

PRESIDENT'S SELECTION

The Newsletter from the ETH Zurich President

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THE GOTTHARD BASE TUNNEL

High expertise underground



A world's first in tunnel construction at great depth: flexible steel arches control the huge mountain pressure.

On 15 October, with its final breakthrough in the Gotthard Base Tunnel, the NEAT project will set a milestone in the history of railway engineering. ETH Zurich has made a major contribution to the success of this 21st century work with pivotal experiments and a newly-developed building technique that finally conquered the mountain.

Visiting any of the Gotthard AlpTransit construction sites is an overwhelming experience. A huge team has performed outstanding work: planners and engineers, geologists, miners and site workers along with experts from several other disciplines have been working on the project for years. And the goal is clear: by the end of 2017, the Gotthard Base Tunnel must be ready for operation.

Expert knowledge and research have played a decisive part in the design and construction of the longest railway tunnel in the world. Without extensive scientific work in geology, underground construction and geodesy – and also zone and traffic planning – the ambitious structure may not have been accomplishable.

Compression tests with butter-soft rock

With its wide range of technical competencies, ETH Zurich contributed significantly to cope with major technical challenges. Of exemplary significance are the rock mechanical experiments that

were carried out for certainly the most critical section of the tunnel: the Tavetsch Massif. This was one of the hardest nuts for the tunnel engineers to crack. The rock, which is composed of granites and gneisses, was partly literally pulverised during Alpine Faulting, leaving butter-soft rock granules with incalculable geotechnical characteristics, so-called kakirite. The vital issue for the experts was to establish how much the rock would expand under the high mountain pressure arising after excavation.

The mountain goes wild

With inclined exploratory borings, samples were taken from the critical zones and examined in the rock laboratory of the ETH Institute for Geotechnical Engineering. From extensive compression tests, the mechanical characteristics of the samples could be determined and by numerical calculations the rock behaviour estimated. Because the mountain 'went wild' (mining jargon) after excavation, expanding up to 70 cm radially, a newly developed construction method was put into action. Heavy steel arches with sliding joints absorbed the large rock displacements before a thick 1.2m concrete shell was installed.



A kakirite sample severely deformed after testing.

Uniquely complex problematics

The Gotthard Base Tunnel presented unparalleled challenges to the engineers. At 57 km, the tunnel is not only the longest railway tunnel in the world but it is also overlaid in parts by 2,5km of rock mass. With no previous experience to draw on, it was uncertain how the rock would respond to the excavation. On top of this, there were two geologically critical zones to overcome: the Pióra syncline, with what was initially thought to be sugar-grained dolomite, and the Northern Tavetsch Massif, with its damaged rock mass of almost tooth-paste consistency.

EDITORIAL

Simply ingenious

Dear Reader,



With its two base tunnels, the NEAT venture is an achievement that will undoubtedly go down in history. From the outside, many people initially

saw the monumental project as a wild adventure with an uncertain outcome.

However, the experts commissioned with the project planning were no gamblers. Conducting a clear problem analysis based on scientific and technical facts they were able to point their clients in the right direction even when faced with highly-complex challenges.

Science and research are not secret doctrines or magic. Thanks to expertise, systematics, brains and a bit of luck, even projects such as NEAT can be successfully accomplished without a prototype.

It was the search for ingenious solutions with calculable risks that brought about the literal breakthrough. I wish you an interesting read.

R. Eichler

Prof. Dr. Ralph Eichler,
President ETH Zurich

"QUOTE ... UNQUOTE"

"We faced a totally unknown outset situation and had absolutely no example to work with."

Kalman Kovári, former ETH Professor for underground construction, on his task of chairing the Panel of Experts of Design and Construction for the Base Tunnels (1990–2003), a kind of NEAT task force.

PLANNING



Photo: AlpTransit
Lower Reuss Valley: a NEAT point of entry and a test planning area.

Space for development

The NEAT high-speed axis links together many of the strongest economic regions in Europe. In order to develop this corridor zone effectively, it is essential to use appropriate planning methods. ETH Zurich has been conducting research in this area for decades.

70 million people live within the scope of influence of the Gotthard and Lötschberg Base Tunnels and 700 million tonnes of goods will be transported on both axes, representing 50% of the rail freight traffic travelling north-south. These dimensions raise basic questions on the economic, spatial and rail developments of the future.

A new procedure, co-developed by ETH, involves test planning in which contributing ideas, switching between design and criticism, are crystallised into potential solutions. In the Lower Reuss Valley, for example, where 80% of the population of Canton Uri live, complex issues of settlement, infrastructure and land use development could be resolved in this way. The aim is for Uri to develop into a desirable residential canton with good transport connections to the nearby centres of Lucerne, Zug and Zurich but without abandoning local efforts for developing its economy independently.

GEODESY

Centimetre precision

Engineering surveying in tunnel construction is a crucial discipline as precision to the centimetre is needed to drive the bores through the rock. ETH Zurich actively supports geodesy in practice by developing and testing various surveying and evaluation procedures for tunnels of exceptional length.

In tunnel constructions abroad, geometric guidance led to discrepancies of up to 1 metre because atmospheric light refraction and other influences had not been sufficiently considered. These errors would have had catastrophic consequences for the Gotthard Base Tunnel since measurements of geographical north using a gyroscope are also dramatically distorted in this area due to irregular plumb line variances in the Alpine region. The huge masses of rock in the Gotthard Massif cause significant deviations in the plumb line between the mathematical shape of the Earth (ellipsoid) and its actual shape (geoid). For this reason, the underground bearings measurements need to be adjusted accordingly.

Latest technical expertise

For this specific purpose, the ETH Institute of Geodesy and Photogrammetry developed optimised mathematical models that were tested with a high-precision gyroscope theodolite even before construction on the Gotthard Base Tunnel had begun. This rapidly rotating gyroscope oscillates with the Earth's rotation and accurately determines geographical north.

Since the results were urgently required in the Gotthard, ETH always published the experiment results immediately and made them available to seminars of further education. In this way, interested engineering offices, who then wanted to offer their measuring services for the NEAT project, had access to the latest technical expertise.

IN SHORT

ETH knowledge

The NEAT construction triggered huge numbers of research projects and over a dozen dissertations. In addition, several hundred ETH graduates in engineering and natural sciences have been actively involved in project planning, development and execution. The transfer of knowledge from university to industry on this giant project – with total costs of approx. 20 billion Francs – has proven indispensable. If expertise and services had not been available in Switzerland, the result could have been added costs in the region of billions.



The water risk

Water is not always a precious commodity – in tunnel construction it is a problem (see water inrush above). The prognosis and modelling of tunnel inflows and rock mass deformations by experts from the Geological Institute at ETH Zurich were therefore essential for the NEAT construction. By combining basic research and practical expertise, the researchers were able to perform valuable predictions and analyses of ground surface deformations in the areas of sensitive concrete arch dams.

UNDER THE SPOTLIGHT: EINSTEIN SHOWS THE WAY



Photo: ETH Zurich

For the most challenging task of checking bearings in the Gotthard Base Tunnel, an inertial measuring system was used, such as is also used in flight navigation. But it was a world's first for ETH Zurich and TU Munich to take measurements underground with this system (without any visible points of reference or GPS!).

Descending with the lift down the 800 m deep shaft of Sedrun, acceleration sensors (according to Newton's laws) measured the way down, and gyroscopes (according to Einstein's theory) measured the changes in bearings, enabling the required coordinates to be calculated (the picture shows one of the precision theodolites used).

FINAL WORD

Debacle at the Gotthard

In 1996, the «Beobachter», a widely-read and traditional magazine, had commissioned a survey on the construction of the Base Tunnel. «A debacle looms at the Gotthard» was the title of the accompanying article in which selected professors and geologists warned of a fiasco. They claimed that the geology was much worse than the Swiss Federal Railways had admitted and in the worst case the tunnel couldn't be built at all. Today this statement sounds more like a media flop than a technical one. It's lucky that paper – almost like a mountain – patiently submits to all kinds of human effort.