Sissach's Saved by a Bypass

by Daniel Herzog

The small village of Sissach, near Basel, in Switzerland is one of the nicest Swiss villages in the country, but the serenity is plagued each rush hour by heavy commuter traffic. The solution was a bypass tunnel running through the Chienberg hill to the north side of the village. Shallow cover, unconsolidated material at the portals, a TBM pilot tunnel, and the potential for squeezing ground conditions distinguish the Sissach tunnel from many tunnels currently under construction in Switzerland.

The 2284 m (7500 ft) long Sissach bypass tunnel runs a maximum of 120 m (395 ft) beneath the Chienberg hill and beneath the picturesque homes of the Sissach village. It was originally intended to run the two-lane bidirectional bypass up and over the hill on the surface, but protests by the local villages forced the local Canton government to adopt an underground route for the heavy commuter traffic currently passing through the village.

To accommodate the shallow underground route, the alignment is divided into three separate sections: a section of 550 m (1800 ft) cut-and-cover and 200 m (656 ft) cover and cut on the west end, followed by a 1440 m (4725 ft) length of mined tunnel, and a 94 m (308 ft) section of cut-and-cover at the east end.

The first 550 m (1800 ft) of cut-and-cover on the west end of the project was completed under a separate contract and included the boxed section over the Ergolz River. The contract for the main bypass civil works, including the mined tunnel, was awarded to the Arge Chienbergtunnel Sissach, a joint venture led by the Batigroup, Switzerland's largest construction company formed by a merger in 1997 of former Swiss companies Stuag, Schmalz, Preiswerk, Stamm, and T&K. At 120 million SFr ($80 million U.S.), the Arge's tender was the second highest of five bids, and, although the lowest bidder did contest the result, the Canton highways authority, with its project designer, the Aegerter & Bosshardt/Gruner joint venture, favored the technical content of the Batigroup-led tender. While much of the construction detail is designed and specified by the project engineers, the tunnelling work is complex and requires specific technical input and expertise by an experienced contractor.

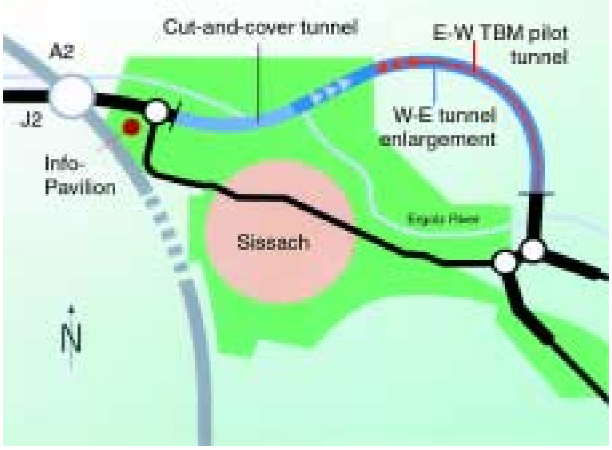

Figure 1: The new 3 km (1.86 mi) long bypass with its 2284 m (7495 ft) tunnelled section will rescue the picturesque village of Sissach from incessant commuter through traffic to and from nearby Basel.

Squeezing ground

One of the greatest concerns was the potential for squeezing ground. The principle geological deposit of the area is a dry, competent, and medium-strength anhydrite. When in contact with water, the material will swell. A 30-year-old tunnel in the same region is currently undergoing expensive and complex remedial work to repair damage caused by this phenomenon. The solution for the Belchen Tunnel was a drainage tunnel beneath its alignment.[1] For Sissach, the design and construction sequence was adopted to solve the potential problem.

Excavation of the rock tunnel was specified to begin with a full-length TBM pilot tunnel in the top and center of the full tunnel profile, followed by enlargement to full section using drill & blast on a top heading and bench sequence. The use of water was limited to the suppression of dust during excavation of the TBM pilot and to flushing out the drill holes in the drill & blast enlargement. In addition to confirming geological data, the TBM pilot was required to minimize the volume of explosives in each blast to limit vibrations and to reduce the creation of cracks through which water could permeate the host rock from the surface. Finally, the finished tunnel would have a fully hydrostatically sealed waterproofing membrane behind its unreinforced in-situ concrete final lining of up to 1 m (3.3 ft) thick.

Within the design and as a further consideration to the swelling nature of the anhydrite, the 1 m-thick in-situ final lining must be in place and completed within 3 months of opening up the tunnel's enlargement top heading—that is, all the various stages of tunnel building, from excavation

[1] *TUNNEL Journal*, Issue 6/99 (September): Drainage gallery beneath the Belchen Tunnel.

Figure 2: After excavation by the ITC-Schaeff, tunnellers erect lattice girders ahead of immediate shotcrete support in the central pilot heading through the 340 m (1115 ft) section of unconsolidated material in the west portal zone.

of the top heading through immediate primary support, excavation of the bench, installation of the waterproofing membrane in the invert, casting of the invert deck, and installation of the arch waterproofing membrane. Casting of the concrete lining arch must progress together in a rolling program of no more than 3 months between the first operation and the last. This process, spanning a distance of about 300 m (984 ft) from the top heading excavation and the concrete arch formwork, required careful planning and execution.

Work on the site by the Arge started at the end of January 2000 and began with excavation of 340 m (1115 ft) and 140 m (459 ft) lengths of poor material at the west and east portal sections of the mined tunnel, respectively. An ITC-Schaeff excavated the unconsolidated soil in these portal zones and work began with a small central pilot heading of about 19 m^2 (200 ft^2). In August 2000, the pilot in the west heading was 220 m (722 ft) completed and work from the east portal had just started. Once the pilot in the west heading reached the solid rock face, excavation of the full 55 m^2 (592 ft^2) top heading began using an umbrella of 15 m (49 ft) long spiling with a 5 m (16.4 ft) overlap to pre-support the crown. The poorer, more unconsolidated material from the east portal required stabilization with chemical grout injection before excavation could start.

Figure 3, 4, 5 (above): The Aliva AL-500 shotcreting units at the west and east portal headings ready to apply the steel fiber-reinforced, wet-mix shotcrete (left and right) with a closeup inset of the nozzle fixture.

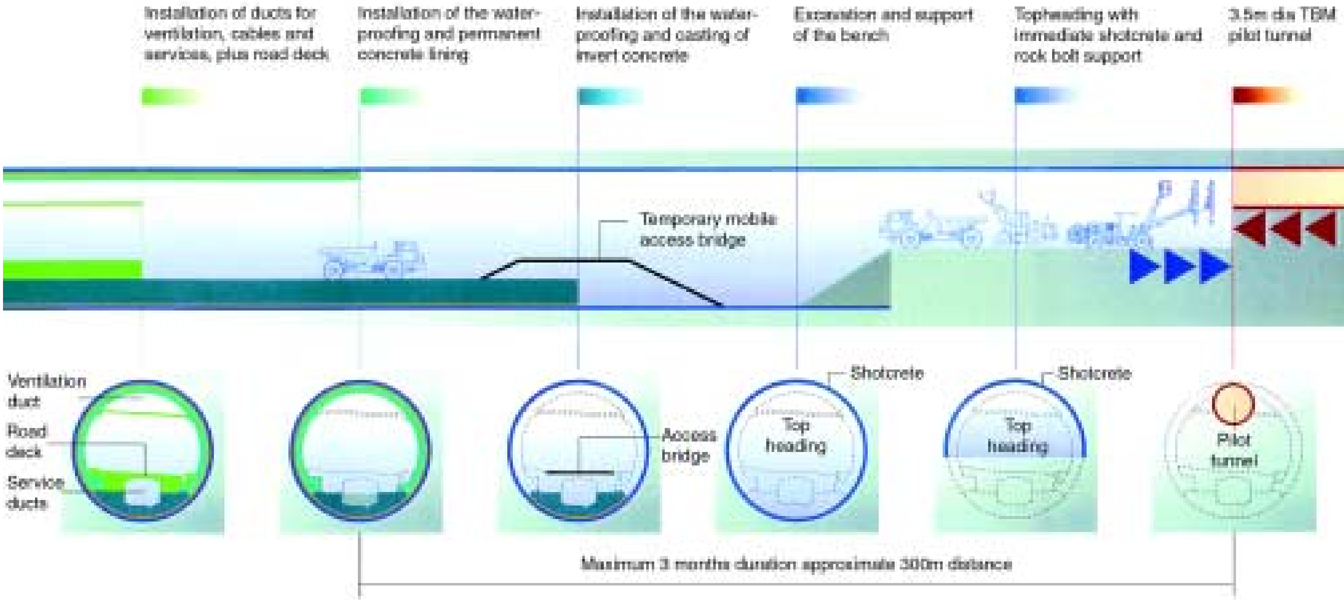

Figure 6: After completing the TBM pilot tunnel, excavating and lining of the drill & blast enlargement must advance in a 300 m (985 ft) long rolling program to seal the excavated tunnel within 3 months and avoid deterioration of the moisture-sensitive anhydrite.

Immediate support

Immediate support in these challenging conditions was based on steel fiber-reinforced, wet-mix shotcrete—or sprayed concrete, as many prefer—in combination with steel arches in the unconsolidated portal sections and patterns of 3 m (9.8 ft) and 4 m (13.1 ft) long rockbolts in the rock section. As part of the design specification, the Aegerter & Bosshardt/Gruner design team required a minimum 28-day compressive strength of the shotcrete of 35 MPa (5070 psi) and a minimum toughness or load-bearing capacity of 1,000 J when tested to the EFNARC square plate test.

Using a high-quality 52.5 cement blend in a mixture of 450 kg of cement per m^3 (758 lb/yd^3), a maximum aggregate size of 8 mm (0.3 in.), a water-cement ratio of 0.5, and appropriate shotcrete additives, the Arge mixture obtained strength results higher than specified. Test results after 28 days were up to 50 MPa (7240 psi), and early-age strengths were equally as impressive at up to 10 MPa (1450 psi) after 8 h and between 15 to 20 MPa (2170 to 2900 psi) after 24 h. Sika's superplasticizer Sikatard B10 was added to the mixture at the on-site batching plant at an additional rate of 0.8% of cement, and Sika's L53-AF liquid, alkali-free accelerator was introduced at the nozzle during application.

Toughness tests (or the ability of the shotcrete to carry load beyond its flexural capacity) were conducted in accordance with the flexural toughness plate EFNARC 10.4 standards. The minimum 1,000 J toughness before failure was achieved using 40 kg/m^3 (67 lb/yd^3) of Dramix steel fiber added to the mixture at the batching plant.

Shotcrete was applied using two mobile Aliva AL-500 shotcreting machines. The rigs were equipped with an Aliva two-piston AL-278 wet-mix concrete pump, an AL-403 accelerator dosing unit, and a telescopic AL-307 nozzle robotic arm. There was space on the carrier deck of the units for up to four containers of accelerator as well as space for an on-board compressor if required. The units were driven from a protected driver's cabin with a fully reversible driver's console. Sturdy outriggers ensured a level and stable setup for the rigs at each face, and the pump itself was mounted on a lifting device, which assured easy access to the truck mixer. In addition, the electric cable reel was mounted within sight of the driver to ensure controlled roll-up of the cable at the end of a shotcreting cycle.

All functions of the mounted units were regulated from a central control box that provided clear displays of operating functions. Output of the AL-278 pump could be adjusted in increments of 1 m^3/h (1.3 yd^3/h), and a programmable logical control (PLC) system automatically adjusted the compensator in steps of 1% to minimize pulsing in the flow of the shotcrete at the nozzle. The PLC also provided accurate feed of liquid accelerator from the dosing unit ensuring that the accelerator was fed automatically and in proportion to the set working capacity of the pump. The PLC also automatically shut off the pump if the feed of accelerator was interrupted.

The nozzle mount at the end of the boom provided a 360° nozzle rotation through a spraying angle of 240°. The remote control console provided the nozzleman with the flexibility to ensure optimum spraying performance for small, confined tunnel faces to large, open tunnel faces.

In August 2000, the project manager for the Arge explained that once the top heading through the 140 m (459 ft) weak zone from the east portal had reached the rock face, the TBM would be transported to the site, assembled, and would be ready to start the pilot tunnel through the central 950 m (3117 ft) of the rock tunnel in April 2001. "The TBM for the pilot is a 3.5 m (11.5 ft) diameter Robbins machine that was owned originally by the T&K arm of Batigroup. It is one of the earliest Robbins machines built," explained Schwarz. "It was bought about 35 years ago and has been refurbished about 10 times. The TBM pilot bore is in the crown of the full 12.5 m (41 ft) diameter road tunnel and will be supported using steel arches and steel fiber-reinforced shotcrete before being demolished as part of the drill & blast enlargement phase. The machine will be launched from the east end of the tunnel, and it is expected to take about 3 months to complete the 950 m (3117 ft) drive."

Working schedule

Excavation of the 1440 m (4725 ft) long mined tunnel with its previous TBM pilot and concurrent lining operation are expected to be completed by mid-2003. The new 200 million SFr ($133 million U.S.), total 3 km (1.86 mi) long bypass with its two associated bridges and cut-and-cover tunnel connections is scheduled to be opened and in operation by the end of 2004.

Daniel Herzog is Regional Sales Manager for Sika-Aliva, a manufacturer of concrete admixtures, concrete spraying machines, systems and accessories for wet, semi-wet, and dry spraying processes. He is responsible for the regions of Europe, Near East, Africa, and North America. Most of his experience relates to the field of sprayed concrete in several disciplines such as concrete repair, slope stabilization, and rock support for excavation in tunnelling and mining. His fields of expertise include equipment, execution, and concrete technology.