Crossrail Monitoring - Delivering the three Rs

The decision to take monitoring in-house has allowed Morgan Sindall to create a tailor-made solution that delivers the three Rs sought by Crossrail, Network Rail, and Docklands Light Railway on the C350 Pudding Mill Lane contract.

In 2018 Crossrail services are due to commence through central London. The £15bn project will pass through 37 stations and run 118 km (73 miles) from Maidenhead and Heathrow in the west to Shenfield and Abbey Wood in the east. The project's C350 Pudding Mill Lane contract, won by Morgan Sindall plc, is worth in the region of £100 million and will link the new Crossrail tunnels to the Network Rail infrastructure in the London Borough of Newham. Work comprises the construction of a tunnel portal and a new elevated Docklands Light Railway station at Pudding Mill Lane, plus associated structures to bring the subterranean railway into the above ground existing rail network. The project will also link new Crossrail tunnels to the existing Network Rail infrastructure.

Critical to the smooth running of the project is an awareness of how the cut and cover tunnel construction work is affecting adjacent rail lines, in this case, a 480m stretch of Network Rail track and two sections of DLR track totalling 380m. Twenty-four-hour monitoring of the track's condition is therefore imperative if any tilt or slew of the rails is to be efficiently detected and acted upon to avoid the possibility of a derailment that could compromise both the safety of passengers and the works' schedule. A monitoring system had been established by Crossrail at the beginning of the project but was not delivering reliable, consistent readings, especially in wet weather conditions.

Responsible for surveying and automated and manual monitoring is Morgan Sindall chief land surveyor, Nick Giles. In 2014, having already successfully implemented an innovative 3D laser scanning solution on Crossrail's Bridge 53 – a project with restricted access that ruled out an optical solution – Nick was presented with a new challenge: replacing the existing optical monitoring system on the Network Rail and DLR stretches of track (which now fell under his mandate) with a system that would restore the confidence of all parties reliant on its data.

Raising the Bar

Crossrail was clear in its requirements for a new monitoring system; it had to be robust, reliable and repeatable if it was to provide total confidence for those depending on it. For Nick, that meant finding a new approach that not only rectified the issues of the old system, but raised the bar even higher. Working with Morgan Sindall Monitoring data manager, Dave Gibbs, and monitoring surveyor, Pawel Owsianka, Nick assessed a number of possibilities before opting for a unique two-pronged approach that would provide a level of confidence that had been missing from the old method.

His solution was to have two systems working in tandem; an optical system for monitoring horizontal displacement, comprising total stations and monitoring software, and a Flat Mesh bi-axial tilt sensor system for monitoring cant and twist, comprising several hundred Senceive high-precision wireless tilt meters attached directly to the track. This approach would not only see the two systems providing constant back-up checks for each other, but would also enable Morgan Sindall to reduce the number of vulnerable trackside optical instruments.

As part of his optical instrument research, Nick Giles contacted UK Trimble distributor, KOREC, who had supplied the Bridge 53 laser-scanning solution for his previous Crossrail project. During these consultations, Chris Harris, KOREC's geospatial and deformation monitoring specialist, introduced Nick to Trimble's 4D Control monitoring software which provides support for Trimble's most advanced total station platform, the S8.

Following the evaluation of several manufacturer's optical systems, Nick selected the KOREC supplied solution of ten S8 Trimble VISION robotic total stations, all managed in real time with Trimble's 4D Control monitoring software. The S8s provided Nick with the established technology and reliability that he sought along with sub-mm accuracy and the extra benefits of the total station's Magdrive technology designed to reduce friction and ultimately wear and tear, and a Trimble VISION onboard camera for remotely observing anything that might compromise the instrument's performance such as an obstructed view to a prism.

Ten S8 total stations were subsequently positioned at regular intervals along each section of the Network Rail and DLR track and prisms fixed to the rails every 3m. This allowed each total station a line of site to up to 60 of the evenly spaced rail mounted prisms.

Flexibility and Analysis

For Nick, the real strengths of selecting a Trimble system lay with the Trimble 4D Control monitoring software which offered his team a high level of customisation and flexibility along with remote management of all measurement cycles and communications.

The system delivers twenty-four hour coverage with a pre-programmed hourly cycle that first sees the S8s take readings from up to four reference targets for each set-up before moving on to the rail-based prisms. This data is then collected by the 4D Control software which computes and records the results to provide the rigorous data analysis that Nick Giles and Pawel Owsianka, require. The results arrive quickly and easily and because the raw information is stored in an SQL database, it is easy to extract data to create visual results such as the maps, charts and graphs needed for meetings and client reports.

For Pawel, who looks after data analysis and remote access to the instruments, the customisable nature of the software has been invaluable, allowing him to create the specific software routines he requires for both analysis of the data and report generation.

A drawback to the previous system had been its sounding of multiple alarms which alerted a large number of stakeholders, but without the 'filter' of the expert knowledge required to interpret them. This had caused frequent delays to works with action being taken when none was necessary. With 4D Control, Pawel can customise the alarm triggers to provide specific information including tolerances for displacement at any point with pre-programmed trips at 8mm, 15mm and 20mm. This allows him to observe trends rather than ad hoc measurements. Other sets of alarms alert him to factors such as instrument maintenance, damage to an instrument or prism or if the line of sight to a prism has been obstructed.

A major advantage to the system is that Pawel can use it to manage who receives the alarms, allowing the Morgan Sindall monitoring team to establish a new level of security. If an alarm is triggered, an email alert is sent to just three selected members of the monitoring team rather than multiple shareholders as the old system had done. One of the three team members can then immediately log onto the system, even from home, and analyse the data before deciding if action is necessary and further parties need to be alerted.

Typically, an initial alarm is triggered if a prism records a movement of 8mm. This information is compared to the findings from the Senceive tilt sensor system and the prism is then 'watched' over the next three monitoring cycles, a period of 3 hours, to detect any changes.

Nick reports that a perfect example of the system working exactly as required occurred recently. An alarm had triggered at 8mm alerting the three selected members of the Morgan Sindall team who then closely monitored the affected prism through its subsequent cycles. No further movement was detected over the next 3 months. Network Rail was aware of the 8mm alarm from the outset through the regular update meetings but because no action was necessary, there was no distraction to other parties because of Morgan Sindall's filtering process. Consequently, when a second alarm was triggered at 15mm, the monitoring team immediately alerted Network Rail, and all stakeholders were informed with full confidence that the alarm was genuine. The track was realigned in less than 12 hours.

Turning Data into Information

Morgan Sindall produces a daily monitoring report for Crossrail. This textual report details any recorded movement, with a graph if an alarm has been triggered, and is a part of the Shift Review Group made up of Crossrail, DLR and Network Rail which meets every morning. A report generated by the Trimble 4D Control software is also used at a weekly Review Panel meeting. Additionally, all the data in Crossrail's preferred format is uploaded onto UCIMS, the underground construction information management system developed to monitor construction data for Crossrail.

Nick is quick to stress that the customised nature of the reports that Pawel has been able to generate has enabled Morgan Sindall to quickly and efficiently analyse and observe trends and present their findings in the preferred formats of their shareholders. Pawel agrees and emphasises that the flexibility of this software is key to the smooth running of the optical system. He can set up infinite formula to provide customised analysis which is especially useful for examining trends. For example, if settlement on a prism is detected, he can immediately set up a graph that will enable him to compare its behaviour with the five other prisms in closest proximity to provide a wider picture. For Pawel, the software's flexibility means that it is a work in progress and as the project progresses, so does the sophistication of the information he can provide.

With a project target end date of 2016, Nick reports that the system is going from strength to strength as Pawel continues to develop and improve the routines on the Trimble 4D Control software. Nick concludes, "managing the monitoring on this project in-house has brought us innumerable benefits, not least satisfied clients and stakeholders. Thanks to the dedication and enthusiasm of the monitoring team, combined with the reliability of the Trimble hardware and software, we have been able to restore the confidence of those reliant on the information we supply. This has allowed Network Rail and DLR to avoid any unnecessary possessions and also means that should a significant movement in the track occur, there is no ambiguity and consequently, in the case of a genuine alert, trains can be stopped immediately. Both Network Rail and DLR have reported back that the system has restored their confidence in the monitoring data presented and met their 3R requirements for a robust, reliable and repeatable system. KOREC has been a good partner providing both consultation and support and the end result is a system that enables fast and informed decision making, which benefits all involved."

The Solution

10 No Trimble S8 total stations, each a 1" instrument providing <1mm accuracy at 300m and equipped with Trimble VISION technology – a calibrated metric camera for taking pixel measurements. The S8's detect targets without interference from

surrounding prisms with Trimble's FineLock technology and SurePoint accuracy assurance which automatically corrects instrument pointing.

For the software, Trimble 4D Control is used to control the measurements, manage and analyse the data, triggering alarms, and providing decision making support. The software supports automated measuring 24/7 with high-level functions for visualisation, analysis, alerting and logging.

This article was published in Geomatics World July/August 2015