

SPECIAL EDITION

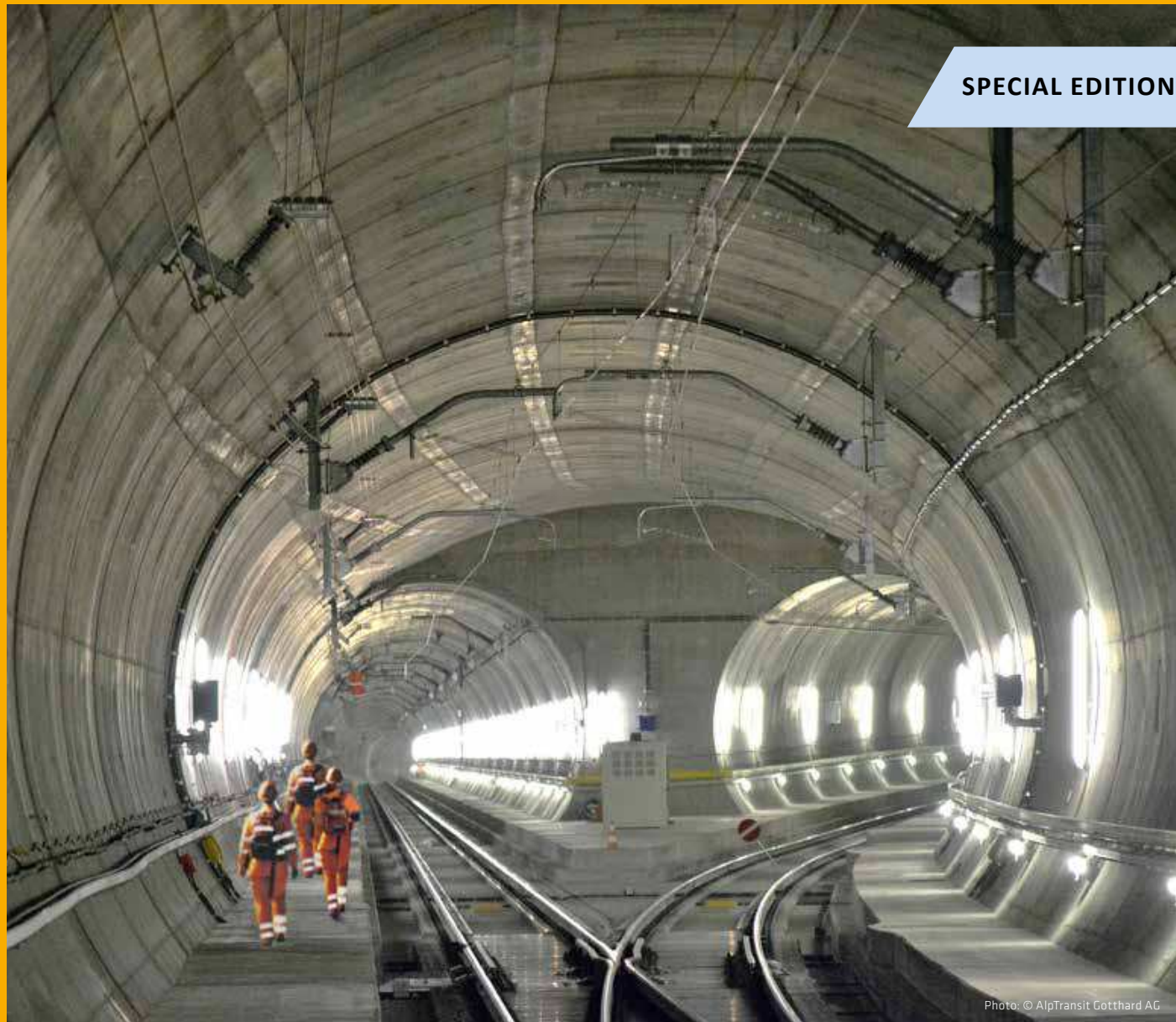


Photo: © AlpTransit Gotthard AG

SIKA AT WORK

GOTTHARD BASE TUNNEL

Project of the Century

BUILDING TRUST



EDITORIAL



Dear Readers

Twenty-five years after my first project meeting with the client Swiss Railways (SBB), the longest rail tunnel in the world is being officially opened. The Gotthard Base Tunnel is a world record.

In 1992 Sika began the initial preliminary tests for SBB at the Zurich Concrete Laboratory, at a time when the client and their engineers were still unsure what material characteristics should be demanded for the high specifications needed for the “100 year service life” structure. Sika was a pioneer again here with its specialist expertise and experience in concrete and admixture technologies, leading to many new product developments.

The two separate main tunnel tubes, each 57 kilometres long, with 100 connecting, access and ventilation tunnels, together form a 152 kilometre long system. In total, over 28 million tonnes of rock had to be broken out and removed, equivalent to a volume of over 15 million m³. Around 25% of the material was classified, washed, crushed and reprocessed to produce high quality concretes by using concrete admixtures. Sika contributed its advanced technology to the production of more than 2 million m³ of quality concretes (concrete with special properties). What began in 1993 in the Piora exploratory tunnel with new accelerator technology development, resulted in the main tunnel construction process with up to 4 concrete admixtures in innovative and at the time, unique mix designs. So the Gotthard project was also one of superlatives for Sika. More than 2/3 of the construction packages were awarded to Sika, with a material value of over > 200 million Swiss francs. Jointly with SikaBau AG, we obtained the largest contract in Sika's history, the waterproofing of the two southern sections of the Gotthard.

Sika put in prior investment of over 3 million Swiss francs for a year-long prequalification process and new material developments before a single kilogram of building chemical products could be supplied. This required both courage to take the business risk and great conviction that the huge technical challenges could be overcome with new products and solutions. Much new ground had to be broken – “Doesn't work” and “Doesn't exist” were not part of the Sika vocabulary. After a highly selective development process, the new products and systems were subject to rigorous field testing by Sika and officially appointed test institutes such as EMPA for approval before going into production.

I would like to thank Sika Management for its entrepreneurial vision and all of our colleagues involved in the project from Research, Engineering and Sales for their impressive commitment and perpetual desire to achieve great things on the Gotthard. The Gotthard Base Tunnel was a pioneering project of Swiss engineering, built by “underground heroes” from many countries and made possible by the most modern and advanced concrete and waterproofing technologies from Sika. Many new Sika products now on sale throughout the world contain the “DNA” of the Gotthard specifications within them, because they were originally developed for a specific solution on the “hundred year structure”.

On that note: “Happy Birthday Gotthard” and congratulations to all Sika colleagues and project participants. Together you move mountains and astonishment and pride at what was achieved must be felt. The Gotthard Base Tunnel is a monument against which many future tunnels and other major infrastructure projects will have to be measured.

ERNESTO SCHÜMPERLI
President Concrete & Waterproofing Division

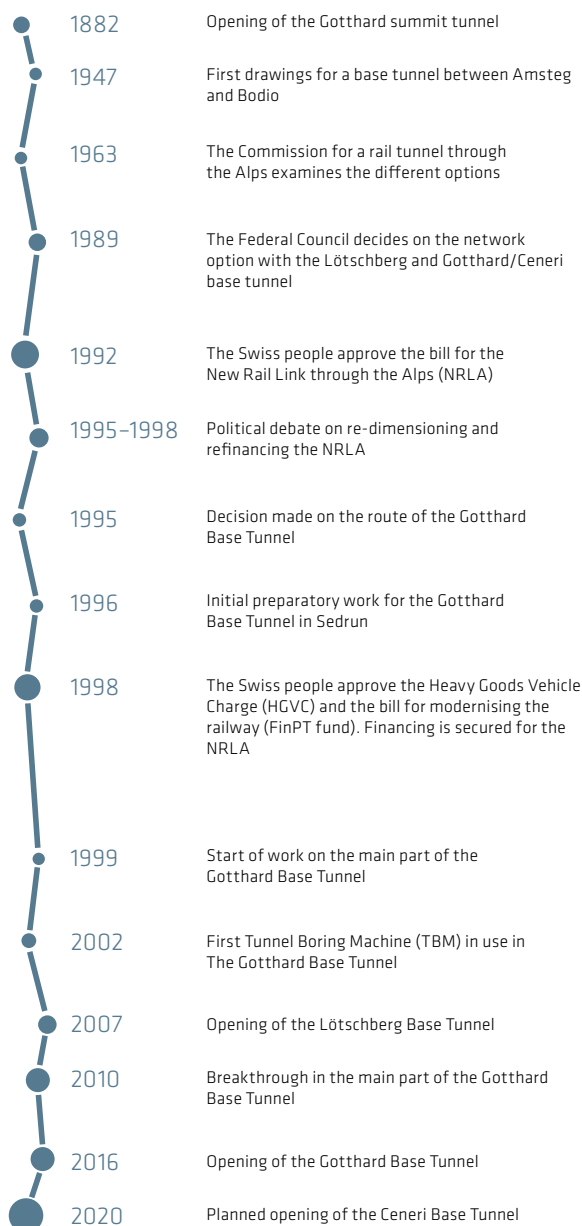
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FACTS AND FIGURES

The Gotthard Story



- Length: 57 kilometres (the longest rail tunnel in the world)
- 152 kilometre tunnel system in the rock
- Tunnel transit time: just 20 minutes for passenger trains
- Tunnel capacity: up to 260 freight trains and 65 passenger trains per day
- Maximum speed: Freight trains 160 km/h, passenger trains up to 250 km/h
- 60 minutes faster from Zurich to Milano
- Two single-track tunnel tubes, connected every 325 metres by cross cuts
- Tunnel summit: 500 m above sea level
- Maximum rock cover: 2,300 metres
- Construction period (excluding exploratory work): 17 years
- 28.2 million tonnes of material excavated
- Main tunnels drilled with tunnel boring machines (80%) and blasted (20%)
- 43,800 hours working non-stop to lay the ballastless track
- Qualification process 1996 – 2002 with extensive tests and prior investment of over 3 million CHF
- Total cost of the NRLA with Lötschberg, Gotthard and Ceneri Base Tunnels: CHF 18.2 billion (1998 prices excluding inflation, VAT and building loan interest; effective total cost: about CHF 23 billion)
- Project participants: 2,600 people
- Gotthard Base Tunnel commissioning: 11 December 2016

Sika products and services

- Sika admixtures for over 2 million m³ of concrete
- Sheet waterproofing membranes and jointing systems for over 3 million m² of waterproofed area
- 20,000 tonnes of concrete admixtures
- 40,000 tonnes of materials handling
- Sprayed concrete systems and robotic equipment on the tunnel boring machines for efficient heading
- Consumables and add-on products from the full Sika range
- 12,662,500 minutes of work

SIKA AND THE GOTTHARD

A resounding success



THE SUCCESS STORY BEGAN OVER 100 YEARS AGO

When the Base Tunnel is officially opened on 1st June 2016, the Gotthard, the barrier between north and south, will finally be conquered. Thanks to the longest rail tunnel in the world, trains will race through the Alps and scarcely have to climb. A milestone in transport and for the mobility of the future.

The Gotthard Base Tunnel is something new and special in tunnelling. It crosses one of the highest massifs in the Alps. Under the highest peaks, the tunnel runs some 2000 metres under the rock and is only about 550 metres above sea level at its summit. For heavy freight trains and modern high speed trains, this new line reduces the journey time from Zurich to Milan by about an hour.

The breakthrough on 15 October 2010 was the moment when it was clear that this hundred year structure – the Gotthard Base Tunnel – would be successfully completed. Eleven years after the first blasting operations, the 57 kilometre long Gotthard tube was broken through. By the time of commissioning on 1st June 2016, a total of 152 kilometres of tunnel section will have been built and 28 million tonnes of rock excavated from the mountain.

Gotthard – where it all began for Sika

Just 100 years ago, the success story of the Sika Group – now a multinational operation – also began on the Gotthard in tunnelling. With the waterproofing for the rail tunnel electrification in 1918, Sika created the conditions for the success of the railway on the north-south axis and also the basis for the company's global success. The Gotthard Base Tunnel posed similar challenges to those of 1918 along with some quite new ones.

It was not just the structural dimensions that placed huge demands on the tunnelling engineers; above all it was the high temperatures of 30 to 40°C underground which had to be managed. The high material and engineering specifications, such as the concrete lifespan of 100 years, were a central issue on this hundred year structure and had to be met.

Sika's total construction expertise

The new Gotthard Tunnel required Sika's total construction expertise. We supplied the waterproofing system, the building chemicals know-how and machine solution on this project. The complete tunnel waterproofing system has also been installed very professionally by Sika. The tunnel excavation is stabilised by sprayed concrete using high-quality Sika admixtures and sprayed concrete machines. Sikaplan® sheet waterproofing membranes were then installed on top of this lining by SikaBau AG. The concrete inner lining with Sika admixtures was then installed, with high-precision specifications for the surface geometry of the tunnel.

People build for people

The longest rail tunnel in the world forms the heart of the new AlpTransit rail link (NRLA). It embodies Swiss values: innovation, precision and reliability. Values that the Sika personnel involved also brought at all levels to contribute to the success of this hundred year structure, in partnership, with pride and satisfaction, throughout the 14-year construction period and including the preliminary works from 1996. Sika builds with and for people – as is impressively demonstrated here on the Gotthard.



KEY DATES IN THE STORY

The Gotthard Base Tunnel is a further milestone in the long and colourful story of the Gotthard that began with mail coaches

1830 – THE FIRST MAIL COACHES

When the new road was opened in 1830, a through coach ran between Flüelen and Chiasso three times a week. One-horse carriages with two or three seats were used. The great period of the Gotthard mail did not begin until 1842 when a five-horse, ten-seater coach ran daily in both directions. The trip from Como to Flüelen took precisely 23 hours.

1882 – OPENING OF THE GOTTHARD RAILWAY

The 15 kilometre summit tunnel on the Gotthard railway was the longest tunnel in the world. Mail actually began to be sent through the tunnel in 1881 when only the structural work was completed. The difficult and dangerous journeys over the mountain pass then became a thing of the past.

1918 – ELECTRIFICATION OF THE RAIL TUNNEL

On 16 February 1916 the Board of SBB decided to electrify the Gotthard railway from Erstfeld to Bellinzona. The major problem of obtaining supplies of coal during the First World War brought pressure to complete the plans quickly. Electric locomotives are also much more efficient than steam ones, resulting in a faster journey time. This electrification began according to plan in 1918 and the full Erstfeld to Biasca section was opened on 12 December 1920.

1922 – FIRST CROSSING OF THE PASS BY MAIL VAN

The first car is said to have travelled through the Gotthard pass in 1895. The last horse-drawn mail coach crossed the Gotthard in 1921. The following year saw the arrival of the Car alpin; the first mail van operation had begun.

1980 – OPENING OF THE ROAD TUNNEL

The next Gotthard record belongs to the 16.9 kilometre road tunnel, inaugurated in 1980 and for many years the longest in the world. There was then a fast, year-round link for mail and traffic between Uri and Ticino.

2016 – OPENING OF THE GOTTHARD BASE TUNNEL

The new hundred year structure on the Gotthard: Thanks to the base tunnel, future high-speed trains will race through the alpine massif at up to 250 kilometres per hour, although the tunnel has been built mainly for freight trains. Up to five of these per hour are planned in each direction. They will run daily between Härkingen and Cadenazzo, reducing the journey time by more than 45 minutes.



Photo: Zurich Central Library, graphic collection and photographic archive



Photo: Zurich Central Library, graphic collection and photographic archive



Photo: © AlpTransit Gotthard AG

THE PREQUALIFICATION PROCESS

100 YEAR SERVICE LIFE REQUIRED

The client AlpTransit required a 100-year service life without significant maintenance to the concrete, i.e. de facto 100-year durability for the concrete and the waterproofing systems. For the first time the client specified a prequalification process under which bidders had to qualify separately over three stages for the works on all five of the project construction contracts:

- Stage 1: Aptitude certification; technical and production certification "Stage 1 Application Documents March 1996".
- Stage 2: Preliminary tests; independent completion of concrete tests with original aggregates, but without having to comply with difficult temperature conditions; results determining who could participate in the main tests.
- Stage 3: Main tests; production of concrete grades OB 1 & 2 and SB 1 & 2 under the client's supervision, complying with all the external conditions; successful results were the basis for inclusion in the list of grades in the tender documents.

Table 1: Durability requirements for concrete grades OB 1 and OB 2

Concrete grade (OB = site placed)	OB 1	OB 2
Strength class SIA 162/1, tests 1 / 2	B 45/35	B 45/35
Watertightness (water conductivity) SIA 162/1, tests 5 / 7	$\leq 12 \text{ g/m}^2\text{h}$	$\leq 8 \text{ g/m}^2\text{h}$
Chemical resistance (sulphate) XA2 under prEN 206, 1997 Final assessment after 720 days	–	$\leq 0.50\%$
Shrinkage SIA 162/1, test 4	–	As low as possible
Minimum cement content	$\geq 325 \text{ kg/m}^3$	$\geq 330 \text{ kg/m}^3$
Maximum water content	≤ 0.50	≤ 0.50

Table 2: Workability requirements for concrete grades OB 1 and OB 2

Concrete grades (OB = site placed): OB 1 and OB 2
Working time requirement: Pumpable for 6 hours and 100 metres – Fresh concrete temperature: no significant increase over 6 hours – Fresh concrete storage temperature: 25 to 30°C – Aggregates: Material excavated from the Gotthard
Early strength development requirement: > 5 N/mm ² after 12 hours – Production of test specimens after 4 and 6 hours – Specimen storage temperature: 35°C

The main tests were carried out in the specially constructed VSH (VersuchsStollen Hagerbach AG) test tunnel, under the supervision of the client's representative. Bidders had to form bidding teams, in each case with a cement producer and an admixture manufacturer forming a team for each construction section and only allowed to be involved as a team. For the tests, the companies were supplied with lists of the teams approved for each section to select their supply partners. Chronologically, the prequalification process took place years before construction actually began. This added design security and was also necessary because a test lasting two years was specified to obtain the required sulphate resistance from the concrete. This test method was replaced by a faster test during the actual construction period.

In addition to scrupulous compliance with the durability limits, potential workability requirements were defined in the prequalification process to ensure that the concrete grades tested also met the site requirements of the contractors. The concrete had not just to be produced but also to be transported, delivered and installed as specified in the prequalification process.

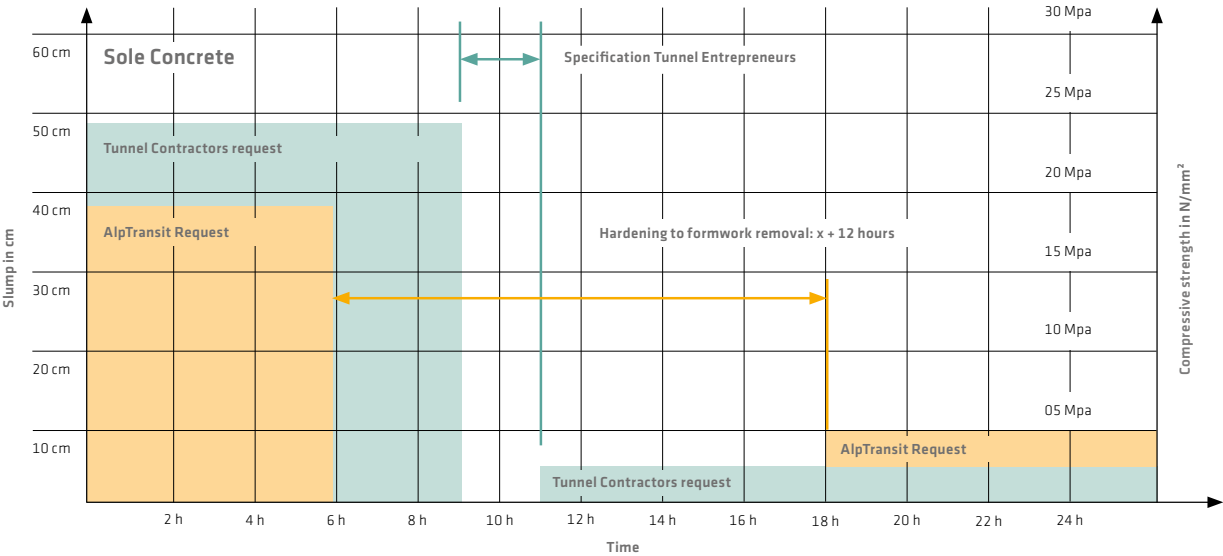
Then when construction began, it soon became clear that the contractors set different and sometimes widely varying requirements for installation. This meant that when construction began the concrete mix designs approved in the prequalification process had to be tested and approved for installation in the tunnel once again.

This had the advantage that developments in binders and concrete admixtures made in the meantime were not excluded per se. As at just that time, major development and application advances were also made in polycarboxylate (PCE) based plasticizers and durable binders (CEM III), for the production of high performance durable concretes.



ALPTRANSIT CONCRETE REQUIREMENTS

Working time and strength development requirements for the concrete
(AlpTransit specification and the tunnel contractor's requirements)



CONSTRUCTION HIGHLIGHTS

Jürg Schlumpf, Corporate Target Market Manager Concrete



In the case of durable concrete for infrastructure projects many of these different performance requirements are combined coincide. Specifically for the Gotthard Base Tunnel these were:

- Durability and workability (transport and installation)
- Durability and early strength development (formwork striking times)
- Workability with crushed aggregates (fines)
- Temperature differences and uniformity (between portal and installation point)

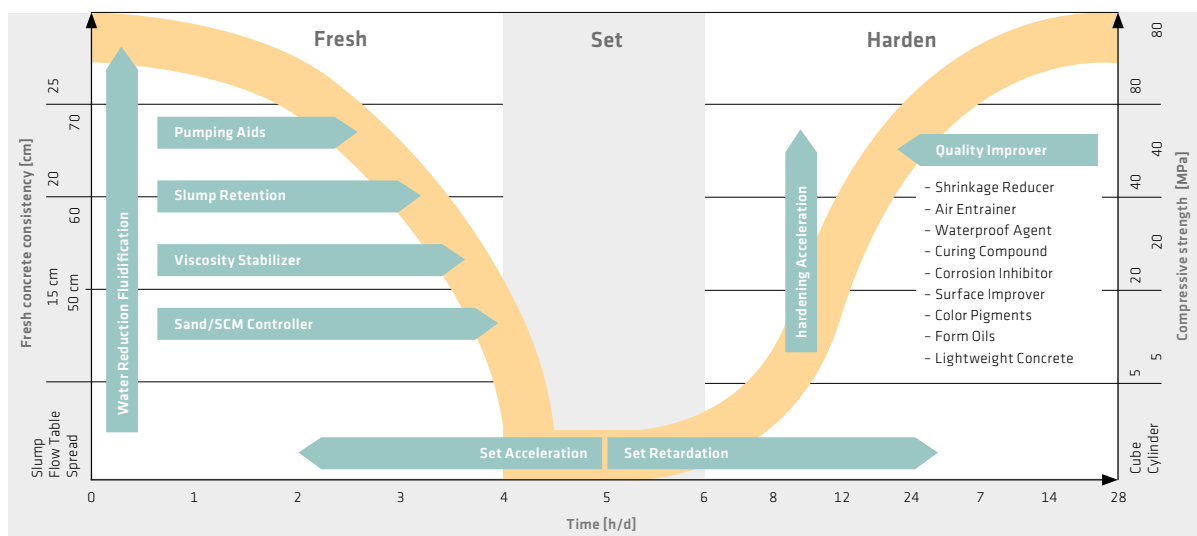
Good workability despite high durability requirements

To achieve good and very extended workability properties, whilst maintaining the performance to the stringent durability requirements, concrete admixtures or combinations of them that were suitable for the different concrete grades had to be added. In addition to considerable water reduction (standard with Sika® ViscoCrete® types), the main requirements for the Gotthard project concretes were good mix stability and minimal fluctuations in the characteristics, because all of the concrete had to be produced with aggregates excavated from the tunnel. The sands in particular made plasticizer selection very complex. For some sections, new solutions had to be formulated again and again during the construction works in order to suit the site conditions and demands; whilst from the start others used combinations of different plasticizers at the same time, added in variable dosages. This system also allowed a flexible response to the requirements at different ambient temperatures and increasing transport distances.

CONTROL OF CONCRETE CHARACTERISTICS BY CONCRETE ADMIXTURES

Today's concrete technology is unthinkable without admixtures to adjust and control specific fresh and hardened concrete characteristics. There are numerous different products available with which to control primarily the working time, retardation or acceleration, homogeneity, fluidity and degree of compactability in the fresh concrete. Whilst in hardened concrete the main effect is generally to minimise the porosity by reducing the water and thereby increase strength, resistance and durability. Other admixtures to increase aspects of durability can also be used alongside them, which can have a positive influence on concrete shrinkage or the corrosion resistance of the reinforcement, for example.

Concrete admixtures toolbox (Overview of concrete admixture use to control the fresh and hardened concrete characteristics)



An example of these plasticizer combinations was:

- Type 1: high water reduction, good early strength development, short working time, mix stabilising
- Type 2: Low water reduction, long working time, especially at high temperatures, mix stabilising

All of the concretes for the project were reliably produced using this concept, throughout the construction period and over several years (summer and winter); with the initial transport distance of a few hundred metres, increasing to over 30 kilometres.

Controlled and extended working times despite high temperatures

In one phase, tunnel sections of over 30 kilometres had to be driven. The concrete mix had to be designed for these long transport distances and in all of the sections the concrete was carried by train to the installation point. Due to the topographical conditions at the concrete production points, widely varying weather and temperature conditions existed. Minus temperatures frequently occurred during the day in the winter, whilst in some sections the temperature at the installation point rose to over 30°C. The concrete working time conditions then had to be adjusted for both the transport distances and the constantly changing temperatures.

In addition to defining the requirements for transport and working times, the installation contractor also set minimum specifications for the early age strengths required to achieve the necessary formwork striking times. Admixtures based on modified PCE were developed to control the consistency (Sika ViscoFlow® slump retention polymers). These products are widely used today, but they did not yet exist in the years leading up to the construction works involved in building the Gotthard Base Tunnel, so these developments can certainly be called an innovation by Sika. Nowadays these so-called slump keepers are often added separately and have undergone massive further development for use in combination with many different binders.

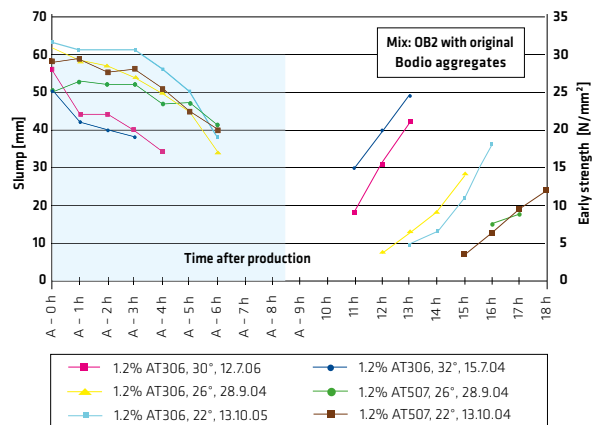
Early striking times despite extended working times and the durable binder concept

When concrete is transported to the installation point and pumped into the formwork, the stripping time schedule is another requirement that has to be met. This does not cause problems with sprayed concrete because the reaction is triggered with an accelerator immediately before application at the nozzle, irrespective of the retarding time. The early strengths required after one, two, four and eight hours can now be obtained almost independently of the required working times. But with poured or pumped structural concrete (mainly for inner

segment and invert concrete), this “sprayed concrete activation” immediately before installation is complex and therefore not practically possible to achieve.

Therefore the planned working times and the stripping times required, including the early age strengths to be obtained, had to be pre-planned when the concrete was produced. On the Gotthard Base Tunnel it was +4 hours for the invert concrete and +12 hours for the inner segment concrete formwork after concrete placement. The compressive strength required was > 5 N/mm² on a 15/15/15 cm test cube. A suitable balance had to be struck in the concrete mix between plasticizing for workability, retardation and then rapid hardening. This was adjusted accordingly by using three different concrete admixtures in different ratios that were also adjusted according to the ambient conditions.

Table: HOCHTIEF test results, Bodio /Faido



Graphic: Results of the laboratory tests with original base materials as part of a feasibility study for long-distance transport of concrete in 2004 by the contractor HOCHTIEF Consult Materials.



SIKA PRODUCTS AND SERVICE ON THE SITE

On large tunnel construction sites, the main works of tunnel excavation, stabilisation, waterproofing and lining are accompanied by an almost endless series of other works, from minor concrete repairs to complete flooring systems, railfixing or fire protection. The main works such as the concrete, sprayed concrete concepts and tunnel waterproofing systems, are determined in complex preliminary tests before the final contracts are awarded (such as in the case of the Gotthard Base Tunnel by the prequalification process), but the solutions for the many other works have to be found quickly on site. Concepts and products are then evaluated and tested by site and the rest of the professional team. Sika is an ideal partner on such projects because of the wide range of different products and applications we can offer for almost any site construction requirement. Sika specialists and our Technical Support team can advise and help meet these challenges with the “right” solution. This cooperation was further strengthened on the Gotthard Base Tunnel by the year-round presence on the project of our on-site support team. Whenever a challenge had to be overcome, our people were on the spot; that creates trust!

In total, Sika supplied more than **40,000 tonnes** of products, including over 3 million m² of waterproofing systems.

The most significant Sika products and systems supplied are listed briefly below, although there were also many more every-day products and systems used as well:

Sprayed concrete (SB), blasting and TBM drilling:

- Sika® ViscoCrete® SC Plasticizer
- SikaTard® Retarder
- Sigunit® Accelerator
- SikaFume® Concrete additive
- SikaPump® Start-1 Pumping agent
- FlexoDrain W Channels
- Sika® PM-500 PC sprayed concrete system
- Sika® PM-702 Concrete pump
- Aliva®-503 Concrete spraying machine
- Aliva® L-1/L-2 TBM sprayed concrete system
- Aliva® AL-278 Concrete pump
- Aliva® AL-403 Dosing unit

Site-placed concrete (OB):

- Sika® ViscoCrete® Plasticizer
- SikaTard® Retarder
- SikaPump® Pumping agent
- SikaPump® Start-1 Pumping agent
- SikaFume® Concrete additive
- Sika® Separol® W Formwork release agent
- Sika® Mixer Protector, Surface protection



Sprayed concrete stabilisation behind the excavation with wet sprayed concrete in the TBM section.



Inner segment concrete for durable final lining of the two main tubes.



Temporary excavation stabilizing with dry sprayed mortar.

Immediate stabilisation and anchor bonding at critical points:

- Sika® Rock Shot-3 Dry sprayed mortar
- Sika AnchorFix® Anchor adhesive
- Sika® Intraplast® Injection additive
- Sika® Fix T-10 RX Injection resin
- SikaCem®-501 Rapid hardening cement
- Aliva®-252 Concrete spraying machine



For constant supply readiness, a warehouse was set up on site with the main Sika products identified as being required – “Shop on the Job”.

“Shop on the Job” – Everyday support:

- Sika MonoTop® Patching mortar
- Sikadur® Repair mortar
- Sika® FastFix Rapid hardening mortar
- Sika®-4a Rapid hardening binder
- SikaGrout® Grouting mortar
- Sikafloor®-2530 W Floor coating
- Sikaflex®-11 FC Sealant
- Sika Boom® Foam filler



Durable waterproofing systems applied after stabilising with sprayed concrete and before the inner segment concrete lining.

Waterproofing of tunnel structures:

- Sikaplan® Sheet waterproofing membranes
- Sarnafil® Sheet waterproofing membranes
- Sika® Waterstops
- Sikaplan® W Felt Protective geotextile
- Sikaplan® WT Tape jointing system
- Sika® Trapezoidal Profiles-Formwork inserts
- Sikadur-Combiflex® System Joint waterproofing
- SikaSwell® Sealing profiles



Sika specialists on site during the early strength testing of the sprayed concrete.

Technical advice and service locally:

- Site supervisors
- Technical advisors
- Concrete & mortar service team
- Equipment service engineers
- Product managers
- Customer service - Orders and deliveries



WITH SIKA, STEP BY STEP SAFELY INTO THE NEXT CENTURY

WATERPROOFING / CONCRETE PRODUCTION / CONCRETE PROTECTION / FIRE PROTECTION /
EQUIPMENT / SPRAYED CONCRETE



ALIVA SPRAYING MACHINES

SPRAYED CONCRETE SYSTEMS

In the spring of 2002 we were able to deliver the first two ALIVA-500's (shotcrete systems) to Faido. After training and support, set-up adjustments to the equipment and with constant support from Sika, they found they were able to work better with this type of mobile. As time went on the users learned to appreciate the advantages of the Aliva equipment. At that time the ALIVA-500's were from our own production with our own ALIVA-278 piston pumps with a capacity of up to 20 m³/h.

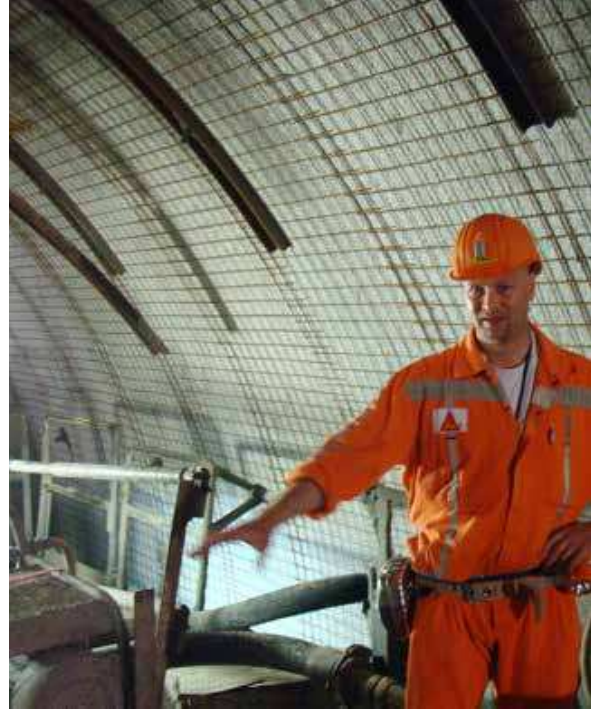
In autumn 2002 we also delivered two more ALIVA-500's to Sedrun for the Transco consortium. With continuous professional support from the Aliva technical and customer service teams, the machines also survived the initial prejudices at Sedrun. These machines were extensively used more than normal due to some adverse conditions in service and the 4/3 shift operations.

In mid-2003 the strategic alliance between Putzmeister and Sika was agreed and Aliva stopped making its own mobile sprayers. Between 2003 and 2006 nine more mobile sprayers were in use at the Faido and Sedrun sites, making a total of 13 mobiles in operation at these two NRLA sites.

Specific project sprayed concrete equipment for the Herrenknecht TBM S-210 and S-211 of the Consorzio TAT Bodio/Faido

At the end of February 2002 Sika signed the contract with Herrenknecht AG to provide the concrete spraying equipment for the two tunnel boring machines in the Bodio and Faido contract. Installation began at Schwanau in April for the first TBM, which went into service in the September. Equipping for the second TBM began in parallel about three months later. Final acceptance was only given after 500 metres of tunnel were driven on the site and was confirmed at the end of 2002 for the first TBM and the beginning of 2003 for the second one.





Manufacture and equipping of the two TBMs therefore took about a year. The two tunnel boring machines were in service in the Faido section for about eight and a half years, including interruptions and rebuilds. All of the concrete spraying equipment installed operated reliably in service and we completed this large and important contract to the satisfaction of Herrenknecht and the Consorzio TAT.

Various items were installed on both TBMs:

- System controls
- Accelerator dosing unit
- Compressed air system
- Mortar tubs
- Shotcrete pumps with conveyor lines
- Robotic sprayer in L1 and L2
- ALIVA-503 for levelling shotcrete
- ALIVA-263 rotor machines for levelling shotcrete
- ALIVA-252 and AL-237 rotor machines for immediate stabilising with dry gunite
- Other ancillary shotcrete equipment

At Sedrun, a PM702D shotcrete piston pump with AL-403.5 dosing device and an AL-246 small rotor machine were also used. An AL-246 was also used at Faido. An AL-504 (wheeled robotic machine) was used with an AL-263 for the cross-cuts in the Bodio and Faido section. To fill the large cavities in the TBM assembly cavern, it was decided to use pneumatic stowing with 8 – 16 mm gravel. The material was fed by the low-build process with an AL-285 and AL-262.

Sika and Aliva successfully demonstrated all their core competencies in the NRLA project on the Gotthard. Along with the engineering, we manufactured, supplied and installed the bespoke systems mounted on the TBM. All the rotor machines and spraying systems and equipment that we had in the range at the time were put to use. Our local customer service played an important part in the overall success with their many deployments for repairs and modifications at Sedrun, Faido and Bodio.

We are proud to be part of this magnificent project. Sika products and Aliva machines and services have a vital share in its success.

SIKABAU

SPECIAL TO THIS PROJECT

The largest contract ever undertaken by SikaBau AG was for the southern Gotthard Base Tunnel in the Bodio and Faido sections. The Bodio section has a total length of 31.5 kilometres and the Faido section 27 kilometres.

Due to the tight construction programme and sequences within the TAT consortium's lining installation system ("Wurm"), up to 36 metres of TBM profile (ca. 800 m² area) had to be waterproofed per day. That meant both a very high performance from the two semi-automatic installation systems per waterproofing workstation (Wurm) and a logistics masterstroke. Since only a limited quantity of material could be stored on site (fire risk and just lack of space), the waterproofing materials had to be ordered and delivered just-in-time.



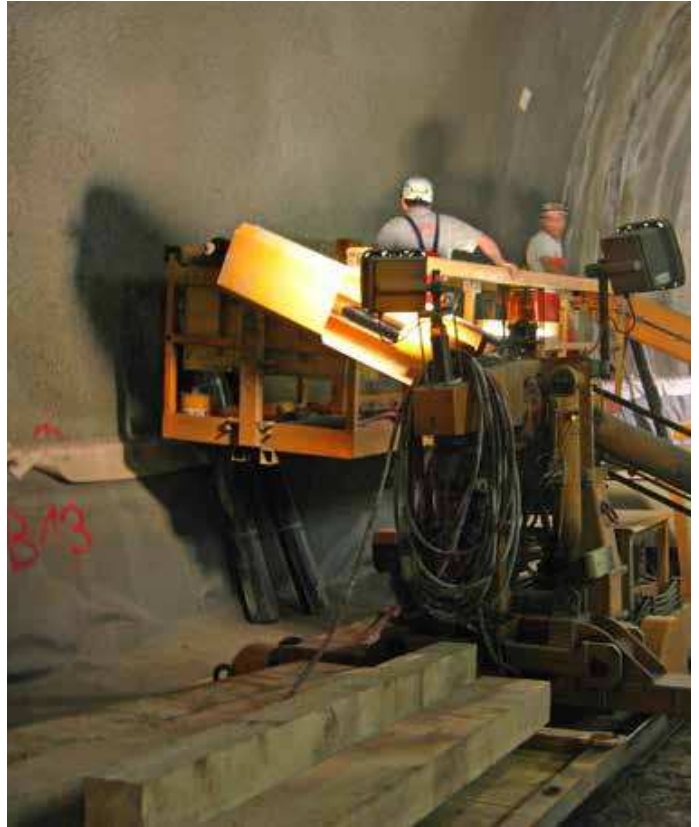
The single-track-tunnel profiles of the TBM and the special profiles such as for cross-cuts, multifunctional areas and tunnel branch-offs were all specified as lining sites. They often had to be handled simultaneously with the main waterproofing works. The team regularly worked 7 days in 2 shifts and the crew had to be increased temporarily to up to 32 people. Lining interruptions or hold-ups within the workstation works (which were subject to a high penalty clause) were prevented by very flexible working schedules and technical expansion to twin installation systems for each workstation (redundancy of key installations). The management personnel permanently on site were a quantity surveyor and a foreman. The construction manager and his Technical Manager were at the lining sites several times a week.

The shortest – but not the easiest – NRLA was Sedrun

The access tunnel was 909 metres and there was then a shaft system over a depth of about 850 metres. The EST's of the east and west tubes total about 17.3 kilometres in length. The shaft base divided the Sedrun lot into a north/south section, the northern part totalling only 6 kilometres. The materials and labour could only be taken to the working areas through the existing shaft system. At the north and south arch lining sites, it was possible to carry out the waterproofing works with two installation units. The SikaBau AG team applied the waterproofing on 5 days a week, resulting in an average weekly lining output of at least two blocks or 20 metres of tunnel per day (ca. 450 m²). The maximum team size was reached with 15 people working a 2-shift operation. Local management support was implemented by regular checks by the construction manager and a team of supervisors working permanently on site.

Some 25,000 m² of waterproofing membrane and drainage material per kilometre of tunnel were installed in the two main sections, Bodio/Faido and Sedrun, or about 2.5 million m² of waterproofing materials over the full construction period. Special waterproofing systems had to be developed and then approved for these NRLA requirements.

In all, SikaBau AG carried out over 12 years' work on these two sections of the Gotthard Base Tunnel.



THE NRLA FROM MY PERSPECTIVE

Christian Anderrüthi, Sales Manager Tunnelling



THE NRLA BEGAN FOR ME ABOUT 16½ YEARS AGO

Shortly before Christmas on 19 December 1999, together with Coni Sommerauer, I carried out the sprayed concrete tests with the Pizzarotti SA / Muttoni SA consortium at Faido Plomengo. At -11 °C it was icy cold and a special experience. The work on the Faido access tunnel with the Italians was very instructive and interesting. At first the executives and construction managers were rather overwhelmed by the quality specifications and the hard line taken by the site supervision.

After about six months and one kilometre of tunnelling, everything gradually started going to plan. The fact that the main contractor consortium was multinational did not necessarily make things easier all of us. Tenacity and obvious know-how won through in the end and we were able to service and supply the site from start to finish. Pizzarotti SA even strengthened its operations in Switzerland as a consortium partner in the Sedrun contract and opened a branch in Bellinzona.

Base Tunnel

The concrete system made it necessary for the Holcim-Sika bid consortium jointly to undertake to supply specific advice and support services to accompany its products. For each of the Sedrun, Faido and Bodio sites, a Technical Site Support person was made available and was permanently on site.

Their functions were very extensive and included:

- Supervising some sprayed concrete works in the tunnel (early strength measurement / checking of all tests during sprayed concrete application according to the inspection and test plan)
- Reporting to the Holcim-Sika consortium
- Contributing to development / implementation of the quality assurance plan
- Inspecting the fresh concrete during concrete qualification tests
- Contributing to technical modifications and economic improvements to the concrete mixes (OB/SB) with Holcim-Sika
- Emergency backup in case of problems:
 - Cement, additive and concrete admixture logistics
 - Holcim-Sika consortium application equipment
 - Concrete systems support

As a result of my close relationship with the site supervisor and regular close contact and support meetings on the concrete and sprayed concrete, as the Technical Advisor & Sales Engineer of Sika Schweiz AG I was viewed and accepted almost as an employee of the consortium. I could move around fairly freely on the sites and was given my own personal electronic access badge. So I was also able to accompany visiting groups from various divisions and other Sika companies and guide them around any of the three construction sites at Faido, Bodio and Sedrun.

The contacts were just as close during construction of the shell, with Holcim (Schweiz) AG, Engineering and Production. From my perspective I can say that this focussed and detailed cooperation resulted in client and project relations which were very close, solution-based, fair, friendly and good, in a spirit of partnership.

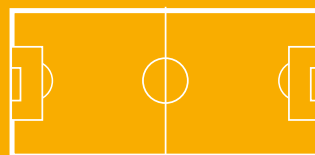
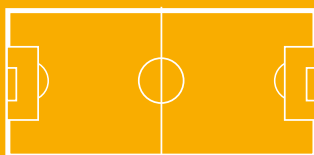
I am happy to be part of the NRLA.

Christian Anderrüthi

SIKA RECORDS ON THE GOTTHARD

3.3 MILLION m²

of Sikaplan® waterproofing membrane
equivalent to about 330 football pitches



**40 000 TONNES
OF MATERIALS
DELIVERED**

equivalent to
1700 rail wagons



**20 000
TONNES**

of admixtures
equivalent to
222,222 Emmental
cheeses



**12 662 500
MINUTES**

of work by Sika employees



INTERVIEWS ON SITE

The views of Daniel Spörri and Urs Streuli



Daniel Spörri, Divisional Manager Implenla Tunnelling Schweiz.



Urs Streuli, Branch Manager Underground Construction SikaBau AG.

In the light of compliance with the concrete and waterproofing systems specified by the client, there was close cooperation between the consortium (on site) and Sika. For the two contracts in Ticino at Bodio and Faido and the Sedrun section we could call ourselves the system supplier along with today's Holcim. In the south, Daniel Kalbermatter was the site supervisor responsible and permanently on site. Peter Gander was responsible at Sedrun.

Ticino interviewee

DANIEL SPÖRRI – then site manager of the TAT consortium for Faido and Bodio and now divisional manager, Implenla Tunneling Switzerland.

Sedrun interviewee

URS STREULI – then Technical Manager of Transco Sedrun. Now Branch Manager Underground Construction at SikaBau AG.

What impact did this close cooperation have on the construction quality in general?

Urs Streuli

The good and very cooperative technical relations between us enabled many different problems and requirements to be handled and resolved promptly. The desire for a very good quality result was ever present and this was achieved.

Daniel Spörri

With the professional support of the two system suppliers Holcim and Sika, all of the fresh and hardened concrete specifications were met, despite extremely challenging external conditions. Overall we were able to achieve very good concrete quality. There is nothing standing in the way of the required 100-year service life.

What impact did this close cooperation have on the concrete technology in general?

Urs Streuli

The stringent of the concrete specifications was relaxed by technical improvements and modern products. The technical and quality requirements were well, even very well met by the concrete systems and mixes used.

Daniel Spörri

The client's concrete specifications posed major challenges for everyone involved in the concrete works (producers, suppliers and ourselves as main contractor). The mixes originally approved did not meet our needs at all, particularly in terms of workability, but close and good cooperation with Holcim-Sika enabled suitable solutions to be developed. The experience of the cooperative team and the technical expertise of these suppliers, and the concrete producers with the contractor generated

concrete solutions and technical advances that would have been considered unthinkable five years earlier.

How do you define the relationship with Sika during the NRLA shell construction phase generally?

Urs Streuli

Very good and to be recommended. The basic reason for this success was certainly that the people involved all had the same level of technical understanding and we did not have to work with different languages or ideas.

Daniel Spörri

We always had a very good relationship with Sika generally and with our direct contacts in particular. It was a successful, cooperative and professional collaboration of partnership at all levels.

Can you recommend the concrete system with site supervisory model?

Urs Streuli

Due to the short information paths and regular site visits by the concrete system Technical Advisors, successful workmanship supervision and monitoring were guaranteed at all times through the contract.

Daniel Spörri

As I have already said, the concrete system was initially quite an uncomfortable issue for us and was very difficult for us to control, because the workability under real conditions was obviously not a criterion in the concrete system approval process. In addition, the aggregates supplied by the client were obtained from recycled material excavated from the tunnel and surrounding quarries and so were subject to wide variations over long sections in mica content, fines and in some cases even chemical reactivity. This directly affected the fresh concrete characteristics and therefore the workability.

It led to very many meetings and discussions in the initial phase. Fortunately the concrete characteristics were improved so much by continual optimisation that we were increasingly supplied with high tech concrete which was not sensitive to the variations in the aggregates. With these improvements to the fresh concrete characteristics, working times of 6 – 9 hours for site-placed concrete and up to 15 hours for sprayed concrete were achieved without adversely affecting strength development. With these good, stable mixes we could then also transport all the concrete from Bodio to the Sedrun site boundary and also use it there. It was not necessary to build the Faido

concrete plant underground. I can recommend this concrete system only if there is good service provided on site.

Is there anything else you want to mention particularly?

Urs Streuli

I can look back on these works and on the concrete systems with pride and satisfaction. We resolved all the trials and tribulations together to ensure that a more reliable concrete could be installed. The relationships with colleagues became one of friendship and warmth which continues to this day with anecdotes from the past often accompanied by a glass of good wine.

Daniel Spörri

We dealt with the same main contacts from Holcim-Sika the whole time. That certainly helped and also created trust.

Last word

Urs Streuli

Many thanks for the many good ideas and tireless courage that was needed for this project success.

Daniel Spörri

The experience showed that we banked on the right partners and system suppliers. I also have fond memories of the paella parties and barbecue evenings for our colleagues from the office and on-site who grappled with the concrete day after day. Sincere thanks!





STATEMENTS

Impressions and experiences of Sika colleagues

CONRADIN HÜRLIMANN, HEAD OF TECHNICAL DEPARTMENT

- **What was the most important experience?** One of my jobs was to improve the concrete mix for the inner segment in Sedrun so that the strength at stripping could be reached more quickly without reducing the working time. We soon realised that for this problem it was impossible to simulate the site conditions reasonably. After a brief rough evaluation in the laboratory, we soon focussed on field tests on site.
- **What was the most difficult challenge?** The concrete tests on site mentioned above had to be carried out at the concrete plant at the base of the shaft while construction operations continued. Each test took at least four hours, many were hard to schedule and at times we had to improvise at short notice. The greatest challenge was to think of everything despite all this and to prepare the tests well enough to obtain results which could be compared with one another.
- **What was the most memorable experience?** Naturally the Sedrun site was very exciting. I was particularly fascinated by the logistics. But my best memory is of the sausages that we cooked in an empty kiln pan to eat whilst we were waiting between concrete tests.

THOMAS HIRSCHI, REGIONAL MANAGER CENTRAL SWITZERLAND

- **What was the most important experience?** Working as a team with many internal and external players and always pulling together. It was clear that for a key project of this size, prior investment is always necessary and pays off in the end.
- **What was the most difficult challenge?** Meeting requirements that were previously considered impossible. Breaking new ground in concrete technology.
- **What was the most memorable experience?** They are many: Such as driving to Ticino at all possible and impossible times to carry out concrete tests yet again, often fruitlessly. The breakthrough celebration is a highlight of every tunnel project and the Gotthard was no exception. I also remember many site visits with Sika personnel from around the world. It was always a pleasure to see and amaze those people.

MICHAEL VORWERK, PRODUCT ENGINEER (EX-IMPLENIA)

- **What was the most important experience?** I met people on the Sedrun section who were prepared to put personal advantage behind them. I found very strong motivation and activity to achieve the team goals. This good experience was what I took away with me.
- **What was the most difficult challenge?** People from different nations and cultures coming together and stood side by side to create a monumental structure together that would continue to astonish many generations to come.
- **What was the most memorable experience?** At every St. Barbara's Day celebration I saw pride on the faces of friends and colleagues that they were helping to build this tunnel day by day. With these people we overcame all the setbacks and now we can celebrate our success on the mountain.

JÜRGEN SCHLUMPF, CORPORATE TARGET MARKET MANAGER CONCRETE

– **What was the most difficult challenge?** At the time of prequalification in 1996 the client required a concrete working time at $> 25^{\circ}\text{C}$ of six hours with subsequent high early strength. During the construction phase this requirement was increased by the contractor to a pumpability time of eight hours. This was totally unique at the time. Through extremely close cooperation between the contractor responsible, Sika Concrete Technology and Sika Research & Development, these standards were reached unerringly throughout the construction phase. Ultimately these project requirements also became the starting point for the Sika ViscoFlow® product range which is now so successful around the world.

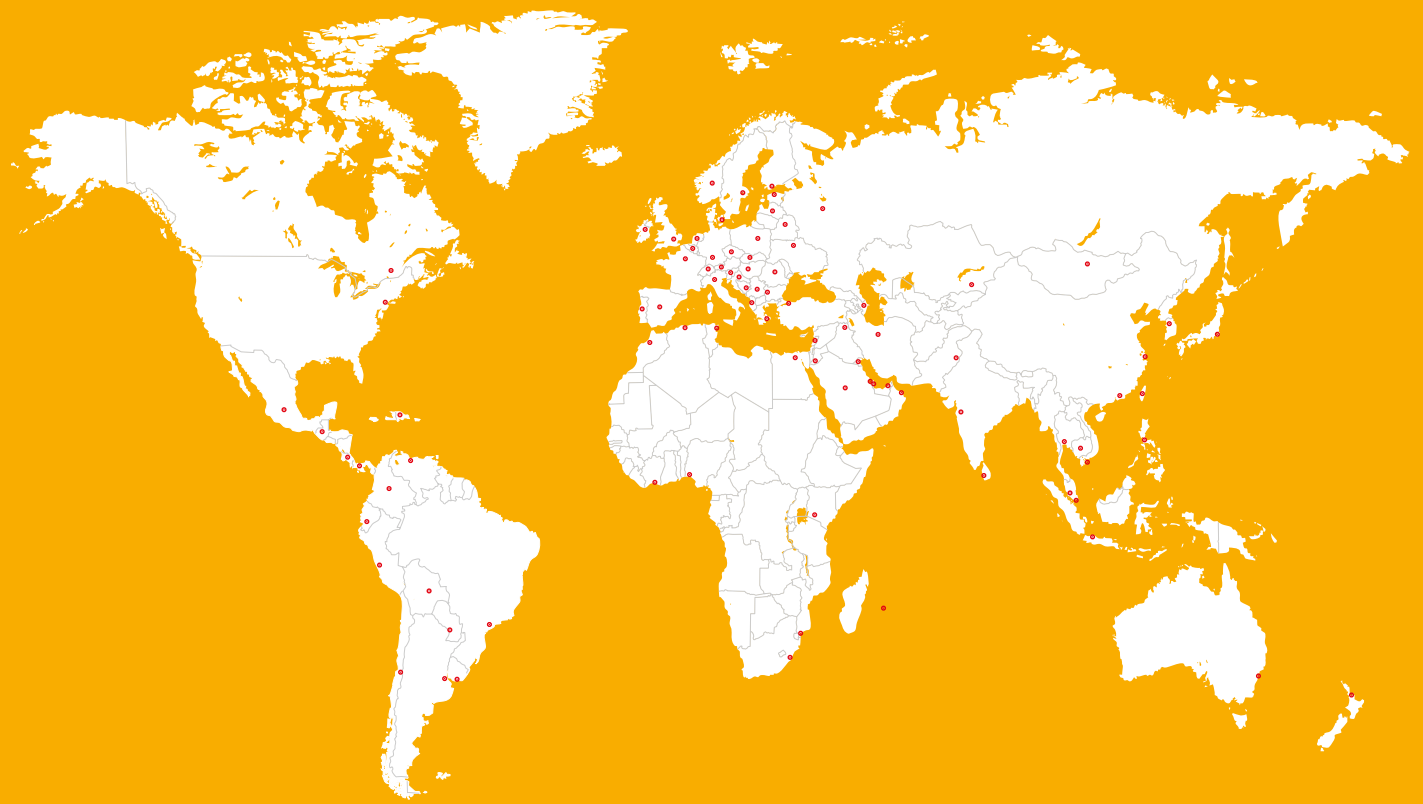
– **What was the most memorable experience?** After I joined Sika as Product Engineer, Concrete Admixtures in 1993, only a year passed before I had my first contact with the Gotthard project. It was concerning high early strength concrete in the Piora exploratory tunnel. We developed a solution suitable for the client – Sikament® HE-200 – and were awarded the contract. Even then I spent days (and nights) on the site. Later during the prequalification process from 1995 onwards I even spent entire weeks in the Hagerbach test tunnel to check out our main concrete systems. At the end of 2001 the “actual” concreting works began in the tunnel, where members of my teams turned the preliminary work into reality. For me the years that followed tended to be filled with meetings on the potential and limits of the systems on the Gotthard. It all ended for me on 15 October 2010 with the breakthrough between Sedrun and Faido. For 15 years the Gotthard Base Tunnel was part of and defined my working life. Almost anything is possible!

CHRISTIAN ANDERRÜTHI, SALES MANAGER TUNNELLING

– **What was the most memorable experience?** It was in 2000 only about 4 or 5 months after the start of the Faido access tunnel. After the blast round (around three metres of tunnel were blasted) I walked with the experienced older site manager from Amberg, Franz Walker, towards the working face and climbed with him onto the newly collapsed excavated material. Franz had seen a fissure and assumed there were minerals. It was dangerous to climb onto the broken rock because some of the corners and edges were razor sharp. When Franz and I were standing right at the open, unprotected working face and he was working at the fissure with a hammer, there was a loud bang. About a metre behind us a large lump of rock 2 – 3 m² in size and 25 – 30 cm thick fell down from the roof onto the heap of rubble. I was so frightened that my knees went weak and I was unable to climb down from the rubble without help from Franz. After that experience I am rarely to be found in the unprotected area in the tunnel bore, and unwillingly if so. I experienced in my own body how dangerous daily work is for miners and tunnellers and why they regularly give thanks to their patron saint, Saint Barbara. When I go underground I have great respect for the mountain and celebrate the Feast of Saint Barbara with the miners on 4 December. Now and again I make the sign of the cross to the blessed statue found on the portal of every gallery or tunnel.



GLOBAL AND 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, industrial flooring as well as roofing and waterproofing systems.

Vor Verwendung und Verarbeitung ist stets das aktuelle Produktdatenblatt der verwendeten Produkte zu konsultieren. Es gelten unsere jeweils aktuellen Allgemeinen Geschäftsbedingungen.



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