

Leica Geosystems **TruStories** Monitoring



- when it has to be **right**

Leica
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Leica Geosystems **TruStory**

Monitoring Along the Construction Site of the Warsaw Metro Line 2



The Warsaw Metro (Metro warszawskie) is a rapid transit system serving the city of Warsaw, the capital of Poland. Currently it consists of a single north-south line (Line 1) that links central Warsaw with its northern and southern suburbs. The first section was opened in 1995 and then gradually extended until it reached its full planned length in October 2008. The construction for building the initial section of the second, east-west line (Line 2) started in August 2010, with completion planned for late 2013. This section will be 6.1 km long (including a tunnel under the Vistula River) and has 7 stations, one of these a transfer station shared with Line 1. The transfer station 'Świętokrzyska' also connects the center of the city via its Central Railway Station (Warszawa

Centralna) with the National Stadium for the Euro 2012 championships. Then, at the second junction (Stadium station) the line divides in two parts, one running toward the North-East (Bródno) and the other toward the South-East city region (Goław). The completion and operation of Line 2 is planned for 2015.

This tunnel project belongs to one of the most interesting underground building challenges in Europe, due to the fact that the construction is carried out below the densely built area of Warsaw's city center, the Vistula River and the Metro Line 1.

To complete such a giant project, there is a need to simultaneously lead construction works in a few places. According to the planning, three tunnel boring machines (TBMs)

■ Customer

AGP Metro Polska S.C. (Astaldi - Güllermak-Przedsiębiorstwo Budowy Dróg i Mostów Sp. z o.o.)
Metro Warszawskie Sp. z o.o.

■ Objective

3D deformation monitoring of an urban area along the construction site of the Warsaw Metro Line 2

■ Challenge

Providing geodetic real-time monitoring along the construction site of the Warsaw Metro with limited access

■ Date

June 2011 – ongoing

■ Location

Warsaw, Poland



■ Project Summary

Instruments

Leica TM30 Monitoring sensor
Leica GMP104 monitoring prisms
Leica GPR112 prisms
Meteo sensors

Software

Leica GeoMoS Monitor + Analyzer
Leica GeoMoS Adjustment
Leica GFU24 messaging modem

Communication

Moxa NPort

■ Benefits

- Stability control on the construction site
- 3D deformation control of over-laying buildings and infrastructure



are going to start in parallel with the drilling of the new metro tunnel in April 2012. In addition, some metro stations will be built with dig-and-cast method.

Above the designed metro there are many buildings, streets, historical places and public institutions. Therefore, beside the main tunnel work there are many other tasks related to such a tunnel construction, for example, securing overlaying buildings and infrastructure with 3D deformation monitoring and controlling the possible impact of the newly built tunnel on the existing north-south metro line 1.

The required and absolutely necessary deformation monitoring system is

being implemented by IMG, an Italian company with experience in deformation monitoring installations (the Metro line C in Rome, Italy). IMG works as a subcontractor for the consortium AGP Metro Poland.

Monitoring System Setup

In the central Warsaw underground section, more than 10 high accuracy total stations Leica TM30 are mounted. They are mounted on tunnel walls AND on buildings inside especially designed glass-aluminum housings boxes situated either on buildings' roofs or inside buildings. They measure 3D deformations to over 100 reference prisms Leica GPR112 and thousands of deformation control points situated on surrounding buildings.

All Leica TM30s are controlled via GPRS modems Moxa NPort from the main operation centre with the Leica GeoMoS software.

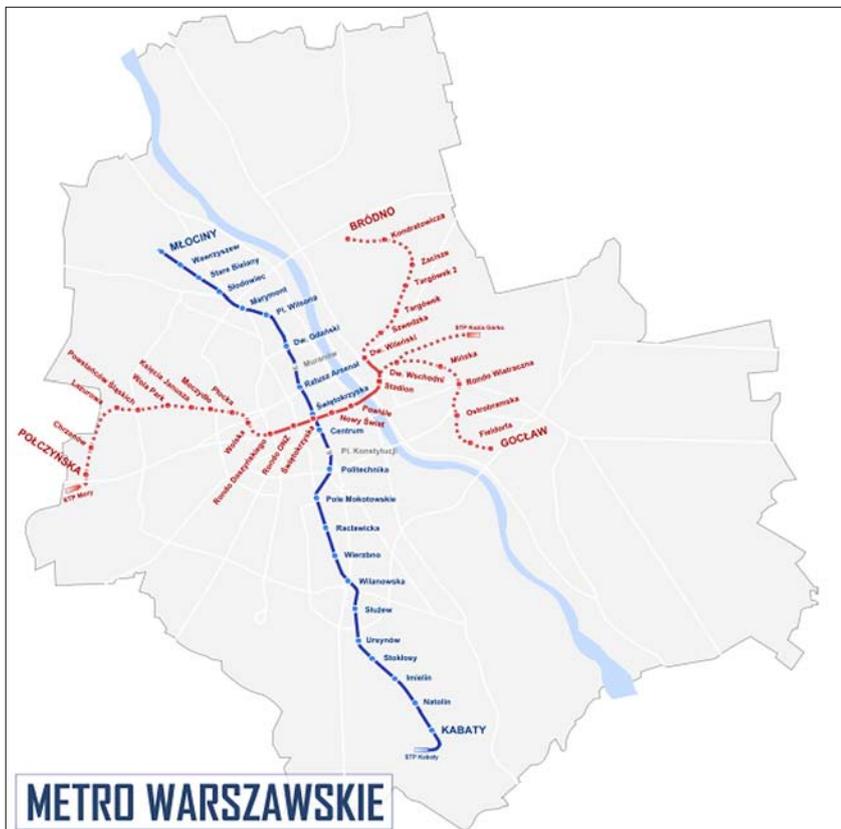
In such a large-area survey, there is undoubtedly atmospheric refraction which impacts on distances and vertical angles, so there is a need to control the refraction coefficient and to apply proper corrections in calculating the final deformations. For that reason three meteo sensors are located in the monitoring area, measuring in real-time the current atmospheric parameters, temperature and pressure. These measured values are automatically applied to the raw measurements with the Leica GeoMoS software.

Collecting and Analyzing Monitoring Data

The monitoring data is mainly presented in GeoMoS Analyzer and in addition, IMG has the access to use GeoMoS Adjustment for network adjustment and deformation analysis.

Beside the automatic deformation monitoring system, there are classical surveys performed for example, precise leveling and additional total station survey.

The complexity of the project combines the fields of geodesy and geology. Therefore, geotechnical sensors and data are part of the project. Supplementing the geodetic and geotechnical measurements with each other helps to understand the reasons for any detected movement and to improve the intervention



existing in the software solution. In Warsaw, the monitoring system is being operated exclusively by the Leica GeoMoS software package with no 3rd party solutions.

Robust and Flexible Equipment

The customer is a global, well experienced company providing construction works and other services. They have been using Leica Geosystems equipment for many years as well as being one of the most important Leica Geosystems partners worldwide.

The customer appreciates the robustness, interoperability and flexibility of the implemented monitoring system. Due the software integration, there is no need to install other supporting applications like warning systems, analytical tools etc.).

with appropriate actions. The collected geotechnical data (provided mainly by SisGeo) is analyzed in the operation center together with the geodetic results displayed with GeoMoS.

Data Sharing

There is an agreement between the consortium (AGP Metro Poland) and the purchaser (Metro Warszawskie Sp. z o.o. and The City of Warsaw) allowing the possibility of exchanging data with

scientific and public institutions for analytical purposes.

In Poland, the described deformation monitoring system is a completely new approach in terms of underground and tunnel monitoring. The customer, however, is experienced, as they provided a similar integrated surveying system in Rome, Italy, deciding to trust the already checked solution. Nevertheless, there are differences between Rome and Warsaw, mainly



Leica Geosystems **TruStory** Monitoring Europe's Tallest Building



'When it comes to structural monitoring, there is no room for risk. At Bryne Bros we pride ourselves in ensuring the delivery of best in class structures with the upmost of safety and care. It is integral for us to be able to work with a technology that is adaptable to the project and delivers without fail. That's why we chose Leica Geosystems and that's why we were able to deliver one of the largest engineering projects with absolute precision.'

Donald Houston, Bryne Bros

Renzo Piano, the architect for The Shard, considers the slender, spire like tower a positive addition to the London skyline. The sophisticated use of glazing with expressive facades of angled panes is intended to reflect light and the changing patterns of the sky, so that the form of the building will change according to the weather and seasons. The Shard London Bridge will tower 306m (1,017 feet) into the sky and will be the tallest building in the European Union and the tallest building in the United Kingdom. When completed in 2012 it will soar more than 70 floors above London.

Byrne Bros (Formwork) is one of the UK's premier concrete frame contractors. Byrne Bros were appointed by MACE to carry out the concrete substructure and superstructure works in a contract worth more than £50 million. The substructure will adopt 'top down' techniques and the main structural core will be slip formed in parallel solutions which will deliver significant programme advantages.

The top 30 floors, culminating at a public viewing gallery between levels 69 and 72, will be constructed using a post tensioned slab construction. On completion The Shard will house offices for Transport for London, a hotel and luxury apartments, all with exclusive views over the capital.

In the summer of 2009, Leica Geosystems was approached by Byrne Bros one of the UK's and world's leading formwork construction companies to develop a realtime slip-form rig positioning system which would be used to construct the central concrete core of The Shard. Slip-form construction is perhaps one of the safest, efficient and economical methods of building vertical structures. It enables formwork construction to rise at rates of up to 8 metres per 24 hours. Traditional methods of controlling

■ Customer

Byrne Bros (Formwork)

■ Project period

August 2009 – June 2012

■ Location

Southwark, London, United Kingdom



■ Project Summary

Provision of a real-time slip-form rig positioning system to maintain verticality of the concrete core construction.

Hardware

Leica GMX902GG Receivers
Leica AS10 GNSS Antennae
Leica GRZ122 360 Prisms
Dual Axis Inclination Sensors
Campbell Data logger
Anemometer
Meteorological Sensor
Leica TPS1200

Software

WLAN bridge
Leica GeoMoS
Leica GNSS Spider
Leica Geo Office

the position of a slip-form rig as it rises is often a time consuming and labour intensive process. Normally a site surveying team will compute traverse computations from observations taken with total stations and precise optical plummets. These calculations allow the position of the rig to be obtained in the site grid coordinates. As the vertical concrete core has known offsets from the rig it is therefore possible to guarantee the core is being-constructed vertically in relation to its design coordinates.

The required tolerance for this project was that rig plan position should not exceed +/- 25mm of deviation against the design coordinates. The height component is not as critical but is often useful to know. After some consultation between Leica Geosystems and Byrne Bros a combined system of TPS, GNSS and dual axis inclinometers was agreed. Real-Time GNSS positions would allow determination of the rig's position. Both the translation and rotation of the rig could be determined using GNSS technology but it would be unable to provide information on the rig's inclination which could be up to +/-75mm over the 20m square rig dependant on the correction factors applied by the rig manager. It was therefore necessary to calculate the tilt on the rig. This was achieved using data acquired from the 4 x dual axis inclinometers. By using the virtual sensors functionality (mathematical formulae) within the Leica GeoMoS software it was possible to compute a 'tilt compensated' position of all four corners of the rig. Third-party inclination sensors were chosen due to the large expected range of tilt and were integrated into the systems via a Campbell Scientific Datalogger.



Datalogger configuration for Inclination Sensors and Anemomete

As with any other city working with GNSS technology in London can often prove challenging. Existing buildings and infrastructure can obscure the satellites signals and mean that unreliable or no position can be achieved.

For this reason 360° prisms were co-located with the Leica AS10 GNSS antenna to allow both total station and GNSS observations to be gathered simultaneously which would also provide a check on the GNSS results particularly whilst the rig was near ground level and potentially encountering difficulty in having a clear satellite window.



Co-located AS10 GNSS Antenna, 360 Prism° and Dual Axis Inclinometer.

To allow the GNSS and total station results to be correlated a set of transformation parameters were calculated within the Leica Geo Office software.



4 x GMX902GG GNSS Receivers inside the slip form rig.

In addition to the problem of actually using GNSS technology in the 'urban canyon' the provision of both reliable and stable reference stations is extremely difficult. Often easy access to a stable location that provides both the necessary power supply and communication is hard to obtain. Negotiation with other building owners and businesses can be prohibitively expensive. For this reason it was decided that a real-time data feed from Leica SmartNet NRTK correction service would be utilised.

The 4 x GMX902GG receivers are connected to the site computer running on the rig. Leica GNSS Spider software takes the incoming data streams for these receivers and a real-time data stream from the SmartNet service. The internet connectivity is provided by a WLAN bridge system which comprises of 2 x directional antennae which guarantee reliable internet connectivity to the site computer on the rig as it rises nearly 3 metres per day.



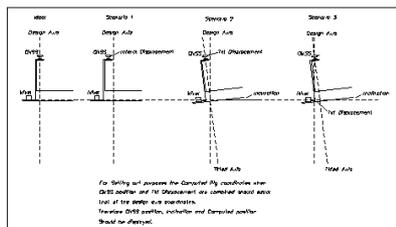
Leica SmartNet provides Reference Data Information



WLAN Bridge System

The position of each antenna on the rig was computed with respect to nearest SmartNet reference station which was approximately 1.5 miles away. This yielded a 3 dimensional coordinate quality of better than +/-25mm.

The GNSS positions are computed every second within GNSS Spider and the median result of these observations are sent every 10 seconds to Leica GeoMoS where they are synchronised with the data from the dual axis inclinometers and the wind speed. A computation is simultaneously carried out within GeoMoS which applies the lateral shift caused by the tilt of the GNSS antenna to the vertical position.



Effects of Tilt on GNSS position

The rig positioning interface uses the open architecture of GeoMoS which is built on a Microsoft SQL database. An ODBC link is established between the GeoMoS database and the bespoke interface which displays the results graphically and that is easy to understand by the rig manager. This interface enables the rig manager to make adjustment to the rig position via the use of hydraulic pumps. traffic light system of warnings are displayed within the interface. If the computed results exceed +/-25mm lateral displacement against the design position or +/- 4mm/m of tilt on any corner of the rig then an orange display is shown. A exaggerated rig display and level 'bubble' display allow instant visualisation of results.

Project Results

This new and innovative approach for controlling the position of a slip-form rig has proved highly successful on The Shard project. The fact that the results obtained could be verified and correlated to those obtained via traditional methods was extremely important in building confidence in the system. This allied to the fact that Leica Geosystems Monitoring Support team could support this system remotely even during out of hours meant that in the early stages of this project in particular confidence in the system was assured. Already other tall buildings in London being constructed using slip-form methodology have adopted this system and Byrne Bros plan to use this system again on future projects.

For more information on monitoring solutions from Leica Geosystems Ltd contact James Whitworth on +44 (0)77 958 440 75 james.whitworth@leica-geosystems.com

Leica Geosystems **TruStory**

Monitoring of the Central-Wanchai Bypass During Construction



■ Objective

Deformation monitoring of bridge construction works

■ Customer/Institution

Chun Wo Construction and Engineering Company Limited

■ Challenge

Planning and installation of a temporary monitoring system within a daySmooth transition from a temporary into a permanent monitoring system Real-time deformation monitoring throughout the construction

■ Date

Since February 2011

■ Location



■ Project Summary

Instruments

Leica TM30

Leica Geosystems Monitoring prisms

Software

GeoMoS Monitor / Analyzer

Web viewer for displaying data and reports

Communication

Cables

Uninterrupted Power Supply (UPS)

■ Benefits

- Continuous and remote monitoring
- The safety of the bridge can be ensured round the clock during operation

The Island Eastern Corridor is a major expressway connecting Causeway Bay to Chai Wan, which was completed in the 1980's. In February 2011, a bridge abutment supporting the slip road was found to have unusual structural movements, causing the temporary suspension of underground works and soil stabilization and measurements to be taken immediately. As further settlement is still possible and construction work needs to continue, which could potentially threaten the safety of road users, further monitoring of the bridge structure is required to provide real time deformation information to the engineers, so that they can make a correct decision to ensure the highest degree of safety. The automated deformation monitoring system

(ADMS) was initially set up temporarily to automatically operate round the clock, providing precise deformation measurements. However, in March 2011, the system was turned into a permanent system.

The temporary monitoring system was originally set up on a rental basis with a Leica TCA 2003 total station, but after one month, the customer purchased a new permanent monitoring system with a Leica TM30 total station, which was specially designed for monitoring use. The TM30 can operate 24 hours, 7 days a week even under severe environments. It also performs well throughout a wide temperature range and is protected against wind driven rain, sand and dust, which is omnipresent in this monitoring site as it is an open-air area with cars



travelling around. Incorporating all these features, measurements could be taken round the clock and the system remains stable and precise at all times. Measuring over a hundred monitoring prisms mounted on bridge abutments and other surfaces, monitoring data were measured in a one-hour cycle. For the monitoring of such a critical road bridge, with cars frequently passing by, outliers or data gaps cannot be tolerated. With the Leica TM30 total station, the system provides high accuracy angular measurements of 0.5" and precise distance measurements with 0.6 mm + 1 ppm. With the direct drives and the SmartEye vision the total station can perform the measurements to all the monitoring prisms in a short cycle.

Monitoring System Setup

The monitoring consists of a TM30 total station, a computer and more than one hundred Leica prisms. The total station is mounted on a platform next to a bridge abutment and protected by a fixed metal stand, once the system became a permanent set-up. The prisms are mounted on various surfaces, which are distributed around the concerned slip road in the construction site. Reference prisms are installed in stable areas to provide a control network for the Leica TM30 total station. The computer, with Leica GeoMoS for the total station control and data acquisition, is located just next to the total station in a heavy transportable box. In addition, an uninterrupted power supply (UPS) is installed so that the complete

system is still operational during any short-term power outages. A backup database is used to store backup data, as past data plays an important role in future analysis and comparison. To enable monitoring users to access the monitoring data anywhere, the computer is connected to a web server in a data centre and all the data is uploaded in real time to the Internet. To ensure the monitoring system operates smoothly, reliably and accurately in spite of all the construction work nearby, regular system maintenance checks and cleaning of optical prisms is done to prevent coverage by sand and dust or movements caused by vibration.

Temporary to Permanent

After the initial structural movements in February 2011, the customer demanded a fully automatic monitoring system from Leica Geosystems Hong Kong with only a half-days' notice. The monitoring system planning, with the position of the total station, prisms and setup, had to be done within hours. The Leica monitoring system components were set up very easy with plug & play for a one month temporary installation. To reach the highest standards of a monitoring system, it was turned into a permanent setup one month later. During the installation period of the permanent set-up, the temporary set-up continued operating until it had worked for two whole months, so that surveyors could compare the data between the two set-ups and adjust them accordingly.



the reasons behind the notification and confirm whether the message was due to faulty equipment (displaced prism), human error or construction activities. They decide what kind of actions need to be taken, e.g. increasing monitoring frequency or even a temporary suspension of all nearby works.

Conclusion

The implementation of the automatic deformation monitoring system after the initial structural movements has been highly beneficial, as with the help of the monitoring system, the Central-Wanchai Bypass project could be resumed safely and the public can be constantly kept informed about the situation. The monitoring system has allowed the progress of construction projects to continue, in addition to ensuring public safety.



Data Visualization

All the measured monitoring data is first processed by the computer with GeoMoS Monitor. The responsible surveyors can then view the data directly with GeoMoS Analyzer on the computer located on the construction site or via a web interface, as the data is immediately uploaded to the Internet. After logging into the web page the users can display the data with numerical or graphical reports, their associated limit levels and download raw data. The actual monitoring data can be displayed with reference to the initial values measured at the start of the monitoring or as trends.

Messaging System

As the name of automatic deformation monitoring system suggests, every process should work without human intervention. Therefore, instead of employing a person to watch the data 24 hours a day, computers notify surveyors and engineers immediately when any deformation beyond tolerance occurs with the system. After the monitoring positions of the prisms are measured, they are compared with the set limit levels. If any monitoring data reaches or exceeds one of the three limit levels, the messaging system is immediately activated. The designated personnel are notified through various media and by e-mail. The surveyors in charge then investigate

Leica Geosystems **TruStory**

Yesterday's Negligence Becomes Today's Problem



While pumping and active charcoal filtering is taking place, the new building is continuously monitored with several inclination Leica Nivel220 sensors.

The level of pollution at the Schnepfenmatt site in Zuchwil makes it one of most contaminated pieces of ground in the Swiss canton of Solothurn. Although the pollution threatens two of Solothurn's public drinking water sources, it has not been possible to successfully remediate the land until now. Emch+Berger is working on the remediation of this contaminated waste site.

Background

In 1998, during the course of a redevelopment project in Zuchwil, it was discovered that there was considerable contamination of the ground (soil, groundwater), on what is now the Schnepfenmatt site, with chlorinated hydrocarbons (CHC). Previous attempts at remediation using conventional methods have not proved successful. Their failure was due to local conditions, the

geology and groundwater levels. Remediation works for a new building to the east of the Schnepfenmatt site led to the realisation that the pollution could be treated by extracting water through wellpoints without risk to the surrounding buildings.

"Decades of careless handling of environmentally hazardous materials and wastes have left their mark in the soils of Switzerland." Swiss Federal Office for the Environment (BAFU), 2009

Site work

Emch+Berger is responsible for the site work and the evaluation and interpretation of the monitoring data. The CHC-contaminated groundwater is purified by passing it through an active charcoal filter water treatment system. The site manager must ensure that the 92 filter strings installed to extract the

Emch+
Berger

<http://vermessung.emchberger.ch/>

Objective

Subsidence monitoring of a building

Customer/Institution

Emch+Berger AG Vermessung, Solothurn

Challenge

Real-time subsidence monitoring during remediation
Notification via SMS when any sensor exceeds set limit levels
Pure geotechnical monitoring project

Date

2010 – 2015

Location

Zuchwil/Switzerland



Project Summary

Instruments

- Leica Nivel220
- Groundwater piezometers
- Flow sensors
- Water pressure sensors

Software

- Leica GeoMoS Monitor/Analyzer
- Leica GeoMoS Web

Communication

- ComBox20
- Campbell Scientific datalogger



■ Benefits

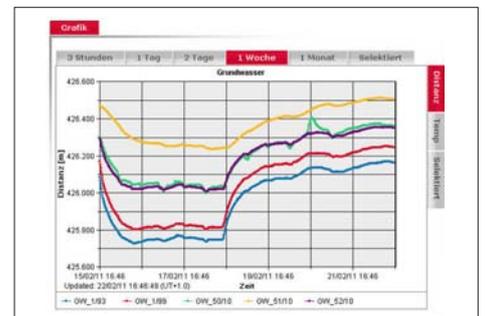
Leica sensors and third party sensors combined in a single monitoring system simplifies support and interpretation of the measured data. Two geotechnical sensors systems increase the systems reliability

groundwater do not obstruct or delay progress on the new building to the east. The individual filter strings are connected by several pump lines to the treatment plant. Each filter string must be designed and installed so that it can be individually controlled by a shut-off valve. Remediation is expected to take five years.

Monitoring

While pumping and active charcoal filtering is taking place, the new building is continuously monitored with several inclination Leica Nivel220 sensors. The Leica Nivel220 inclination sensors are directly connected, via two separated RS485 bus systems, to the central communication unit. Every 15 minutes, each sensor registers the longitudinal and transversal inclination of its position. Furthermore, groundwater levels are automatically measured every five minutes by five groundwater piezometer stations spread out over the site. The treatment plant also has two integrated flow sensors and

a water pressure sensor. A Leica ComBox20, a central communications unit, controls the groundwater piezometers, the flow and water pressure sensors (using a Campbell Scientific datalogger) and provides them with electrical power. All data is transmitted via a wireless GPRS router in real time to the Leica GeoMoS Monitor software in the Emch+Berger AG Vermessungen office. The Leica GeoMoS monitoring system controls the data acquisition of the Leica Nivel220 inclination sensors and the other sensors, displays the measured data, calculates displacements and checks, in real time, whether the tolerances are exceeded. If the tolerances are exceeded, the system notifies the project partners by SMS. To allow other interested parties (geologist, system maintenance engineer, construction engineer etc.) to see the data, the data viewing application Leica GeoMoS Web is available on the Internet. This allows the data to be analysed from anywhere at any time.



Graph of the groundwater level in Leica GeoMoS Web

Results

The customer receives a truly multi-faceted service including the measuring concept, installation, maintenance of the system and user support in the interpretation of the measured data. The monitoring system includes two independent measuring sensors that increase the reliability when the CHC-contaminated groundwater is purified.

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Leica Geosystems **TruStory**

Landslide Monitoring in Acri, Italy



Leica TM30 above the town of Acri

In 1998 a landslide occurred close to the city of Acri, located in Calabria in southern Italy. The landslide had a dimension of approximately 100 x 400 m width and 500 m length. Fortunately, nobody was injured and no important buildings within the landslide area were destroyed. Only the security of the national SS660 road is affected.

Between 1998 and 2010 the military manually monitored the landslide area every 24 hours. This was very expensive and therefore the customer (ANAS S.p.A.) decided to install an automatic deformation monitoring system.

ANAS S.p.A. is the main national company responsible for the management of the road network maintenance & refurbishment. They are already a Leica Customer for a different application: Laser

Scanner, GPS/TPS for survey and Monitoring System.

Monitoring objective

The deformation monitoring system's target is to observe the landslide over the main road, SS660, which connects the town Acri with the highway.

System concept

The geodetic monitoring system is composed of a Leica TM30 0,5", installed on a historical tower, which measures 20 monitoring points every 6 hours covering an area of approximately 1 x 1 km. Inside the tower there is a Leica Nivel210 to control the stability of the structure.

In addition, four Leica GNSS baselines built up with Leica GMX901 antennas, located on the landslide, compute independent and absolute coordinates of the landslide movements. A Leica GMX902 high-precision monitoring GNSS receiver located

■ **Scope/Objective**

Monitoring of a landslide over the main access road. This road is the only way to connect a town with the main highways.

■ **Customer/Institution**

ANAS S.p.A. - Calabria

■ **Challenge**

Replacing the 24/7 military garrison with an automatic monitoring system

■ **Date**

Started in August 2010

■ **Location**

Acri, Italy



■ **Project Summary**

Instruments

Leica GMX901
Leica GMX902
Leica TM30 0,5"
Leica Nivel 210

Software

Leica GeoMoS Monitor
Leica GNSS Spider

Remote communication

Cellular router; GSM as backup

Communication on the field

Wireless LAN and cables

Office

SystemAnywhere (data synchronization & calculations) and Analysis (data view)

■ **Benefits**

- Remote data handling with automatic backups
- Real-time messaging of landslide deformations Absolute coordinates

on the tower is used by each of the baselines.

"PC box" on site

The installed communication structure consists of a robust enclosure on the site called the "PC box". This contains a cellular router, an industrial windows based PC, power and cabling. The Leica TM30, Leica GMX902 receiver and Leica Nivel210 are directly connected by cables to this box. The four Leica GMX901 monitoring points are connected via a local Wifi network (5GHz) to the "PC box". All collected monitoring data is downloaded to a monitoring system PC, at the headquarters of ANAS, with a direct high-speed Internet connection. In addition, a GSM connection provides a backup communication line in case any internet problems occur. A 220V power supply with a backup battery provides continuous power to all the devices. To ensure absolute waterproof characteristics of the enclosure, all cable connections to the "PC box" are wired via "Amphenol" plug connectors. To allow maximum flexibility of the box every component and device is DIN-Rail mounted.

"GMX901 box" on site

Each of the four GMX901s is powered by solar panels. Inside the Leica GMX901 box a datalogger reads out and stores the charge of the battery. This information is automatically downloaded to the "PC box" so that the system operator can proactively react and exchange

batteries if required.

In addition, the "Leica GMX901 boxes" are equipped with a Serial to TCP converter and an Ethernet switch, to ensure an easy on-site connection with a laptop to check the status of all the connected devices. Identical to the "PC box" these boxes also have a power supply, backup battery, "Amphenol" plug connectors, Wifi / GSM connection and are assembled with DIN-Rail.

Data Acquisition

The total station and Nivel210 inclination is controlled with the Monitoring software Leica GeoMoS. The software schedules the measurement to the prisms and the read out of the inclination values. The raw data is stored in the open SQL database. The GNSS baselines are processed with Leica GNSS Spider. Both software packages are installed on an industrial windows based PC inside the on-site "PC box".

The acquired raw data from Leica GeoMoS and Leica GNSS Spider is downloaded from the monitoring site, with the local Leica Selling Unit software called "SystemAnywhere", to another dedicated monitoring system computer located in the headquarters of the customer. SystemAnywhere retrieves the pure raw data and then automatically computes the total station corrections as orientation, free station, ppm etc. Total station and GNSS baselines are combined and limit checks computed.

Messages are sent via SMS and E-mail and in addition, automatic reports can be generated.

The PC has an Internet connection and a GSM backup connection to allow quick downloading of the monitoring data from the "PC box".

Maintenance & Backup

All the data from the "PC box" is also backed up on an FTP site. The backup software installed in the "PC box" checks the completeness of the GeoMoS measurement cycle and the GNSS Spider baseline results, and automatically creates a backup of the SQL database on a FTP server. The backup gives maximum security for data collection and minimum intervention, in terms of a PC failures etc. For the on-site management of the different components, various means of remote access to all devices are available.

Results

As a result, the customer receives all the results as simple and clear graphs that show, at a glance, the behaviour and deformation of the landslide.



Leica GMX902 as reference station

Leica Geosystems **TruStory** Structural Monitoring of Michigan's Highway Bridges



■ **Company/Institution**

Michigan Department of
Transportation
Construction and Technology
Division

■ **Challenge**

Reliable Real-Time Deformation
Monitoring of many bridges within
the State of Michigan with wireless
data coverage

■ **Date**

2010 - ongoing

■ **Location**

State of Michigan / USA



■ **Project**

Instruments

Leica TS30 Total Stations
Leica GRX1200 Reference Station
Receivers

Software

Leica GeoMoS

■ **Objectives**

- 3D determination of bridge deformation
- Checking for bridges that need to be maintained or reconstructed
- Maintaining secure traffic by verifying the stability of the structures

A temporary bridge being monitored while work is completed on the rebuilding of the permanent bridge.

The State of Michigan (USA) is surrounded by the largest source of fresh water in the world, the Great Lakes. Lakes Superior, Michigan, Huron, Ontario, and Erie play tremendous environmental and economic roles, and are of vital importance to Michigan and the United States in terms of shipping, fishing, tourism, and a clean water source. Between the Great Lakes, their associated watershed, and the State's extensive highway system, there are also a significant number of highway bridges that require service, maintenance, and reconstruction in order to ensure and maintain safety to the motoring public.

During the 1960's and 1970's, a significant highway construction effort took place in the State of Michigan. As time was of importance to open up routes of commerce to the far reaching areas of the State, many of these structures were built on spread footings, sometimes on less than desirable ground. Over time and millions of vehical crossings, these bridges need to be reconstructed to support the larger loads of semi-trucks and increased vehical traffic. As is the case with any critical traffic structure, it is most desirable to safely perform as much work as possible on the bridges without interrupting traffic flow. In order to ensure that construction activities around a bridge do not compromise the

structure, the Michigan Department of Transportation (MDOT) has implemented the Leica GeoMoS Monitoring software system and Leica TS30 total stations. This system allows highway engineers to constantly verify the stability of the structures and provide instant updates in the event of any unforeseen movements or changes.

Under the direct supervision of Mr. Shawn Roy, P.S., Chief Monitoring Surveyor of the MDOT / Design Survey Division (Lansing, Michigan), many bridges over the past two years have been successfully reconstructed under the watchful eye of Leica TS30 Total Stations' Automatic Target Recognition (ATR) and GeoMoS Monitoring Software.

Long-standing Positive Experience with Leica Geosystems

MDOT is no stranger to the high quality and precision of Leica Geosystems total stations, digital levels, and GNSS receivers. They currently utilize a massive fleet of Leica Geosystems instrumentation,

as well as maintain the Michigan Spatial Reference Network (MSRN), consisting of nearly 100 Leica GRX1200 Pro GNSS receivers and Spider Software. MDOT has long since established itself as a worldwide leader in the application of Leica Geosystems hardware and software, and continues to provide the tax paying citizens of Michigan with the most productive and precise measuring technology available on the planet.

Economic Benefits of Structural Monitoring

While the mighty Mackinaw Bridge is probably the State's most iconic bridge, Michigan also has thousands of smaller bridges, associated with their tens of thousands of miles of public roadways in their state highway system. As is the case with any physical structure exposed to the elements of a harsh winter environment, eventually these bridges require maintenance or replacement. Most certainly, the ideal case in a bridge reconstruction

■ Benefits

- Real-Time 3D Monitoring
- Easy Monitoring Configuration
- Effectiveness of measuring real-time deformation
- Robust sensors suitable for permanent monitoring
- Bridge Safety
- Preventing catastrophic failure
- Minimizing road closures during maintenance and reconstructions

would be to close the bridge to all traffic, perform the reconstruction, and then open the new structure to vehicle traffic. Unfortunately, a complete bridge closure has a massively negative impact on local commerce. As the State of Michigan's economy is greatly driven by the agriculture (getting crops to market), automotive (getting parts to factories), and tourism (getting people to the state's many great vacation destinations) industries, shutting down a bridge can easily cost millions of dollars in lost commerce, as well as inconveniencing everyday citizen travel and increasing traffic on auxiliary roads that may not be designed for such loads. The cost of bridge closure is computed by the engineering staff at the Michigan Department of Transportation using a standard numerical study resulting in a User Delay cost.

Economic Benefits of Structural Monitoring

As a result of the Leica GeoMoS/ Leica TS30 monitoring system a bridge reconstruction can take place with minimal bridge closure and traffic delays. Obviously, keeping traffic moving on a bridge under construction carries larger risk it is absolutely critical to provide continuous, absolute measurements



Small bridges: just as important as big bridges



of the existing structure in real-time while reconstruction work is performed. The Leica GeoMoS system with Leica TS30 total stations has proven to be exactly “what the Doctor ordered” for this scenario. When fully implemented on a bridge reconstruction, all of the critical project engineers can monitor the structure to be sure there is no unnecessary movement, thereby preventing catastrophic failure. In the event there is any abnormality relating to the structural stability, the appropriate personnel are immediately notified via text message, e-mail, or the web interface on their mobile device and can quickly analyze the real-time measurement data and make an informed decision as to the project’s course of action.

**Small Bridge Monitoring:
A Tactical Approach**

Although the typical bridge monitoring project takes place over a relatively short period of time (4-6 months), the security that the Leica GeoMoS system provides is immeasurable for project engineers and surveyors. The cost savings however, are very real. As has been the case in the past when a complicated reconstruction

is in progress, a conventional surveying crew must be on site every day to provide measurements relating to the stability of the structure. The full implementation of a Leica GeoMoS monitoring system, with Leica TS30’s spinning the data streams 24/7, eliminates the need of a costly surveying crew on site day after day, and also ensures that any movements that might occur when the surveying crew is absent will be duly recorded.

The Leica GeoMoS/TS30 installations for an MDOT Bridges depend on many variables, including the extent of repairs (or in some cases, replacement), length of project, and the critical points of measurement as defined by the project engineer. In all cases, a concrete pillar 6 ft deep and 12 inches in diameter is installed in view of the predetermined prism locations. It is critical to establish the instrument station out of the direct work area in order to prevent potential obstructions between the instrument and its target prisms, as well as ensuring instrument stability. The configuration of the target prisms on the bridge is always determined by the Project Engineer

in discussions with the Chief Surveyor to make sure that all of the critical areas of potential movements are sufficiently monitored.

Reliable Wireless Data Coverage

Michigan is blessed with reasonably stable wireless web coverage in populated areas and along the state highway system. As a result, the connection between the modem attached to the Leica TS30 and the Leica GeoMoS software server can be reliably established via the wireless web. On all of the projects completed in Michigan to date, there has been no data lost due to connectivity between the on-site modem and the server where the Leica GeoMoS software is installed. Certainly, the logistics of a successful and reliable monitoring project would be significantly greater (and more expensive) without access to reliable wireless data coverage.

“The ability to perform real-time monitoring in absolute 3-D via Leica GeoMos Software and the Leica TS30’s has revolutionized how we look at highway bridge reconstructions in the State of Michigan and provides our Project Engineers and Surveyors with added confidence to ensure the safety of the motoring citizens of the great State of Michigan, while providing significant cost savings in survey crew man-hours.”

-Mr. Shawn Roy, P.S. / Chief Monitoring Surveyor / Michigan Department of Transportation.

Secure Installation of the Monitoring System

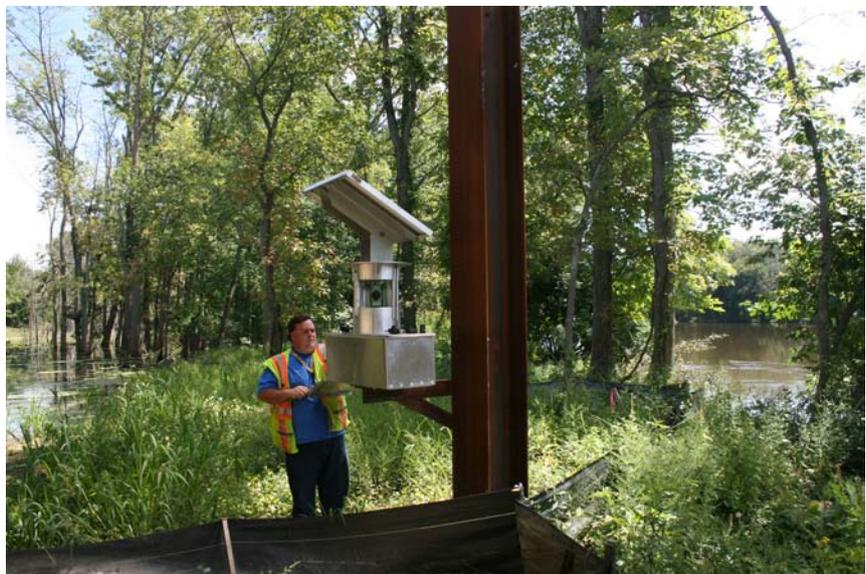
Security is also a concern, since Leica GeoMoS monitoring instrumentation is left on-site 24/7, unattended, especially during off-construction hours. In order to keep potential thieves at bay, the Michigan Department of Transportation has designed theft-proof semi-portable

equipment enclosures. The TS30 is mounted solidly onto the concrete instrument pillar and the theft-proof box containing the power supply, solar panels, inverter, and modem is lowered over top of the instrument. The original design plan of the innovators of this theft-proof setup (Mr. Andrew Semenchuk, P.S., and Mr. Shawn Roy, P.S.) called for a curved Plexiglas housing around the outer shield. However, upon testing, it was de-termined that the curved surface resulted in poor measurement accuracy to the prisms. The Plexiglas was removed so the instrument has an unrestricted view of the prisms. The theft-proof enclosure, even without the Plexiglas, eliminates the ability to remove the instrument from its mount and has been proven to be very effective in maintaining security.

As the Michigan Department of Transportation has perfected the TPS bridge-monitoring procedure for low frequency / high-precision bridge projects, they are currently looking to extend the capability of their existing Leica GeoMoS processing and analysis package to explore the utilization of GNSS sensors for applications where higher frequency (20+ Hz) may be required to facilitate project needs. The ability of both TPS and GNSS data to be combined simultaneously has a multitude of existing applications and opens the door to even more possibilities for ensuring the safety of future monitoring projects.

Productivity and Cost Savings

The Leica GeoMoS Monitoring Software, in conjunction with Leica TS30 total stations, is most certainly the most effective combination of safety, productivity, and cost savings for structural monitoring. Even the smallest country road bridges can directly result in User Delay fees of \$12,000 per day if closed to vehicular traffic. Larger interstate highway bridges can easily cost hundreds of thousands of dollars to close. Therefore, in addition to increasing the safety of everyone involved in these projects, the ability to minimize road closures during maintenance and reconstructions directly results in cost savings to the tax payers of Michigan.



Chief Monitoring Surveyor, Mr. Shawn Roy, P.S. inspects a monitoring station with a Leica TS30 situated on an IBEAM driven into the ground.

Leica Geosystems **TruStory** Slope Monitoring at Adaro Tutupan Coal Mine/Indonesia



Tutupan mine is one of the largest open cut coal mines in Indonesia, situated in the South Kalimantan province 300 km from Banjarmasin. The mine has a total coal production of over 40 million tons per annum. The Tutupan's pit dimensions are approximately 16,000 x 2,500 x 250 m.

The Adaro Tutupan mine is a long standing customer, having used Leica Geosystems monitoring sensors for slope monitoring since June 2004.

Currently, 11 Leica Geosystems total stations with hundreds of monitoring prisms are installed in the pit slopes to perform slope stability monitoring. The monitoring prisms are installed on the slope surface with intervals of 100-150 m and the process of installing many more prisms to cover all the pit slopes is ongoing. The total stations measure distances between 800 and 2500 m in a nearly continuous measurement cycle.

In addition, six meteo sensors are installed within the mine, automatically measuring atmospheric conditions and changes. In order to receive reliable measurement data, the total station slope distance measurements need to be corrected with the calculated PPM.

Radio devices (Mikrotik 2.4 GHz) are used for data communication between the Leica GeoMoS Software in the main office, all total stations, and the meteo sensors. Each instrument uses a ComServer to convert the RS232 feed from total stations and meteo sensors into RJ45/IP for radio communication.

Leica GeoMoS monitoring software controls the total stations and the meteo sensors. As a result of using GeoMoS, the customer receives long term monitoring deformation of the pit slopes.

The monitoring data is used for the study of slope stability for the monitored areas to protect work-



■ Scope/Objective

Monitoring the open cut coal mining slopes' deformation to predict the time of slope failures and to protect personnel and equipments from slope failures

■ Customer/Institution

Adaro Indonesia, South Kalimantan, Indonesia

■ Challenge

Continuously operate the complete system within immediate distance to the excavation

■ Date

Project started in June 2004

■ Location

Banjarmasin, Indonesia



■ Project Summary

Instruments

Leica TM30 Monitoring Sensor
Leica TCRP1203 Total Stations
Leica TCRA1201 Total Stations
Leica Geosystems Monitoring prisms
STS DTM Meteo sensor

Software

Leica GeoMoS Monitor
Leica GeoMoS Analyzer

Communication

Mikrotik 2.4 GHz Radio Modem

Office

Leica GeoMoS

ers and equipment and to research the slopes' 'behavior', especially the failure history.

Due to the variations of soil/rock types inside the excavation area, studies to obtain accurate deformation level limits are in a continuous development process, carried out by the surveyors responsible for the monitoring data and by geotechnical engineers. The geo-technical engineers and surveyors also estimate the time of failure of the mining slopes using the "Inverse Velocity" analysis. The time of failure is a very important indicator used to predict collapse of the slopes that have accelerating trends in deformation/velocity.

In addition, the automatic monitoring measurements are an essential data set to verify geotechnical assessments or recommendations made by production engineers.

Since the monitoring system has been installed, the geodetic and geotechnical sensors controlled by the monitoring software have been able to detect some slope failures in advance. The experience that was gained due to these events is now applied to limit levels for the measured deformations of the pit slopes.

To perform nonstop, 24-hour slope space stability activities in the mine, the monitoring crews run three shifts to ensure the delivery of real time slope stability information to the responsible staff. The main challenge of this huge monitoring project is to maintain, for example, the data communication and to schedule service times for the installed equipment.

Besides geodetic sensors (total stations with meteo sensors) and

■ Benefits

- 24 hour slope stability monitoring to protect personnel and equipment from slope failures
- Predict time of failure
- Optimize the excavation

the Leica GeoMoS monitoring software, the Adaro mine also uses geotechnical monitoring sensors such as inclinometers, crackmeters and of course visual inspection/monitoring. Combining all variations of monitoring methods/technologies increases the reliability and accuracy of the deformation data. Responsible slope engineers gain confidence when two independent measuring technologies indicate the same measurement results. Nevertheless, a final visual inspection is done before large-scale actions are taken by the engineers.



A combined power supply station with a solar panel is used for data transmission to the main office for data analysis (top).

Several High-Precision Leica Geosystems total stations are used to monitor the slopes of the Adaro Tutupan Coal Mine (left).

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- when it has to be **right**

Leica
Geosystems

Leica Geosystems **TruStory** Monitoring System at Tsuen Wan West Station, MTR West Rail Line



The TW7 area in Tsuen Wan West Station Hong Kong, is the planned location for the development of a new urban infrastructure. Since the construction is very close to an existing MTR (Mass Transit Railway, the rapid transit railway system in Hong Kong) tunnel and station, an automatic deformation monitoring system (ADMS) must be installed for security, because any deformation to the MTR could threaten the lives of thousands of passengers.

A Netherlands company has been contracted to monitor the development of this project for any deformation that may occur due to earth and piling works. To perform the deformation monitoring Leica Monitoring solutions has been selected. This is because the realtime monitoring is able to continuously detect any deformation, therefore providing an alert to any possible disasters.

System design and setup

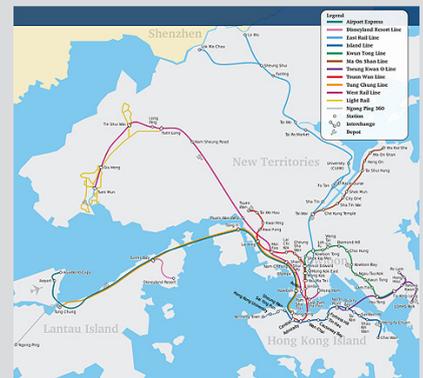
The design of the tunnel monitoring system started in 2009 and required two months to complete the design, preparation, setup and testing. In total, six high accurate Leica TM30 total stations, two computers, one backup computer, 42 reference prisms and 234 monitoring prisms have been installed for the monitoring system. The locations of the total stations and prisms were carefully selected so that measurement coverage, efficiency and the costs of the project were balanced. The total stations were distributed along a 400 meter segment of the railway tunnel. The total stations we installed in three groups of two, with one total station of each pair was set to monitor the uptrack, the other the downtrack (see Figure 4). The monitoring prisms were installed next to overhead line cables, on the sides of the tunnel and next to the pedestrian walkway.

■ **Scope/Objective**
Tunnel deformation monitoring

■ **Customer/Institution**
MTR, Hongkong

■ **Date**
2009 - ongoing

■ **Location**
Hongkong



■ **Project Summary**
Used Instruments

Leica TM30

Leica Geosystems L-bar prisms

Software

Leica GeoMoS Monitor / Analyzer

Web Service for data viewing of the SU Hongkong

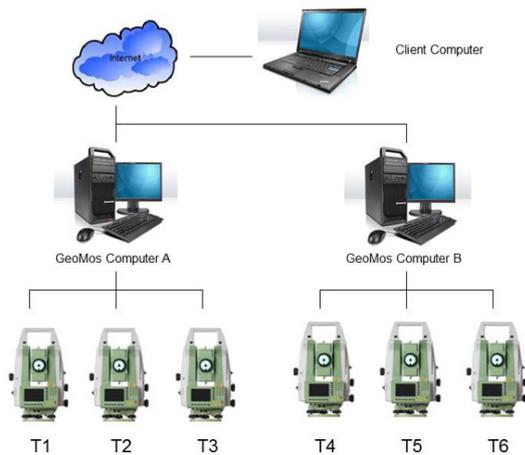
Third party adjustment software

Communication

Cables

■ **Challenge**

- Monitor a length of 400 meters
- Ensure the required clearance between installation and railway infrastructure
- Fully automated and reliable system to very limited access to the site



■ Benefits

- Ensure the safety for the daily railway operation
- React proactive on any occurring deformation to avoid downtimes of the railway tunnel / station

For each prism a clear line of sight to the total stations and safety clearance to the tracks and overhead lines was required.

Communication

was established between the total stations and the dedicated monitoring computers using cables. These computers were located in a separate office with a workstation equipped with Leica GeoMoS Software. This is responsible for the Leica TM30 control, data collection, analysis and visualization. In addition, third party network adjustment software was used. Reliability to the system was ensured by using uninterrupted power supplies (UPS), to reduce the problems of power outages, and data was frequently backed up. Regular maintenance and checks including cleaning the optical prisms twice a week, allowed the system to operate smoothly and accurately as the trains, running frequently next to the instruments, could cause unwanted displacements and dust coverage of the prisms.

Monitoring Network

The stable reference prisms were installed along the tunnel, partly

outside the monitoring area and partly inside the monitoring area. As not every total station had a line of sight to the outside stable reference points, it was necessary to compute network adjustments for the complete network based on the outside stable reference points, so that the inside reference points could be updated. For that reason, at the beginning of each complete monitoring cycle, the total stations measure all the reference points. These measurements are used to compute the network adjustment. The coordinates of the total station standpoints and the reference points inside the monitoring area are updated with the results. Leica GeoMoS software then measures the monitoring points based on the updated reference points. This complete measurement cycle, with stable reference and monitoring points, occurs every 2 hours.

Deformation Data

The monitoring data is available in real-time for displaying through the Internet. The monitoring staff, with appropriate access codes, can login to the complete monitoring system information and display both deformation values and the system health. In

addition, the end customers have the ability to access via a web interface the measured monitoring data that represents the deformations in easily understandable graphical and numerical deformation reports.

Messaging System

To enable quick response to any irregularities in the project area, a messaging system was implemented. This system automatically informs the responsible staff via e-mails in any situation when a measured displacement exceeds set limit levels. These limit level values have been set through the system beforehand by the surveyors. After a limit level is exceeded, the surveyors in charge investigate the reasons behind the exceedance and confirm whether the measurement was due to outliers, human errors, construction activities or a real movement.

Conclusion

In the last decade, it has been proven that the automatic deformation monitoring systems have effectively prevented accidents from happening since its implementation in various projects in Hong Kong.

Leica Geosystems **TruStory**

Chemical Plant Monitoring



■ Scope/Objective

Monitor of a highly explosive plant during consolidation works

■ Challenge

Continuously evaluate data to check the position of the pipes in the plant

■ Date

December 2011 - ongoing

■ Location



■ Project Summary

Field

"PLANT 1" and "PLANT 2"

Leica TM30 0.5"

Leica GeoMoS Monitor

SystemAnywhere (data synchronisation & calculations)

Analysis (data view)

Sensor communication in the field

Wireless LAN for sensors

Remote communication

Cellular router

Office

Analysis

■ Benefits

- Absolute data and differential values for real-time check of the pipes
- Reliable and precise Sensors
- Cost savings

The plant is located in the center of Italy and is a chemical plant for the production of high explosive chemical liquids.

Maintenance work inside the plant by a construction company making some consolidation works (like micropiles, etc.) is required. To avoid any effect and to maintain the plant's activity, the customer is obliged to monitor the pipes during all the construction operations. Any unforeseen deformation of the pipes causes a total stop of the production, which costs approximately 1.000.000 EUR per hour. Therefore, the stability of the pipes related to their absolute as-built positions in the plant are monitored in real-time with very close human supervision of the gathered results.

Each pipe carries high explosive liquids through the plant. The monitoring area is sub-divided in two plants called "PLANT 1" and "PLANT 2".

A total station monitoring system was selected for the plant monitoring due to its flexibility during the installation of monitoring prisms on the pipes with a minimum time & work impact, the ability to easily add and remove monitoring points, the cost saving for the increase of monitoring points and the ability to measure prism's absolute position with high precision.

On each site the total stations are directly plugged into a so-called "TM30 box". These boxes are connected via WiFi to a so-called

PC box that contains a cellular router, industrial windows based PC, power and cabling. The GeoMoS Monitor software is installed on the industrial PC and manages the measurements, the calculation and the limit check computation. The complete monitoring data is transferred from SystemAnywhere to the office PC via a secure FTP server.

In the main office of an engineering company, that is contracted by the construction company and responsible for the monitoring system, the software for data analysis is installed. In this project, the local Italian SystemAnywhere software is used to analyze and validate the measured monitoring of the sites. With the SystemAnywhere software on the SQL database it is possible to work from three different workstations.

"TM30 boxes"

Installed next to every Leica TM30 is a so-called "TM30 box". All the Leica TM30 total stations are connected directly to a 220V power supply, without backup battery (because it is not allowed in the plant). Inside the "TM30 boxes" are the required devices e.g. a datalogger that reads out and stores the charge of the battery, serial to IP converters, WiFi devices and an Ethernet switch, to ensure easy connection with a laptop to check the status of all the connected devices. To allow maximum flexibility

of the box, every component and device is DIN-Rail mounted.



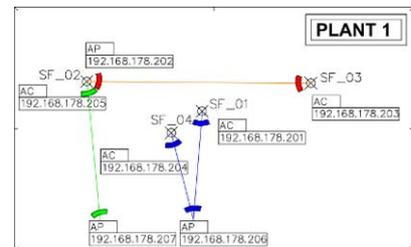
Leica TM30 field view

The battery information is automatically downloaded to the "PC box" so that the system operator can proactively react and exchange batteries if required.

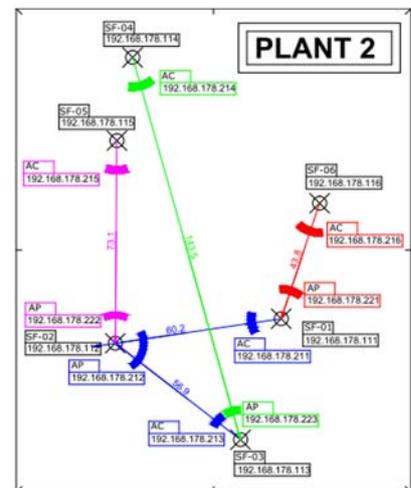
To fulfill the customers' requirements it was necessary to measure assigned 3D positions within the plant and the pipes. These coordinates are then used in a virtual sensor computation. With virtual sensors, the output of one or more sensors can be modelled using constants, mathematical functions and/or logic operators. In this project three main virtual values have been computed; height difference between two points on the same pipe but on different planimetric position, 3D vectors between points in different sections of the pipes line (like convergence measurement in the tunnel) and 2D vectors (planimetric) between points on the same pipe to check the alignment.

Based on the computed virtual sensors, automatic limit checks are computed and messages given to the customer. Based on the limit checks, the operator can make decisions about the safety of the plant.

As a result, the customer receives all the results as simple and clear graphs that show, at a glance, the behaviour and deformation of the plant.



Wifi network "PLANT 1"



Wifi network "PLANT 2"

Leica Geosystems **TruStory**

Railway Bridge Monitoring

Kirchtobel – Switzerland



100 year old railway bridge "Kirchtobel" and the monitoring system setup

The extension of the railway line between St. Gallen – Arth-Goldau is part of the integration of Eastern Switzerland with the New Railway Link through the Alps (NRLA). There are several engineering projects associated with this enlargement, such as the building of the new railway bridge close to St. Gallen. As the new bridge will be built close to the existing one hundred year old bridge, the project is complex as the old bridge is made of natural stone and the foundation of its pillars are not accurately defined. This means that construction work can affect the old bridge in the forms of settlement and torsion. A permanent monitoring system is required to monitor these

movements and inform the key people in the railway service "SOB Südostbahn" in any case of emergency.

Monitoring Object

The railway bridge crosses a steep forested ravine and has a length of 150 m and the maximum height is about 30 m. The overpass consists of four minor and six main arcs, and there are trains crossing the ravine every 15 minutes in both directions.

During the building process of the new bridge, the structure of the old bridge and the overlying tracks has to be monitored. Due to a geological report, the people in charge concluded that the existing bridge foundations will be influenced by the construction work around the old bridge, especially during the building of a temporary road through the ravine, which could lead to subsidence and rotation of the piers. Movements in the foundation of a railway bridge can be disastrous for the railway service and distortions in the railroad



Important swiss railway connections

Schällibaum AG
Ingenieure und Architekten



- **Monitoring Company**
Schällibaum AG, Switzerland
www.schaellibaum.ch
- **Builder**
Schweizerische Südostbahn AG
- **Challenge**
Monitor and display the movements of a railway bridge during the construction of a second parallel bridge
- **Date**
November 2011 to May 2012
- **Location**



- **Project Summary**
- **Instruments**
Leica TCA2003, Leica TCA1800
Leica Prisms
Leica Nivel220 Bus System
W&T Meteo Sensor
Webcam
- **Software**
GeoMoS Monitor and Analyzer
GeoMoS Web
- **Communication**
Leica ComBox20
Leica TCPS27 Radio Modem
GSM/UMTS, Ethernet, RS232/485
- **Power**
Fuel Cells
- **Alarming**
SMS and E-Mail



Distributed monitoring prisms

tracks are the most critical factor in the rail geometry. Therefore, in addition to monitoring the various foundations, focus is also placed on the bridge head where the tracks lay. The expected movement at the foot of the bridge could be in the millimetre to centimetre range. In addition to these conditions, the location of the object, the different weather conditions and the progress of construction of the new bridge must be also considered during the design process of the monitoring system.

Monitoring System

For this monitoring project primarily tachometric measuring equipment (Leica TCA2003, TCA1800) was selected. The required measurement accuracy is $\pm 2\text{-}3\text{ mm}$. The total stations have been placed on each side of the bridge in the ravine. With the choice of these instrument stand points, the piers of the arcs can be monitored from each side, leading to redundant. A total of 81 prisms are mounted in a uniform pattern on the bridge. For setting up and orienting the total stations, there are twelve stable fixed points available around the viaducts that are mounted on concrete pedestals.

Special pillars are created to ensure the stability of the total station locations. These pillars are made of a solid foundation, where the frost depth is considered, a stable outer shell serves to protect against temperature and mechanical damage. The measuring device is installed on the core of these pillars.

To use optical measuring instruments as total stations, a clear view of the monitoring object must be ensured. For that reason several problems need to be taken into account for this project. Firstly, because this gorge is heavily wooded, certain shrubs and trees have to be felled. Secondly, the new bridge will obscure a face of the old bridge during its construction progress, which cannot be prevented. Thirdly, in winter months, fog often

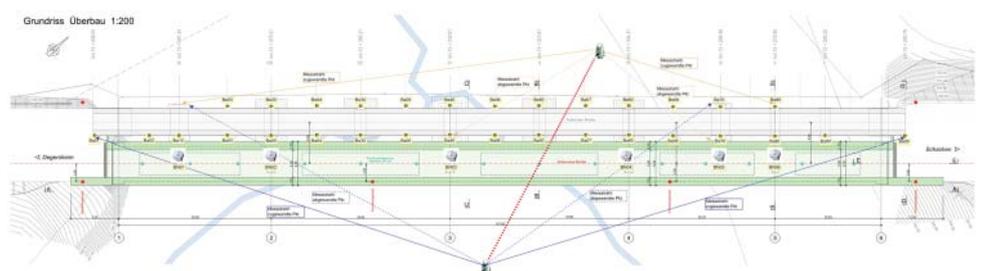
Benefit

- Redundant measurements of monitoring points from different TPS locations
- Nivel220 Bus System as a fallback system for bad weather conditions
- Data access anytime and anywhere over Leica GeoMoS Web
- Efficient messaging via SMS and E-Mail
- Flexible and secure communication setup
- Fuel cell technology provides a secure and self-sufficient power supply in the outback
- Automatic versus manual monitoring systems reduces costs
- Leica Geosystems Support

covers this region, which impedes geodetic measurements. Due to these problems, six inclination sensors (Leica Nivel220 bus system) are installed at the bridge head. These high-resolution sensors monitor the longitudinal and transverse tilt of the bridge. They form redundant measurements and a fall-back for the monitoring system, if optical measurement techniques fail.

The automatic monitoring system also determines the atmospheric corrections for geodetic measurements with meteo data (temperature, pressure and humidity) from a meteorological sensor. Furthermore, these weather data are helpful for the concreting phases of the new bridge elements.

Beside all these measuring sensors, a rotating webcam is



Monitoring System Calibration

Before a system is set to active, a proper null measurement of the monitoring object is necessary. During this phase, the measurement data of the stationary bridge, and thus the intrinsic behaviour of the bridge are studied. It is also an opportunity to fine tune the monitoring system.

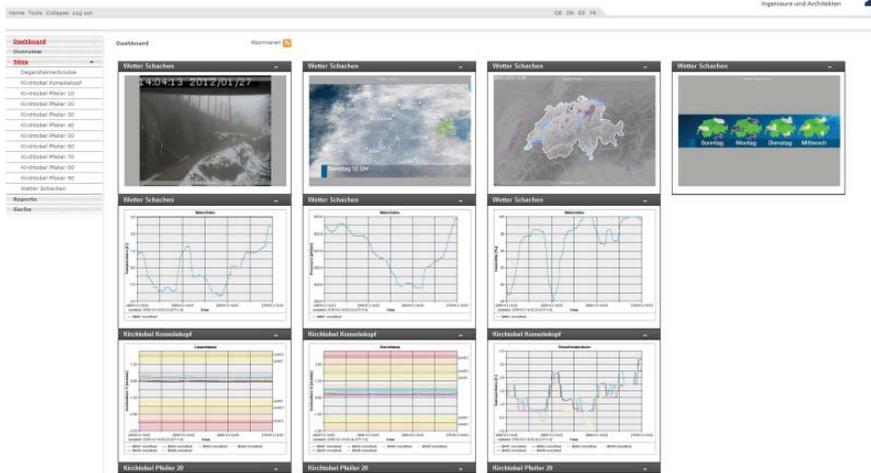
Conclusion

By using such an automated monitoring system through the construction, the companies involved get an image of the health status of the constantly monitored object. With high-resolution and independent measuring techniques and the deployment of modern means of communication, the reliability and quality of measurement results can be increased. These are essential prerequisites for monitoring tasks. Such



Power-Box (fuel cell) and ComBox

a monitoring system increases the efficiency and flexibility of the construction and therefore allows costs to be saved (e.g. insurance premiums for constructions, manual monitoring costs, etc.).



Graphical visualisation of the monitoring data in Leica GeoMoS Web: web cam image, weather forecast, rain radar, meteo data, inclinations with shown limit levels, etc.

also used to monitor the surveying process and the measurement equipment. The measured data of the individual sensors (Leica total stations and Nivel220) are collected in a master station (Leica ComBox20) and are transferred, on the mobile internet (GSM/UMTS), to the control centre (Leica GeoMoS) where the whole system is supervised. The connection from the master station to the different sensors is done via cable and/or wireless connections and the data transfer interfaces are serial RS232/485 and TCP/IP protocols.

Via the SMS service, the connection status (e.g. UMTS signal strength) of the master station can be queried and in addition, the station may also be rebooted in the event of various faults in the communication. Since the project is in rural areas, the power of the monitoring system is somewhat more complicated. Before the construction of the new bridge, mains electricity

is not available at the site and must therefore be supplied by fuel cells. The development of power-boxes in combination with fuel cells and batteries generates emission-free electricity and runs the system self-sufficiently for several days or weeks.

By using Leica GeoMoS in the control centre, the data is validated on the basis of filter criteria, processed and stored in a database. If any measurement results exceeds set limits and satisfies the filter conditions, the messaging system notifies the appropriate people in charge.

These messages are sent via e-mail and SMS service. After the messages are sent, further action will be taken based on set regulations. This begins with a consultation of the monitoring data through the Leica web portal GeoMoS Web, then a site visit if necessary, which can lead to immediate closure of the railway operation.

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- when it has to be right

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Geosystems

Leica Geosystems **TruStory** GNSS Observation of Volcanic Activities in Sakurajima



Sakurajima is a volcano on the island of Kyushu. It is located on the southern edge of the Aira Caldera and erupts from the summit of Sakurajima. This summit is split into three peaks known as the Kita-dake (the northern peak), the Naka-dake (the central peak) and the Minami-dake (the southern peak). The volcano is located in close proximity to the densely populated Kagoshima city area. It is very active and is known to be the largest active volcano in Japan. The crater at Sakurajima's Minami-dake summit erupted in October 1955 (Showa 30). Since then, the volcano has been spewing volcanic products (volcanic gas, ashes, lapillus and cinders), and creating earth and rock avalanches, which continues to cause damage in every direction. Because of this, no person is allowed, without

permission, within a 2 km range of the Minami-dake crater.

The volcanic explosion in October 1955 (Showa 30) was the starting point for volcanic eruption predictions at the Disaster Prevention Research Institute, and transitive volcanic activities have been monitored attentively ever since. In June 1956 (Showa 31), observation of volcanic activity in the mountain summits was on a full-scale level and it was determined that the duration would be of a long-term continual nature. This prompted the necessity to consider the construction of a permanent observation facility. The Sakurajima Volcanological Observatory was inaugurated in December 1960 (Showa 35) and originally constructed as an auxiliary facility to the Disaster Prevention Research Institute and was endorsed by the Ministry of Education, Science, Sports and Culture.

GEOSURF

■ Objective

Volcano monitoring to predict volcanic eruptions

■ Customer/Institution

Geosurf Corporation
Disaster Prevention Research
Institute Kyoto University, Sakurajima
Volcanological Observatory

■ Date

Start August 1994

■ Location

Kagoshima Prefecture, Japan



■ Project Summary

Instruments

Leica GMX902GG Receiver
Leica GRX1200 Receiver
Leica AX antenna
Leica AT502 antenna

Software

Leica GNSS Spider
Geosurf RIP (developed by Geosurf
Corporation)

Communication

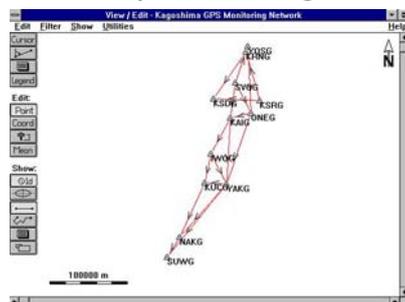
Internet

■ Challenge

Monitoring volcanic eruptions and predicting volcanic eruptions by utilizing the GNSS system

Emphasis is placed on seismic observation and ground deformation observation, both of which are conducted at the Sakurajima Volcanological Observatory. In order to capture a versatile picture and reach a comprehensive understanding, additional observation content is made sequentially observation to attain diversified observation. In Spring 1994 (Heisei 6), a total of 18 dual frequency GPS Leica SR299E receivers were installed, with 9 receivers at Kirishima Volcano Station and 9 at the Sakurajima Volcano Station. GPS Network Monitoring started in August of the same year.

Network System Coverage



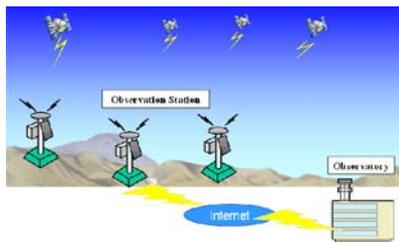
Network range is 70km x 300km

Network System Configuration

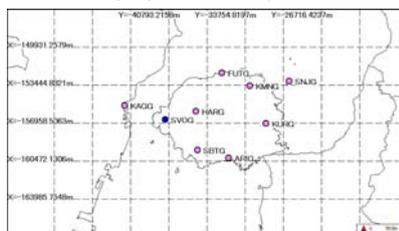
An upgrade of the GPS Network System began in 2005 (Heisei 17) and consisted of the latest in receiver and analysis software. The GPS network revision resulted in improvements in the positional system, system reliability and system efficiency.

- The implementation of the latest GNSS receiver resulted in the GNSS Network System enabling

- GPS + GLONASS reception
- The latest version of Leica GNSS Spider was installed on the analysis software
- The implementation of GEOSURF RIP enabled confirmation of positional data
- The enablement of GNSS receiver operation from remote areas (by Leica GNSS Spider) was accomplished
- Back-up of observed data through the implementation of CF cards on the newest receivers (Leica GRX1200) was performed in the event of problems with transmission.



Monitoring system setup



Locations of 9 observation stations in the Sakurajima network

Establishment of Observation Stations

The Leica GMX902 GG GNSS receivers were newly implemented and installed in 2 brand new observation stations and the Leica GRX1200 was updated in the existing observation station.



GPS antenna at "Kurogami" site

Characteristics of the new GNSS receiver model

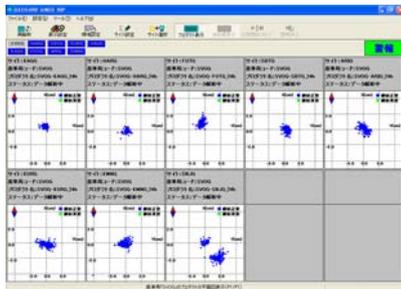
	Leica GRX1200	Leica GMX902 GG
GPS	✓	✓
GLONASS	✓	✓
Dual frequency	✓	✓
Electricity consumption	4W	2W
Leica SmartTrack	✓	✓
Web interface	✓	✓
CF card	✓	✓
Leica GNSS Spider connection	✓	o

Improvements were made in longterm reliability and static observation, by implementing Leica Geosystems "SmartTrack" function. Also, the web interface makes it possible to remotely control multiple receivers by using one computer terminal, eliminating the necessity to go to the observation station to modify the receiver configuration. Additionally, a CompactFlash card is used as a backup function for the observation data. This is particularly beneficial in volcano monitoring and observation, where circumstances do not necessarily guarantee the stability of transmitted data. With 1 GB, the CF card can

hold up to 7 weeks' worth of data. The GMX902GG design is compact and solid and is a GNSS receiver that was exclusively developed for monitoring purposes.

Observation Data and Analysis

"Leica GNSS Spider" and "GEOSURF RIP" are both installed on the same computer terminal for analysis of observation data, which is then sent to the Volcanological Observatory. The main function of "Leica GNSS Spider" is positional analysis.



Main GUI of "Geosurf RIP"

"GEOSURF RIP" is a system equipped with a coordinate transformation function and converts coordinated measurements taken by "Leica GNSS Spider" using WGS84/ITRF into the local frame of reference and it simultaneously performs noise elimination.

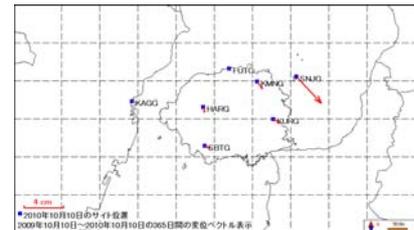
Additionally, "GEOSURF RIP" utilizes the interface which displays a simple and graphic image of the horizontal position, height, and directional position on the monitor screen.

Horizontal Variation

Variation of the horizontal vector is a key element in the analysis of volcanic observation.

The following diagram displays horizontal direction movements, from the past year. The displayed movements originate from the respective observation stations. It

is possible to attain the estimated pressure source positioning and magma output volume from such data, as well as other observations, which in turn lead to and enable volcanic eruption prediction.



Horizontal displacement vector from Oct 2009 to Oct 2010 when reference station is SVOG

Conclusion

The recent update in the observing system resulted in an improvement of positional accuracy.

Leica Geosystems **TruStory** Monitoring to Secure an Area With Hydrogeological Instability



■ Scope/Objective

Automatic and continuous monitoring of a mountain slope affected by hydrogeological instability

■ Customer/Institution

The Region of Valle d'Aosta

■ Challenge

Continuous monitoring of any movements in the area for activation of the Civil Protection plan

■ Date

July 2009 - ongoing

■ Location

Valle d'Aosta, Italy



The Aosta Valley (Valle d'Aosta) is a mountainous semi-autonomous region in north-western Italy. It is bordered by Rhône-Alpes, France to the west, Valais, Switzerland to the north and the region of Piedmont to the south and east. With an area of 3,263 km² (1,260 sq mi) and a population of about 130,000, it is the smallest and least densely populated region of Italy. It is an Alpine valley that, with its side valleys, includes the Italian slopes of the Mont Blanc (Monte Bianco), Monte Rosa and the Matterhorn.

Some areas are affected by slope instability called DGPV (Deep-seated Gravitational Slope). The main State Road 26 section accessing the Mont Blanc Tunnel, as well as the districts of Entrev and Palud are influenced.

Since 2000 the Region of Valle d'Aosta and the department for "Inspectorate for public works, soil conservation and water resources - Geological Service" have carried out a series of surveys in order to gain in-depth knowledge on the instability and to understand its dynamics.

As a result, today this area is monitored 24 hours, 7 days a week with a fully automatic and integrated deformation monitoring system. The system combines geodetic and geotechnical instrumentation as well as ground radar measurements.

Based on the surveying results of the last years and the importance of the regions, dedicated monitoring points on the slopes have been selected for automatic deformation monitoring and stability analysis. About 30 monitoring prism and

Project Summary

■ Instruments

Leica TCA2003 Total Station
Leica NIVEL210 Tilt Sensor
Leica GMX902 GG
Leica AS10
Leica GMX901 with communication box
Leica Geosystems Monitoring prisms
Master Unit PC

Software

Leica GeoMoS Monitor
Leica GNSS Spider
SystemAnywhere (data synchronisation & calculations) and Analysis (data view)

Communication

Wireless LAN
GSM/GPRS

Office

Analysis

5 reference prisms are installed. These prisms are measured with a Leica TCA2003 total station every hour. The total station is installed in a stable area with a pillar secured to a rock on site. In addition, a dual axis inclination sensor Leica Nivel210 is installed to verify the stability of the station with an independent sensor. Near to the Leica TCA2003 total station, a separate GMX902 GG receiver with Leica AS10 antenna is installed. Also, several Leica GMX901 have been installed with co-located prisms that record data with 1Hz. The monitoring prisms and the Leica GMX901 are installed over the slope to monitor critical positions.

Commonly for alpine valleys, human access to the monitoring sensors is very limited. All installed equipment requires a reliable and autonomous energy source that guarantees that the equipment works properly. Due to the amount of snow and the reduced solar irradiation during winter months, a combined power supply system was installed for continuous power and recharging



of the buffer battery on site. The power system consists of solar panels and a methanol tank system. A special electronic device controls automatically and intelligently the correct power input to the monitoring equipment between the solar panel and the methanol tank system.

The complete automatic monitoring system is left unattended in the remote environment of the Aosta Valley. The total station and the Leica GMX receivers are managed by Leica GeoMoS and Leica GNSS Spider, which are installed on a master computer (embedded industrial PC), located inside the total station measurement hut. The total station, the Leica GMX902 GG sensor and the Leica Nivel are connected via cable to the master computer and the GMX901 sensors are connected via 5GHz wireless link.

The acquired raw data from Leica GeoMoS and Leica GNSS Spider is downloaded from the monitoring site, with the software called SystemAnywhere, to another dedicated monitoring system computer



■ Benefits

- Study of landslide dynamics
Protecting the safety of the population
- Analysis and study of an efficient integrated approach to multisensor monitoring

located in the headquarters of the customer. This SystemAnywhere retrieves the pure raw data and then automatically computes the total station corrections as orientation, free station, ppm etc. Total station and GNSS baselines are combined and limit checks computed.

In case the three different set limit thresholds are exceeded, the responsible staff member in charge is informed and the required actions are taken to ensure the safety in the Aosta Valley.

As a result, the monitoring system includes two independent geodetic measuring sensors, total station and GNSS data, that increase the reliability of the system. The data is correlated for further evaluation.

This autonomous monitoring system is beneficial for the Aosta Valley, as continuous monitoring data is collected and analysed providing detailed deformation information. In addition, messages are sent to notify the required personnel of exceeded limit levels providing advance warning of possible problems and protecting the safety of the local population.

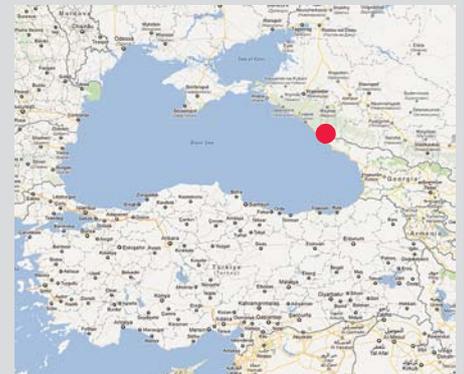
Leica Geosystems **TruStory**

Rail Tunnel Monitoring in Sochi/Russia



www.tunnels.ru

- **Objective**
Rail tunnel monitoring during construction
- **Customer/Institution**
Tunneldorstroy
- **Date**
2011 - ongoing
- **Location**
Sochi/Russia



- **Project Summary**
 - Instruments**
Leica TM30 Monitoring Sensors
Leica Geosystems Monitoring prisms
 - Software**
Leica GeoMoS Monitor / Analyzer
 - Communication**
 - Ethernet via LAN cables and mobile Internet
 - Uninterrupted Power Supply (UPS)
- **Challenge**
Real-time deformation monitoring among frequent rail traffic

A railway tunnel near Sochi in the Russian Krasnodar region is being monitored as part of the construction preparations for the 2014 Winter Olympic Games. The tunnel is part of the only rail line for all passenger traffic to the Sochi resort area from central parts of Russia and for cargo traffic supplying construction sites in Sochi. Due to the planned construction of two road tunnels above the railways, the decision was made in 2011 to set up an automatic monitoring system for the existing tunnel.

The company Tunneldorstroy is building two road tunnels, with a total length of 770m, above the current rail tunnel.

Out of concern for the safety of passenger and freight trains passing through the current tunnel, it was decided to monitor a part of

the existing tunnel to detect possible deformations resulting from the construction of the road tunnels and to detect possible problems before they become critical.

Frequent trains and the necessity of acquiring data every two hours made it nearly impossible to perform classic methods of monitoring. Therefore, total stations and the automatic deformation monitoring system Leica GeoMoS were installed and have been working around the clock. Project planning recommended installing two Leica TM30 (1") robotic total stations in the middle of the existing rail tunnel to have line of sight to all prisms and to measure reliable data. These instruments can achieve an angle accuracy of 1" and a distance accuracy of 0.6mm + 1ppm. Automatic target recognition (ATR) allows the Leica TM30 to reliably aim to the center of each reflector and thus to determine the smallest deformations.



■ Benefits

Once the automatic monitoring system was installed, the system works beside all difficulties caused by lack of electricity and heavy train traffic absolutely reliable and delivers high accurate monitoring data

Because of an unreliable power supply inside the tunnel construction area, an uninterrupted power supply (UPS) and power conditioner had to be set up for continuous operation of the total stations and the communication devices.

Four stable control prisms were mounted on each side of the tunnel. These points are frequently checked by an independent survey campaign. Before the monitoring points are measured, each total station positions to the stable control prisms located in the deformation-free area. These measurements are used to compute the actual total station position and corrections (e.g. orientation or Vz correction) using resection calculations. For the actual monitoring, five monitoring prisms were installed in each tunnel profile. The distances between the profiles are between 1 to 5m. A total of 196 monitoring prisms are located

along the entire rail tunnel structure. All points are measured every two hours.

Communication

The total stations are connected to a GPRS/GSM modem installed near one tunnel end by LAN cable and the Ethernet converters inside the rail tunnel. The communication between the total stations and the software is via TCP/IP and Mobile Internet.

Data Processing Center

The measurements of the Leica TM30 total stations are managed by the Leica GeoMoS. With an integrated TCP/IP connection GeoMoS is able to establish a bi-directional communication with the total stations over the GPRS/GSM modem and the tunnel LAN. The GeoMoS Monitor software is installed at the Tunneldorstroy office on the other side of the city.

It is responsible for control of the total station, data acquisition, data storage and automatic processing of the instrument's resection (free station computation).

In case of a deformation event an SMS or email is sent to the responsible staff for further investigation and inspection of the deformation. The monitoring data analysis including graphs and reports is completed using Leica GeoMoS Analyzer.

Leica Geosystems **TruStory**

Monitoring Bridge Structures Under Static Loads



The Maria Skłodowska-Curie Bridge (Polish: Most Marii Skłodowskiej-Curie, formerly North Bridge) is a road bridge over the Vistula River in Warsaw, Poland. The road bridge in the capital of Poland links the northern suburbs of Białołęka and Bielany and opened on 24 March 2012. The total length of the bridge is 795 m (the main river span is 160 m). The applied precise Nivel220 inclinometers network makes it possible to measure the deflections of a bridge construction under static loads without the necessity of using external reference points. The project has been implemented in cooperation of the Road and Bridges Research Institute in Warsaw, Leica SU Poland and O.N.T Krakow.

The most typical application of the new system is deflection monitoring of various bridge constructions, where installing mechanical sensors would be very difficult or even impossible (road traffic or intensive exploitation of railway tracks).

Why a New Approach?

Before implementing the bridge load monitoring system, the customer had been doing classical surveying (leveling supported by precise measurements TDA5005 high-accurate industrial total station). Such approaches were successful until the construction boom in Poland, resulting in a necessity of applying high-speed online systems, which

are ready to be used in many, usually very distant, places in a short time. Moreover, the research body of the Road and Bridge Research Institute came across the idea of developing new technology, which could bring new possibilities and make the whole process of static load testing more comfortable and useful.

The new architecture of the North bridge load monitoring system comprises an integrated work between 20 precise Leica Nivel220 inclinometers and a Leica TM30 Monitoring Sensor.

Monitoring Setup on the Bridge

The Leica Nivel220 inclinometers have been placed in specially designed adapters, to detect deflections of the bridge construction. The adapters have to be attached to the bridge construction or set up along the construction's edge. Each Leica Nivel220 device is powered and linked to the next one by cables, so that a network (maximum 32 pieces) is built up. The first Leica Nivel220 is attached to a "master station" consisting of a military toughbook, power supply with backup battery and an integrated radio modem. From this "master station" the monitoring data is sent to the monitoring office.

The Leica TM30 total station is operated via Bluetooth® technology, making the whole application more flexible.

■ **Scope/Objective**

An innovative integrated surveying system applied in the monitoring of bridge structures under static loads

■ **Customer/Institution**

Road and Bridge Research institute

■ **Date**

April 2011

■ **Location**

Warsaw, Poland



■ **Project Summary**

Instruments

Leica TM30 Monitoring Sensors
Leica Nivel220 Precision Inclination Sensors
Leica GMP104 Monitoring Prisms
Leica GMP112 Prisms

Software

Leica GeoMos Monitor + Analyzer

■ **Additional Field Equipment**

Specially-designed adapters
Power wires of different lengths (25 m, 50 m and 100 m)
Power supply system with backup batteries
Military toughbook

■ **Communication**

Satellite radiomodems
Bluetooth® Wireless Technology

■ **Mobile on-site Office**

■ Panasonic Toughbook
3rd party analytical software based on Matlab® engine for reading data from the SQL database, calculating the bridge deflection curve and visualizing & saving the data (in on-line mode)



■ Benefits

- Flexible installation
- Reliable and precise sensor network
- Real-time data transmission
- High accuracy and reliability of collected data

www.ibdim.edu.pl
www.mostpolnocny.warszawa.pl

Data Analysis and Results

The Leica GeoMoS monitoring software runs in the monitoring office, schedules the Nivel220 readings and stores the data to the SQL database. Afterwards, a third party application powered by Matlab® core presents the results, by modeling the data with special "spline-curves" algorithm. This application accesses the measured raw data from the SQL database and processes the data to the particular demands of the project.

In addition, the Nivel220 inclinometer network is supported by total station surveying data (high accurate results given by the Leica TM30 0,5" precise total station) exemplifying the deflection progress of the tested bridge structure. Based on the surveying results (inclination angles) the system constantly determines the height displacement line by modeling the data with a specially-developed algorithm using "spline-curves". Moreover, the system delivers very high accurate data as well as high frequency of sampling.

Conclusion

The system was tested on several newly built as well as on already existing bridge structures, examined under static loads, across Poland.

Bridge monitoring was performed during construction works, final tests and further exploitation of a structure. The proposed and successfully implemented bridge load monitoring system brings many benefits for both its user and other customers. First of all, it can compete against the classical methods mainly based on leveling. In many cases, a bridge construction is unique, long and extraordinary, making it difficult to perform time-consuming and in many cases erroneous leveling methods. Moreover, a system user can analyze constructions in real time, considering static loads while examining bridge construction, which is simply crucial.

Customer Benefits

The customer appreciates the highest accuracy and reliability of collected monitoring data. That's the reason why the institute has been using Leica Geosystems equipment, as well as the constant and still thriving cooperation between specialists from both sides. Leica Geosystems, responsible for the delivery of instruments and accessories and also for the whole process of the project implementation. For example, Leica Geosystems provides a full CCP service and maintenance in aftersales. Very often, the specialists

are invited to participate in practical projects run on-site. The customer saves time in addition to getting more reliable and accurate data. Based on the new amount of data, they are able to implement new modeling algorithms running on highly efficient computers, making examined constructions safer and expressing real behavior during the exploitation.

The designed bridge load monitoring system is one of the most precise and at the same time flexible bridge monitoring installations in Europe.

The Road and Bridge Research Institute in Warsaw has been a key customer of Leica Geosystems Poland since 2006. The area of common co-operation comprises integrated monitoring systems, precise leveling and high-accurate total station surveying combined with innovative software and database solutions. The project was carried out by specialists from Road and Bridge Research Institute under the supervision of Dr Ing. Piotr Olszek in cooperation with: Dr Ing. Krzysztof Karsznia from Leica Geosystems Poland. Dr Ing. Mariusz Pauluk, Msc Ing. Miłosz Augustyński & Msc Ing. Paweł Bytnar from Oprogramowanie Naukowo Techniczne, MathWorks distributor in Poland

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- when it has to be **right**

Leica
Geosystems

Leica Geosystems **TruStory**

Monitoring a dam wall in a Polish Copper Ore Enrichment Facility (PL)



View from the monitoring hut towards the tailings dam wall.

In December 2008 the first monitoring project in Poland for the KGHM Polska Miedz SA (Polish Copper) Company was started. Located in western Poland, KGHM Polska Miedz SA (Polish Copper) is the largest company in the region, employing approximately 18000 people. At present it is the 10th largest copper producer in the world.

The tailings dam, Zelazny Most ("Iron Bridge") belongs to the copper ore enrichment facilities, managed by the Hydrotechnical Division. The purpose of this division is to manage the flow of tailings from the three ore enrichment facilities, which process the copper ore using the flotation method. The process of flotation requires the use of large amounts of

water. 4-5 m³/t of enriched ore are sent to flotation and the tailings generated by this process are in the form of a liquid slime. Solids represent 6.5-8.7% of the volume. These tailings are then transported by pipe to the tailings pond.

The tailings dam covers an area of approximately 1400 ha. The total length of the dam wall is 14.3 km long. The project scope involves establishing a continuous, automatic monitoring system for the eastern section of the tailings' dam wall.

Traditionally, the dam wall was monitored using classical surveys techniques involving TPS and distance angular movements. Due to rising geotechnical problems with the dam slopes, such as landslides, the mine operators decided to change technology.

■ Scope

Establishing a continuous, automatic monitoring system for a section of an extremely large dam wall.

■ Customer

KGHM Polska Miedz SA (Polish Copper), Hydrotechnical Department (HD), Rudna (Lubin), Western Poland.

■ Date

December 2008 - Ongoing

■ Location



■ Project Summary

Instruments

Leica GMX902 GG
Leica GRX1200 GG Pro
Leica TCA2003
Leica Nivel210
Leica prisms

Software

Leica GeoMoS
Leica GNSS Spider
Self developed database converter

■ Other

STS meteo sensor

■ Benefits:

- Increased productivity
- Safety control
- Increased data analysis
- Data modeling for scientific purposes
- Cost savings

After a very detailed and thorough analysis, the mine operators choose Leica Geosystems automatic monitoring system, GeoMoS. The Hydrotechnical Department is very demanding and strongly relies on international experts' opinions. All their specialists recognize Leica Geosystems and believe it's a synonym of precision, high quality and robustness.

Leica Monitoring Solution

Initially in 2008, a 2 km section of the dam wall would be monitored with a Leica TCA2003 total station and approx. 30 Leica prisms. The monitored area of the dam wall is subdivided into different sections based on the expected movements. In general the operator expects around 0.05 meter movement per year.



New Reference Station outside of the movement area.

For an independent coordinate check of the Leica TCA2003 total station and their stable reference prisms, a GNSS reference station is built outside of the monitoring area and two GNSS GMX902GG receivers and antennas are installed inside the expected deformation area. One of these GNSS receiver/

antenna is co-located with a prism for the reference and orientation of the TCA2003 total station. The second is co-located at the top measurement hut with the total station to get absolute coordinates of the total station inside the unstable area.

Leica GNSS Spider provides the GNSS receiver control and real-time data collection. The GNSS raw data is collected every 6 hours per baseline (one from the reference station outside to the co-located prism and one to the co-located total station). A highly precise Spider Post Processing Product is created.

The TCA2003 total station is controlled via Leica GeoMoS Monitor, which also retrieves the GNSS base-line results. All the data is combined and stored to the open GeoMoS SQL database. The KGHM monitoring department is in charge of the automatic monitoring systems and reacts to limit messages.

Based on the requirements of KGHM, specially designed software retrieves with SQL statements the computed GeoMoS displacements and transfers them to another especially developed software. This software provides the very specific graphical representation for international experts on slope stability and open pit mining.

The communication of all instruments is established using LAN and WiFi networks.

Benefits

The Leica Monitoring Solution with integration geological software (SyZeM) has been a major improvement in productivity and data analysis of the stability of the slope monitoring in comparison with the previous manual survey. The prediction of slope failures can be done in real-time and the safety is improved.

In addition the GNSS reference station is not only used as a stable reference point for the monitoring system. It is also used to broadcast RTK corrections as a commercial service. The local land surveyors that use these corrections provide additional income to the mine.



Monitoring hut antenna

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Leica Geosystems **TruStory**

Concrete Dam Monitoring in Montereale Valcellina (IT)



Automatic monitoring system with dual station operation with the Leica TM30 station.

The Ravedis dam is located in the municipality of Montereale Valcellina (PN), in the area where the Cellina torrent, (tributary of the Livenza river) runs from the mountain section to the valley section, spreading out over the Friulian plain in the province of Pordenone. It is a mass gravity concrete dam, measuring 68 m high with a reservoir storage volume of 22.6 million m³. The primary function of the basin is to detain the overflow from the Livenza river, its secondary uses are irrigation and hydroelectricity.

The conditions sheet for operating and maintaining dams show an instruction regarding the periodic control of the structure through a complex integrated monitoring

system formed by meteorological, geotechnical and geodetic sensors.

The topographic monitoring system is formed by two Leica TM30 monitoring total stations, one located upstream and the other downstream of the Ravedis reservoir. Each measuring total station is fed by a 220 VCC cabinet with buffer battery. All the equipment has been suitably housed and protected inside purpose-built structures. The monitoring prisms have been arranged along the crown of the dam, both on the upstream and downstream side, in correspondence with significant structural elements and with other geotechnical sensors. Monitoring prisms have also been placed on the stabilised slopes at the back

■ Scope/Objective

Automatic and continuous monitoring of the Ravedis mass gravity concrete dam

■ Customer/Institution

Consorzio di Bonifica Cellina Meduna

■ Challenge

Continuous automatic monitoring of the behaviour of the structure on a daily basis

■ Date

Operational since November 2011

■ Location

Montereale Valcellina



■ Project Summary

Instruments

Leica TM30 Monitoring Sensor
Leica Geosystems Monitoring prisms
Rover Unit

Software

Leica GeoMoS Monitor
SystemAnywhere (data synchronization & calculations) and Analysis (data view)

Communication

Wireless LAN
GSM/GPRS

Office

Teamviewer

of the reservoir in order to verify the area's stability.

The communication between the total stations and the control centre (Centro di controllo), placed in the guardhouse of the dam, is achieved with a 5 GHz Wireless LAN.

The monitoring system software, Leica GeoMoS, and the local data

analysis software with automatic graphic data representation are installed on the dedicated computer in this dam control centre guardhouse.

Responsible staff can access the monitoring system, consult measurements and amend the parameters thereof remotely through appropriate remote software.

■ Benefits

Acquisition of a homogeneous and comparable database for an indepth study of the dam's behaviour during the filling and emptying phases of the reservoir and correlation with measurements acquired from other sensors



Layout of the Monitoring Stations



Prism points measured by both Total Stations



Total station 1 (Postazione 1)

Leica Geosystems **TruStory**

Automated Deformation Monitoring

Apollo Bridge, Bratislava, Slovakia



The Apollo Bridge is one of five road bridges across the Danube in Bratislava, connecting the centre of the city with the district Petržalka. The traffic load and temperature changes cause deformation of the bridge structure. In addition, the use of the developed automated measurement system (AMS) for long term monitoring allows the Department of Surveying of the STU Bratislava to determine actual information about the deformation of the main structure in real time. The AMS consists of the Leica TS30 high-precision total station with Automated Target Recognition (ATR), a Leica Viva GS15 and GPS1200+ GNSS receiver, and a Leica Nivel 220 inclination sensors as well as accelerometers.

One of the main safety tasks of civil engineering structures is the measurement of deformation. The

modern and often very complex structure of these objects underlines the importance of high accurate measurements of their movements.

Bridge Structure

The Apollo Bridge is one of the most important transportation corridors in Bratislava, the capital of Slovakia. The traffic load, the changes Danube water level and many other factors influence the basic function and safety of the bridge. The steel bridge has a total length of 517.5 m and consists of eight sections; the main section is an arch steel structure with a span length of 231.0 m and an arch height of 36 m.

The main structure of the bridge consists of two steel arches and the deck. The bridge deck consists of 6 sections with spans of 52.5 m, 2 x 61.0 m, 63.0 m, 231.0 m and 49.0 m, separated by dilatations and supported by 5 bridge piers. Only one of the piers supporting

■ Company

Department of Surveying of the STU Bratislava

■ Challenge

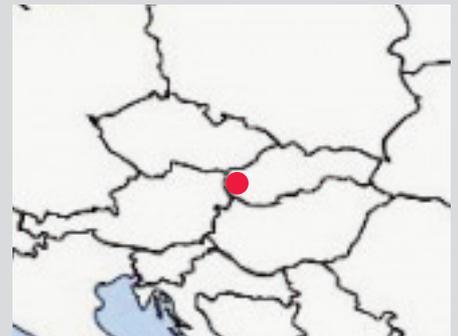
Deformation due traffic load and external conditions (e.g. temperature)

■ Date

October 2010

■ Location

Bratislava, Slovakia



■ Project

Instruments

Leica TS30
Leica Nivel200 Series
Leica Viva GNSS
Meteo sensor

Software

Leica GeoMoS
Data logging software

■ Objectives

- 3D determination of bridge deformation
- Measurement of bridge deck vibrations using accelerometers
- Synchronisation of system components
- Feasibility study for the long-term monitoring of all bridges across the Danube in Bratislava



■ Benefits

- Real Time 3D Monitoring
- Easy Monitoring Configuration
- Effectiveness of measuring real time deformation
- Robust sensors suitable for permanent monitoring

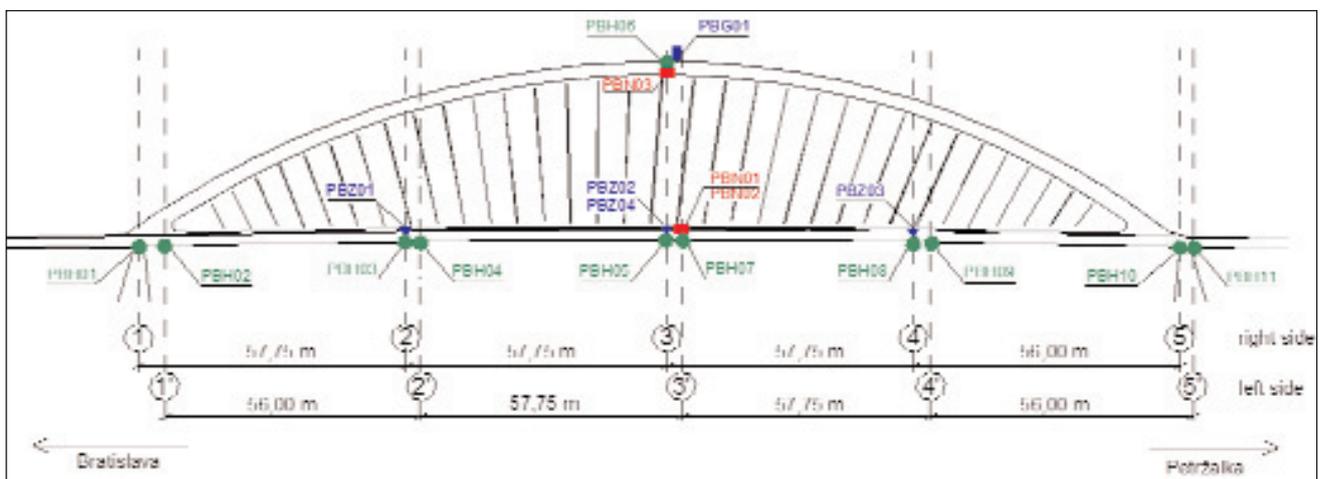
the bridge floor is positioned in the river. The top of bridge arches is 36.0 m above the bridge deck. The main bridge deck with arches was constructed on the river bank and then moved (rotated) to the final position over the piers and crossing the river. This operation of 36 hour duration was fully navigated and monitored by geodetic technology.

Monitoring System Setup

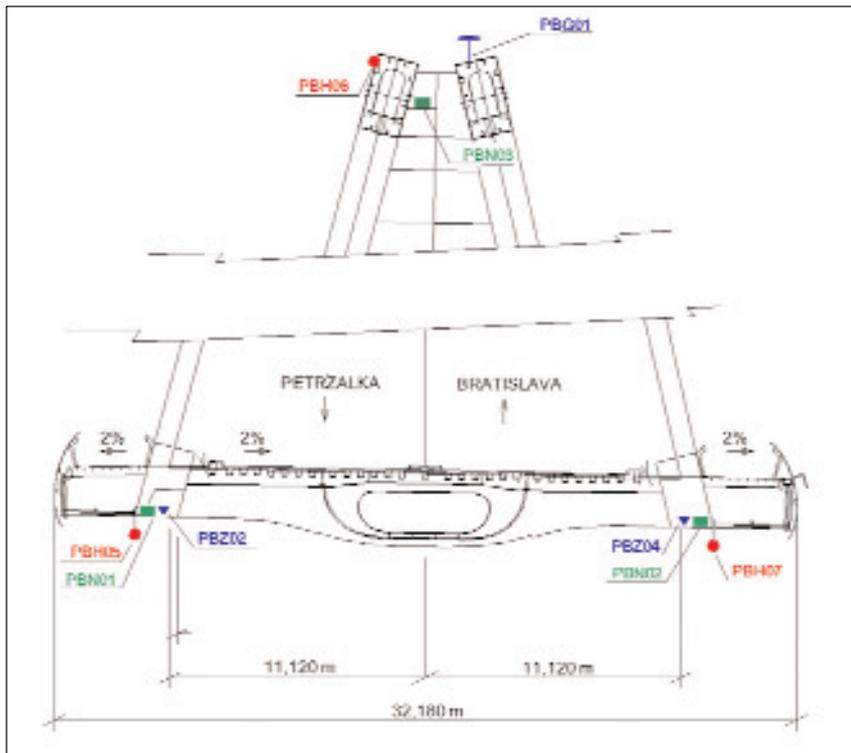
The measurement system was positioned according to the geometry of bridge structure and consists of geodetic and geotechnical sensors connected to the Leica GeoMoS software. The geodetic sensors are a motorised Leica TS30 high-precision total station, and GNSS receivers; Leica Viva GS15 and

GPS1200+. The measurement system was completed by Leica Nivel210 inclinometer sensor, a Reinhardt DFT-1 metrological station, and 13 standard prisms (GPR1) from Leica Geosystems. The angle and distance measurements were made by Leica TS30 using Leica GeoMoS and the ATR function every 10 minutes in two faces with automated data acquisition. The inclination sensor controls the stability of the total station position on the pillar. All three devices are connected to the personal computer and the measurement data is sent directly to the computer with the Leica GeoMoS Monitoring software installed, which is also used for controlling the measurement

cycles and data processing in each 146 epochs. The Leica Viva GS15 and GPS1200+ use GPS (NAVSTAR) and GLONASS satellite signals. The second part of the system comprises of two Leica Nivel 220 inclination sensors and four 1D HBM B12/200 accelerometers. The measured data is registered with 1 Hz and 10 Hz frequency. The homogeneity of data and synchronisation of the notebook time are achieved by using special time server LTS, which use the GPS time signal from GPS satellites. The accuracy of this time signal is ± 5 msec and the time signal from LTS is transferred via WiFi antennas with 5 GHz operation frequency.



Longitudinal section with observed points.



Cross section with observed points.

Automated Monitoring of the Bridge Structure

For 24 hours, between the 27th and 28th October 2010, automated monitoring was used to measure the bridge. The aim of the bridge monitoring was to determine:

- 3D displacements of observed points, positioned at the bridge floor and at the top of bridge arch measured by total station,
- horizontal displacements of the observed point on top of the bridge arch measured by GNSS sensors,
- longitudinal and cross inclination of the bridge measured by inclinometers,
- vertical vibration of the bridge deck measured by the accelerometers.

The stability of the pillar, with the Leica TS30 mounted on it, was controlled by measuring to the neighbourhood control points situated on the riverbank. The measurement results were corrected taking the inclination of the pillar into account and all

measured values were sent to be processed by the Leica GeoMoS software. The accuracy of the 3D position for the observed points was less than 1.0 mm.

The GNSS Leica Viva GS15 was to static mode measurement and receiving data at an update rate of 1 Hz was used to determine the horizontal displacement of the top arch. All the data was stored in the internal receiver's memory (SD memory card). The Leica Nivel220 inclinometers, registered with 1 Hz frequency were used to determine the longitudinal and cross inclination of the bridge. The vibration of the bridge deck was monitored by one-axial accelerometers HBM B12/200 (in vertical direction) with a sample rate of 10 Hz.

Data Processing and Results

The results of the 24 hour measurements were time synchronized data sets from total stations, GNSS, inclination sensors, accelerometers, and meteorological

data. The horizontal deformation in the perpendicular direction to the bridge's roadway (Y) was relatively small; the most intensive changes were registered on the 28th October 2010 at 09:00, this was caused by both the sun shine and the traffic load. The biggest deformation was registered at the point PBH02 with an absolute value of 14.2 mm. The deformation in the parallel direction to that bridge's roadway (X) indicates a trend of the movement of the structure according to the temperature changes. The bridge structure (deck) is fixed at pillar No.10, which avoids the movement of the structure in the longitudinal direction. Pillar No.11, at the left side (Bratislava) of the river bank, is equipped with a joint that allows movement of the bridge structure in the longitudinal direction. With an increasing distance from pillar No.10 the bridge structure trends to longitudinal deformation, which is mainly caused by temperature changes. The maximum value of 18.4 mm is registered at point PBH02 on the 27th October 2010 at 16:00. The minimum deformation was predicted at points PBH10 and PBH11, which corresponded with



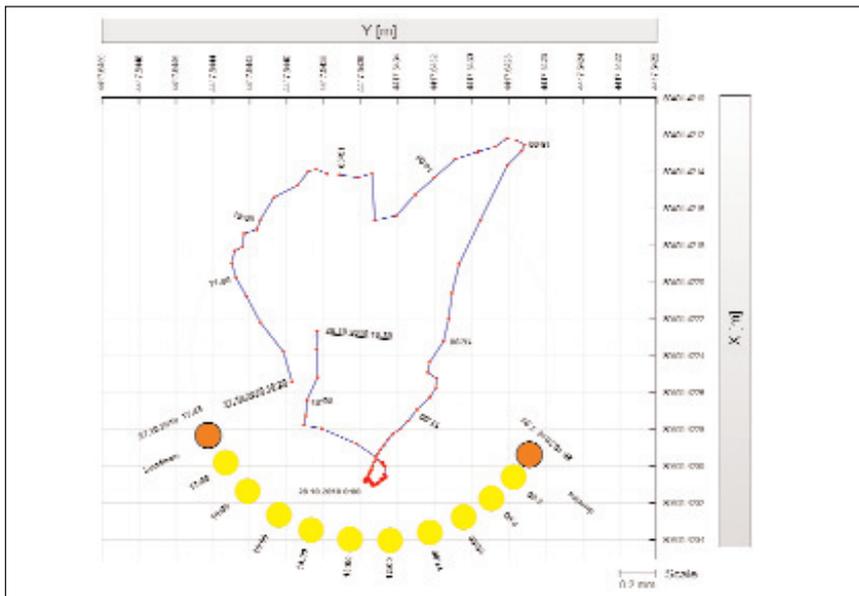
Leica Viva GS15 GNSS receiver on top of the bridge arch.

the largest value 5.0 mm registered at these points on the 28th October 2010 at 05:30. The vibration of the bridge deck is described by the measured vertical accelerations. The registered data sets build time series with high variations. The vertical movement of the bridge deck was derived from these data sets in the form of trend curves. Amplitudes, frequency characteristics of the structure were determined using frequency analysis. The maximum amplitude (deformation) of 19.0 mm was measured at PBH04 on the afternoon of the 27th October 2010. Significant frequencies at level of 0.98, 2.18, 2.88 Hz were calculated, which fit together with the theoretical frequency spectrum of the structure calculated by the designer. Different behaviour (response) of the bridge was derived (described) from these data sets according different effects the air conditions and the traffic.

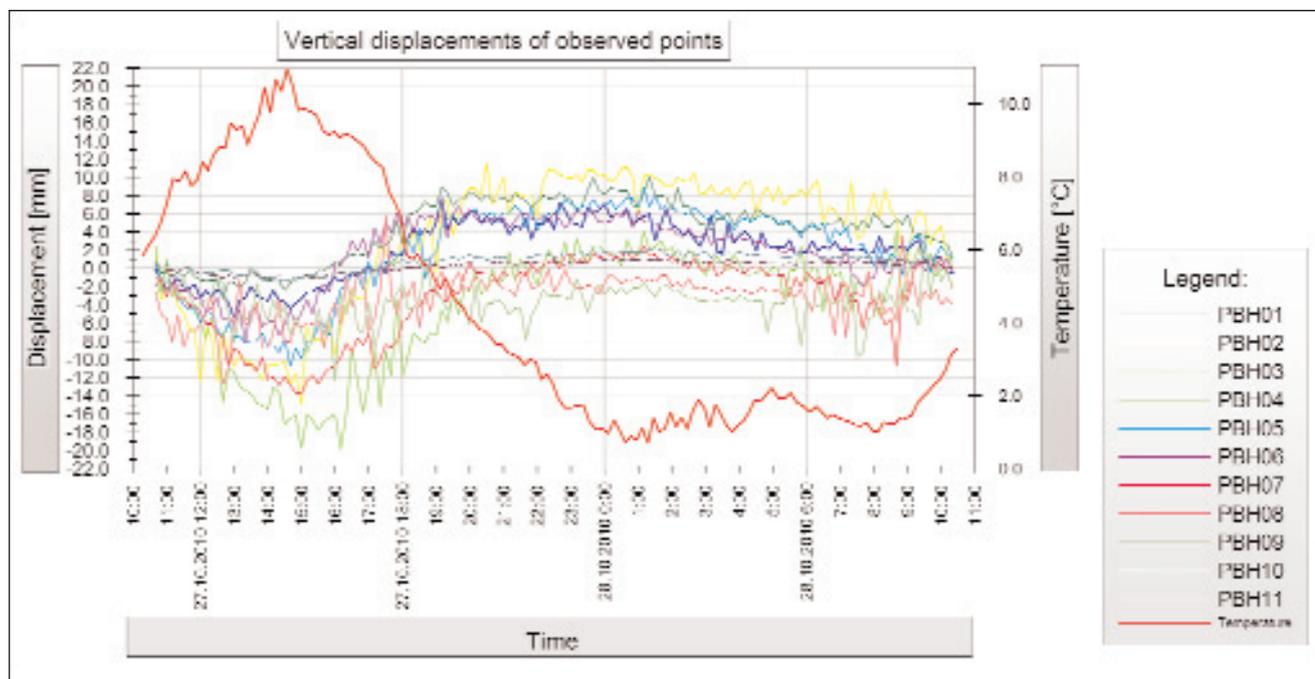
The Apollo Bridge project was used to show the personal (department) responsible for the bridge maintenance the effectiveness of measuring real time deformation from traffic and temperature. The project has proven the use and the feasibility of automatic deformation monitoring systems

and we hope that will therefore lead to permanent monitoring of all the bridges on the Danube in Bratislava in the future.

For more information please visit: http://www.svf.stuba.sk/generate_page.php?page_id=3486



Horizontal displacement of observation point VB16 located on a pillar head.



The graphic shows the vertical displacement of observed points.

A photograph of an ANA Boeing 777-300ER aircraft on a runway. The aircraft is white with blue accents and the ANA logo on the tail and fuselage. It is positioned on a concrete structure that appears to be part of a runway or taxiway. The background shows a clear sky and some airport infrastructure. The title "Heavy Loads on Weak Foundations" is overlaid in large white text on the bottom half of the image.

Heavy Loads on Weak Foundations

by Kazuhiro Nii and Dr. Yun Zhang

The newly opened D-Runway at Tokyo International Airport Haneda was a complex structure to build, as it is located on reclaimed land. Heavy airplanes weighing hundreds of tons each, take off and land on the newly constructed runway daily. Continuous monitoring is important for safe operation, as large movements can influence the safety of the runway.

D-Runway was constructed on Japan's first hybrid structure at the mouth of Tama River in Tokyo Bay, consisting of reclaimed land, platforms of piers, and a taxiway, all connected to the present airport. In the landfill portion, soil needed to be improved and re-filled to prevent consolidation subsidence caused by weak foundations. At the pier site, steel pipes nearly 100m long were sunk into the sea at specified intervals. A cover was built around it to keep the river flowing smoothly.

With this complex structure and construction method, the connection between landfill/pier as well as

the joints between pier/taxiway were assumed to be moving and/or to sink due to secular change. Movements must be accurately measured, especially during earthquakes, as the amount of movement is one of the criteria used to assess whether D-Runway is in a satisfactory condition for safe operation or not.

Installation of the System

The monitoring system was designed for maintenance and management of the runway with its complex characteristics. Dozens of GNSS monitoring points were installed and have been monitoring secular changes as well as any movements during earthquakes since the runway was opened. The system measures the movements of two relative positions; sets of two points were installed in these positions across the joints to measure the movements at the joints in the different structures.

Antennas were installed at ground level near the runway at the landfill and pier sides to avoid interference with aircraft operation, and at the taxiway they were installed at points outside the airport height restriction.

A Leica GMX902 GG with an AX1203+ GNSS antenna were installed on the roof of the Fire Department's east building at the side of the airport, rather than near the runway. The antenna was seismically isolated by fixing a vibration absorber around it so positioning can be performed even in the middle of an earthquake. Since antennas were put in the ground, data reception may be disrupted by aircraft activity, so the system also collects data using GLONASS signals to maintain a horizontal accuracy of 10mm (0.39 in).

Data Collection & Analysis

Monitoring data captured on the runway is transferred to and analyzed by the server located in the monitoring control room in the Fire Department building. Both Leica GNSS Spider and custom designed monitoring software for D-Runway, developed by Leica Geosystems' partner Geosurf Corp. (Tokyo, Japan), are running on the server. Spider continuously analyzes the data at 20Hz and outputs the results to the Geosurf software with a GGQ message uniquely developed by Leica Geosystems. It converts world geodetic coordinates to plane coordinates based on the runway, and then uploads collected data in files to the government server.

The processing system broadly consists of three tasks: constant airport taxiway and runway monitoring, earthquake monitoring, and post processing of an earthquake. Constant monitoring performs real time analysis, transferring LB2 data from monitoring points to Leica Spider via socket communication, by TCP/IP. It calculates each median of the 3D coordinates from data at 20Hz every two hours. It can also improve the accuracy of the results by getting final medians after deleting false values caused by IQR (inter-quartile range). The earthquake monitoring system can capture the exact start and end times of earthquakes by receiving electric trigger signals from the seismometer installed on the runway. ■

About the authors:

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Tokyo International Airport Haneda

The Haneda Airfield first opened in 1931 on a small piece of waterfront land at the south end of today's airport complex. In 1939 the airport's first runway was extended to 800m and a second 800m (2,625 ft) runway was completed.

In 1964, Japan lifted travel restrictions on its citizens, causing passenger traffic at the airport to swell. A new runway and an international terminal were completed in 1970, but demand continued to outpace expansion.

The fourth runway, D-Runway, was constructed via land reclamation to the south of the existing airfield and was completed in 2010. This runway was designed to increase Haneda's operational capacity from 285,000 movements to 407,000 movements per year, permitting increased frequencies on existing routes, as well as routes to new destinations.

Source: Wikipedia

Leica Geosystems **TruStory**

Monitoring of Excavation Slopes in an Open Pit Mine



The Bełchatów is a large brown coal mine in the centre of Poland, 150 km west of the capital, Warsaw. Bełchatów quarries brown coal in open pit mining with a surface of over 30 sq. km. The operator is the Polish Energy Group – Open Pit Mine Bełchatów. Due to the increasing demands for mine efficiency and slope stability in the excavation area, the customer decided in 2006 to implement an automatic monitoring system combined with a mining control system.

The Polish Energy Group required a system for the automatic monitoring of slope stability in combination with a risk management system, which controls the excavation. After a consultancy period for the project, the customer selected Leica Monitoring Solution for the slope stability monitoring as it has online 24/7 data acquisition and analysis software.

After this decision, the customer, mining experts and the local Leica Geosystems representatives worked closely together to design a monitoring system concept with a technical feasibility and implementation planning.

Monitoring System Layout

The monitoring system consists of two total stations and a small GNSS reference network to establish known stable points. The main total station TCA2003, which works permanently, is situated in a measuring container that is airconditioned and equipped with a hydraulic levelling system. The hydraulic levelling system is used for levelling the container. The stability of the container and the inside total station is determined by post-processing a GNSS baseline to a GNSS antenna at the top of the container. This GNSS antenna links the total station and the measuring container with a GNSS reference



Objective

Automatic deformation monitoring combined with a mining control system

Customer/Institution

Bełchatów
<http://www.kwbbelchatow.pgegielik.pl/>

Date

2009 – ongoing

Location

Bełchatów, Poland



Project Summary Instruments

Leica TCA2003 Total Station
Leica TCA1201M Total Station
Leica Geosystems prisms
Leica GMX902 GG
Leica GRX1200 GG

Software

Leica GeoMoS Monitor / Analyzer
Leica GNSS Spider

Communication

WLAN or GPRS

Challenge

Continuous deformation monitoring of the slopes' dynamics and the salt piercing fold beneath the mining area



■ Benefits

- Fully automated and combined monitoring system with total stations and GNSS
- Open system architecture for the interaction with other applications (e.g. mining control system)

station situated on an adjacent area, which is stable and free from any influences imposed by the mine. Apart from the permanently working total station, there is a second Leica TCA1201M total station, that is used for semi-automatic monitoring in areas of the mine where access is quite difficult, but monitoring is still necessary, although not constant.

Slope Monitoring

Both total stations are continuously measuring over 50 monitoring points located on the slopes directly around them, as well as on the ground of an underground salt piercing fold, which divides the mining area into two excavation pits (Szczerców and Bełchatów). The underground salt piercing fold is a geological structure, to be more detailed, a layer of salt beneath the mining area.

The GNSS reference frame consists of three two-frequency GNSS receivers. One Leica GRX1200GG Pro at the reference station and two Leica GMX902GG; one of which is located on the roof of a measuring container and the second is colocated with prisms for the stable orientation of the total station. The offset

values between the GNSS antenna and the total stations as well as the GNSS antenna and the prisms are applied within the monitoring software Leica GeoMoS. In addition, a meteo sensor is installed inside the Bełchatów mine and the total stations slope distances are corrected with the atmospheric corrections.

Communication

A permanent data transfer between each total station and the GNSS antenna / receivers to the centralized computer runs over a wireless network. The monitoring communication has the ability to switch automatically, for example in the case of wireless network disturbances, from the WLAN to the mobile Internet with GPRS as a backup solution.

Data collection and analysis

The data acquisition and baseline computation of the GNSS reference network is operated by the GNSS Spider software. The total stations are controlled with the GeoMoS Monitor software. In addition, the GeoMoS Monitor software retrieves the GNSS baselines coordinates from GNSS Spider and combines the

data for analysis and storage in an open SQL database. As a result, the customer observes the slope stability displacements in a local coordinate system.

System approval and benefits

The automatic monitoring system deployment for the Bełchatów brown coal mine was completed with a final acceptance test based on functioning and accuracy checks of the entire system. The installed system monitors the mining slopes and the open pit ground. It reduces the risk of slope failures during the coal excavation, provides a continuous control of the slopes' dynamics, as well as the possibility of applying integrated management of the mine's work. Moreover, the salt piercing fold that impacts the mining excavation is under control. The slope stability monitoring project in the Bełchatów mine was the first monitoring project for Leica Geosystems Poland set out in a mining area. The customer appreciates the robustness of Leica Geosystems products as well as the high accurate data they provides.

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- when it has to be **right**

Leica
Geosystems

Leica Geosystems **TruStory** Monitoring System for Hong Kong Airport Express Line



The Kowloon Southern Link project connects the East Rail with the West Rail of the Kowloon-Canton Railway.

The Kowloon Southern Link (KSL) will be a 3.8 km connection between the East and West Rail in Hong Kong. The construction of the \$8.3 billion KSL is scheduled for completion in 2009. The Kowloon-Canton Railway Corporation (KCRC) in Hong Kong acquired an Automation Deformation Monitoring System from Leica Geosystems in December 2005 for continuously monitoring settlement and overall deformation of a section of existing Airport Express Railway.

The Kowloon Southern Link project is a 3.8 km extension of KCRC's West Rail Link from Nam Cheong Station connecting to East Tsim Sha Tsui Station of KCRC's East Rail Link. There is about 1.2km of the new extension area located very closely to the existing Airport Express Rail and MTRC Tung Chung Line. In order to ensure

the construction works do not have serious structural effect and distributing daily operation and safety of the Airport Express Rail, an Automatic Deformation Monitoring System is deployed mainly to continuously monitor settlement along the affected rail track.

The 1.2km track is divided into three different sections (600m, 210m and 400m) for continuously monitoring where cover ballasted section, trough section and tunnel section. A pair of mini prisms with tailor-made protection is installed in every 13 m interval along the rail track. TCA2003 Total Station that are driven remotely via a data communication network by Leica GeoMoS software at the Control Center measure the positional change of each target prism automatically in every 2 hours

■ Challenge

There are 3 sections of railways settlement measurement, included tunnel, trough and ballasted sections of total 1.2km, total 18 Total Stations and 600 prisms needed for measurement, Leica GeoMoS measurement cycle with 2 hours each. Running for 24 hours for 36 months non-stop. There are only 2 hours at night and 2-3 days per week to get the installation work and the tasks needed to be finished in two months time. After the system running, everyday, it is necessary to get a line safety report on 5:00am morning to all the related engineers and station manager for status of the railway in order to commerce the construction work.

■ Customer

The Kowloon-Canton Railway Corporation/
Hong Kong

■ Date

December 2005

■ Project Summary

Instruments

Leica TCA2003 and prisms

Field

Metro sensor, stand, pillar,
cable running for 2 km.

Office

Workstations, Web Server with Web Interface,
Leica GeoMoS Professional

■ Benefits:

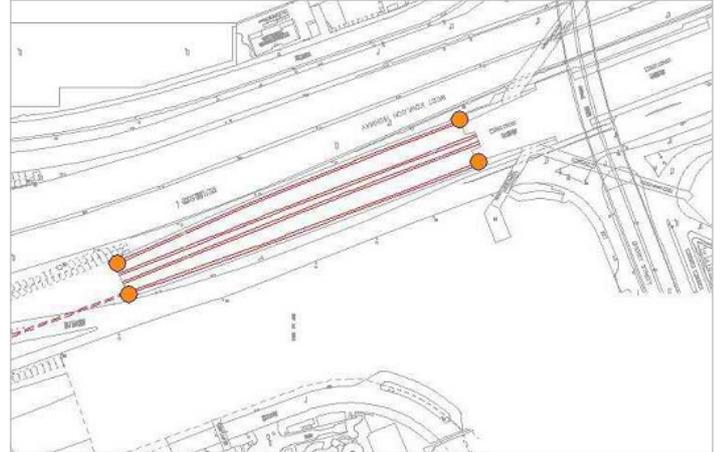
- Real time continue monitoring system with SMS, email alert, web interface for client to get the data in real time.
- Continue monitor the progress of the contractor work if the work disturb the railway systems
- Eliminate the 24 hours manual measurement on MTRC railway and tunnel which are dangerous and labour intensive.
- Complement the existing geotechnical sensors work

- when it has to be **right**

Leica
Geosystems



Through section (210 m)



Total station configuration in the Through section.

interval. To get the best line of sight for measurement, those Total Stations are installed at various locations including tunnel wall, roof of rail station and structure along the track. There is continuous power supply at each Total Station location and they are well protected by special design mounting device and security lock.

To ensure achieving the highest accuracy and reliability of the rail deformation measurement result, the highest accuracy automatic Total Station available in the current market - Leica TCA2003 is used, which can achieve +/-0.5" angular accuracy and 1mm +/- 1ppm distance accuracy. Thanks to the automatic target reorganization technology built in the Leica TCA2003, it can automatically pin-point the center of each target prism and detect slight positional changes. Furthermore, before taking every cycle of monitoring points measurement, each Total Station also first measures assigned control reference points located at stable structures (reference prisms) and then re-adjust its own position and monitoring reading

afterward. Thus, even any structural movement happening at the Total Station location does not have any affect to the overall measurement accuracy and the system can achieve less than 1mm measurement error over a distance of 100m.

The measurement reading is transmitted to Leica GeoMoS software for computing the updated coordinates of all monitoring points. Then, coordinates comparison can be made against the initial reading and the deviation and trend of movement can be easily presented as numeric and graphical presentation report to engineers and surveyors every 2 hours. All the information can be found from an Intranet webpage and engineers can also remote control the system configuration and monitor its performance via the Ethernet. They can also preset various levels of settlement tolerance in the software, so when the measurement result reach the critical level, then various alarm messages will be automatically sent to all mobile phones of assigned persons via

SMS. At the same time, the alarm and a report will also be automatically sent to those persons by email. Thus, engineers and surveyors can verify the settlement immediately and take necessary actions to prevent damages and maintain rail safety to passengers. As said by Mr. Andrew Wong, Engineering Solution Manager of Leica Geosystems: "It is a well-proof solution for engineer making quick and right decisions and also take necessary actions regarding the influence of new construction works to existing structure".

The system installation works since February 2006 for a period of 36 months continuously.

Leica Geosystems **TruStory**

Permanent Slope Stability Monitoring

Brown Coal Excavation, Czech Republic



Severočeské doly a.s. is the largest producer of brown coal in the Czech Republic. The company was established by the Czech National Property Fund in 1994 by merging two major brown coal producers - the Bílina Mines and the Nástup Tušimice Mines. The company's business line includes mining, processing and selling brown coal and associated by-products. The company's domestic market share in 2008 was 46.87%. The Nástup Tušimice mine is the most important mine for brown coal excavation in the Czech Republic. In 2010, approximately 12.3 million tons were extracted, and in 2011 more than 15 million tons are expected. Since 1979 the mine slopes have been monitored with Leica Geosystems equipment. In September 2011 Severočeské

doly a.s. decided to renew its monitoring equipment for the latest Leica Monitoring Solution.

The Nástup Tušimice Mine with its slope declines of up to 20 degrees is located in an area with complex tectonics. When the mine operators started slope monitoring in 1979, observations were carried out manually by angle readings using a theodolite. In 1997 they switched over to a permanent monitoring installation utilizing a Leica TCA1800 and third party software, with the remote communication established via radio.

At the heart of the new, fully automatic Monitoring solution is the Leica GeoMoS software running on the MonBox30 computer installed in the ComBox10. This receives the data of the Leica TM30

■ **Company**

Severočeské doly a.s., Nástup
Tušimice Mine

■ **Challenge**

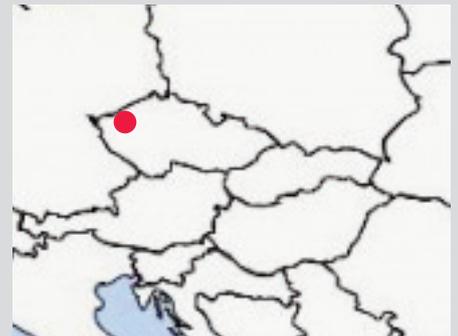
Slope Stability/Landslide Monitoring
and prediction of failures

■ **Date**

Since September 2011

■ **Location**

Tušimice, Czech Republic



■ **Project**

Instruments

Leica TM30
Leica Monitoring prisms
Meteo sensor

Software

Leica GeoMoS Monitor

Communication

Leica ComBox10 using GPRS
Leica MonBox30

■ **Objectives**

- Precise monitoring of possible slope movements and velocity
- Prediction of slope failures
- To avoid injury and damages during coal excavation



■ Benefits

- Precise long-range distance measurements up to 3000m with Leica TM30
- Easy Monitoring system setup with Plug&Play solution and reliable communication
- Leica MonBox keeps system running in case there is a communication breakdown

Monitoring Sensor inside the measurement hut and the DTM meteo sensor outside. Measurement data transfer and communications are established via mobile internet GPRS.

The Leica TM30 currently measures, at hourly intervals, 15 monitoring prisms placed on the slopes at distances of 250m to 2.240m from the Monitoring Sensor. In the near future, measurements to a total of 40 prisms are planned. The measurement cycle can be adapted at any time according to the needs. Compared to the previous monitoring installations, the new system provides a complete Plug&Play solution that was easy to setup. All connections and communication are placed in the rugged ComBox housing. The integrated Leica MonBox also serves as an independent internet backup, which means that data is not lost if a communication breakdown arises.

In addition, the Leica TM30 Monitoring Sensor combines speed and accuracy. As it is especially designed for Monitoring applications the sensor provides high accuracy angular measurements of 0.5". The long range ATR detects and measures to prisms within a range of up to 3000m with millimetre accuracy. The modern drives, based on piezo technology, support a high rotation speed of 180°/s allowing shorter time intervals between measurements cycles, if required. With the TargetCapture technology, obstructions in the line of site can be inspected remotely and documented. Also, with TargetView, the sensor detects the correct prism when multiple prisms are close together.

Additionally, Leica GeoMoS supports the integration of the DTM meteo sensor for data processing, taking atmospheric corrections into account, allowing a precise and

specific analysis, based on meaningful results, to make the right decision if movements should occur.

More information about Severočeské doly a.s. at <http://www.sdas.cz>



All connections and communication are placed in the rugged ComBox housing.

Leica Geosystems **TruStory** Real Time Bridge Deck Guidance Using GNSS Systems (Spain)



Arbizelay's bridge, 380 meters long, 6 spans high, 5 pylons and 12 meters wide is part of the AP-1 Vitoria - San Sebastián Motorway and is located near the city of Mondragon. Thanks to Leica GNSS technology, it was possible to successfully complete the manoeuvre of incremental launching of the bridge's deck over the pylons with an error of less than 3 centimetres.

Using 6 GX1230 GG receivers (5 rovers placed over the deck with 1 reference on a concrete pillar), the whole deck structure can be monitored in real time while the manoeuvre takes place.

Communication between GNSS receivers and Leica GNSS Spider software was established using

406 Mhz Satel radios. Other types of communications (GPRS, Wi-Fi) were tested and finally discarded due to frequency inhibitors and poor GSM coverage.

Both bridge's decks (one from each side of the valley) were built on site by pouring concrete over a steel structure. Once the structure was ready, it was pushed over the pylons with the method of incremental launching of the deck with the help of hydraulic jacks (incremental launching cycles were 3 meters). In addition to the jacks, the hydraulic system relied on a pair of cables that were able to completely retain the bridge's deck in case of emergency.

An auxiliary pylon was built in the centre of each deck with the task of holding steel cables, which

■ **Company**

Dragados S.A. Spain

■ **Challenge**

Real Time monitoring and guiding of a moving structure (motorway bridge)

■ **Date**

March 2008

■ **Location**



■ **Project Summary**

Instruments

6 Leica GX1230 GG Receivers

6 Leica AX1202 GG Antennas

Software

Leica GNSS Spider

Leica GeoMoS

Leica Alignment Monitoring

Communications

Radio, GPRS, UMTS, Wi-Fi

■ **Benefits**

- Real Time 3D Monitoring of the structure
- Displacements Calculations compared to 3D alignments
- Continuous hydraulic pushing manoeuvre thanks to the real time monitoring and GeoMoS alarms
- Database storage of all measurements
- Instant and continuous operation reports with Leica Alignment Monitoring
- Easy Monitoring system configuration and installation and User friendly software

Leica Geosystems **TruStory** Monitoring Rail Tracks during Construction of Noise Barriers/HK



■ Objective

Deformation monitoring due construction works close to existing railway tracks

■ Customer/Institution

MTR (Mass Transit Railway, Hong Kong)

■ Date

2009 – ongoing

■ Location



■ Project Summary

Instruments

Leica TCA2003 Total Station
Leica Geosystems Monitoring prisms

Software

Leica GeoMoS Monitor / Analyzer
Web viewer for displaying data and reports

Communication

Cables
Uninterrupted Power Supply (UPS)

■ Challenge

- Real-time deformation monitoring throughout the construction
- Maintenance of the prisms and total stations in restricted MTR zones

■ Benefits

- Continuous and remote monitoring
- The safety of millions of MTR passengers can be ensured round the clock

As one of the busiest and most crowded rapid transit system in the world, MTR (Mass Transit Railway, Hong Kong) operates high frequency train services from early morning until midnight. Due to the noise of the trains, areas where trains operate outdoors, like Tai Wai, suffer significantly from noise pollution. Serving as the busiest interchange station in New Territories, connecting Ma On Shan Line to East Rail Line, Tai Wai Station and Depot are also one of the busiest hubs for train operation. As residents move into the newly built residential buildings above Tai Wai Depot, the noise pollution problem is expected to affect an increased number of people.

In order to alleviate the noise pollution problem, noise barriers

have been built along the tracks since 2009. However, before any works started, safety had to be ensured. Since the barriers were built very close to the existing tracks, deformation due to digging and various works for the construction of the barriers might have seriously affected the position of the tracks and subsequently train operation. Therefore, an automatic deformation monitoring system was implemented so that relevant preventive actions could be performed if an unpredicted deformation was detected by the real time monitoring system.

Monitoring System Setup

The monitoring systems consists of six total stations TCA2003, two computers, 23 reference prisms and over hundreds of monitoring



Control Center of the Monitoring System

prisms. The total stations were sub-divided into two groups and located in Zone 1 and 2 of the construction site. Each location for the total stations was selected under various conditions, including solid foundations, safe distance from tracks and high-voltage overhead lines, and a clear sight to every monitoring and reference prism.

The monitoring prisms were installed at the upper and lower levels of overhead line masts to check tilting and also on the railway sleepers. The reference prisms were distributed around the total stations so that each total station could measure to approximately six prisms and compute the stability and orientation of the total stations.

An uninterrupted power supply (UPS) was provided to each total station to ensure the system could overcome any temporary power shortage.

The total stations were connected to two computers and the UPS in the workstation via signal cables

and power cables respectively. The two computers were located in a workstation equipped with Leica GeoMoS software which is responsible for the control of the sensors, collection and analysis of data and the. In addition, both computers were connected to a web server via broadband internet, so that users can access the system remotely.

Leica TCA2003 Total Station can achieve an accuracy of $\pm 0.5''$ in angle and $1 \text{ mm} \pm 1 \text{ ppm}$ in distance. To achieve good visibility for the total stations, clean and not fogged prisms in the correct position with a constant light condition with a dark background and no atmospheric disturbance were needed.

Data Acquisition

The operation of the automatic deformation monitoring systems started two weeks before the construction works commenced as so-called reference or null epoch data had to be collected. Throughout the construction, the deformation

monitoring measurements were taken continuously in automatic two-hour cycles using the Leica GeoMoS software. All monitoring results were uploaded to the Internet for instant browsing and were closely monitored by surveyors. Any deviated data would immediately be investigated by surveyors to check the accuracy.

Messaging System

One of the main purposes of setting up an automatic deformation monitoring system was to inform the responsible staff of a situation when irregularities occurred in the construction site. After the monitoring positions of the optical prisms are measured, they are compared with the set limit levels. If any monitoring data reached or exceeded one of the three limit levels, the messaging system would immediately be activated. The designated personnel of MTR and the Contractor would be notified by e-mail. The surveyors in charge would then investigate the reasons behind the notification and confirm whether the message was due to faulty equipment, human error or construction activities. Additional respective measures may be taken according to the severity of the message, ranging from increasing the monitoring frequency to immediate cessation of all foundation and excavation works.

Reporting

All monitoring data was displayed in graphs showing and every 24 hours a report was generated.

Maintaining Stability

Notwithstanding the high precision of the surveying instruments and careful planning, every component in the system must perform

sturdily to provide reliable data. However, maintaining the stability of such a complex system is never an easy task. First and foremost, maintenance of the equipment was carried out annually and wear outs and damages were fixed during this maintenance period. Since most of the instruments were installed along the tracks and masts, which belong to the restricted zone, working group meetings with MTRC were arranged to discuss the permitted working hours and site possession. Other than hardware maintenance, calibration of instruments was another important element to maintain stability. The system was tested prior to installation of the instruments to ensure that they were working and configured properly. From time to time, during the course of monitoring, the positions of the back sight prisms on the total station masts and the selected monitoring target prisms were checked by manual survey to verify that the automatic measurements had been made correctly, as the prisms might have been displaced either accidentally or naturally. The automatic measurements could be corrected using data from manual system checks when necessary. At the same time, all optical prisms were regularly cleaned and checked for stability, orientation and firm attachments. In cases of obstruction to the sight line of the total stations, prisms were relocated to other stable locations. They would also be re-installed if they were found loose. Moreover, not only would

the instruments be examined for damage or defects on regular basis, but surveyors also assessed the system for any possible future damage caused by other construction activities or improvement works carried out by MTRC.

Advantages

Continuous Measurements: The most important reason of implementing an automated system was its non-stop measurements taking. In the past, when measurements were taken by manual survey, data collected could be fragmented as it was impossible for surveyors to work all day resulting in incomplete analysis and the process was not cost-effective. With the automatic deformation monitoring system, comprehensive reports could be generated solely by computers and an efficient messaging system enables deformation to be detected at all times.

Remote Monitoring: A considerably short period of time available for track possession was another significant constraint for works in an operational railway system. With surveyors monitoring the system anywhere via the Internet, the system could be operated without interfering with train services. Surveyors and other staff did not have to travel to the site to check for any irregularities and reports could be seen in just a few clicks.

User-Friendliness: To increase the efficiency of the system, a user-friendly web interface was used to

display the monitoring results to the customer.

High Precision: As surveying has always been renowned for its high accuracy, surveyors strived to produce measurements as accurate as possible. However, human measurements can never be as accurate as those of machines, especially in a dark environment. To provide a highly precise monitoring system, the automatic deformation monitoring system minimizes the use of human labour with the replacement of newly developed total stations, which ensures extremely reliable measurements.

Conclusion

The success of the monitoring system has shown that safety can be ensured with the help of advanced technology, especially for works carried out in a train system which carries millions of passengers every day. Such a flexible yet efficient system has demonstrated that safety can be maintained round the clock and does not necessarily come with interference to our daily lives.



Leica Geosystems **TruStory** GNSS Guide System for Pile Embedding Port of Cádiz (Spain)



The new Bridge in the Bay of Cadiz, known as "Puente de la Pepa" (1812 Spanish Constitution), was the highest bridge in Europe in 2010. Its 3.1 km length, 180 metres height and 540 metres span makes it a true surveying challenge.

Using a Leica GX1230 GG receiver as a reference (GPS and GLONASS) connected to the control centre at Dragado's offices, which in turn was connected to Leica Spider Software, differential corrections were sent to 2 GMX902 GG (small and full performance GNSS receivers). GNSS Antennas were the reference points for which navigation and stakeout tasks were referred to. A crane on the barge with a vibrator head places and drives the steel casing. Leica Spider software receives the signal from the 2 rovers by GPRS, computes the baseline and sends the position to Leica Alignment Monitoring. Coordinates are displayed at 1 Hz with 10-15 mm 3D standard

deviation. This software stores the points to stakeout, tolerances and Coordinate Systems. It is also possible to control the software using a laptop computer on-board the barge.

Firstly, the platform is roughly positioned close to the final pile position. Later it is anchored and its position is fixed to the seafloor using 2 hydraulic jacks, allowing for precision positioning. Leica Alignment Monitoring software is able to store a detailed report of the positioning and stakeout process (1 Hz) in addition to the logging (txt file) of the instant position.

Once the pile's embedding phase comes to an end, the monitoring system can be used in other construction tasks: drawers guidance (as part of the pylon's footings), and final structural bridge monitoring when finished. For these tasks Leica Spider will run together with Leica GeoMoS, controlling possible displacements, registering data and displaying graphics.

■ Company

Dragados S.A. Spain

■ Challenge

GNSS Real Time Guidance of the barge for embedding piles for the construction of the bridge in the Bay of Cadiz (Puente de la Pepa).

■ Date

August 2008

■ Location



■ Project Summary

Instruments

- 2 Leica GMX902 GG Receivers
- 1 Leica GX1230 GG Receiver
- 3 Leica AX1202GG Antennas

Software

- Leica GNSS Spider
- Leica Alignment Monitoring

Communications

GPRS

■ Benefits

- Rover GNSS receivers on portable installation
- GPRS communication between the Monitoring Control Centre and the Support Computer.
- Reference GX1230 GG also transmitting via Radio to the GX1230 GG rovers.
- GX1230 GG very versatile; reference, rover, machine guide, surveying...
- User friendly and intuitive Software.



Whether you monitor the movement of a volcanic slope, the structure of a long bridge or track the settlement of a dam; whether you measure, analyse and manage the structures of natural or man-made objects: the monitoring systems by Leica Geosystems provide you with the right solution for every application.

Our solutions provide reliable, precise data acquisition, advanced processing, sophisticated analysis and secure data transmission. Using standard interfaces, open architectures and scaleable platforms, the solutions are customizable to meet individual requirements - for permanent and temporary installations, for single sites and monitoring networks.

When it has to be right.