The Shard: London's New Skyline

by James Whitworth

Byrne Bros is both one of the UK's and the world's leading formwork construction companies. They were appointed by main building contractor Mace to carry out the concrete substructure and superstructure works for Europe's tallest building – The Shard in London – in a contract worth more than 64 Mio. Euro (78.5 Mio. US Dollar). In the summer of 2009, Leica Geosystems was approached by Byrne Bros to develop a real-time slip-form rig positioning system, used to construct the central concrete core of The Shard.

The substructure of The Shard adopted 'top down' techniques and the main structural core was slip-formed in parallel solutions, which delivered significant program advantages. Slip-form construction is perhaps one of the safest, efficient, and most economical methods of building vertical structures. It enables formwork construction to rise at rates of up to 8 m (26 ft) in 24 hours. Traditional methods of controlling the position of a slip-form rig as it rises are often time consuming and labor intensive. 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.

Tight Tolerances

The required tolerance for The Shard project was that rig plan position should not exceed ±25 mm (±0.98 in) deviation against the design coordinates. After some consultation between Leica Geosystems and Byrne Bros a combined system of total stations, GNSS, and dual axis inclinometers was agreed upon. Real-time GNSS positions allowed determination of the rig's position. Both the translation and rotation of the rig could be determined using GNSS technology, but it was unable to provide information on the rig's inclination which could have been up to ±75 mm (±2.95 in) over the 20 m (66 ft) square rig, depending on the correction factors applied by the rig man-

ager. It was therefore necessary to calculate the tilt on the rig. This was achieved using data acquired from four dual axis inclinometers. By using the virtual sensor functionality within the Leica GeoMoS Monitoring software it was possible to compute a tilt compensated position of all four corners of the rig. The inclination sensors were chosen due to the large expected range of tilt and were integrated into the systems via a Campbell Scientific Datalogger.

Setting Up a Reliable Construction Monitoring System

As with any other city, working with GNSS technology in London can often prove challenging. Existing buildings and infrastructure can obscure satellite signals, resulting in unreliable positions or even no possible calculation. 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 while the rig was near ground level and the potential for difficulties with a clear satellite window were greater.

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

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

The four GMX902GG receivers were connected to the site computer running on the rig. Leica GNSS Spider received the incoming data streams for these receivers and a real-time data stream from the SmartNet service. Internet connectivity was provided by a WLAN bridge system, comprised of two directional antennas, which guaranteed reliable Internet connectivity to the site computer on the rig as it rose nearly three meters per day.

The position of each antenna on the rig was computed with respect to the nearest SmartNet reference station which was approximately 2.4 km (1.5 mi) away. This yielded a three-dimensional coordinate quality of better than ±25 mm (±0.98 in).

Computing Positions Every Second

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

The rig positioning interface used the open architecture of Leica GeoMoS, which is built on a Microsoft SQL database. An ODBC (Open DataBase Con-

The Shard

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 façades 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 towers 306 m (1,017 ft) into the sky and is the tallest building in the European Union. Since its completion in April 2012 it soars more than 70 floors above London. The Shard houses offices for Transport for London, a hotel, and luxury apartments, all with exclusive views over the capital.

'When it comes to structural monitoring, there is no room for risk. 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, Byrne Bros

nectivity) link was established between the GeoMoS database and the bespoke interface, which displayed the results graphically, so that it was easy to understand by the rig manager. This interface enabled the rig manager to make adjustments to the rig position using hydraulic pumps. A traffic light system of warnings was displayed within the interface. If the computed results exceeded ±25 mm (±0.98 in) lateral displacement against the design position of ±4 mm per meter (±0.05 in per foot) of tilt on any corner of the rig, then an orange display was shown. An exaggerated rig display and level 'bubble' display allowed instant visualization of results.

Project Results

This new and innovative approach to controlling the position of a slip-form rig 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 the Leica Geosystems Monitoring Support team could support this system remotely even 24/7, meant that, particularly in the early stages of this project, confidence in the system was assured. Other tall buildings being constructed in London using slip-form methodology have already adopted this system and Byrne Bros plan to use this system again on future projects.

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