

Remote monitoring of a tunnel under restoration and construction activity

The challenges of monitoring in difficult conditions



One of the five monitoring total stations in position in the tunnel.

VICTORIAN railway infrastructure is ageing, degrading in condition and yet being stretched to cope with more and more use. These problems were particularly in evidence during work undertaken on and around the 19th-century Gasworks Tunnel in central London. Less than 500m from Kings Cross Station, this tunnel has two operational bores which carry the East Coast Mainline and a third non-operational bore. In August 2019, Central Rail Systems Alliance began excavating 11,000 tonnes of material from the tunnel's closed eastern bore in preparation for it reopening as part of planned works which will ease pressure on the movements in and out of Kings Cross.

Perfect storm of monitoring challenges

Understanding how much a tunnel moves, particularly an older asset where less is known about how it will react to construction work, presented an immediate set of challenges:

Monitoring

- How to measure a tunnel to an appropriate level of accuracy to satisfy risk models.
- How to transmit this data out of the tunnel to have a constant insight into its behaviour.
- How to classify thresholds for movement and what escalation procedures would be needed.
- How to carry out the process remotely with no need for people inside the tunnel.
- How to overcome dusty, noisy conditions with low visibility and heavy plant usage, no natural light and no phone signal.

There was also the additional problem of the existence of a third-party construction site with active piling and excavation directly above the eastern bore. These challenges created a 'perfect storm' of monitoring conditions with constraints that would limit the number of systems capable of recording movement data in absolute form, at regular intervals, day and night, with no requirement for people to visit the site maximising safety.

System considerations

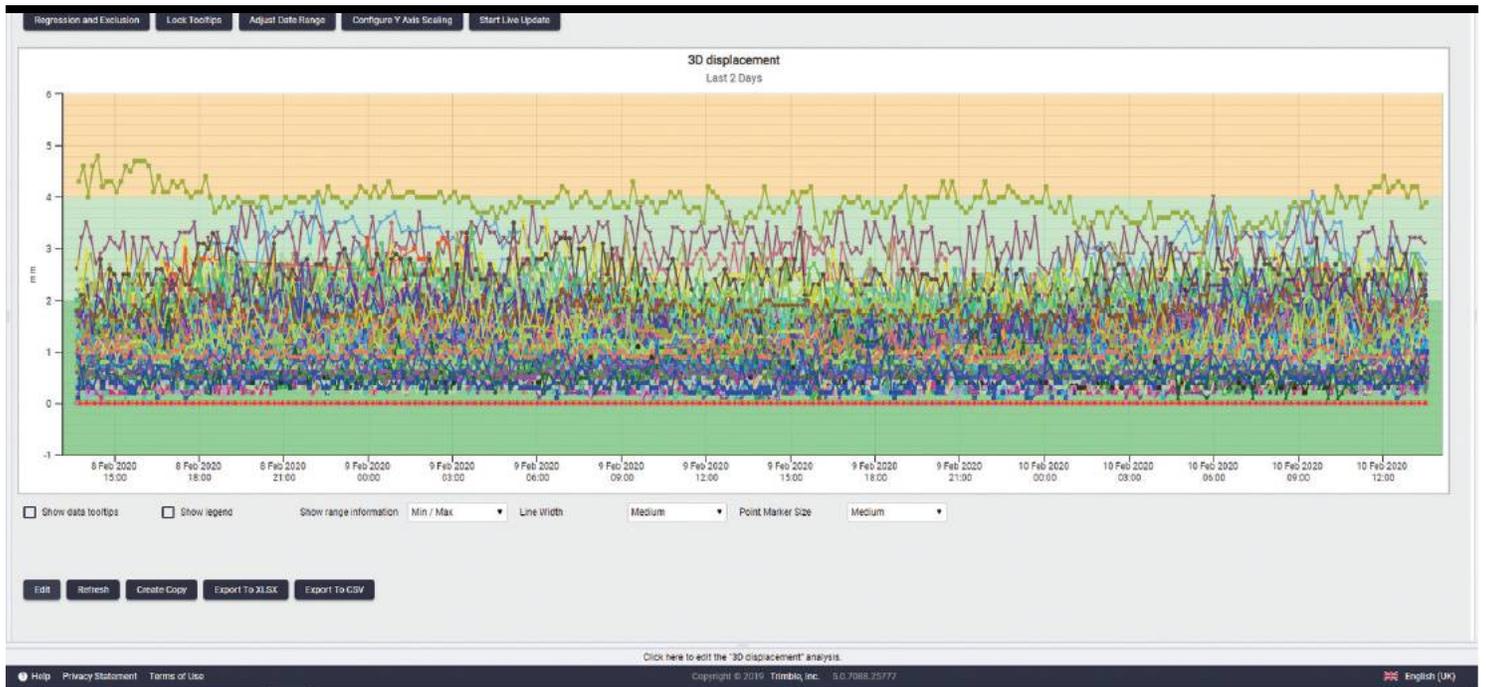
Following a 3D finite element analysis (FEA) conducted by Amey Consulting, it was decided that trigger levels should be set for movements of the tunnel in accordance with its results; green (less than 4mm), amber (between 4mm and 7mm) and red (above 7mm). Two systems were presented by Amey Consulting to Network Rail, one based on tilt sensors and one on a total station approach. The total station approach proved to be the most workable and working with KOREC a final system was selected and installed.

Installation

Upping the original proposal for four high-accuracy total stations to five would provide the best option with communications looked after by five Trimble Settop M1s in toughened cabinets. M1s are robust communication hubs that combine the functionality of a field computer, device server, router and remote switch, streamlining the number of components needed for this monitoring task. However, because there was no phone signal in the tunnel, an alternative method for connection needed to be designed and specified. An OctoHub was used to connect the M1 to a modem via fibre optic cable rather than the usual internal M1 SIM card. This provided fast, robust, efficient data transfer to a 4G gateway at the south portal and in turn to the internet and Trimble's T4D office monitoring software.

Inside the tunnel, the five Trimble S5 Ti-M monitoring total stations were positioned and installed by KOREC along with 150 toughened glass prisms placed in arrays throughout the tunnel alongside a network of reference prisms to coordinate all movement to data control points. Collected monitoring data is processed automatically in T4D software, which Amey Consulting is also using to display the results, to output operational and management reports and to manage alerts, alarms, web access and email notifications. This has enabled multiple stakeholders to gain access to historic and live data in real time, understand trends and, most importantly, see the effect of construction activity on the tunnel. Data is also extracted into Amey Consulting's own geotechnical software.

Monitoring



Showing two of the three colour bands defining tolerances.

Safety paramount

The total stations are functioning well with millimetre accuracy achieved. Data is recorded every 15 minutes, 24/7 providing valuable insights into the tunnel behaviour beyond what could have been learned the traditional way. The system has proved to be a cost-effective, sophisticated high-end solution, measuring data reliably and robustly, providing reassurance for site personnel that the tunnel was reacting in a manner that was within safe engineering tolerances. It also provided reassurance to Network Rail that the tunnel as a whole (eastern, central and western bores) was structurally integral, and safe for the travelling public. By installing this innovative equipment, Amey Consulting removed all boots on ballast during the construction phase of the project.

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