Gateway to Korea

by Joël van Cranenbroeck

The Yeong-Jong New Airport Highway Bridge, a steel, double deck, box-girder suspension bridge, links Incheon International Airport to Seoul city as a real gateway to Korea. It is the world's first 3D self-anchored suspension bridge servicing a highway on the upper/lower decks and a railway on the lower deck. The bridge crosses the sea between Yeong-Jong island and Incheon city and lies between Kyeongseo-dong (Changdo) and Unbuk-dong (Yeong-Jong island) of Incheon city on the Yellow Sea. Leica Geosystems was invited by the New Airport Highway Company to perform a load test with GNSS RTK technology. Equipment and software completed the test smoothly, achieving impressive accuracies in the range of 1 cm. This load test convincingly vindicated the superiority of GNSS based bridge monitoring. After the test the upgrade and modification of the structural health monitoring system was completed using a GNSS monitoring system from Leica Geosystems that focuses on monitoring the girder geometry and the displacement of the bridge towers.

With Leica Geosystems GNSS RTK technology, the geometric structure of the bridge can be monitored in real-time and in all weather conditions. The three-dimensional displacement of towers, main span, and suspension cables can be measured directly. All of this characteristic information reflecting bridge health can be combined with structural models to analyze the internal forces affecting the static and dynamic load components of the bridge.

The reliability of bridge health monitoring and evaluation can be increased and the risk of potential damage to the bridge structure minimized. GNSS monitoring can considerably improve the efficiency and effective-

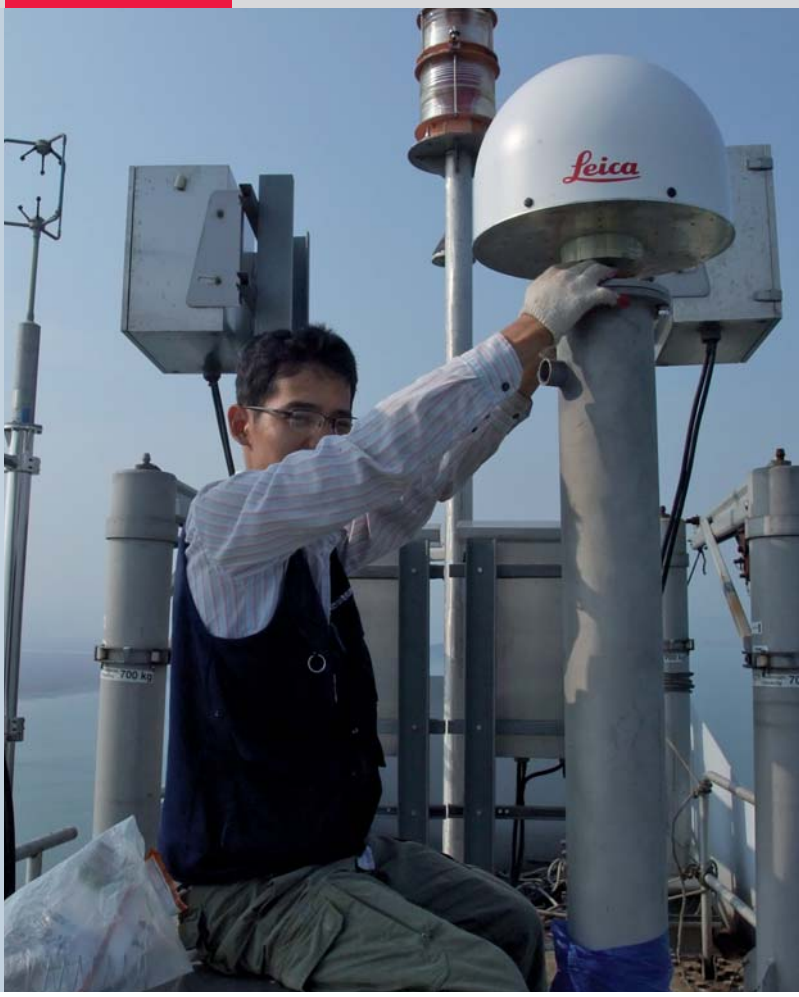
Monitoring Equipment and Software

Hardware

- 2 Leica AT504 GG choke ring antennas
- 2 Leica GRX1200 GG Pro reference station receivers
- 10 Leica GMX902 GG monitoring receivers
- 10 Leica AX1202 GG antennas

Software

- Leica GNSS Spider GNSS reference network controlling and operating software
- Leica GNSS QC GNSS Quality Control and Monitoring software
- 3rd party analysis software

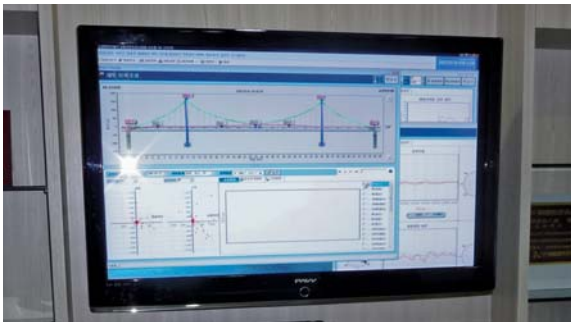


ness of maintenance work by providing vital information to management and decision makers for bridge traffic and structural safety. With the ongoing development and improvement of GNSS hardware, processing algorithms, and software Leica Geosystems' GNSS monitoring systems will be used ever more widely for the monitoring of infrastructure such as bridges, buildings, and other structures in the future. Meanwhile, the Yeong-Jong bridges' structural health monitoring system plays an active role in the promotion and development of digital and intelligent bridge engineering.

The GNSS bridge deformation monitoring system consists of GNSS sensors; seismic and temperature sensors; dual-axis inclinations sensors; communication links; and processing, management, and analysis software. All these components form an integrated system. When designing the system, the environmental situation was considered to be the predominant source of error. Multipath is caused by signals arriving at the antenna which have been reflected by nearby metal objects, ground, or water surfaces. The occurrence of this is different at each measuring site and therefore cannot be eliminated by differential techniques. At the reference station sites, a suitable location of the antenna was selected to mitigate such reflections. The Leica AT504 GG choke ring geodetic GNSS antenna helps reduce multipath effects. Several more GNSS receivers and antennas were installed (see box) to monitor bridge health. They are all connected to Leica GNSS Spider software and Leica GNSS QC for advanced coordinate analysis of the entire system.

Two GNSS reference stations were established in stable areas. As the start point of each baseline, it is vital that the reference stations have precise coordinates within the local coordinate system. One reference station was installed on the roof of the Bridge Monitoring Center, the other at the west side of the bridge. To visualize the deflection and its impact on the bridge, another 10 GNSS monitoring points were installed. These were placed on the two bridge towers; the maximum flexibility point of the main span; the 1/9, 2/9, 4/9, 8/9, and 9/9 points of the bridge; and on the cable. Now, using the transformation parameters provided by the owner, the system provides three-dimensional dynamic displacement results within the bridge coordinate system.

Leica GNSS Spider also provides an interface for third party analysis software via the serial and TCP/IP ports. Any analysis software that uses standard NMEA format can be used. With real time bridge coordinates, the analysis software can display a dynamic view of the distortion curve, store data, and execute statistical analysis and messaging in real time. Moreover, Leica GNSS QC quality control and analysis software can be used to do a comprehensive review of the results. It proved to be an indispensable tool for checking data and results in the design and operational stages.



Monitoring display for analysis.

Leica GNSS Spider – the link between the sensors and the monitoring system

Communication requirements are greatly simplified through Leica GNSS Spiders' centralized RTK concept. Receiver equipment can be remotely controlled and monitored, and the status of the entire monitoring system can be obtained at anytime. Operating at a 20 Hz measurement rate, the bridge monitoring system is able to detect high frequency vibrations. To enhance overall reliability and stability, and according to the recommendations made by Leica Geosystems, the Yeong-Jong bridge monitoring system has two reference stations. Leica GNSS Spider supports multiple reference stations to enable redundant checks. If the communication to one reference station breaks down, the other reference station can be used as a backup for processing any combination of baselines. Leica GNSS Spider can process observations from both L1 single-frequency and L1+L2 dual-frequency GNSS receivers. Thus a single-frequency GNSS receiver can also be used for the bridge monitoring application in a low motion mode.

The installation of the GNSS monitoring system was realized by Leica Geosystems Korea. The integration of the system into the structural health monitoring solution that includes more than 250 other sensors was carried out by BT Engineering South Korea.

About the Author:
Joël van Cranenbroeck is Business Development Manager for Geodetic Monitoring at Leica Geosystems AG, Heerbrugg, Switzerland. He has led the development of hardware and software solutions for GNSS Network RTK for Leica Geosystems since 2001 and has made some significant contributions in Geodetic Monitoring development and applications such as the method statement for aligning along vertical high rise structures (Burj Dubai).

The Yeong-Jong Bridge

The construction of the Yeong-Jong bridge began in December 1993. The bridge was completed and opened to traffic in November 2000. The total length of the bridge and main span of the suspension bridge is 4,420 m and 550 m, respectively. The bridge is 35 m wide and has 49 piers. The east and west towers are 107 m high. The bridge is divided into three parts: suspension bridge (550 m), steel truss (2,250 m), and steel deck (1,620 m).

The Bridge Monitoring Center was built at the east side of the bridge (New Airport Highway office) and equipped with a fiber optic communication system, closed circuit television, information management system, message sign system, emergency call system, broadcast system, etc.