquid waterproofing membranes such as Sikacem®-711 Elato.

The AL-257 is universally usable for dry and wet spray concrete in thin stream process. The machine with its compact appearance performs through its dimensions, weight and efficiency. With only 650 kg and smaller dimensions, it suits any construction site. With its unbelievable output range from 0-2-4.5 m³/h (3 rotor sizes), it works for small refurbishment works as efficiently as for bigger temporary pit support systems or in mining.

The AL-267 is ideal for processing dry and wet spray concretes. Its modular construction is suitable for any requirement. With its conveying output of 4-21 m³/h, it is suitable for temporary pit support systems, tunnel construction, mining, slope stabilization, rock reinforcements. The automatic, pneumatic counter-pressure adjustment of mounting clamps enables an extremely wear and tearless operation.

The three machine types explained here enable to be manually combined with continuously regulated dosage device AL-403.4 Manual for fluid admixtures. The AL-267 can be combined with AL-409.6 Syncro. Thereby, the dosage of admixtures suits synchronously to the actually conveyed quantity of the rotor machine.

The AL-257 and AL-267 concrete spraying machines are suitable also for spraying steel fibre reinforced shotcrete. The AL-257 is frequently used in tunnel boring machines (TBM).

Bigger concrete spraying works or spraying bigger cross-sections require systems with telescopic arm technique. The AL-503 is conceived for narrow conditions, has a crawler chassis and can be operated with the aid of remote control. The usage is optimum with tunnel cross-sections between 2.4 x 4.8 metres.

The mobile concrete spraying system Sika®-PM 500 resulted in cooperation with the company Putzmeister is suitable for spraying works with medium to bigger tunnel cross-sections. The Sika®-PM 500 is obtainable with mounted rotor machine or concrete pump. Thanks to the modular concept, this system offers greater flexibility and higher cost effectiveness.

Aliva sets new standards also with the production of client-specific equipments in tunnel construction and refractory industry. In particular spray-concrete robot AL-303 and backfilling grout equipment AL-267 for tunnel boring machines and also equipment for maintenance works in the steel and cement industry. The most popular models in the industry of refractory are AL-555. AL-572, and AL-623.

OUTPUT OVERVIEW OF SHOTCRETE MACHINES

<table>
<thead>
<tr>
<th>Rotor machines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
</tr>
<tr>
<td>Rotor (L/min)</td>
</tr>
<tr>
<td>Conveying distance [metres] -&gt; Horizontal</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Conveyance quantity</td>
</tr>
<tr>
<td>Drive</td>
</tr>
<tr>
<td>Spray method</td>
</tr>
<tr>
<td>Dosing device</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Telescopic arm spray systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
</tr>
<tr>
<td>Spray arm reach</td>
</tr>
<tr>
<td>Drive</td>
</tr>
<tr>
<td>Spray method</td>
</tr>
</tbody>
</table>
WATERPROOFING IN TUNNEL CONSTRUCTION WITH SIKAPLAN® SYNTHETIC MEMBRANES

Tunnel construction works are designed for a life span of over 100 years. This, especially demands high requirements from the waterproofing systems. Protection of the supporting construction, secure operation, durable and impendement-free functioning of technical installations are in the fore. Not only in operation but also in the construction phase, the waterproofing system must resist chemical and mechanical stresses.

WATERPROOFING CONCEPTS AND SYSTEMS
According to the usage, the hydrological, ecological and climatic conditions, the water in tunnel constructions is either drained away (drainage concept) or kept outside of the structure (pressure concept).

SIKA WATERPROOFING SYSTEMS IN THE DRAINAGE AND PRESSURE CONCEPT

<table>
<thead>
<tr>
<th>CHANNELLING CONCEPT WITH DRAINAGE</th>
<th>PRESSURE CONCEPT WITHOUT DRAINAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. UMBRELLA SYSTEM</td>
<td>2. WATERSTOP SYSTEM</td>
</tr>
<tr>
<td>Laid loosely, with drainage without compartments</td>
<td>Laid loosely, without drainage, 1-layer, with integrated control and injection backup</td>
</tr>
<tr>
<td>- As sealing against moisture, seepage water and ground water</td>
<td>- As sealing against water under hydrostatic pressure</td>
</tr>
<tr>
<td>- For prevention of water pressure, drainage pipes are necessary</td>
<td>- Defined compartments can be injected, if necessary</td>
</tr>
</tbody>
</table>

3. ACTIVE CONTROLS SYSTEM
Laid loosely, without drainage, 2-layer, with integrated active control and injection backup
- As sealing against water under hydrostatic pressure
- High security through leak detection in waterproofing system during construction phase
- Defined compartments can be injected, if necessary

Mined and also open-cut tunnel construction works are successfully sealed for many decades with SikaPLAN® synthetic membranes made of PVC-P (Polyvinyl chloride) and TPO (Flexible Polyolefin) both in the drainage and also in the pressure concept.

WATERPROOFING MEMBRANES
SikaPLAN® WP 1100 (PVC-P) and SikaPLAN® WT 2200 (TPO) waterproofing membrane series possess high durability and flexibility, are durable against ageing, root growth and microorganisms, resistant to mechanical stress and dimension-stable and flexible against cold.

The SikaPLAN® waterproofing membranes fulfill all current standards in the field of tunnelling, such as:

SIA 272 and SIA 281/C (Switzerland)
OsV 302 (Tunneldichtung und RVS 87 Austria)
EN 1504 (Europe (CE))
ZTV-HNC and AIB (Germany)

Further information can be taken from the brochures “Flexible Waterproofing of Tunnels with SikaPLAN® Membranes”
ANCILLARY PRODUCTS FOR SIKAPLAN® WATERPROOFING SYSTEMS

Not only the material selection of membranes but also the system concept is important. Connections, special details, penetrations as well as reinforcement must be executed in accordance with the system. The applied construction materials must be compatible and meet the requirements of construction and usage. The Sikoplan® waterproofing membranes enable simple, durable joining through welding. The greatest advantage of the loosely laid waterproofing membranes is the biaxial elasticity, whereby joints, cracks, and gaps can be bridged. The fixation to the underground can be made differently.

1. DRAINAGE LAYER
For drained systems, the common solution for umbrella waterproofing, Sikalastic can provide a cumbled drainage and protection layer Sikaplan®W Fundrain with high drainage capacity, placed over the shotcrete behind the waterproofing membrane. Fixed with Sikaplan® W/Disc (ondede) made of the same material like Sikaplan® membranes.

2. INTEGRATED CONTROL AND INJECTION BACKUP
Sika® Waterbar, placed on top of the waterproofing membrane, are used as joint sealing and as barriers to form compartments between different areas under pressurized water. In case of a leakage, the water migration is stopped through the waterstop at the joints. The system is controlled and repairable through Sika Injection Flange, so that in case of leakages the water tightness can be re-established through injection.

3. COMPARTMENTS THROUGH SEALING TAPES
To form compartments on external walls and roofs in case of cut-and-cover tunnels, special tapes are used: Sikalastic® Dillo tape for PVC membranes, Sikaplan® WT Tape for EPDM membranes. The tapes are bonded with epoxy resin adhesive Sikadur® to the substrate. The membranes are welded to the sealing tapes over the complete tunnel cross-section to form compartments.

4. DRAINAGE ANGLE
The umbrealla system can easily be connected to the drainage pipes by the unique Sikaplan® WP Drainage Angle. The Sikaplan® membrane is welded to the drainage angle.

5. PROTECTIVE MEMBRANES
In the area of step-and-works or with reinforced concrete, for instance in base slabs, the waterproofing membranes must be protected from mechanical damages. For this, the protective membranes Sikaplan® WP / WT Protection Sheets are used. They are made of the same raw materials as the Sikaplan® WP / WT membranes for full compatibility.

6. INJECTION HOSES
With in-situ-concrete works, mainly in waterproof concrete constructions, the injection hose system SikaFuge® is pre-installed as sealing for construction joints. The injection hoses are set in concrete and subsequently injected with suitable injection resins such as SikaInjection-306 in order to seal the joint.

7. POSTAPPLIED JOINT SEALING TAPES
Constructions adjacent to tunnels like service tunnels are often executed with waterproof concrete. The concrete elements are either created with in-situ concrete or directly delivered as pre-cast elements. The sealing of all joints is ensured through the high value Sikadur® Combiflex® SG system. It consists of a flexible synthetic tape, which is adhered over the joint with associated adhesive on epoxy resin basis.

SPRAYED SECONDARY LINING
In case of sprayed inner linings, for example for short tunnels or for tunnel junctions, a steel mesh must be installed over the PVC membrane. The unique PVC anchor system Sika®Anchor provides a designed weight solution for all the membrane penetrations required for the fixation of the steel mesh.

Expertise & Experience: Over 100 Years
JUNGFRAU
THE HIGHEST TUNNEL CONSTRUCTION SITE IN EUROPE
CONCRETE FOR SECONDARY LININGS AND FOR PRE-CAST SEGMENTS (TUBBINGS)

The inner shell is the supporting and permanent concrete lining of a tunnel construction. Its final character depends on the selected construction procedure. In modern tunnel construction, distinction is generally made in two types of constructions, which are selected according to the structure of the mountain. It relies either to drill-and-blast with shotcrete as primary lining and permanent in-situ secondary lining or to TBM excavation with prefabricated concrete segments. Both types require very different concretes with different features for inner shells.

CONCRETE FOR INNER LININGS
As concrete for inner shells of tunnels is required in very large quantities, a high saving potential is also desired. Therefore, cost-effectiveness is a significant aspect. The concrete must be capable of flowing, so that it can be easily cast in the moulds and no hollow places emerge. Therefore, the concrete should not segregate. In order to ensure a favourable construction process, the concrete must provide high early strength. The requirements to consistency, stability and early strength can be controlled with the aid of Silka® ViscoCote®-PCE technology. Further suitable admixtures are available from the series Silkament® (and Silkaplast®). If necessary, retarder SilkaTard® and Silka®Air air-entrainer round-off the concrete admixture range. Silka® Fume DS, Micro-Silica increases the density of the mix, leading to higher compressive strength and durability.

CONCRETE FOR TUBBINGS
Even with the production of tubbings, it is important that the concrete can be applied without the formation of hollow space and voids. And most important, it should have a high early strength to reduce the curing time and de-mould the elements as fast as possible. With a high plasticizing property, a low w/c-ratio can be achieved, which can result in increased early strength and better durability. After about 5 to 8 hours, the concrete should provide sufficient early strength. In order to comply with these requirements, special admixtures of Silka® ViscoCote®-series are developed. To ensure an easy de-moulding, to achieve higher requirements on the surface. Silka® Separol® mould release agents are suitable.

In case the segment lining is designed to be the final permanent tube, the elements shall be protected with an epoxy coating Silkgard®65 WN, especially in aggressive groundwater conditions. Silkgard®65 WN acts as an excellent combined curing agent and protection layer and will be applied directly onto the fresh concrete after de-moulding of the tubbings in the precast factory.
HIGH PERFORMANCE INJECTION SYSTEMS

CRACK AND JOINT INJECTIONS
Leakages caused by concrete cracks, construction joints, honeycombs or damaged waterproofing systems restrict the functionality of the tunnel construction and can compromise the durability and usage. With the suitable injection technique, the integrity of the construction is rectified efficiently.

Even in tunnel constructions with high quality concrete, cracks and honeycombs can emerge due to extremely high stresses both during tunnel construction and during usage.
In case of a crack and void injection, the injection material must be properly embedded into the concrete. The injection systems of Sika, a combination of the right injection materials, the right equipment (such as Sika* Parkers) and the correct application technology enable to close both the dry and wet seeping cracks securely and to completely fill the hollow spaces.

For crack and hollow space grouting, as per the objective of application and condition of the damaged areas, varied injection materials are applied on the basis of polyurethane (Sika*Injection-101 foam and Sika*Injection-201CE resin), epoxy resin (Sikadur*-52 and Sika* Injection-451), Acrylate resin (Sika* Injection-306) and microfine cement (Sika*InjectoCem*-430).

<table>
<thead>
<tr>
<th>Aim</th>
<th>Moisture condition of crack</th>
<th>Flowing water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry or moist</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Without pressure</td>
<td>Under pressure</td>
</tr>
<tr>
<td>Closing/Filling</td>
<td>Sika*Injection-101</td>
<td>Sika*Injection-201CE</td>
</tr>
<tr>
<td>Sika*Injection-201CE</td>
<td>Sika*Injection-451</td>
<td>Sika*Injection-201CE</td>
</tr>
<tr>
<td>Sikadur*-52 injection</td>
<td>Sika<em>InjectoCem</em>-430</td>
<td></td>
</tr>
<tr>
<td>Waterproofing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sika*Injection-101</td>
<td>Sika*Injection-201CE</td>
<td></td>
</tr>
<tr>
<td>Sikadur*-52 injection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sika<em>InjectoCem</em>-430</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Force transmitting</td>
<td>Sikadur*-52 injection</td>
<td>Not possible</td>
</tr>
<tr>
<td>Sikadur*-52 injection</td>
<td>Sika<em>InjectoCem</em>-430</td>
<td>Not possible</td>
</tr>
<tr>
<td>Ductile connection</td>
<td>Sika*Injection-201CE</td>
<td>Sika*Injection-201CE</td>
</tr>
<tr>
<td></td>
<td>Sika*Injection-306</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sika*Injection-201CE</td>
<td></td>
</tr>
</tbody>
</table>

REFURBISHMENT OF WATERPROOFING MEMBRANES

Even with the usage of qualitatively high-value synthetic membranes, damages can occur, for instance through mechanical damage during installation or through unforeseen high local settling leading to voidages in the sealing membrane.

For critical waterproofing systems, such as pressure systems, Sika provides an integrated control and injection back-up. The waterproofing membrane is divided into compartments by Sika*Waterbars. Thus, the damaged part is limited locally. For later injection, Sika* control sockets are installed on top of the waterproofing membrane. Leaking compartments can then be sealed by Sika*Injection-304 acrylic resin.

If no membrane is in place, a quick-setting gel curtain behind the concrete lining can be injected, which stops the water successfully. Sika*Injection-304 is a high-value, quick-polyacrylate injection gel. It possesses very high elasticity and durability and fills the movements of the construction.

Further information can be taken from the brochure “Sika* Injection Systems for Concrete Structures”.
FUNCTIONAL SURFACE PROTECTION SYSTEMS IN ATTRACTIVE VISUAL APPEARANCE

For permanent protection and for visual design of the tunnel construction, effective surface protection systems are used. They have a firm bonding with the substrate, are resistant against stress from de-icing salt, moisture and damages from air and act as a protection against carbonation. These coating systems do not restrict the diffusion of water vapour and slow ageing process of concrete. All systems of Sika are tested and certified in accordance with the applicable rules and regulations.

Basically distinction is made between surface protection systems for surfaces that cannot be tread on and driven (e.g., parapets, ceilings, tunnel walls) and systems, which are mechanically stressed (e.g., cycling and pedestrian paths).

PROTECTION OF SURFACES THAT CANNOT BE WALKED-ON OR DRIVEN

As simplest protection system, hydrophobic impregnations are used. The products Silkgard®-204S and Silkgard®-705L (liquid) penetrate into the substrate, create water-repellent surfaces and protect the substrate from penetration of harmful substances. Hydrophobic surfaces are less prone to contaminations; hydrophobic impregnations do not change the aesthetic appearance of the substrate.

Protective coatings (Acrylic dispersion basic offer a higher protection and act additionally as a brake against carbonation. Silkgard®-E50 W Elastic plus Silkgard®-545 ElasticFill can additionally bridge the cracks. The product is available in different colours in order to ensure the aesthetic needs of the product.

In the tunnel area, both products Silkgard®-Tunnelcoat or Silkgard®-67 are used. Both products can be applied by hand or through machines. Silkgard®-Tunnelcoat was specifically developed for use in tunnels. The product presents an excellent cleaning possibility; a high UV-durability and a very good other technical specific values, the application is made solely in the work process. Besides the standard colour tone signal colours are available also in order to highlight the refuges in colour. The protective coatings for tunnel area are compatible with Silkgard®-720 EpoCem®, superfine epoxy cement sealing mortar.

DIRECT WALKABLE AND DRIVABLE SURFACE PROTECTION

The walked-on or driven surfaces require crack-covering, mechanically resistant coating systems. For this purpose, one or more layered structures are applied. Sika offers both with products that perfectly match each other.

The best single-coated surface protection system comprises a combination with the primer Silkafloor®-161 and sealing with Silkafloor®-359 N.

The two-layered surface protection system based on Silkafloor®-161 and Silkafloor®-360 N Elastic, is additionally supplemented through a wearing layer with Silkafloor®-375 and a sealing with Silkafloor®-359 N.

The Repair and Protection of Reinforced Concrete with Sika in Accordance with European Standards EN 1504,
SUSTAINED CONCRETE MAINTENANCE

All concrete surfaces in tunnel constructions are exposed to severe stresses. On the driving surface, mainly the mechanical stress through the traffic and the stress through chloride entry are significant. The latter can cause corrosion of concrete reinforcement and chipping in concrete. Even in the case of less stressed vertical and overhead surfaces in the tunnel tubes chloride and the processes of carbonation attack the reinforced steel and lead to corrosion. This can lead to endangering the supporting capability in individual cases.

The usability of the tunnel structures depends on the long-term stability of the support system. This demand includes the durability of concrete and the reinforcement and is to be achieved only through constructive measures with products and methods specially developed for this purpose. Sika possesses best, practical maintenance concepts for these applications, which are used in consonance with the applicable rules and regulations in constantly optimized and successful manner.

CONCRETE MAINTENANCE

Before the maintenance of concrete the substrate preparation is necessary in accordance with recognized rules of construction. Damaged spots and loose parts up to film, supporting parts must be removed. This is carried out mostly by hydroabrating. The corroded reinforced steel is mostly cleaned, cleaned and subsequently treated with the flowy modified cementitious bonding agent and protective coating for steel rebars to prevent corrosion such as SikaTop®-Armature-310 EpoCem®. This product is applied in two layers and simultaneously serves as protection against corrosion and as bonding course for subsequent re-profiling mortar.

As replacement to concrete, a ready-to-use single component, polymer modified high strength cementitious mortar SikaTop®-122 HS is applied. This product can be applied both by hand and machine application (by wet spraying process with Sika® Allvac® machine).

After the maintenance of local or large surfaces or damaged areas and before application of a surface protection system, a levelling of the substrate is necessary. For the blocking of pores and also as wall putty, Silkgard®-720 EpoCem® is used. In combination with different surface protection systems.

For maintenance of tunnel works, the usage of products of a single manufacturer is recommended. The products required for the individual working steps are compatible with each other and are designed as a system.

Further information can be taken from the brochure "The Repair and Protection of Reinforced Concrete with Sika in accordance with European Standards EN 1504".
Severe heat effects may occur in case of a fire and lead to chippings in concrete. Even the steel in the concrete loses its solidity due to greater heat effect. This, during fire, can lead to a collapse of the underground construction.

In order to protect the reinforced concrete from high temperatures caused by fire accidents, Sikacrete® fire protection mortar is used. Sikacrete® is a filling material, which offers extraordinary heat insulation properties. The material exerts through simple application and a thin coating which is necessary for fire protection. The mortar is tested as per ISO 811 and with a coating strength of only 20 mm (Sikacrete®-213 F) fulfills the requirements of the stringent fire rating curve RWS of the Netherlands during 2 hours.

With higher requirements to tensile bond strength, Sikacrete®-223 F is used. This frost-resistant mortar presents high stability, so that it can be cleaned using hydro-jet machines. Sikacrete®-223 can be coated with Sika®-223 Wallcoat T, and is also frost-resistant like the Sikacrete®-223 F. The Sikacrete® fire proof mortar protects the concrete structure with minimum coating thickness in a reliable manner from the effects of fire.

The material consumption for fulfilling the RWS fire curve with both Sikacrete®-213 F and also Sikacrete®-223 F is significantly lower than synthetic fibrous gunitas. Sikacrete®-213 F stands out especially through its lesser gress density. With very less material, the requirements of RWS can be fulfilled. Sikacrete®-223 F shows higher density, has a higher solidity and is also resistant to defrosting salt without any coating. Further information on the Sikacrete® fire proof mortars are given in the brochure “Sikacrete® Fire Protection Mortar”.

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**Graphs:**
- RWS - Fire test: 30 mm Sikacrete®-213 F
- RWS - Fire test: 30 mm Sikacrete®-223 F

**Material consumption for RWS:**
- Sikacrete®-213 F
- Sikacrete®-223 F
- PP modified bitum
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For usage and processing, always consult the updated product specification sheet of the applied products. Only our updated General Business Conditions are applicable.