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Web-based data visualisation for tunnel and deep excavation monitoring

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ABSTRACT: Some large and small scale geotechnical monitoring projects like tunnels, landslides and deep excavations have been carried out, using automatic real time monitoring combined with data visualization on the internet as a powerful tool.

Three projects (a tunnel project and a potential landslide in Switzerland together with a deep excavation in Germany) are explained, the monitoring system used, including sensors and automatic monitoring system, is described and the web-based information access for the project-engineers is presented.

1 INTRODUCTION

Tunnels and excavations in built-up areas often require automatic monitoring and an alarm if the limit values, e.g. of displacements, water levels and forces are exceeded. The alarm is always given early in order to be able to implement countermeasures, a change in the building process or additional constructional measures.
In order to be able to implement safety measures involving all those involved in the project (client, consulting engineer, resident engineer and contractors) in good time it is necessary to make available in a simple way the results of the measurements of the monitoring system together with other important information. With the Web-Davis system measurements obtained with the GeoMonitor are presented on the Internet as graphics, showing the construction site and the monitored object. The extension of automatic monitoring by means of Web-based data visualization has proved highly successful both in large and small monitoring projects.

2 AESCHERTUNNEL, SWITZERLAND

2.1 *Project Overview*

In the Aeschertunnel, an important part of the Western By-Pass of Zurich, roughly the first 200m of both tunnel tubes were driven using a blade shield. During the excavation work settlements of up to 40 cm were observed at the ground surface. The tunnel support system consists of precast concrete elements at a spacing of 2.5 m. With a view to the subsequent enlargement (by the heading-and-bench technique) in this part of the tunnel strengthening by means of steel supports was carried out, and the soil being strengthened by means of vertical jetting piles.

Figure 2.1. Aeschertunnel North Entry

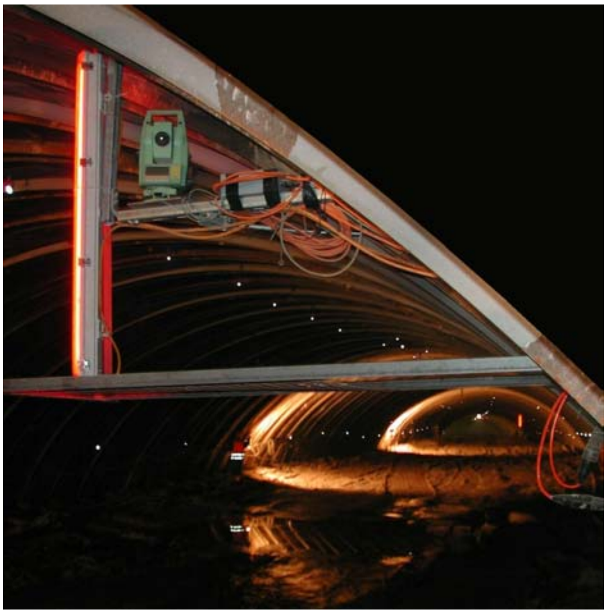


Figure 2.2. Robotic Total Station installed in the tunnel

2.2 *Instrumentation*

Two tachymeters of the type Leica TCA1101 were installed and connected to the GeoMonitor measuring control unit using bus cables.

The unit consists essentially of a standard PC with the GeoMonitor software, a controller and the modem for data transmission and alarm signals. The control unit services both tachymeters with the help of the GeoMonitor software. These measure automatically in an interval of 90 minutes all 88 and 66 measuring points. The fixed points, which are located at the portal, in the middle and at the end of the monitoring stretch, are checked periodically by Elektrowatt Infra. The changes in the heights of the fixed points are updated by Solexperts via modem on the GeoMonitor PC. Three times a day the results of the measurements are transmitted to the offices of Solexperts, there converted into graphics and transferred to a password-protected internet page using the Web-DAVIS system. The determinations of the heights of the fixed points, which are performed by the Elektrowatt Infra, have a measuring accuracy of less than ±1-2 mm and the automatic measurements exhibit a standard deviation over a period of 24 hours for an individual target point of ±0.5 mm.

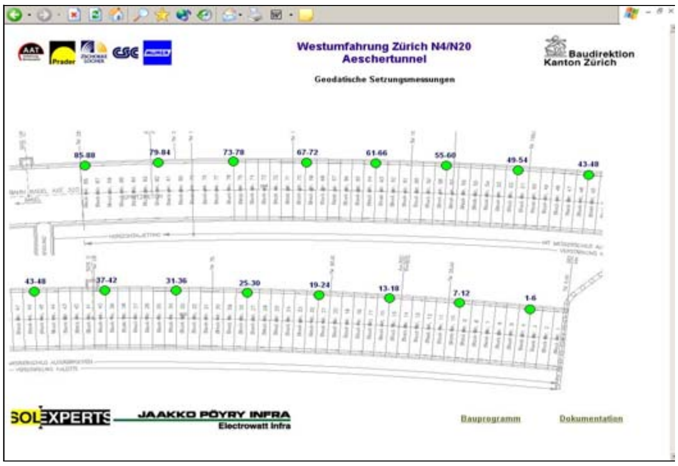


Figure 2.3 Project overview displayed on website

2.3 *Data Visualisation*

The data visualization on Web-DAVIS system includes for the instrumented tunnel section a plan view, the current construction program which is drawn up by the site engineers and sent to us by Email, documentation with pictures and a list of activities regarding monitoring. In addition, we make available a table with the results of the measurements for the purpose of further evaluation. The evaluation of the settlement profile (settlements along the stretch of tunnel) is also displayed.

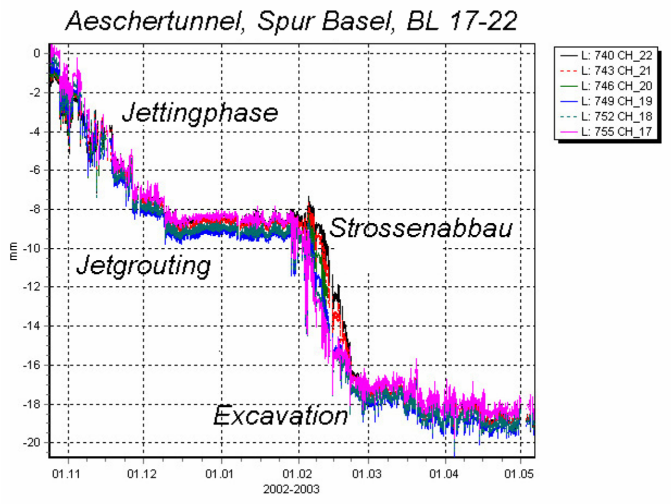


Figure 2.4 Settlements of points 17-22

3 FRUTIGEN SWITZERLAND – DEEP EXCAVATION,

At the north portal of the Lötschberg base tunnel in Frutigen two tunnel tubes are being constructed alongside the existing railway line over a length of about 2.5 km using the cut-and-cover method. For the support of the excavation a multiply-anchored wall with interlocking piles and a nailed wall are employed. In this type of ground, consisting of Engstligen river gravels with some sand inclusions, critical settlements and displacements could occur in the vicinity of the railway lines and of existing buildings. This requires a precise geodetic and geotechnical monitoring of these structures. The displacements of the walls of the excavation and the forces in the anchors are also monitored. With an automatic measuring system, the Solexperts GeoMonitor, these quantities are measured continuously, evaluated and the information is made available on the Internet for the responsible engineers.

Figure 3.1 Overview of the construction site

3.1 *Measuring systems*

Geodetic displacement measurement of the walls of the excavation: The walls of the excavation are monitored over the roughly 1km long stretch of tunnel with the aid of 5 tachymeters (Leica TCA1800 and TCA1101). Each tachymeter station has 4-5 reference points (free positioning by means of online-executed Helmert transformation) and measures at up to about 40 observation points, which are arranged in measuring cross section on the walls of the excavation.

Figure 3.2: Tachymeter Station T1 with measuring point (mini-prism)

Measurement of forces in anchors: In systematically arranged measuring cross sections, each with up to 5 anchor positions, load cells to monitor the anchor forces were installed.

Figure 3.3: Anchor load cells

Figure 3.4 Head of the instrumented rod anchor of the nailed wall

Displacement measurement of the nails: In the region of the nailed wall 10 rod anchors of the nailing are instrumented with single-rod extensometers and are measured continuously. In this way the loads in this nails can be determined.

Horizontal displacement measurements in the region of the nailing: In boreholes that extend deeper than those of the nailing Sliding Deformeter measuring tubes were installed for displacement measurements at 1m spacing. In each of these measuring tubes, after the zero measurement, 3 fixed micrometers (base lengths of 3 m or 4 m) were installed to allow an automatic measurement of the soil displacements. With borehole extensometers, which could also have been used for this purpose, there is the danger in the present case, that the measuring rods would be blocked due to radial (to the borehole direction) soil deformations. This danger is given in the case of fixed micrometers only if very large radial displacements occur with respect to the borehole. Each sensor has a measuring distance of ±10 mm, whereby an accuracy of 0.01 mm and a resolution of 0.001 mm is guaranteed.

Measuring inclination changes in the rail tracks: Above the nailed wall the transverse slope of the track, which is in operation, is permanently monitored using inclinometers. These are introduced in 4 cross sections on each of the two tracks (Figure 3.6). With the aid of a metal tube, which serves as a basis of measurement, these are mounted on the wooden sleepers.

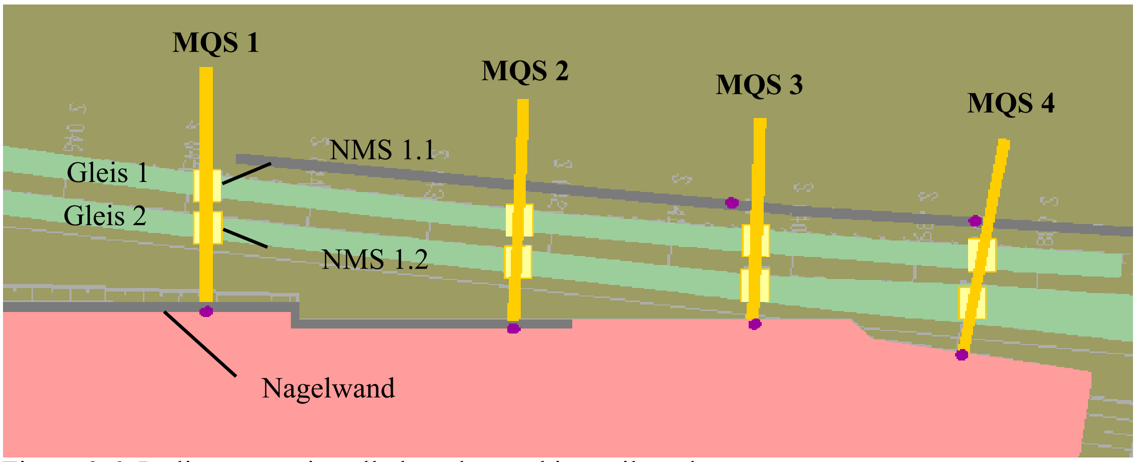


Figure 3.6: Inclinometers installed on the working rail tracks


Figure 3.7: Inclinometer mounted on the rail sleeper

The inclinometers have the following specifications:

- Range of measurement ±10°, resolution 0.001 mm/m
- Capacitance, gas-damped inclinometer in temperature compensated version
- Inclinometer sensor in watertight stainless steel housing with height of installation above the sleeper of about 80 mm

3.2 *Data recording and data visualization*

The DAVIS data visualization equipment is installed at the site office of the resident engineer. It gives a detailed insight into the GeoMonitor measuring system and the results of measurement.

In addition, every hour the Web-Davis system is updated with the latest measured results. Via Internet and protected by means of a password the responsible persons of the client, the planning and design engineers as well as the contactors have access to the current measured results. If limit values are exceeded for individual measured values an alarm is sent by GeoMonitor by FAX and individual persons are notified using mobile telephone.

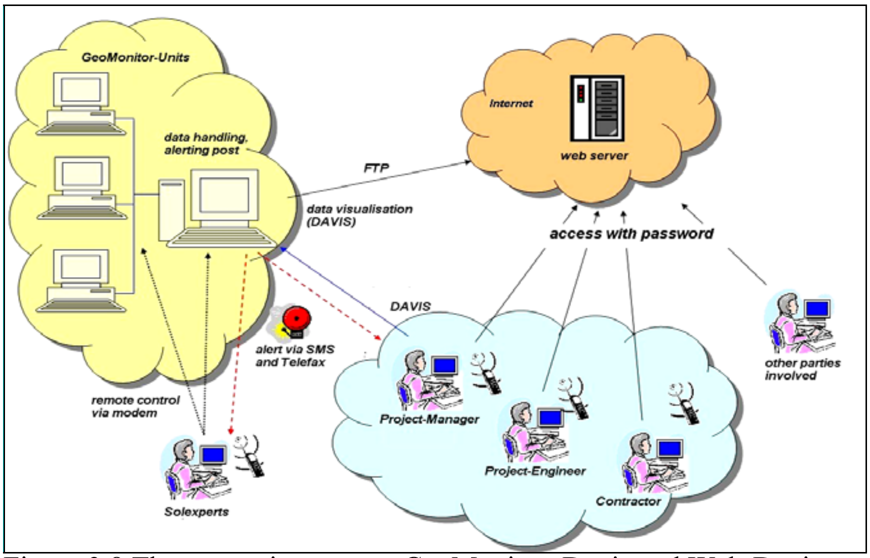


Figure 3.8 The measuring system GeoMonitor, Davis and Web-Davis

The Web-Davis system produces essentially a diagram of the construction site and the objects to be monitored. By clicking on the symbols individual parts of the site monitoring or of the measured values of the groups of sensors of the last 10 days are displayed. Since the beginning of monitoring, with few exceptions, no displacements or anchor forces have been measured outside the limiting values. Within a few minutes (around 5 minutes) the responsible persons can gain an overview of the automatically transmitted results of the measurements from a number of measuring positions, of different measuring systems.

4 KIRCHENWALD TUNNEL, SWITZERLAND: MONITORING THE APPROACH CUTS TO THE TUNNEL

4.1 *Project Overview*

The new Kirchenwald tunnel is a vital part of the north-south road link from Lucerne in the direction of the Gotthard tunnel and the Brünig pass.

The Hergiswil portal lies in loose talus material consisting of blocks and stones. It was built with the aid of a multiply-anchored pile wall and a composite wall interlocked with bored piles. For the geotechnical monitoring of this portal zone the forces in 27 anchors are automatically measured and checked against limiting values.

The Stansstad portal is situated directly alongside the portal of the existing Acheregg tunnel with a complex rock surface support using anchors. Here 13 anchors are automatically monitored and the deformations of the rock are measured with 8 up to 24 m long 6-fold extensometers.

Figure 4.2 Portal Stansstad

Figure 4.3 Portal Hergiswil

The extensometers used (modular extensometers) have been adapted to the difficult conditions encountered at the site (among other things the danger of rock fall). The extensometer measuring head with the displacement transducers is completely lowered into the borehole.

Figure 4.4 Modular Extensometer before installation Figure 4.5 Installed Modular Extensometer

The measured soil and rock displacements and the anchor forces are an important part of the use and safety plan of constructional measures. In order to make the results available to all those involved with the project they may be accessed at a password-protected Web site.

On the overview of the Kirchenwald tunnel, by selecting the corresponding symbols the graphics of the measured results can be displayed. If the limiting values are exceeded the automatic measuring system issues an immediate warning signal.

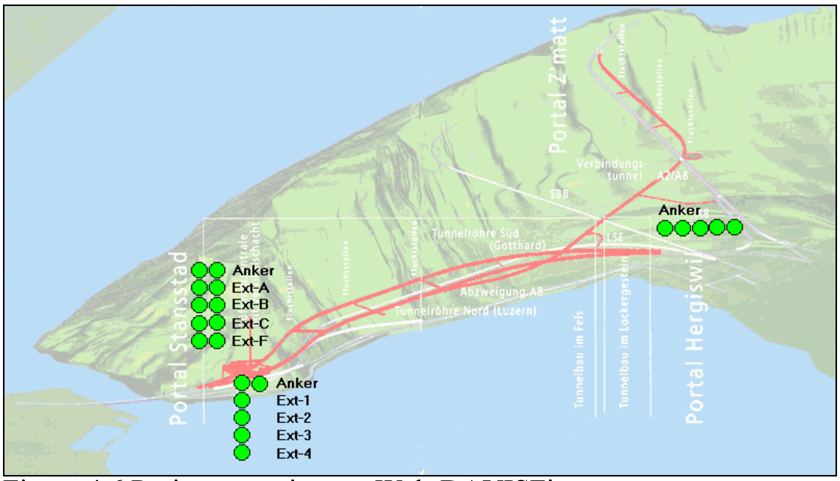
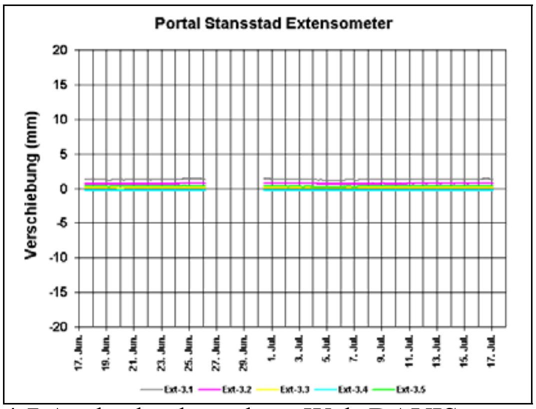


Figure 4.6 Project overview on Web-DAVISFigure



4.7 Anchorload graph on Web-DAVIS

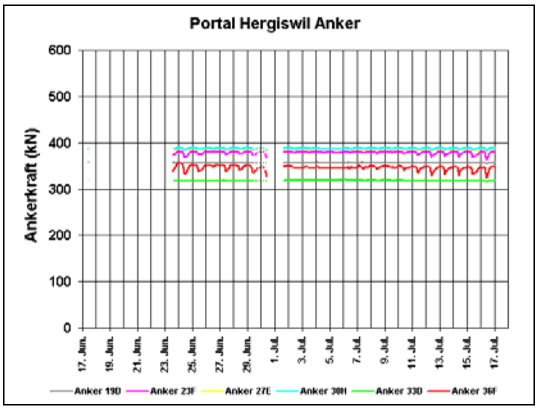


Figure 4.8 Extensometer graph on Web-DAVIS

4.2 *Conclusion*

Some of the current GeoMonitor projects, with various automatically carried out geodetic and geotechnical measurements are equipped with the Web-Davis system for data visualization on the Internet. It turned out that the possibility of accessing this information over the Internet by the engineers involved in the projects is a greatly appreciated and is used a lot. Within a few minutes the measurements can be evaluated even of a complex monitoring system with many different sensors. This is very important, above all in critical situations. In addition, on the Web-Davis monitoring system other relevant information can be obtained (telephone alarm lists, documentation, plan of construction phases, etc.).

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