- when it has to be right
Dear Readers,

A challenging first half of 2009 lies behind us. Like most other industries, the measurement technologies market has been affected by the worldwide economic crisis. Nevertheless, this crisis also shows us that Leica Geosystems chose the right way as we boost the strengths we underline in our company portrait: "With close to 200 years of pioneering solutions to measure the world, Leica Geosystems products and services are trusted by professionals worldwide."

Because we focus on the innovation power of our research and development teams now more than ever – from fundamental research to product development. And once more it proves that this is the right way: Leica Geosystems is still a healthy company and a strong brand that our customers are right to trust in. At Intergeo in Karlsruhe, Germany, from 22 to 24 September we will present our most recent developments – our new flagship product, the highly precise Leica TS30 total station; the Leica ScanStation C10, the next generation of 3D laser scanning; the new system solution Leica Viva; and new models within our handheld laser distance meter-range.

In this edition of the “Reporter” we collected exciting customer projects from all around the world – from the Ukraine, France, Germany, China and the USA. They show the broad spectrum of Leica Geosystems’ products and solutions, and highlight the variety of our customer’s applications with them. Even for us this is always a new and exciting experience!

Enjoy reading, and I would be pleased to see you at Intergeo!

Ola Rollén
CEO Leica Geosystems
Holy Caves in 3D

by Valentyn Kovtun and Yuriy Serebrianny

Kiev Pechersk Lavra in Kiev, Ukraine is a unique monastery complex. In the course of its history it has been visited by over 43 million tourists from all parts of the world. It consists of an above-ground part (a complex of religious buildings) and an underground part (caves). A Leica ScanStation 2 and total stations now help preserve this UNESCO World Heritage Site.

The caves of Kiev Pechersk Lavra form a system of underground corridors subdivided into several parts – the Near Caves, the Far Caves and the Varangian Caves. The caves are first mentioned in the chronicles in the year 1051. Initially occupied by the monks, they were later used to bury deceased monastery settlers. The caves serve as a resting place for imperishable relics of saints.

The idea of creating a 3-dimensional model of Lavra’s caves was suggested by Kiev Pechersk Lavra coe-nobites. “Our aim is to attract public attention to the problem of preserving the Lavra Caves for future generations. Today the caves are in a desperate state and urgently need repair work,” says Archbishop Pavel, Father Superior of Kiev Pechersk Lavra.

Laser Scanning Using Leica ScanStation 2
In November and December 2008, laser scanning of St. Anne’s Conception Church in the Far Caves of Kiev Pechersk Lavra was performed by Ukrgeodezmark Subsidiary Company in cooperation with the official Leica Geosystems dealer in Ukraine, Doka. The work was carried out within the scope of a cave laser scanning project with the goal of creating a visualization of the cave interior. Work specifications for this scanning project were developed by Ukrgeodezmark Subsidiary Company specialists Sergey Marchuk and Maksim Mikhailov.

Laser scanning with 2 cm resolution was performed using the new Leica ScanStation 2. The work was carried out at night due to high cave attendance...
in the daytime. Previously created survey networks in the local coordinate system were used as a geodetic base for scanning. Additional measurements in those parts of the caves that presented difficulties were performed using a Leica TCR1201+ total station. “This is the most advanced equipment in the world today,” assured Yuriy Serebriannyy, Director of Doka, Ltd.

The Leica ScanStation 2 demonstrated high reliability in the work process and the scanning results are yet another testimony to its unparalleled performance. According to the statement made by Ukrgeodezmark’s Director Nikolay Belous at the press-conference organized by Kiev Pechersk Lavra priests, the equipment is so accurate that it records the slightest wall irregularities and even murals. “After all the work is done, it will be possible to walk through all of Lavra’s caves while sitting on a couch with a cup of tea,” said Mr. Belous. However, according to Project Manager Valentyn Kovtun, some of the caves remain unexamined since their entrances are still blocked up.

**Labyrinth Modelling**

Based on the results of surface scanning and 3D modelling, the next step is a visualization of the entire cave labyrinth using proprietary technology. First, triangulation models of object surfaces are created with a 50x50 mm increment. This increment may be reduced to 25x25 mm for places with complicated surfaces and room interiors. Then the entire object is modelled by combining individual triangulation modules of object surfaces (walls, ceiling, floor etc).

All walls, floors and ceilings of caves and rooms are modelled using primitives of Polyface Mesh type. The scanning results are processed by the Leica Cyclone software suite. Three-dimensional models are created using specialized software by combining triangulation models generated based on scanning data with high-quality photographic material. As a result, a user can view the completed model, freely move around it and get additional information.
Future plans include creation of a three-dimensional Kiev Pechersk Lavra geographic information system (GIS). Availability of such a 3D GIS would allow reproduction of the unique Lavra architecture, including its smallest details, at any time with maximum possible accuracy and speed.

3D Technologies: the Future of Visualization

Today 3D laser scanning is an integral and the most promising part of engineering surveying in the field of architecture, construction and historical and cultural heritage. Use of the latest laser scanning technologies from Leica Geosystems opens up new horizons for humankind in such areas as preservation of valuable historical and cultural objects for our descendants and ensuring general availability of the world’s cultural heritage that would help spread culture and knowledge among citizens of all countries. A 3D visualization model would enable many pilgrims who cannot come to ancient Kiev in person to take a virtual “walk” through the holy caves of Kiev Pechersk Lavra and pay their respects to the sacred Christian relics.

About the authors:
Valentyn Kovtun, Project Manager at Ukrgeodezmark, is a general surveyor specializing in engineering, surveying and construction. Yuriy Serebrianny is Director General of Doka Ltd. – the official Leica Geosystems distributor in Ukraine.

Ancient Kiev

Ancient Kiev is over 1,500 years old. People call it “The Heart of Rus” and “The Mother of Rus Cities”. Kiev was the historical centre of Slavic culture and the capital of powerful Kievan Rus.

According to legend, brothers Kiy, Shchek and Khoryv and their sister Lybid founded the city on the steep right bank of the River Dnepr in the late 5th – early 6th – century and named it Kyiv in honour of the eldest brother. The first mention of Kyiv in the Old Russian Primary Chronicle dates back to 862 A.D.

The history of the city of Kiev has been turbulent. In the 11th century it was already one of Europe’s largest cities with a population of 50,000. Throughout it’s history the city, strategically located on the banks of the (navigable) Dnieper river, was repeatedly attacked and conquered – by Mongols, Poles, Russians and Nazi Germany to name just a few.

Kiev has been the capital of the Ukraine since the Ukrainian parliament declared it’s independence from Russia on 24 August 1992, and today it is the country’s largest city with a population of nearly three million. With it’s many churches and monasteries it is of great importance, particularly to orthodox Christians.
The journalists staking out the logo with the help of Leica GPS1200.

600 Liters of Red and a GNSS system

by Hélène Leplomb

When the French magazine "Paris Match" celebrated its 60th anniversary, it did so on a large scale. The weekly magazine with the slogan: “the weight of words, the effect of photos” is very influential. For this anniversary, the editorial staff, together with a glaciologist, decided to attract the public’s attention to the melting of the icecaps by spelling out the letters “Paris Match” on Greenland’s ice. A Leica GPS system was an essential tool during the expedition.

The goal was to analyze the progression of the melting of the logo and therefore the ice. Obviously, this adventure could only be carried out by using biodegradable paint and limiting CO₂ emissions as much as possible during the trip. To have sufficient visual impact on the immense size of the ice field, the logo measured 70 by 36 meters. But how can a logo this size be painted on the ice? The journalists quickly understood that a professional tool was necessary to obtain the desired graphic effect. The required precision of the figure and resistance to extreme temperatures soon led them to Leica Geosystems.

Training Session on the Beach

In December 2008, the journalists contacted Leica Geosystems France and presented their quandary. The team, sensitive to the ecological aspects and
challenges represented by the project, agreed to support them. Product manager Farouk Kadded, himself used to extreme conditions, proposed a Leica GPS1200, a twin frequency GNSS sensor he himself uses to measure the altitude of Mont Blanc every two years. Following two quick training sessions, one to become familiar with the instruments, the other to perform a life-size test on a beach, the Paris Match team was finally ready.

Once at Ittoqqortoormit in Greenland, the journalists spent two days getting their bearings and locating the perfect spot: a large ice-covered surface with an iceberg coming out of it. From now on, the success of their mission depended on their Leica Geosystems equipment.

Mission Accomplished in 4 Days
The technical specifications of the Leica RX1250 controller enable it to operate at -30°C (-22°F). Under -35°C (-31°F) the system slows down but if the air warms up just a few degrees, full capacity is available again. The journalists began to mark out the logo, but the “C” was barely finished by nightfall, forcing them to continue the next day. On the fourth day of the expedition the journalists worked more quickly and finished marking out the letters “Paris Match”. The intended one hundred wooden stakes were not sufficient to mark all the letters, so some had to be cut in half to finish the outline of the logo.

After 600 liters of carmine paint were used to trace out the letters, the team was proud of the result — mission accomplished. The aerial photo taken from a helicopter gives a sense of the magnitude of the project. Back in France, the journalists thanked us and told us about their adventure. They appreciated the collaboration with Leica Geosystems and the time spent on training and simulation. The material fully met the needs for use in the Arctic stakeout and the adventure once again proved the robustness and precision of Leica Geosystems instruments.

About the author:
Hélène Leplomb is Marketing Manager for the Geomatics and Scanning Division at Leica Geosystems France.
Lost in the vastness of the South Pacific, a unique island rises out of the ocean. The inhabitants call it “Rapa Nui”. The European “discoverer” who sighted the island lying thousands of kilometers away from the nearest continent, or even another island, on Easter Sunday in the year 1722, several hundred years after the Polynesians, rather unimaginatively named it Easter Island. Milosch Dryjanski journeyed there with his team of speleologists and three Leica DISTO™ laser distance meters to unlock some of Easter Island’s subterranean secrets.

The island’s isolation, resulting from its extreme remoteness, fostered the development of a remarkable culture, of which we have scarcely any knowledge today. The most famous symbols, which every European associates with Easter Island, are the giant stone sculptures, referred to as “moai” in the local language. Although the culture of the original moai builders was already in the process of disintegration by the time the first Europeans arrived, their culture and history, conserved and passed down in oral histories, were soon completely lost by exploitation of the island, deportation into slavery and the importation of disease. Today there are several theories, some quite absurd, about the island’s culture and the reasons for its demise; however, they all have one thing in common: They are virtually impossible to prove or disprove.

To make a small contribution to solving the puzzle that the original island dwellers left behind, a speleological expedition under the patronage of National Geographic and Explorers Club traveled to the island, the top of an extinct volcano rising out of the 4,000m deep ocean. Due to its volcanic origins, the island has an abundance of lava caves, from very small to extremely splendid examples – in the opinion of the speleologists. These caves were used up to the middle of the last century by the indigenous population for a number of different purposes. They often served as living space, but sometimes as defensive refuges for wives and children during war-like local conflicts. They were also used for storing water, keeping poultry and, last but not least, for entombing bodies. Many caves contain the remnants of hundreds of years of their former uses.
Most caves are also very familiar territory for today’s islanders – they played in them as children. But until now very few of the smaller caves had been documented and surveyed. That was the task of the expedition, which was comprised mainly of Polish speleologists and a US-American TV crew.

In garish orange or blue overalls – many European speleologists call them “Schlatzen”, which is thought to refer to the mixture of mud and water often found in caves – for four weeks under a tropical sun, the expedition members roamed through the sectors of the island identified together with the local national park administration, searching for small cave entrances. Every instance was marked on the map using GPS and the interior was described and surveyed. For the countless spiders and cockroaches living in the small caves, it was no doubt seen as a serious case of trespassing!

In view of the huge number of mostly small caves, it was particularly important to carry out the measurements as efficiently as possible. It was less about absolute accuracy and more about the methodical capture and cataloguing of the caves and their most important features. The Leica DISTO™ A3, A6 and A8 laser distance meters used in combination with external instruments for measuring inclination and magnetic azimuth, sometimes also with PDAs, considerably accelerated the work.

For speleologists, who often have to squeeze through narrow gaps along with all their equipment, the versatility of these instruments despite their small size, their low weight, convenient, simple power source when remote from civilization and their robustness, play a crucial role.

To the team, the strength of the Leica DISTO™ instruments lay in their speed of distance measurement. They were able to survey the caves without having to make their way over to all the most significant points with a tape. Measuring wide but very low caves (with heights of about 40 cm and widths of several meters) using a tape would have been extremely time-consuming and strenuous due to the high temperatures encountered in caves close to ground level. In the larger caves, the roof height was determined quickly and precisely at the touch of a button on the Leica DISTO™.

>
With the laser they worked in teams of two. One person measured, the other drew. There was no need for a third person as there would have been with a tape. Working the instrument is simple and no real training is necessary.

It was important to the speleologists that the instruments were resistant to substances like dirt and water, and could be easily cleaned and operated, even when wearing gloves. In addition, they were able to survey and draw up the salient features of the caves without stepping on potentially important archaeological sites.

The built-in video viewfinder of the Leica DISTO™ A8 was particularly useful for accurate pointing. It was impossible to see the laser dot in the tropical sun in caves with large openings or holes in the walls. But with a writing pad as a target and the camera to establishing bearing, the arrangement worked wonderfully. For caves with dimensions larger than 10 m, surveying with a tape through undergrowth would have presented quite a problem.

The Leica DISTO™ A6 transferred the data via Bluetooth to a PDA and was used with an external module for determining magnetic azimuth and inclination for computer-aided mapping.

The 18 person strong speleologist team captured and recorded over 300 caves during the expedition. This would hardly have been possible using conventional cave research surveying methods. We would like to express our sincere thanks to Leica Geosystems for its generous support. The instruments worked excellently under the difficult conditions in the lava caves on Easter Island.

About the Author: Milosch Dryjanski, by profession an electrical engineer, is Head of Building Management Systems in the Building Management Department, Technical University Munich. For over 25 years he has spent his free time on Alpine cave exploration.

Photos: Marcin Jamkowski/AdventurePictures.eu (p. 9) and Tomasz Snopkiewicz (p. 10)
TSG 1899 Hoffenheim was the surprise of the German soccer season 2008: It only took a few years for the team from Sinsheim, a small town near Heidelberg, to make it into Germany’s top soccer league, the Bundesliga. And now, with the opening of the Rhein-Neckar Arena at the beginning of 2009, the club has a new home stadium. The enthusiasm in the region for the Bundesliga’s newly promoted TSG 1899 Hoffenheim is as high as it has ever been. The surveyors for engineering consultants Kieser + Dr. Neureither who were commissioned with the work for the new stadium, were also filled with enthusiasm.

In the summer of 2006, Dietmar Hopp, the main sponsor of TSG 1899 Hoffenheim, started looking for a site for a new soccer stadium. The decision in favor of Sinsheim and the appointment of a consultancy firm sounded the starting whistle. Parallel to the design of the stadium, it was also necessary to produce a legally compliant land development plan; that was the first task for the surveyors.

At an early stage, the project manager appointed Mosbach-based engineering consultants Kieser + Dr. Neureither to perform all the surveying for the contract. Their first job was to create a digital terrain model of the existing site over an area of approximately 50 hectares along the A6 motorway opposite Sinsheim’s Auto & Technik Museum. This survey was to serve as the basis for the general development plan and to determine the location and elevations of the proposed stadium complex, including all the car parks in the subsequent detailed design. The new development lies in the undulating countryside of the Kraichgau Hills, therefore it was particularly
important to establish final ground levels that would optimize cut and fill earth movements.

Surveys to create the terrain model were performed using a Leica GPS1200 system and augmented with laser scanning data from the Baden-Württemberg Land Survey Authority. Levels were transferred from the state's network of benchmarks to survey stations nearer the project site by trigonometric leveling with a Leica TPS1200 total station.

After completion of the design phase by the lead consultant, Ibbenbüren-based agn Niederberghaus & Partner, ground was broken in May 2007 and work began on the construction. The digital terrain model of the existing site and the new design were handed over to the main contractor Leonhard Weiss, who used the data to control the earthmoving machinery and ensure excavation proceeded efficiently. Approximately 350,000 m³ of earth had to be moved throughout the area of the site for the new stadium and its 2,300 parking spaces.

A local network of survey stations was established in the direct vicinity of the stadium site. The measurements to determine the positions and levels of nine concrete piles were carried out using a combination of Leica GPS1200 and Leica TPS1200 and calculated using network adjustment. By employing multiple reciprocal observations, positional and level accuracies of less than 2 mm were achieved, dispensing with the need to determine the heights more accurately using a precision level.

Foundation work for the stadium commenced in August 2007. All the reinforced concrete structures for the main building and the stands were built on over 900 concrete piles, some up to 25 m long. The piles, placed in groups of 2 or more at the intersections of 55 axes running diametrically and 4 axes running parallel to the edge of the pitch, were re-exposed after concreting and anchored into sleeve foundations. The stake-out of these sleeve foundations required a positional accuracy of 3 cm. This would not generally be a problem but it is not easy when piles are being driven around you at the same time. The measurements to establish set-up and stake-out points had to be done in the breaks between driving. The circles in the Leica TPS1200 total station remained relatively stable over the long term, despite very obvious vibrations.

In the middle of October 2007, when the ground plate for the main structure was complete and the formwork erection for the in situ concrete staircases had been started, it was time for the first precast reinforced concrete columns to arrive on site. To comply with the specified tolerances for the main beams, deck slabs and supports for the stand components that were to be attached to the columns, the stake-out engineers had to establish the positions and levels of the columns fixed into the sleeve foundations precisely. To do this, three axis points were marked out by steel nails on each of the concrete foundations, which were then used to align and position the columns. On the four-storey main structure, each of the columns extended over two floors. The ends of the upper and external columns for the stands had a large steel anchor plate that the roof construction steel supports were attached to.

The major part of the in situ reinforced concrete works and the installation of the precast units was complete when the first roof construction elements were delivered and erected in May 2008.

The client and the designer had stipulated that the roof should give the impression of a floating cloud and that there should be no cable stays or columns in the stands. The whole roof structure rests only on the external columns and the designated primary support structure.

The construction of the stadium called for highly accurate surveying. First of all, the heights of the installed concrete column heads had to be determined and the axes for the steel roof supports marked out on the column head plates to millimeter accuracy. The elements of the primary support structure, some weighing several hundred tones, were preassembled in the area earmarked for the future soccer pitch, then measured and the results compared to the specified dimensions. The axes to align and position the main beams were marked on temporary towers erected specifically for their installation. The primary structure carried the “polygonal trusses”, on which the roof covering, Makrolon panels and inner membrane lining were fastened.

Checks on the erected roof construction were necessary to ensure compliance with the manufacturing tolerances for the roof covering. The Leica TPS1200 total station used for surveying and setting out was
sometimes set up directly on the roof to check the parallel alignment and distance between the holes for the attachment of the foils to the polygonal trusses. Working from the stands, the position and level of each steel beam was checked against previously marked points with the help of a steep sight eyepiece. These measurements were all taken without a reflector.

After removal of the temporary towers, completion of the roof lining and covering, and the installation of video screens weighing around ten tones each, further measurements were made to check the elevations and vertical position of the columns.

During the entire construction phase, surveying and setting out were required, for example for setting level reference plates on each floor, checking the position and level of the completed components, establishing the axes for facade and window installation and for interior works.

The original mesh of survey stations was continuously augmented with further points around the site and on the structure itself. Self-adhesive reflective foil markers were used wherever possible. Determination of these points, as well as stationing using these points, was done with reflectorless measurements using both instrument faces. This measurement procedure proved to be much quicker and more accurate than measuring using reflectors. Using at least 4 fix points, the mean error of station coordinates was in the order of 1 to 2 mm for position and height. The high levelling accuracy of the Leica TPS1200, even over longer distances, meant that geometric levelling was not necessary. A Leica GPS1200 was also used wherever possible for setting out and surveying work in and around the new stadium.

In summary, it can be said that the Leica Geosystems equipment was reliable and highly accurate at all times and allowed the required surveying and setting out to be efficiently and precisely carried out.

About the Author:
Dipl.Ing. (FH) Hardy Schwalb is a surveying engineer with Kieser & Dr. Neureither in Mosbach, Germany and was responsible for the engineering surveying for the construction of the Sinsheim Stadium.

Rhein-Neckar Arena, Sinsheim

Location: Sinsheim, Germany
Owner: Dietmar Hopp
Club: TSG 1899 Hoffenheim
Architect: agn Niederberghaus & Partner, Ibbenbüren
Opened: 24 January 2009

Capacity: 30,164
Cost: US$ 86 mil. (EUR 60 mil.)

Events:
- FIFA Women’s Football World Cup 2011
- Deutsches Turnfest 2013
Iowa DOT: Investment in the Future

by Vicki Speed

The Iowa Department of Transportation (DOT) recently implemented one of the world’s largest DOT-owned statewide networks of GNSS Continuously Operating Reference Stations. Called the Iowa Real Time Network IaRTN, this statewide network provides authorized public and private users near-instantaneous GPS satellite corrections for accurate and precise positioning anywhere in the state.

Mike Jackson, Special Projects Engineer with Iowa DOT, says, “The IaRTN significantly improves the efficiency and accuracy of determining survey-level GNSS coordinates, and, in most cases, eliminates the need to install base stations or proprietary networks. It’s a network built with unlimited potential that can be used by a vast array of users from surveyors and contractors to farmers."

Provided by Leica Geosystems, the IaRTN includes a total of 80 stations. Each station includes a Leica GRX1200 GG Pro GNSS receiver with ethernet capabilities. Continuously Operating Reference Stations (CORS) are spaced about 70km apart and the network is designed to provide coverage anywhere in the state of Iowa. The satellite referencing network utilizes more than 40 currently operational satellites, as well as another 40 or more that will become operational with system upgrades and additions to the GPS and GLONASS systems as well as Galileo satellites. Real Time Kinematic (RTK) data are available to the agency and public 24/7 via the Internet.

The backbone of the network is Leica Geosystems’ SpiderNet network software, an integrated suite of networking software that adjusts for ionic and tropospheric conditions and solves for ambiguities throughout the network before sending a network-corrected signal to the rover or end user. Rather than
merely getting information from the closest reference station, the user is getting corrections based on the entire network. Leica SpiderWeb is used to distribute the GNSS data via the Internet for access using a standard Web browser.

Wendy Watson, Leica Geosystems project manager for the Iowa DOT project, adds, “Reference station networks like Iowa’s provide a fundamental tool for engineering and survey professionals throughout the state. Beyond surveying, the network can be used to monitor the movement of bridges and dams, support machine control activities on road construction projects, play a role in accident reporting of local police departments and so much more. It’s an investment in the future.”

The IaRTN was launched to the public in February 2009, just one year after receiving a Notice to Proceed, making it one of the fastest reference station networks ever constructed. Leica Geosystems has a contract to manage the administration and monitoring of the Iowa DOT network as well.

For more information on the IaRTN, go to Iowa DOT’s Web site http://www.iowadot.gov/rtn/

About the author:
Vicki Speed is a freelance writer who has specialized in the engineering and construction market for over 10 years. Vicki is based out of Denver, CO.
Real Time GNSS Bridge Monitoring

by Hélène Leplomb

The French surveying company 3GE worked hand in hand with Leica Geosystems to install the first GNSS automatic monitoring systems in France on two exceptional bridges: the Tancarville Bridge and the Normandy Bridge.

The Chamber of Commerce and Industry (CCI) of Havre manages two exceptional works of art: the Tancarville suspension bridge, spanning 608 m (1,995 ft), which is celebrating its 60<sup>th</sup> anniversary this year, and the Normandy cable-stay bridge with a central span of 856 m (2,808 ft), inaugurated in 1995. These two bridges are crucial for the economic development of the region: more than 12 million vehicles cross the bridges each year and more are expected in the coming years.

Because French regulations stipulate increased monitoring of bridges spanning more than 500 m (1,640 ft), to date they have been regularly monitored using manual tachometry. In 2007 the Havre CCI launched a tender for the implementation of monitoring services. Among the responses for monitoring by tachometry was an alternative proposal for automatic monitoring by means of GNSS technology proposed by the company 3GE (Garrigou and Gaillet Géomètres Experts au Havre). After studying the different proposals, Didier Jean, the Technical Manager
Products Used

- Leica GMX 901 GPS Antennas
- Leica AX1202GG Multi-GNSS Antennas
- Leica GNSS Spider Software for single stations and networks
- Leica GNSS QC Software for reference station quality control and data analysis

Three-dimensional point sets allow continuous, comprehensive monitoring of deformations caused by climate-related changes. Because suspension and cable-stayed bridges are dynamic by nature, the data must also allow comparisons between actual movements and theoretical models and behavior observed in wind tunnels. In addition to the fluctuations, the Havre Chamber of Commerce and Industry is also interested in the works’ internal frequencies. With the new installation, it is now possible to permanently study and monitor the behavior of the bridges, in particular during storms, periods of strong wind and heavy traffic. Since the data are synchronized, an exact dynamic model of the structures is obtained at any given moment in real-time or time-lapsed. In the context of sustainable development of bridges, there is no doubt that these exemplary works will help advance the state of the art for monitoring of dynamic bridges in France.

About the author:
Hélène Leplomb is Marketing Manager for the Geomatics and Scanning Division at Leica Geosystems France.
3D laser scanning has become established in many applications over recent years due to its potential for rapid, non-contact data capture at a high scanning density. That this process can also be used successfully for the investigation of deformations of large surfaces is demonstrated by a research project at the Technical University Munich, Germany (TUM). The Leica HDS6000 laser scanner proved to be a success when scanning the area around the working face of an extension tunnel to the underground railway system in Stuttgart.

Diplom-Ingenieur Johannes Ohlmann is Senior Lecturer and Research Associate at the Department of Geodesy at the Technical University Munich (TUM). As part of his diploma thesis and as a continuing research project in cooperation with the Geotechnical Center (Department of Foundation Engineering, Soil Mechanics, Rock Mechanics and Tunneling at the same university), he is investigating the extent to which 3D laser scanning can be used to determine deformations of large surface areas during tunneling. A suitable project for this task was the extension to metro line U6 in Stuttgart - an approximately 400 meter long section of driven and sprayed concrete tunnel. The local Office of Public Works supported the research in this field.

Terrestrial Laser Scanning in Tunnel Construction

Tunnel scanning using 3D laser scanners is now a common measurement procedure in many tunnel construction phases. “For geodesy and geotechnics, current and complete information on the deformation of large surface areas is of interest, particularly to projects using the technique known as the ‘New Austrian Method of Tunnel Construction’ (NÖT), in which deformations occurring during tunneling are an important criterion for decisions during the construction process,” says Johannes Ohlmann. The traditional practice is to carry out displacement surveys only at certain cross sections.

Drawing Conclusions from Tunnel Surface Deformations

At the Department of Geodesy, surface measurements are now completed using laser scanning, to analyze deformations of large areas in real-time using sets of 3D point clouds captured at intervals.
The Geotechnical Center has produced models that should make it possible in the near future to draw conclusions about the settlement of the ground surface, and of buildings in particular, from the deformations of the tunnel surfaces during driving.

The working face is where all the action takes place when driving a tunnel. Its stability during the drive is not something that can be measured. However, deformations can be measured and evaluated using laser scanning, which enables engineers to obtain information about how the stability of the tunnel changes over time. The increases in deformations, evident from the measurements taken at specific time intervals, can be calculated and used to draw conclusions about the stability of the working face.

**Economic and Safe**

3D laser scanning can be easily integrated into the process of tunnel driving and has proved to be economic and compatible with construction operations. “In less than ten minutes, a Leica HDS6000 captures the surface profile of the whole tunnel driving area, including the working face, while causing hardly any disruption to normal site activities.” Ohlmann also mentions the quality and financial advantages for clients and contractors: “Optimizing the periods of use of temporary tunnel safety works shortens the construction period. Laser scanning also provides an extensive and comprehensive record of events captured directly as the work progresses. Safety is improved. By using this non-contact method of data capture, the survey engineers do not have to enter the potentially unsafe zone around the working face.”

**Measurements and Evaluation**

“At the end of September 2008, working around the tunnel driving operations, engineers began using the Leica HDS6000 to complete seven static surveys of the working face, spread out at intervals over a period of ten hours. The first and fourth surveys were used as references. With the Leica HDS6000, each survey was completed well within the available 15 minute time-frame. “On average, we needed only seven minutes for a scan, and that was using the required resolution of just a few millimeters and a safe remote operating distance of ten meters,” explains Ohlmann. The point clouds were registered using Leica Cyclone 6.0 and referenced in relation to a local coordinate system. Both sphere and B&W targets were tested for the transformation, which had an average registration accuracy in the order of 1-2 mm.”
To evaluate deformations, the working face was divided into a grid, over which the point clouds were superimposed. The differences in the components of the interpolated grid points perpendicular to the working face defined the deformations of each set of measurements in relation to the reference surveys. The mesh size of the grid was adjusted to suit the point density, which ensured that calculated values were representative of the deformation of the surfaces. By developing special data filters and calculation algorithms to eliminate changes intentionally introduced as part of the works, such as the application of the sprayed concrete lining or installation of temporary supports, it was possible to arrive at reliable values for the deformations, accurate to within a few millimeters. The deformations were presented in color-coded graphs produced with the TunnelDefo software written by TUM.

**Huge Application Potential**

The researchers working on the project at TUM are convinced of the huge potential of drive-attendant tunnel scanning. “Laser scanning during tunnel driving was included in the tender for the first time here in the current ICE tunnels and will become standard practice,” says Ohlmann confidently. The advantages of the Leica HDS6000 and its successor, the Leica HDS6100 model with expanded specifications, will play an important role in ensuring successful projects in this future-oriented area of application.

During the surveys and the positive discussions of the process with all project partners, the Department of Geodesy was able to continuously develop the analysis algorithms and the software for calculations of the working face deformations. Johannes Ohlmann: “Our objective is to be able to provide the tunnel driving manager with reliable reports on the deformations immediately after scanning the area on site.”

**About the author:**

*Konrad Saal is Marketing Communications Manager at Leica Geosystems in Heerbrugg, Switzerland. He holds a degree in surveying from the University of Applied Sciences Munich.*
At 2 m per hour, the box tunnel is jacked into place.

One Hundred and One Hours

by Hugh Anderson

In a world where there is no such thing as absolute stability, movement is an ever present phenomenon. How much something moves and when, is of different importance to different people. One aspect of movement that we take for granted is the adequate, reliable and safe provision of transport infrastructure.

There are over 410,430 km of roads and rail track in Great Britain (according to the Department for Transport), a figure that is constantly being extended as population demands increase. This network is linked by over 7,600 railway crossings on both public and private land. Each year, 2,000 motorists and pedestrians are reported to have misused these crossings, as we are reminded in the news. Trains can reach speeds of 200 km/h and cannot stop quickly enough, making crossings extremely hazardous and constantly exposed to risk.

The risks posed by railway crossings can be eliminated by replacing them with bridges or underpasses. One location where this is currently taking place is the Owen Street Level Crossing where the B4517, Alexandra Road, crosses the West Coast Mainline near Tipton Station in the West Midlands, UK. The crossing is being replaced by 300m of road, which will pass under the railway line by means of a 55 m by 9 m box tunnel. The work is being carried out by the civil engineering contractor, BAM Nuttall Ltd.

The £20 million (EUR 23 mil., US$ 32 mil.), 18 month project to replace the Owen Street Level Crossing is the first of four major physical regeneration schemes scheduled to take place in Tipton over the next three years. A newly constructed tunnel and high quality road layout aims to improve traffic flow and boost business in the town.

It was in the 1950s that Sandwell Metropolitan Borough Council first started the process of replacing the Owen Street level crossing, which is believed to be the last of its kind on the West Coast Main Line. This is a busy line with many high speed trains, many not stopping at Tipton Station, so the barrier can be down for long periods, sometimes as long as three quarters of an hour at a time, which is not conducive to encouraging business in town.
The contract to design and construct the Owen Street Relief Road, with funding from the Department of Transport, was awarded to BAM Nuttall Ltd in August 2007.

60 Meters in 30 Hours
The two year project commenced in October 2007 and the new relief road is scheduled to be opened soon. The site investigations revealed that the ground presented a major challenge as the area used to be a canal basin, which had been filled in with poor materials, and former industrial workings meant that the site was contaminated. This was further complicated by a geological fault running across the site.

BAM Nuttall has considerable experience in the field of jacked box tunnelling, its most recently completed project being the successful jacking of a box tunnel under the live M1 motorway near Northampton at junction 15A. There is however, one major difference between the project in Tipton and their previous contracts. In the past, the box tunnel was jacked at the rate of two and a half to three metres in a shift, but at Tipton the whole process had to take place during the one possession and the 60 metre move was achieved in 30 hours, an impressive average of two metres per hour!

For most people the Easter beak began at midnight on Thursday 9th April 2009, but for the engineers at BAM Nuttall Ltd it was the beginning of a one hundred and one hour possession of a one hundred metre section of the West Coast Main Line.

During the preceding months Jamie Beech, Agent for BAM Nuttall Ltd., and his engineers had constructed a box structure which was to become a road bridge under the railway line to replace the Owen Street level crossing in Tipton. For the next four days, the BAM Nuttall team used the John Ropkins system of jacked boxed tunnelling to jack the concrete structure into place.

Requirements exceeded
The possession began with taking up the existing track. A task that took up the first ten hours of their allocated time. During the sheet piling and construction of the access on either side of the tunnel location this rail track had been continually monitored using two permanently mounted Leica TCA1201+ Total Stations measuring to 300 mini-prisms fixed to the rails, gantries and other relevant structures. The data from these instruments were continually processed using Leica GeoMoS. GeoMos is capable of collecting data from virtually any sensor required for monitoring, and displaying this data in an easily understood, meaningful and user defined manner. A meteo sensor was included to monitor temperature and pressure, which was used to correct the observations so that the accuracy of the results was not affected by the weather. The reliability and repeatability of the system exceeded the requirements of the project, which was for points to be recorded to <5 mm. The repeatability of measurement was an impressive ±2 mm. Twenty mini prisms were transferred to the ballast shoulder to monitor the coffer dams during the jacking process.
Jacked Box Tunnelling System

The jacked box tunnelling system developed by the Kent based company John Ropkins Ltd UK, an independent civil engineering consultancy specialising in box tunnelling techniques, evolved from the pipe jacking methods of the mid-1960s. It is a non-intrusive method for constructing new structures beneath existing surface infrastructure, such as the M1 motorway in Northamptonshire and the West Coast Main Line in Tipton. Unlike traditional construction methods, which can severely disrupt traffic flows and greatly inconvenience the locality, this method enables traffic flows, whether road or rail, to be maintained throughout the construction process, minimising the cost of disruption.

Once the track had been lifted and the ballast removed the excavators could take up their positions to dig the material ahead of the box construction. The box is fitted with a cutting head so that it cuts its own path. This minimised the amount of backfill required, with its inherent necessity of compaction and the possibilities of settlement in the future, and eliminated overdig. This process also meant that a full height channel did not need to be excavated, but the excavators were required to remove the material that was excavated by the cutting head as the box edged forward.

The inert excavated spoil from the site was deposited using a temporary haul road to the nearby Tibbington Open Space, which is known locally as “The Cracker”. This is a recreational area which will be landscaped to create new sports playing fields for the community. This minimised waste disposal and vehicle movements.

The box tunnel has a plated steel soffit and was constructed on top of 120 steel wire ropes that were laid on top of the jacking slab. The wire ropes were greased to provide lubrication during the sliding action. The box was moved forward using three packs of 6 rams, each capable of 200 tonnes of thrust. As the box moved forward, an additional 512 wire ropes were fed under the box. These greased wire ropes formed a “track” for the steel soffit plate to move on, reducing friction. The progress of the tunnel was monitored by another Leica TPS1200+ Total Station reading to a 360° prism on the structure to ensure that it was moving in the required direction and that the correct height was maintained.

Using GeoMoS and other equipment from Leica Geosystems to continually monitor the state of the track and other structures as the work progressed, provided cost savings to the project, since work could proceed with the confidence that the system would alert the engineers to potential movement before it became critical.

Jamie Beech, Agent for BAM Nuttall, comments: “We were thoroughly impressed with the automated monitoring solution from Leica Geosystems. The off-the-shelf package not only provided us with the level of precision, detail and accuracy that was demanded of the project. The solution gave us 100% confidence in the project and allowed us to collect valuable information to analyse and submit to Network Rail, giving them evidence that their infrastructure remained unaffected and confidence in our continuing works.”

The effectiveness of the solutions employed by BAM Nuttall on this project are well demonstrated by the fact that not only was the box jacking completed and the track restored within the one hundred and one hours, but was actually completed two and a half hours before termination of the possession.

About the author:
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Olympic High Speed

by Hansruedi Amrein

Due to great economic growth and social development, the People's Republic of China is rapidly expanding its railway network. The great speed of growth demands quick work: The long-term plan of the MOR (Ministry of Railways) is to expand the network from the current 75,000 to 100,000 km by the year 2020. To increase capacity, both passenger and freight lines are being developed, however, freight and passenger transports are separated. The plan is for around 50% of the total network to be double-tracked and electrified and for the network to conform to modern standards in terms of quality and comfort. The construction plan also features high-speed lines – including the 114 km section between Beijing and Tianjin, linking a venue of the Olympic sailing competition with the Olympic metropolis Beijing, which went into operation on schedule for the Olympic Games 2008 after some three and a half years of construction.

The section is a Slab Track system and, for the most part, is supported on bridges due to the poor ground surface. This new high-speed line is the first in China to allow travel speeds of up to 350 km/h and train services with a frequency of three minutes. Travel time on the section comprised of three stops, is approx. 30 minutes. Building costs for the new section were US$ 1.73 billion (EUR 1.2 billion).

Leica Geosystems Technology in China

The surveying task involved high-precision positioning of 24 high-speed turnouts and complete geometric inspection surveys of the high-speed section between Beijing and Tianjin.

Three main challenges were faced by the surveying team during the construction phase:
- to quickly and effectively set up a high accuracy and high density Control Point III survey network (CPIII network),
- to adjust the Slab position with the highest accuracy and
- to achieve the highest level of track position, accurate to the millimeter for perfect driving dynamics and safe and comfortable operation, as well as to execute high-performance surveying with maximum accuracy for fast construction.

The tasks were complemented with comprehensive
documentation and compliance for checking relevant track geometry parameters.

**Amberg GRP 1000 System Combined with Leica TCRP1201+**

Eight GRP 1000 Slab Track measuring systems from Leica Geosystems partner Amberg Technologies, Switzerland, were used on the section between Beijing and Tanjin. Amberg Technologies is a leading provider of specialized system solutions for civil infrastructure, particularly railways and tunnels. The GRP 1000 system consists of a track surveying trolley, prism column, special GRP Slab Track software module and an external, radio-controlled Leica TCRP1201+ precision total station. It allows precise track measurement during automated measuring processes. The system delivers 3D track co-ordinates in real time, performs gauge and cant measurements and displays the current track deviation relative to the design position. The GRP 1000 system accomplishes fast track positioning accurate to the millimeter before concreting work or track geometry acceptance measurement, with an output of up to 700 m an hour. The Amberg GRP 1000 also offers extensive options for final track documentation.

**Millimeter Accuracy**

The GRP 1000 in combination with a Leica TCRP1201+ allowed fast, efficient track surveying. Thanks to a well thought-out operating concept designed for the special requirements of the construction of the Beijing – Tianjin Olympic High Speed Line, tracks could be built with millimeter accuracy and comprehensively documented for quality assurance purposes. The real-time results contributed significantly to fast execution of construction work. Precise measuring provided a basis for the immediate start of subsequent processes (e.g. slab track concreting work). This helped prevent incorrect positioning of turnouts, as it is not possible to correct the position of turnouts once they have been concreted without expensive and time-consuming dismantling. Final track acceptance using the Amberg GRP software served as quality control and as the building contractor’s documentation for the client. The results of the analysis with the special Slab Track software regarding deviation of position and relevant track geometry criteria were an important addition to acceptance of dynamic behavior using track surveying vehicles.

**Three Key Systems**

To successfully meet the survey challenges, three key systems based on Leica Geosystems high-end instruments were used:

- 10 Leica TCA2003 total stations for CPIII network measurements (Third Railway Institute)
- 22 Leica TCA1800 and Leica TCA2003 total stations for Precast Slab (type Boegl) positioning (China South Survey)
- 8 Leica GPS1201+ systems in GRP 1000 Slab Track measuring systems from Amberg Technologies, Switzerland.
Automating Grader Control to Maximize Efficiency

by Daniel Brown

Grading contractor Bernie Schmidtlein recently invested in an automated grader control system, and he’s glad he did. Last spring Schmidtlein used the system – a Leica PowerGrade 3D system – on its first project: a Home Depot warehouse in Topeka, Kansas.

To use a trimmer, stringline and surveying hubs would have taken “three or four times longer,” Schmidtlein says, than the scant 45 hours he spent fine-grading the 10.5-acre (4.3 hectares) building pad. In fact, he says the Leica PowerGrade 3D will pay for itself in just two projects the size of the big warehouse job.

In addition to the building pad, the Topeka project entailed grading 20.5 acres (8.3 hectares) of parking. Cuts and fills balanced each other on the site. The total earthmoving quantity was 200,000 cubic yards (153,000 m³), and the maximum cuts and fills were each 12 feet (3.6m). “Our whole grading process is much more efficient with the new system,” says Schmidtlein. “It’s not so much in the volume of earthmoving that you recoup the cost, it’s in the total grading area – 31 acres.”

Grading the site involved several steps; the first was to strip 6 inches (15.2 cm) of topsoil and stockpile it for future use. For the stripping job Schmidtlein used three large farm tractors plus a Volvo truck-tractor, all pulling tow-behind scrapers. The next step was to add water as needed and scarify the sub grade, using a dozer pulling a disk. “Then we started grad-

ing with the scrapers – cutting and moving earth to the fill areas. In the fills, typically we used a dozer to knock down the material the scrapers had dumped. We compacted the fills with a sheepfoot roller. And in the cut areas, we used a Caterpillar D6N dozer fitted with a Leica Geosystems GPS working on Indicate-only,” says Schmidtlein. “The dozer had a Leica GradeSmart 3D controller on board that we could run with a base station at our shop 13 miles away.”

The dozer’s indicate system responded to GPS signals from satellites, but those signals were corrected by a cellular modem signal from the reference station at Schmidtlein’s shop, explains Bob Parker of Laser Specialists, Schmidtlein’s Leica Geosystems dealer. “The reference station is connected to the Internet and has a dedicated Internet address,” says Parker. “Users in the field can connect to the reference station using a cellular telephone connection.”

Schmidtlein says the scrapers typically made fills of 6 to 7 feet (2m) deep on the building pad. The Leica Geosystems-equipped D6N graded the fills to within plus-or-minus 1/10 foot (3 cm). He says the GPS system will permit vertical accuracy of 6/100 foot (1.8 cm), but he wanted to leave the grade a tenth high for the finish motor grader. “The Leica GradeSmart 3D shows the dozer operator a detailed plan of the job,” says Parker. “It shows him the exact horizontal and vertical location of the blade.”

Setting up the GPS system and the new PowerGrade 3D system is a relatively simple matter, says Schmidtlein. “We get a Computer-Aided Design (CAD)
file from the engineer, and my son converts that to a usable 3D model – a Digital Terrain Model. That model is on a flash card and we install it into our two dozers, the finish motor grader and the rover.”

Fitted with the Leica PowerGrade 3D system, which uses a total station for control, the Volvo motor grader can accomplish greater accuracy – 3 to 5 millimeters – than the GPS system can perform. Every morning, Schmidtlein sets up the robotic total station and backsights it using two control points. It takes about ten minutes to shoot the two control points with the battery-operated total station. “Position is calculated using a laser signal – an Electronic Distance Measure – and the robotic total station uses a radio system to send location information to a prism on the motor grader,” says Parker. “The robotic total station tracks the motor grader wherever it is on the site. Position information on the total station is being updated at the rate of 12 times a second. That information is continuously being compared to the 3D model on the grader. Cut and fill information is generated, and whatever movement is needed is sent by Leica PowerGrade to our electronic-hydraulic valve on the grader. That valve is tied to the machine’s hydraulic cylinders – where elevation, cross-slope and side shift can be controlled.”

Says Bernie Schmidtlein: “We really like the automated Leica Geosystems system. If we didn’t have that, we’d need somebody out there checking grade. This saves wasted time checking grade. Plus, I can meet the one-tenth accuracy in third gear on the grader, which is about 2-1/2 miles per hour.”

Next, the contractor rolls the sub grade into place. Lime is spread on the building pad area to stabilize the soil; the parking lot areas take less-expensive fly ash as a stabilization agent. Using a stabilizer, which works like a tillage tool, the contractor works the lime or fly ash into the soil 9 inches (23 cm) deep. Compaction follows. After stabilization, the contractor fine grades the fill with the finish motor grader equipped with the Leica PowerGrade 3D system. Actual accuracy is plus-or-minus ¼ inch (6 mm). Then the fill receives 6 inches (15 cm) of crushed stone, spread over both the building pad and the parking lot areas.

The Leica Geosystems system saved untold labor, Schmidtlein says. If he were to use a trimmer and stringline, grade preparation would take four people – the trimmer operator, a supervisor to set grade, and two laborers to set stringline pins. “That would take three or four times longer than we need with the Leica Geosystems automated system,” says Schmidtlein, who operates the Volvo fine grader. “A stringline would take 90 to 120 hours of prep time. But when they shoot the two points in the morning, I go over and set the blade on a control point to calibrate the control system. We drove an I-beam into the ground to serve as a bench mark. The first time we used the Leica Geosystems system I checked the grade with a rotating laser to see if it was as close as they said it would be. It was that close, so we don’t even check grades anymore after the blade has done its job!”

About the author: Daniel Brown is founder of Techni-Comm, Business Communications Inc.