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Concrete Deep Within a Mountain: Specialty Silanes Protect the Roof of the Swiss Gotthard Tunnel

No matter how important water may be in the production of concrete, salt water and concrete form a lethal cocktail. When the salt is washed off winter roads and seeps deep into the pores of bridge piers, tunnel roofs and tunnel walls, danger lies ahead: dissolved chlorides in the water attack the steel inside the concrete. This corrosion can have serious consequences: crumbling concrete, accidents, and costly and lengthy renovations accompanied by congested traffic. Materials experts from WACKER have developed water-repellent specialty silanes which protect concrete for years on end by preventing salts from penetrating into concrete. Highway bridges in Bavaria, Germany, are routinely protected in this way already. Recently, the roof of the Gotthard tunnel in Switzerland was also treated with specialty silanes.

Traffic artery through the Alps

The Alps may present a fabulous panoramic backdrop for skiers, but they are a real nuisance to traffic. In 2008, about 1.27 million trucks crossed over the four major Alpine passes in Switzerland alone. But the burgeoning stream of traffic also flows underground through the more than 50 road tunnels that traverse the Swiss Alps. Closing off just one of these extremely busy arteries – such as the Gotthard tunnel – can be as harmful as an obstruction in a blood vessel, and the results can be similarly devastating: there is a serious risk of congestion.

The Gotthard tunnel is at the heart of the most direct road link between the North Sea and southern Italy. And the flow of cars, buses and trucks under the legendary massif of gneiss and granite rarely comes to a standstill. Vehicles have been passing through the 16.9-kilometer tunnel since 1980, carrying holiday-makers, auto parts and electrical goods from north to south, and hauling tomatoes, machinery and textiles back from Italy to Germany, the Netherlands and Denmark. Every year, some 750,000 trucks alone trundle through the single-lane corridors in the depths of the Gotthard massif.

**An insidious danger:
Salt within the
reinforced concrete**

And every winter, these vehicles unintentionally transport additional freight into the tunnel – salt water. For the spray thrown up from the wet road surface by millions of tires splashes directly onto the roof and walls of the tunnel. The deposited salt attracts more water, and the constantly damp conditions favor its slow penetration into the concrete. Over the years, the porosity of the concrete enables the chlorides to eat their way further and further inside. Then, once salt-laden moisture makes contact with the steel bars, or reinforcing iron, an ominous corrosion process is set into motion.

Usually, the pH of concrete is high enough to protect the steel. But it is powerless against salt chlorides, which cause the pH to fall and the protection to disappear. Because corroded steel is bulkier, it presses against the concrete from the inside and forces parts of the concrete to eventually break off. This can have serious consequences: “An accident could occur if pieces of concrete suddenly start raining down from the roof onto vehicles

**Impregnation helps
against corrosion**

traveling at 80 km/h,” says Ralph Minery, the responsible sales manager from the Construction Chemicals business team at WACKER Switzerland.

Since 2002, therefore, a special “Suspended Ceiling” working group at the Swiss Federal Roads Authority (ASTRA) has been keeping tabs on the structural condition of the Gotthard tunnel, initiating repairs as needed. In 2006, it instigated rehabilitation work to the entrances, treating some 250 meters of the tunnel with a water repellent. The concrete was impregnated with an active ingredient that lines its pores and renders them water-repellent while retaining their vapor permeability. The concrete thus continues to breathe.

Measurements and on-line monitoring of corrosion currents showed that these steps greatly reduced the extent of corrosion. It was therefore decided to impregnate a further 750 meters of the tunnel with water repellent. Though the concrete construction is already protected by a complex coating, the tunnel roof needed to be repaired.

Structural or rehabilitation work of this kind requires extensive preparation and safety precautions, and so both are very costly and almost impossible to do so long as the tunnel remains open. This is especially true of the busy Gotthard tunnel, which can only be closed for brief periods because of the huge volume of traffic. More comprehensive measures, such as the application of an epoxy coating, are nearly impossible to carry out in such a short period of time.

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Silane active ingredients provide effective protection

For this reason, the tunnel operators opted for deep impregnation and arranged for more than 7,000 square meters of ceiling to be impregnated with silane in a single night. This protects the concrete in the ceiling against the ingress of salt water. "It has been shown that highly alkylated silanes, such as SILRES® BS Creme C, are the best products for such tasks," says Dr. Johannes Ihringer, a WACKER materials expert. "Unlike conventional liquid products, they can be applied in the right thickness at one go. The substrate's porosity determines how quickly the active ingredient can penetrate." This was a key argument for the decision to use the WACKER product in the Gotthard tunnel. After all, time was of the essence.

Start of "Operation Gotthard"

All systems stop: at precisely 8 p.m. on September 21, 2009, the tunnel is closed. Work starts simultaneously on the northern and southern entrances. The workers on both sides of the tunnel have until 4.30 a.m. to finish the job, because the traffic cannot be held up any longer than that.

Swiss precision

With all the proverbial precision of a Swiss watch, the repair gangs swing into action. As soon as the last truck has passed, some two dozen workers dressed in white clothing and high-visibility jackets begin "Operation Gotthard" at the southern entrance. First, painters and concrete repair specialists cover the entire roadway with sheeting. Arnold Wyssen, a master painter, specially commissioned a device for unrolling the sheeting for the southern side: "We have to cover 7,000 square meters of road in three hours." Afterwards, a Novaplica robot will spray water repellent onto the tunnel roof. "The spray mist containing the

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Race against time

silane cannot be allowed to get onto the road surface because that would make it as slippery as soap and cause drivers serious problems," says Ralph Minery, whose job is to monitor the work's progress throughout the night.

After everything is covered, the high-tech spray gun can get to work: twice, the automatic sprayer will traverse the 750 meters of tunnel, its twelve nozzles covering the roof with about 500 grams of material per square meter. After around five hours of loud hissing, the job is done: the workers from Novaplica have sprayed around three-and-a-half metric tons of material onto the ceiling. The tunnel ventilation system is running at full blast to dry the roof, not stopping until the dripping has ceased. Then the workers quickly remove the sheeting from the road and clean up the site. At 4.04 a.m., the construction gang leaves the tunnel, some 25 minutes ahead of schedule.

At precisely 5 a.m., it's all systems go: the column of trucks once again starts to move through the heart of the mountain. "It was a risky undertaking, and we all knew we had to work at full power. Never before did a project like this have to be done in such a short time," says Paolo Gattulli, branch manager of SikaLavori in Cadenazzo (Switzerland). This company, which was commissioned by ASTRA to do the work on the south entrance, has been using silane active ingredients from WACKER for many years.

Prior to applying the water repellent, the SikaLavori experts had hosed down the roof with a high-pressure spray, and then

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Proven protection for concrete structures

hammered it by hand to sound out defects. Any that were found were cleaned out and repaired with specialty mortar. Only then could the waterproofing begin. Everyone knew the stakes were high – just one night had been allocated for the job, and any over-run would have cost tens of thousands of Swiss francs.

Highly effective, thanks to its pasty consistency

At the northern entrance, the waterproofing was performed by Mapei. Its Swiss sales manager, Martin Schneider, also opted for SILRES® BS Creme C: “Because it is a paste, you can apply it much more thickly to every square meter. The cream sticks to the surface better, and that enables more of it to penetrate into the concrete.”

To do the work in such a narrow time span would “not have been possible with any other material,” says Schneider, who has been working for over 20 years in construction chemicals and collaborating for some 15 years with Minery. “The silane cream has a long contact time and is designed to ensure maximum penetration of the concrete by the active ingredient. That way, it offers optimal protection against water absorption and damage by road salt,” Minery explains. The depth to which the waterproofing agent penetrated the concrete is now being examined by materials experts, who took drill cores when the work in the tunnel was completed.

“The goal of deep impregnation with our silane active ingredients is to penetrate to a depth of about six millimeters, to provide a water-repellent lining within the concrete pores and to keep out saltwater,” Dr. Johannes Ihringer explains. The

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**Impregnation saves
money, energy and
resources**

high viscosity of the WACKER silane active ingredients ensures that they are not washed away again by water splashes and that they provide long-lasting protection. “Conventional repairs to concrete structures, such as tunnels and bridges, can cost ten times as much as preventive measures such as hydrophobic impregnation. With this innovative technology, it’s possible to prevent the need for repairs – and so avoid high costs and consumption of energy and resources,” adds Ihringer.

Gattulli, a construction expert at SikaLavori, is confident of winning further deep-impregnation contracts in the future – after all, there is no shortage of tunnels in Switzerland. “Salt water will always be the arch-enemy of reinforced concrete. And the concrete needs to be given lasting protection,” says Gattulli. Specialty silanes from WACKER are clearly just as effective in tunnels as they are on highway bridges.

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Background information on silanes from WACKER**Effective Protection against Moisture:**

Organosilicon compounds (silanes) are long-established water repellents. They feature excellent water repellency, and will not significantly impair the water-vapor permeability of concrete. On the concrete, they form extremely stable covalent bonds with the silicate matrix of the pores and capillary walls. The colorless, non-film-forming silane impregnating agent fabric prevents water and dissolved aggressive substances, such as salts, from gaining ingress into the building material via the capillaries. Silanes possess excellent durability and are extremely resistant to external influences, such as UV radiation, thermal stress, aggressive substances and microbes.



A race against the clock: in late September, the ceiling of the Gotthard tunnel was impregnated with SILRES® BS Creme C from WACKER. The treatment affords the tunnel lasting protection against moisture and salt. (Photo: Wacker Chemie AG)



Completely closed to traffic: to provide protection against moisture and salt ingress, the ceiling of the Gotthard tunnel was impregnated in late September with a specialty silane cream made by WACKER, the Munich-based chemical group. (Photo: Wacker Chemie AG)



Renovating the Gotthard tunnel: specialists used compressed air to apply the silane impregnating agent. (Photo: Wacker Chemie AG)

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Note:

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<http://www.wacker.com/pressreleases>

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The company in brief:

WACKER is a globally active chemical company with some 15,900 employees and annual sales of around €4.3 billion (2008).

WACKER has 27 production sites and over 100 sales offices worldwide.

WACKER SILICONES

Silicone fluids, emulsions, rubber and resins; silanes; pyrogenic silicas; thermoplastic silicone elastomers

WACKER POLYMERS

Polyvinyl acetate and vinyl acetate copolymers in the form of dispersible polymer powders, dispersions and solid resins used as binders for construction chemicals, coatings, adhesives, paints, plasters and nonwovens

WACKER FINE CHEMICALS

Fine chemicals, PVAc solid resins, biologics and other biotech products such as cyclodextrins and cysteine

WACKER POLYSILICON

Polysilicon for the semiconductor and photovoltaics industries

Siltronic

Hyperpure silicon wafers and monocrystals for semiconductor devices