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STRUCTURAL BRIDGE HEALTH MONITORING WITH GLONASS AND GPS – THE YEONG-JONG BRIDGE IN SOUTH KOREA

Key words: Structural Health Analysis, GLONASS, GPS, Bridge, Centralized Processing, RTK, Geodetic Monitoring.

SUMMARY

The New Airport Highway Co., Ltd. – Republic of Korea requested to renew the complete monitoring system installed on the Yeong-Jong bridge that links up Sicheon Island with Soul city.
Leica Geosystems was willing to provide a cost effective and innovative solution for delivering 3D positioning information at 20Hz from 10 GNSS Monitoring stations to advanced analysis application software developed by the engineering company in charge of the whole structural monitoring project.

The installation has been finalized in October 2008 and included Leica GNSS GRX1200 GG Pro Reference station, Leica GNSS GMX902 GG Monitoring station, Leica GNSS AX1202 GG Geodetic Antenna and Leica GNSS AT504 GG Choke ring Antenna.
In the control facility the software installed on dedicated PC servers were Leica GNSS Spider software including positioning option and the Leica GNSS QC data analysis software including the Advanced Coordinate Analysis option.

The author designed the GNSS monitoring network and organized the pre-analysis that consisted to evaluate the contribution of the possible multi-path's errors induced by the environment (pylons and cables) and therefore to select the ideal monitoring points. The installation of the GNSS stations including monuments, accessories, communication and cabling has been carried out by the expert people from Leica Geosystems Korea. They also organized the measurement of control points to define a local transformation from WGS-84 to the bridge coordinate system.

The installation of Leica GNSS Spider software, the connection to the optic fibre communication network, the configuration and the interface to the analysis software, training and maintenance has been realized by the Leica Geosystems Korea support team jointly with BT-Consultant – the Leica Geosystems partner in Seoul Korea.

INTRODUCTION

The Yeong-Jong New Airport Highway Bridge is the steel double deck box-girder suspension bridge which links Incheon International Airport to Seoul city as a real gateway to Korea.

It is the world first 3D self-anchored suspension bridge which services a highway on the upper and lower deck, and railway on the lower deck crossing the sea between Yeong-Jong Island and

Incheon city. It lies between Kyeongseo-dong (Changdo) and Unbuk-dong (Yeong-Jong Island) of Incheon city on the Yellow Sea.

Construction began in December 1993 and the bridge was finally opened to traffic in November 2000. The total length of the bridge and main span of suspension bridge is 4,420m and 550m respectively. The bridge width is 35m and there are 49 piers. The east and west towers are 107m high. The bridge type is divided into three parts such as suspension bridge (550m), steel truss (2,250m) and steel deck (1,620m) bridge.

The Bridge Monitoring Center was built at east side of the bridge (New Airport Highway office), equipped with fiber optic communication system, closed circuit television, information management system, message sign system, emergency call system, broadcast system. Monitoring sensors were also installed to mainly detect deformation, deflection, temperature, seismic impact, dual axis inclination and acceleration.

Fig 1: The gateway to Korea – The Yeong-Jong New Airport Highway Bridge

In 2007 Leica Geosystems was invited to perform the loading test with GPS RTK by the New Airport Highway Company and that method was able to complete the test smoothly while even alternated proposals couldn't get acceptable results. With that advanced RTK technology, impressive test accuracies at the 1cm level were achieved.

This loading test convincingly vindicated the superiority of GPS based bridge monitoring. After this, the upgrade and modification of the superstructure health monitoring system was completed using GLONASS and GPS monitoring system that focused on the monitoring of the girder geometric form and the displacement of the bridge towers.

Fig 2: One of the GLONASS and GPS Reference station on the roof top of NAH office

GLONASS AND GPS BRIDGE MONITORING SOLUTION

The GLONASS and GPS Bridge monitoring system consists of GNSS receivers, communication links, processing, management and analysis software, and accessories.

All of the above components form an integrated system. In the design stage, the environmental situation has been considered as the predominant error source in the bridge environment. Multipath is caused by signals arriving at the antenna which have been reflected by nearby metal objects, ground or water surfaces. The error is different in each measuring site and cannot be eliminated by differential techniques.

At the reference station site, the position of the antenna has been selected to avoid such reflections. Leica Geosystems' AT504 GG choke ring geodetic GNSS antenna helps to mitigate the multipath effects. The advanced dual-frequency GNSS Reference Stations comprising two Leica GRX1200 GG Pro and two AT504 GG choke ring antenna. The monitoring system included ten GMX902 GG receivers and ten AX1202 GG antennas.

The Leica GNSS Spider software with the positioning option and GNSS QC with advanced coordinate analysis option were adopted as the software of this system.

A GNSS reference station should be established in a stable area. As the start point of each baseline, the reference station must have precise coordinates within the local coordinate system.

One Reference Station was installed on the roof top of the Bridge Monitoring Center and the other Reference Station was installed at the west side of the bridge on the top of another NAH facility.

To show to maximum effect of the distortions and dynamic characteristic of the bridge, the ten GNSS monitoring antennas have been installed at the maximum flexure location of the main span, at the 1/9, 2/9, 4/9, 8/9 and 9/9 points of the bridge and on the cable.

Finally, based on the transformation parameters provided by the user, the system is delivering three dimensional dynamic displacement results within the bridge coordinate system.

Leica GNSS Spider software also provides an interface to other analysis software over serial RS-232 interface and with the TCP/IP protocol. Any analysis software that uses the standard NMEA format can be used.

The engineering partner of Leica Geosystems, the company BT Engineering, provided that kind of solution. With real time bridge coordinates, third party analysis software may perform dynamic display of real time distortion curve, storage, statistical analysis and warning.

Moreover, Leica GNSS QC quality analysis software can be used to perform the quality analysis and research on the results. This is and indispensable tool for checking data and results in the design and operational stages.

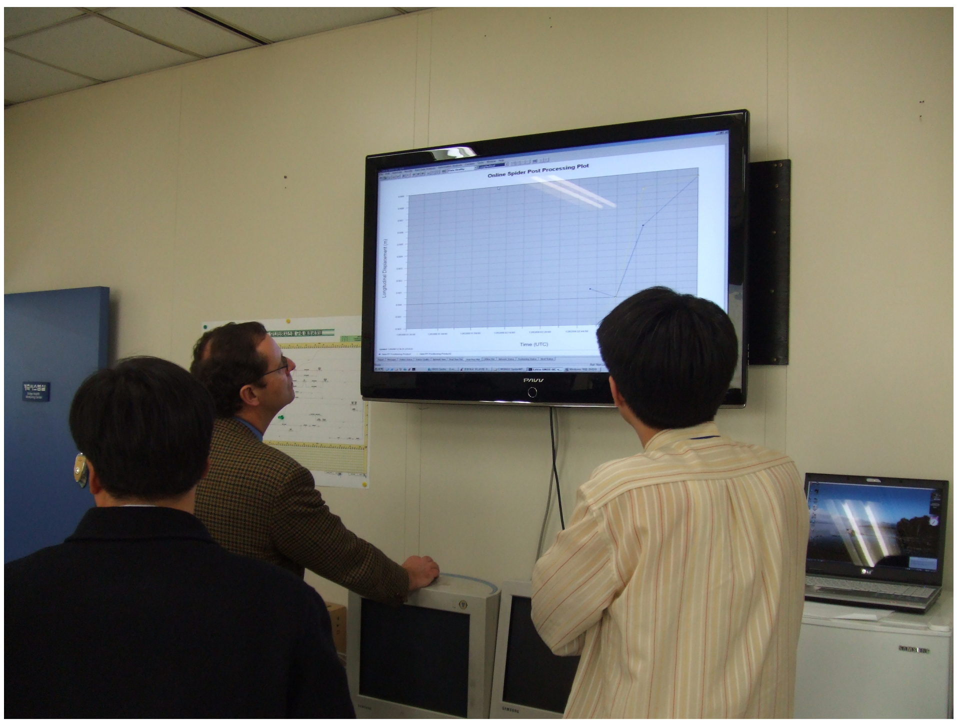

Fig 3: Monitoring display in NAH office

THE ADVANTAGES OF USING CENTRALIZED RTK FOR BRIDGE MONITORING

The advanced GLONASS and GPS Spider Bridge monitoring solution with centralized RTK functionality developed by Leica Geosystems is superior to the traditional RTK solution. The communication requirements are greatly simplified and multiple Reference Stations can be used. The receiver equipment can be remote controlled and monitored, and the status of the system can be obtained at anytime.

With the standardized output interface, it can be easily connected with third party analysis software. Operating at a 20Hz measurement rate, the bridge monitoring system is able to detect high frequency vibrations.

According to the recommendation by Leica Geosystems to enhance the reliability of the system, Yeong-Jong Bridge established two reference stations. Leica GPS Spider supports multiple reference stations to provide redundant checks. If the communication to one reference station breaks down, other reference station can be used as backup for processing any combination of baseline.

Leica GNSS Spider can process the observations of L1 single-frequency GPS receiver and L1+L2 dual-frequency GLONASS and GPS receivers. Thus single-frequency GPS receiver also can be used for the bridge monitoring application if they are located on the slow motion places like the top part of the pylons.

Fig 4: Monitoring station on the cable

Fig 5: Monitoring station on the top of pylon

CONCLUSIONS AND PROSPECTIVES

With GLONASS and GPS RTK technology, the geometric form of the bridge can be monitored in real time and in all weather conditions. The three dimensional displacement of the towers, main span and suspension cables can be measured directly. All of this characteristic information that reflects the bridge's health can be combined with structural models to analyze the internal forces affecting the main components of the bridge.

The reliability of the bridge health monitoring and evaluation can be increased and the risk of the potential damage to the structure bridge can be detected. Therefore, GNSS monitoring can improve the efficiency and effectiveness of the maintenance work, provide the quantification information to the management and decision making of the traffic and structure safety of bridge, and make reliable assessment of the safety of the bridge.

With the ongoing development and improvement of GNSS hardware, processing algorithms and software GNSS monitoring systems will be applied widely to the structural monitoring such as bridges, building and other structure. Meanwhile, the Yeong-Jong Bridge's structure health monitoring system will play an active role in the promotion and development of the digital and intelligent bridge engineering.

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