Building on tradition

Heinz Ehrbar originally trained in hydraulics, which led to him specialising in hydro tunnels and culminating in his work on the Gotthard Base Tunnel (GBT) in Switzerland. He has now gone to new pastures. He spoke to George Demetri

Outline your education and career to date.
Having studied civil engineering between 1975 and 1980 at the Swiss Federal Institute of Technology, Zurich (ETH), specialising in hydraulic engineering, structural engineering and underground construction, I subsequently did my practical training in highway construction in the Ivory Coast (1978), followed by more practical training (bridge construction) in Finland in 1979.

Following my MSc in civil engineering in 1980, I worked at Electrowatt Engineering, Zurich (1981-96). This was my first job as a hydraulic engineer, doing calculations for hydropower projects in Switzerland, Asia and Latin America; I was subsequently project manager for several hydropower projects in Switzerland.

From 1996 to 2000, I was project manager and head of the AlpTransit group within Electrowatt Engineering, responsible for the design of the Sedrun construction lot on the GBT, and also deputy chief engineer of the engineering joint venture.

I was AlpTransit Gotthard deputy chief construction officer (2001-06) and from 2006-12, chief construction officer for the civil works of the GBT. In 2012, I started my own consulting practice (Heinz Ehrbar Partners) for large infrastructure projects.

In January, I was appointed head of large projects at German Railways (Deutsche Bahn).

Which tunnel project have you found the most challenging and educational?
From 1996 until 2000, I was in charge of the design of the 57km GBT in Switzerland; from 2000 to 2012, I was the owner's representative. The project was very challenging due to its large size and the risks involved.

From 1999, in parallel with the Gotthard project, I was engaged as an expert on the underground works of the San Gaban hydropower plant in Puno province, Peru. This project was very important for my professional career and the most educational one. Fault zones, stability problems of cavern walls, and large water inflows were just some of the challenges to be overcome on an isolated site with very limited resources and without any further support from other experts. Together with my design engineer, we had to make informed decisions on site, which proved to be excellent experience. The San Gaban project was my personal proving ground for the GBT.

What was the biggest challenge you faced as chief construction officer from 2006 to 2012 on the GBT?
Many project criteria had to be met, like those concerned with health and safety, environment, quality/functionality, cost targets, the overall schedule, aspects of project organisation, design and construction processes, and also the requirements of the various stakeholders, especially public opinion.

The biggest challenge for the entire organisation is still health and safety. Even if our accident rates were low compared to former projects, they would still be too high. 'Target zero', as featured on London's Crossrail project, must be the future.

The optimisation of the general construction schedule in order to reduce final costs by reducing the total construction time by one year was also a very big challenge. The talks could finally be finished within a few months, thanks to the good partnership with all contractors.

Outline the current progress on GBT.
Preliminary work on the GBT began in 1994, with the main contracts starting in 2002. In 2011, excavation was completed, and exactly a year later, the inner linings of the tunnel tubes were completed. Since then, civil works have concentrated on the two multifunction stations of Sedrun and Faido, as well as the finishing of access tunnels and portal zones.

Since 2010, technical infrastructure systems, such as doors, ventilation systems and dewatering systems, are installed in parallel to the civil works. In 2010, installation of railway infrastructure began. In some sections, the installation is practically complete and ready for the first test drives (Bodio western tube). Commissioning will start in 2015, with the aim of opening the tunnel for commercial operation in 2016.

Outline some of the problems you find when tunnelling through very high overburdens and the impact this has had on design.
High overburden (1,000m and above) is related to the following phenomena: high initial stresses causing rock bursts in good rock conditions, or squeezing in poor rock conditions, high rock and water temperatures and also high water pressures. High overburden also prohibits a systematic and economically feasible pre-investigation of the ground conditions. The residual risks are generally higher under such conditions.

In the San Gaban hydro-power project, rock bursts and water inflows were the main challenges, whereas at the GBT, the whole spectrum of hazard scenarios was encountered.

Strong rock burst was a major problem in the area of the Faido multifunction station. In contrast to squeezing, which is a slow, observable process, rock burst is a sudden incident without clear advance warnings, creating major challenges in fulfilling health and safety requirements.

In the construction section of Sedrun, squeezing rock phenomena occurred over a length of 1,150m. This zone was overcome with full-face excavation at an average daily advance rate of 1m without major incident, thanks to a sophisticated tunnelling concept based on mining technology.

In the Faido section, unexpected squeezing rock due to two major unknown fault zones necessitated the reconstruction of certain tunnel sections, which entailed a delay of two years plus high additional costs.

Briefly outline the historic and current tunnelling situation in Switzerland.

Switzerland has a long tradition in tunnelling. In August 1708, the first Alpine traffic tunnel, the 68m Urner Loch, was completed on the Gotthard road.

Railway construction started in the mid-19th century, with the old Gotthard Tunnel (1882), the Lötschberg Tunnel (1913) and the Simplon Tunnel (1906/21) as showpieces.

After the Second World War, extended hydropower schemes with long tunnels, shafts and caverns were constructed. From 1970 to 2000, road tunnels were the most important project category. The Gotthard road tunnel, one of the most challenging projects, became the world's longest road tunnel when it opened.

Political decisions to improve the railway infrastructure were taken in the 1990s. Since then, many large tunnel projects have become a reality or are still under construction, such as the Zimmerberg Tunnel and the Lötschberg-, Gotthard- and Ceneri base tunnels.

Currently, two major pump-storage schemes with large underground systems are being constructed, and a third one is planned. New rail and road tunnels are required in the near future to improve the traffic infrastructure on the east-west axis, and in urban areas.

Finally, Switzerland must also solve the task of constructing a nuclear waste deposit that will entail 100km of tunnels – and more will be required. Since 1950, Switzerland has continuously produced 200-300km of tunnels per decade, which is an impressive figure for such a small country.

It looks like a second bore will be constructed for the Gotthard road tunnel to complement the existing road tunnel. Eventually, the two will operate in tandem, but with reduced capacity, as each is required to have one traffic lane and one emergency lane. Do you feel this constitutes a huge waste of resources?

Switzerland is a federal country with a system of direct democracy. For the past 20 years, there has been a clear political will to shift heavy transalpine traffic from road to rail. In 1994, Swiss voters accepted a public initiative, now part of the Swiss constitution, which forbids an increase in transit capacities on the roads.

Some elements of the Gotthard road tunnel have come to the end of their design life and will soon require major rehabilitation work. From economical, safety and operational aspects, it will be best to construct a second tunnel before starting to rehabilitate the existing. As road capacity cannot be increased, the two tubes will finally operate in single-lane mode. This may be considered a waste of resources for a few outsiders, but it is the will of Swiss voters who, in the past, have supported large infrastructure projects; their will must be accepted.

Altered groundwater conditions during tunnelling on the GBT could have caused settlement in the rock massif and thus posed potential risk to four nearby reservoir dams. What measures were taken to avoid this?

Since the incident at the Zeuzier arch dam in Switzerland during construction of the Rawil exploratory gallery, we know that the dewatering effects of tunnel drives in saturated hard rock can cause surface deformations of more than 100mm over distances of more than 1km.

The GBT alignment is near two important concrete arch dams. There was a high risk of differential deformations at both dam sites, causing damage to the arch dams. To avoid such scenarios, AlpTransit Gotthard installed a surveying system which monitored surface deformations over a large area in the Alps during a 12-month period. A team of experts defined the design criteria. In one case, the total amount of water drained from the ground was limited, though this was after grouting had been carried out.

In the second case, dam behaviour was monitored. In conjunction with the dam operator, mitigation measures were defined for the case of dam strain (fissure and joint grouting) or dam compression (appearance of additional deformation joints). To date, no damage has occurred to either dam.

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Can you say why a student or young engineer might choose to specialise in tunnelling over, say, structural, bridge or dam engineering?

The basic principles of engineering are, at least according to Swiss practice, the same for all categories of civil engineering. Based on their conceptual designs, civil engineers carry out their structural analysis and final dimensioning, having considered all relevant hazard scenarios.

Nevertheless, tunnelling is different from structural engineering due to the fact that the main construction material, the ground, is often either not well known or not completely known, and can change within a short distance. In certain cases, ground behaviour is also related to the construction method.

These boundary conditions, the static loads and unknowns from the ground, make tunnelling special and challenging. There are no recipe books or standard solutions that will give fast answers and allow the engineer to escape analysing each task separately. Unfortunately, in some countries, there is a trend to treat engineering challenges with predefined methods or classification systems based only on a few parameters. This is a questionable approach in my opinion and could even be dangerous in certain cases.

Nevertheless, I recommend tunnelling to engineering students who are interested in fast-changing and challenging situations, and who are not afraid of dealing with uncertainties.

What in your opinion has been the greatest technological advance in hard-rock tunnelling over the past 30 years?

Over the past few decades, both TBM and conventional tunnelling methods have made big advances. Experience from the GBT has demonstrated that TBM technology has attained very high reliability. No major delay was caused by any of the four TBMs, even in very hard and blocky rock.

Nevertheless, the challenges of supply chain optimisation to increase the overall availability of TBMs remain for the design engineers, contractors and manufacturers involved in the construction of future long tunnels.

Also, in conventional tunnelling, the industrialisation of tunnel drives has become reality. Full-face excavation for large diameters, hanging platforms and slurry explosives are some of the key factors in the development of conventional tunnelling over recent years; these have allowed safer, faster and more economical tunnel construction.

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