

Modified measurement

Refurbishing three tunnels in Spain and modifications to the Chipping Sodbury tunnel in the UK required new wireless monitoring solutions to safeguard the structures.

Engineers that are responsible for tunnel construction and management require precise and reliable data about the behaviour of the ground, the tunnel and third party assets within the zone of influence. The use of wireless remote monitoring is becoming widely accepted within the tunnelling and underground space sector as a means of providing this data to reduce uncertainty and manage risk.

Measuring deformation and convergence during construction work helps protect people and tunnel integrity, but challenging tunnel conditions preclude many of the well-established survey methods. An optical displacement sensor can, however, provide an automated and precise solution. Over the last year, this type of wireless device has played a key part in several tunnel upgrade projects in Spain and the UK.

The established survey methods for precise measurement of convergence and divergence include manual measurement using tape extensometers and automated methods using laser scanners or automated total stations. Some of the drawbacks of these methods include the need for frequent access, fixed power supply, cabling and high costs.

Further challenges can arise from highly restricted access to many tunnels, distance from the portal, physical space constraints, and aggressive conditions such as excessive heat, moisture, vibration, humidity, acidity/alkalinity, dust and

combustible gases.

Taking these challenges into consideration, instrumentation equipment manufacturer Senceive has developed a wireless laser-based optical displacement sensor (ODS).

The device is, in effect, a laser extensometer that can be used for precise displacement measurement.

COSTA BLANCA TUNNELS

As part of the strategic Mediterranean Corridor project, three railway tunnels are being refurbished in the Catalonia region in north eastern Spain.

The project engineers responsible for modifications, including sprayed concrete linings and track lowering, needed real time insight into tunnel behaviour, specifically convergence, divergence, settlement and heave.

Spanish monitoring instrumentation supplier and Senceive distributor Instop recognised that the challenging site conditions did not suit the more conventional methods. Using automated total stations was ruled out because construction plant and temporary props would obscure line of site, and very dusty conditions would obscure prisms without frequent cleaning. The absence of a power supply further complicated matters. As a result, the company selected the Senceive ODS system.

In this case, a long range wireless communications system was chosen, because it had the power to relay data from the sensor locations to a



solar powered gateway at the tunnel portal. This then forwarded it to an online user platform via the cellular network.

As well as measuring movement at points across the tunnel, longitudinal movement was monitored using a series of tilt nodes mounted on aluminium beams fixed to the tunnel side walls. The tunnel monitoring system was fully integrated with rod extensometers installed in six boreholes above the tunnel to monitor settlement.

This integration of data enabled main contractor Dragados to remove ballast and lower the track while monitoring in near real time the impact of the work on the behaviour of the structure and the ground.

Instop business development manager Toni Escudero was responsible for designing and implementing the monitoring scheme.

He explains the thinking behind the wireless configuration: "We had to fit



the system to the structure in just a few hours, and it had to keep on working throughout the construction programme with people and heavy machinery working just a few metres away. This system was self-powered, rugged and had no cables that would probably have been damaged by the construction activity.”

CHIPPING SODBURY TUNNEL

The solution applied at the Costa Blanca project in Catalonia was the first of its kind. However, a comparable approach has been taken for several UK rail tunnels, where electrification and the need to accommodate new trains has required structural modifications.

One of these was the Chipping Sodbury tunnel near Bristol.

Extensive and complex works were required in the 4km long tunnel as part of the Great Western Route electrification project. This involved



Left: The Chipping Sodbury tunnel's length was a challenge for wireless monitoring
Top right: Sensors were fitted to tunnel walls in Spain to monitor movement
Bottom right: A trackside sensor

lowering more than 1km of one of the two tracks and improving track bed drainage.

The length of the tunnel made the use of wireless monitoring challenging, particularly as the project required reliable, lag-free, or delay-free, data transfer from the sensor nodes to the internet in case sudden movements took place.

Aecom and Senceive monitoring experts designed the Chipping Sodbury system using the latter's Flat Mesh platform, because it is capable of high-frequency readings from dense sensor networks with minimal lag.

The system combined three types of sensor: 880 tilt nodes were fixed to the track to record cant and twist measurements; 234 Nano tilt nodes were fixed to horizontal and vertical aluminium beams on the tunnel walls to detect and measure movement of the side walls; and 15 optical displacement sensors were installed on

500mm beams across the tunnel profile on the side walls, haunches and crown to monitor relative tunnel convergence and lateral displacements.

Data transfer to the outside world was fulfilled by a series of Flat Mesh gateways that collated the sensor data and transferred it to the Wi-Fi network established in the tunnel before the project began.

Aecom's instrumentation and monitoring team assessed available technologies for the required application. It determined that the wireless combination of an ODS with an onboard tilt sensor and thermistor would be best suited to achieve a less intrusive method of monitoring during all stages of construction. The provision of this monitoring network provided reassurance of structural stability and safe work rates during all construction phases.

REMOTE MONITORING TECH

With growing pressure to make tunnel construction and modification more efficient, wireless remote monitoring looks set to play an important role.

According to Senceive, applications for its ODS are not exclusively found underground, as it can be considered for many situations where there is a need for remote measurement of convergence or displacement. It is currently being used on a major bridge refurbishment in the United States, for example, to monitor movement between concrete bridge piers.

Like other technologies in the Internet of Things arena, the remote monitoring landscape is rapidly changing. Increasing levels of intelligence and automation are being built into systems. For example, sensor networks can be configured so that an event above a certain threshold such as sudden movement at one location can trigger the wider monitoring system to react. That reaction can take various forms, but typically includes triggering more frequent movement readings, more photographs, and the sending of SMS/email alerts to stakeholders.

Further changes across the industry include integration with other data streams such as weather data in the case of slope management and borehole geotechnical instruments in the case of excavation and foundation projects.