Gotthard Base Tunnel: Tunnel technology for the future

The Alp Transit Gotthard is an ambitious railway construction project, which will incorporate the world's longest railway tunnel of 57 km travelling through the Swiss Alps and under the St. Gotthard massif. Future passenger trains will journey at speeds of up to 250 km/h, adding further to the highly successful European high-speed network and bringing a huge reduction in travelling time. The combined surveying systems of Leica Geosystems and Amberg Measuring Technique Ltd are greatly assisting the tunnel workers in their day-to-day work - not only reducing time needed to ensure that excavation is correctly undertaken, but also making the whole construction process much more efficient and accurate.

The Gotthard Base Tunnel has been divided into five sections: Erstfeld, Amsteg, Sedrun, Faido and Bodio

In order to integrate Switzerland into the modern rail network, lines must be prepared which can be travelled at high speed. The Gotthard Base Tunnel, which will cost around seven billion francs, is thus the foundation stone of the Swiss railway of the future. The connections in international transport, built up around the nodes of Zurich and Milan, will become considerably faster, thus presenting a real alternative to travelling by car or by air. It is anticipated that between 200-220 goods trains will run daily following its completion.

The Gotthard Base Tunnel consists of two single-track tunnels that lie approximately 40m apart and these are linked by a series of connecting galleries every 325m. The entire tunnel construction has been divided into five sections, each with its own separate access point:

- Erstfeld - northern portal
- Amsteg - horizontal access tunnel, 1.2km long
- Sedrun - two blind shafts, 800m deep and 8 m in diameter accessed through a horizontal tunnel about 1km long
- Faido - a 2.7km long inclined access tunnel (adit) with a 12% gradient and a height difference of 300m
- Bodio - southern portal

The Gotthard Base Tunnel will pave the way in quality and safety with an extremely comprehensive safety system. By using two tunnels the possibility of head on collisions is eliminated and the two pairs of cross-over tunnels allow the trains to move from one tunnel to the other, which is particularly important during maintenance work. The Sedrun and Faido sections each include a Multi-functional Station that, in the event of an accident, provides safe rooms for passengers and emergency train stations. Connecting galleries provide track cross-over tunnels, a ventilation system and a quick route to the outside in the event of an evacuation. These intermediate access headings not only allow these safety features to be incorporated, but also allow up to four Tunnel Boring Machines (TBMs) to operate at the same time thus reducing the overall con-

struction time of the tunnel by almost half to nine years.

The geology and rock type of the area determines the method of tunnelling and therefore engineers must create different tunnelling profiles according to the rock encountered. Nearly 90% of the Gotthard Base Tunnel has rock that is suitable for mining using TMBs, with the remaining areas - the Sedrun section and the multi-function station at Faido - having to be excavated by drill and blast. Over major sections of the tunnel, the overburden will be extremely high, including 5km with more than 2000m where rock temperatures can be as high as 45^{o}C. These conditions all affect the methods and complexity of the tunnelling operation.

Tunnel Measurement System

It is in the depths of the tunnel at Faido that Leica Geosystems and Amberg Measuring Technique Ltd are providing an integrated surveying solution for the drill and blast method. Over 300m of this section has been excavated so far, and due to the immense pressure from the rock, the tunnel in this section is being excavated in two sections - firstly the upper part of the face and then the lower part, known as the heading and the bench. Approximately 450kg of explosive is required to advance each round and the tunnel advances at around one to three metres per day.

The LEICA TMS (Tunnel Measurement System) offers automatic profile surveying and setting out using total stations from the LEICA TPS 1100 Professional series. The concept behind this was to identify the production tasks required for the job and to automate them so that a non-surveyor, such as the tunnel foreman, could carry out the setting out.

Previously, in order to position the arches accurately in a tunnel, the excavation crew would finish a tunnel to the approximate profile required within which to fit the arches. The site surveyors would then be called back on site to examine the work, place the arches in the face and then direct further work. If the face had not been excavated to a large enough profile, then the arches had to be removed and the excavation continued. Alternatively, if the profile was too large, the quantity of shotcrete required in between the arches would be increased considerably. Both activities significantly increase the costs of the tunnel construction.

In the tunnels, Leica TCRA1105 total stations are mounted high on the walls and are controlled by the Leica TMS which automatically performs the surveying and monitoring work such as alignment, excavated profile, position of arches, or thickness of shotcrete required. Each Leica total station contains the powerful onboard LEICA TMS SETout PLUS software. The surveyor prepares and enters all the project data and geometry using the Leica TMS OFFICE on an office based computer and then transfers this information to the total station via a PCMCIA card prior to job commencement.

Kurt Weidner, Senior Surveyor from Amberg Measuring Techniques, is one of the contracting surveyors on-site at Faido. "We are using completely Leica tools here at this site," he said. "TMS, the combination of the Leica total stations and the Amberg software, is currently being used in four tunnel sections. The total stations are used directly for the controlling of the arc position and the profile situation after we drill and blast and to ensure that the surface of our gauge is in the right form."

Setout made easy

Obviously in the construction industry, time is money and as such the Gotthard Base Tunnel is a 24-hours a day operation with eight-hour shifts for each six-person tunnelling crew. Every four days there is also an eight-hour period when the machines undergo maintenance. Handover between shifts only takes a couple of minutes and one or two people per crew are trained in using the TMS and are responsible for passing on information to the next shift. The Leica TMS greatly assists in a smooth handover and the continuation of work because all the project data is already there on the machine.

"The principle is very simple: the installation is undertaken by the surveyor and then we can explain and train people so they know what points need to be entered into the program," Kurt said. "We prepare the information plate describing what the section is and what the points are. These people can then use the instrument alone without any more support from the surveyor."

Once installed, the operation of the system is carried out by the construction site personnel, who do not need to have any specific knowledge about surveying. The key benefit of this approach is that there is no delay waiting for the surveyor and the work carried out by the excavation crew is more accurate and productive, thereby improving the process and saving costs.

"During any one shift there are six surveyors available on-site. The new system saves a lot of time and the surveyors are freed-up to continue with design work and solving other problems."

Leica TCR1105 total stations are mounted high on the walls where they undertake surveying and monitoring work

Senior Surveyor from Amburg Measuring Techniques, Kurt Weidner

Surveyor Elke Fischer prepares and enters all the project data and geometry using the Leica TMS OFFICE

About Amberg

The highly specialised companies of the Amberg Group cover a wide spectrum of underground construction tasks, developing solutions in order to advance into new dimensions of underground construction. Amberg Engineering Ltd. plans and designs new structures and refurbishment projects, provides site management, delivers expert opinions and carries out damage and state assessments. Amberg Measuring Technique Ltd. develops systems and instruments that address measurement problems in underground construction and the rail industry, which includes initial reconnaissance, site supervision and surveying.

The tunnelling foreman can do routine production surveying tasks using the TMS SETout PLUS in production mode, including:

- Drill and blast
- Conventional advance
- Roadheader advance
- Jetting and pipe umbrella
- Alignment laser
- Position arches

"It's very easy to use, people are working with it and they are happy with its performance. The remote control can be held in your hand, directly in front of you or you can control it over a wireless system," Kurt said. "We also have a special place for the computer that is set back 100-150 metres away from the work, for safety distance."

The Sedrun section and the multi-function station at Faido - have to be excavated by drill and blast

Adverse conditions at Faido

Although geological sampling and assessment can be carried out prior to the commencement of tunnelling, it is not until the excavators actually begin work that they know for certain what type of rock is to be encountered. This has been the case at Faido where, in April of 2002, a partial collapse occurred in the cross cavern vault, leaving a cavity about eight metres high. Despite the prediction of exploratory drill cores, a fault zone containing a very poor rock layer of silty Lucomagno geniss was encountered. This meant implementation of modified work methods and strengthening of the excavation support was necessary with deformable steel arches and a dense anchoring system.

"Deformations required some re-design of the tunnelling," Kurt said. "We prepare the theoretical profile based on the design drawings and change the profile according to the rock conditions. With the LEICA TMS, to prepare only a few coordinates of the profile, is no longer a problem. Previously, this all had to be done manually and took a lot of time."

Profile measurement

Another program available as part of the LEICA TMS is the LEICA TMS PROFILE which enables profile measurement and monitoring, providing a comprehensive comparison of design vs actual measurement and project data.

"We can also now monitor our precise position in the tunnel. We can establish if we are in exactly the right position for the profile, by comparing the measured tunnel meter with the theoretical one and we can adjust this immediately if it is wrong," Kurt said.

"Before we were never able to have this control and had to use a tape."

"Electronic Distance Measurements (EDM) defined on the integrated software of the total station allows us to have each point measured precisely after 10 seconds," Kurt said. "Alternatively we can use a special function of the program when we want exact control so that we can also select individual points. This is the part that is new in surveying."

Monitoring

As the tunnel progresses, it is necessary to monitor the tunnel profile for deformation. A lot of pressure is built up using the drill and blast method, and as such there is normally a difference between the powerpoint direction and the control point at the front. A Leica TCA2003 is used for this type of monitoring as it is more precise when millimetre accuracy is needed. Yellow targets with a white faces are used for reflection, and these are placed in the heading (at three points) and the bench (two points) of the tunnel.

"Over 300-400 targets have been installed so far for deformation monitoring," Kurt said. "These points are controlled one to two times a week in order to provide a record of the movement. The highest deformation measured so far has been 50 cm. Using the software you can see the calculation and check the points from 50-100 metres being the current head. Over a four-month period, the control points are checked twice, and the control brackets are checked once every four months.

Bt