

Cochem Tunnel: A Tight Fit

by Gerhard Weithe

Trains have been running through the Kaiser-Wilhelm Tunnel under the center of the historic town of Cochem on the Mosel in Germany for 130 years. Renovations are now being carried out on this tunnel, while at the same time work is in progress on a second tunnel. The new tunnel is 4,242 m (2.64 mi) long and scheduled to open to rail traffic in 2016. The 200 Mio. Euro (261 Mio. US Dollar) tunnel construction project is part of the Deutsche Bahn plan to extend the Coblenz/Trier line and bring its infrastructure up to current safety standards. Due to critical geological conditions, an automatic monitoring system was developed to transmit measurement data to the shield driver on the tunnel boring machine in real time.

The tunnel can be divided into sections based on the ground conditions it runs through. There is a 3,750 m (2.3 mi) section through sand- and mudstone and a 500 m (1,640 ft) unconsolidated rock section. This section passes under numerous buildings and roads and was driven in closed earth-pressure balance mode by the tunnel boring machine (TBM). The tunnel excavation work started in relatively favorable conditions at the southern portal in a sparsely popu-

lated valley of a Mosel tributary. The adverse effects of a TBM excavating a 10.12 m (33.2 ft) diameter tunnel below them were not felt much by the people living here. Not so to the north on the Cochem side, where the tunnel goes directly under the suburbs of Cochem and ends in the historical town center.

Continuous Deformation Measurements

Tunneling under the critical buildings of uptown Cochem required special ground improvement measures, a grout curtain injected ahead of the machine, and an extensive monitoring program. Even with continuous monitoring using numerous sensors, tunneling just three meters (10 ft) under four of these critical buildings was delicate business. A further 50 buildings were within the influence zone of the tunnel construction works.

To detect damage to buildings as early as possible, all points were monitored around the clock for any movement. A parallel system of high-precision hydrostatic pressure sensors captured deformations of the critical buildings in the sub-millimeter range. In the critical phase with minimum cover, these measurements were sent to a control center at ground level and continuously entered into an information system. If necessary, grout could then be injected under the buildings when required as the work progressed.



To comply with the special requirements for monitoring, the metrology department at tunneling contractor Alpine BeMo Tunnelling GmbH (ABT) developed an extensive modular measuring and monitoring system concept with long-term Leica Geosystems partner VMT GmbH (VMT). This allowed the automatically collected monitoring data to be transferred to the shield driver in the control cabin of the tunnel boring machine in real time.

System Characteristics and Components

The automatic deformation monitoring system in the city of Cochem was designed on a modular basis. More than 150 prisms were installed and monitored as necessary for the current excavation progress by up to nine Leica TS30 total stations. Additional satellite-supported baseline points were measured with GNSS sensors, then processed and evaluated with the terrestrial measurements in the VMT TUNIS deformation software with real-time network corrections. Three extensometers measured movements in the subsoil.

The site network and TBM results were visualized using a secure Internet data communications link with VMT's IRIS (Integrated Risk and Information System). This guaranteed complete monitoring of the points in real time and automatic notification. The

project duty personnel were informed as soon as the values exceeded the predefined limits.

Tunneling Under Cochem

Detailed planning of the surface metrology began in December 2010 with the preliminary design of an extensive metrology program. The concept called for the continuous monitoring of all buildings within a 30m (98ft) corridor around the tunnel. The obvious sensor choice was the high-precision Leica TS30 total station, as this is the only instrument that could meet the project requirements with respect to accuracy of the measurement results and distances to be measured.

Schwelm-based Goecke GmbH, a long-established Leica Geosystems GmbH Vertrieb marketing partner, provided the technical infrastructure for the installation of the system components. The instruments were cost-effectively protected against weather and vandalism on special consoles with plastic cladding and a roof-like cover.

Special Wi-Fi technology continuously transferred measurement data via access points from the total stations and meteo sensors to "mesh nodes", which were able to work together intelligently and bypass any failed nodes in the system.





■ The tunnel crosses under numerous houses in Cochem, some a mere three meters above.

In case of component failure the back-up systems were particularly important. For example, UMTS routers could operate the system if DSL failed. In the end, the reserve components were never called upon during tunneling.

A team of surveyors, electricians, construction engineers, operatives, and IT specialists were on site for several weeks installing the extended monitoring system. The system was commissioned and tested before the approaching tunnel boring machine reached town. By the time tunneling started in October 2011, no malfunctions had occurred and the monitoring system went live with an excellent reliability and accuracy record.

Monitoring Made an Essential Contribution

As tunnels excavated by a mechanized drive afford less opportunity than conventional tunneling methods for underground deformation measurements, for this project it was particularly important to continuously monitor deformations of the above-ground infrastructure.

The project partners had access to current data at all times on the information system IRIS supplied by VMT. A monitor in the control cabin of the boring machine displayed the instantaneous position of the machine in real time on the satellite photo image and showed all the surface sensors along with the current measurement results.

In the area of the critical buildings the designer's calculations proved to be accurate: the predicted and actual settlements of the buildings were almost exactly the same throughout the tunnel driving.

On 7 November 2011, the tunnel boring machine precisely broke through the portal in downtown Cochem. Without the excellent standard of metrology with high-precision instruments and the reliable operation of the automated deformation monitoring system, this challenging project could not have been completed. ■

About the author:

*Gerhard Weithe is a qualified surveying engineer and responsible for the metrology department at the contractor Alpine BeMo Tunnelling GmbH (ABT).
gerhard.weithe@alpine-bemo.com*



■ Current measurements at the TBM control center.