New challenges for tunnel inspection

Today's rail operators have inherited more than a thousand tunnels from Britain's 19th century rail transport revolution

This gift horse provides immense benefit to the travelling public and has an asset value that is immeasurable; resourcing and financing replacement with modern structures would make today's biggest high-speed rail or nuclear projects pale into insignificance.

Most passengers give little thought to the challenges of maintaining these vital links as they speed noisily under hills, rivers and cities. Tunnel engineers and asset managers, on the other hand, must consider a raft of challenges if they are to ensure the availability of rail tunnels to future generations.

These challenges include the need to maintain masonry structures in aggressive conditions, to better understand the risks associated with unrecorded and hidden structures – principally hidden construction shafts- and to modify and adjust the structures to accommodate modern traffic.

The ability to meet these challenges with targeted maintenance relies on reliable and accurate information, gathered from a range of sources including historic records and legacy data, from routine inspections and from bespoke surveys, often carried out by specialist consultants and contractors.

Fugro is one of those specialists – a global geoscience expert providing asset owners with information and advice to help them manage risk in the design, construction and operation of a wide range of infrastructure.

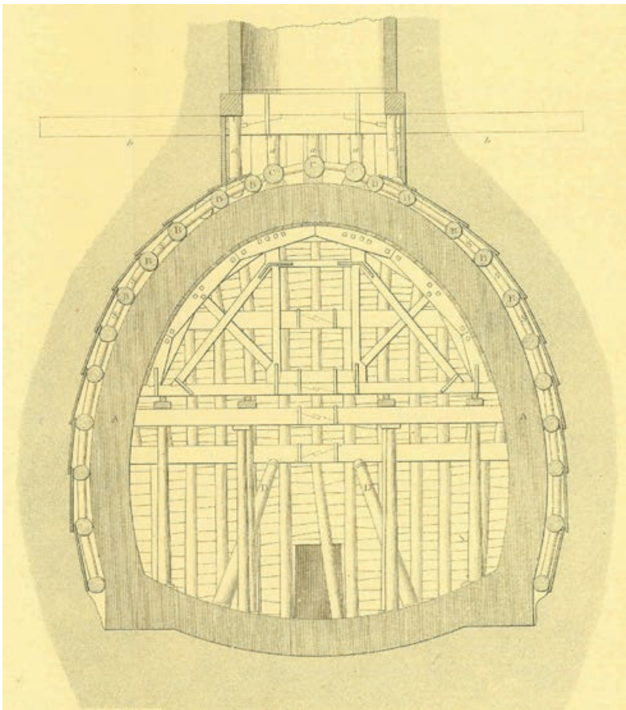
The tunnelling challenge

Most UK rail tunnels date back to the 19th century heyday of rail building when hundreds of tunnels were built with impressive ingenuity and speed, though with little conformity in design or construction.

Built to various shapes, using various materials and with construction thickness changing in response to ground conditions the Victorian tunnel stock never

displayed the uniformity of its modern equivalents. Added to this as-built complexity is the legacy of 150 years of repair, alteration and general tinkering plus some patchy record keeping.

Tunnel owners recognise that, with replacement not an option, maintenance is a must, so they need efficient and affordable ways to assess and monitor asset condition. They must routinely check for changes in condition in order to fix minor defects before they become major issues, they must adapt the structures to meet changing needs such as electrification, and they must be confident that subsurface features such as hidden shafts do not pose a threat.



Adapting for change

Thanks to the belt and braces engineering adopted by Britain's 19th century tunnel builders, major defects are actually very rare. Where problems do occur, early identification is crucial.

Experienced tunnel inspectors can identify surface defects, but for any meaningful perspective beyond depths of a few centimetres, drilling or core sampling have long been the only options.

However, ground penetrating radar (GPR) can determine the presence of cracking and voids, and map delamination between brick rings. Radar surveys are generally carried out from a hydraulic access platform, with the antenna swept over the intrados at a fast walking pace. Multiple profiles are collected to build a dataset of many thousands of measurement points – contrasting with the widely spaced sampling achieved by coring or drilling.

With the electrification of routes, accurate, up-to-date condition and structural data are crucial for the successful installation of overhead line equipment in tunnels. Tunnels are not the same from portal to portal, or side to side. Care is needed in determining the optimum positions for fixings that will be crucial in powering the next generation of trains. Similarly, appropriate spatial and condition data is vital in designing changes such as track lowering to increase structure gauge or line speed.

Finding hidden shafts

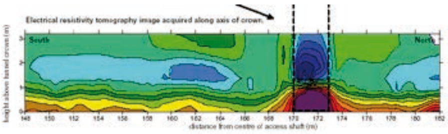
Hidden construction shafts are a widespread remnant of the

Victorian railway boom; they were used to drive multiple headings and accelerate the building process. It was common for a tunnel of a mile length to be built from a dozen construction shafts, with maybe a quarter being retained for ventilation. This left many to be capped and buried at the surface, and bricked-over within the tunnel.

Decades later, they pose a variety of risks. They act as a conduit for groundwater movement which can damage masonry and foul electrification and signalling systems. They can also complicate development of land above the tunnel, and present the risk of a potential catastrophe should a shaft collapse.

Network Rail's business management document, 'Management of Existing Tunnels', stipulates that tunnel management strategies must include an action plan to determine the existence and location of shafts.

This has not proved straightforward however. To locate a shaft position with confidence may require examination of records, aerial photographs and anecdotal information; it may require the use of indirect geophysical surveys and is likely to require a programme of intrusive investigation to verify findings.



With two decades' experience, the structural investigation team at Fugro has learnt that there is no magic bullet and that careful consideration needs to be given to the selection of indirect methods. The most extensively used has been GPR.

Reconnaissance surveys based on three to four profiles through the tunnel can target suspect locations for further investigation and can often be completed in a single shift. More detailed surveys can target suspected shaft locations with a greater density of profiles and with different frequency antennae to investigate near surface and deeper features.

Success is by no means guaranteed however, with soot deposits, groundwater and the presence of conductive materials, such as grey engineering brick, all potential pitfalls.

With these constraints in mind, Fugro geophysicists have borrowed technologies more commonly used to look down into the ground from above and adapted them for use inside tunnels.

Radar alternatives

In highly conductive conditions (such as clay-rich, wet or highly oxidised ground) electrical resistivity tomography (ERT) can be an ideal alternative to radar. This technique can identify structural and geological features several metres beyond the tunnel lining.

It typically requires a shift to investigate a single suspected shaft location; it also requires holes to be drilled into the masonry lining to insert metal electrodes. Ground conductivity is a more rapid geophysical method that is attracting renewed interest for shaft investigations.

In response to increasing pressure on track access there is growing enthusiasm for investigations that can find shafts from the top down. Surface investigations can take many forms, with methodologies tailored to suit different land uses. Investigation is more straightforward in rural areas where there has been little development and ground disturbance compared to towns where any relics of tunnel construction may be buried under tarmac and concrete.

The most indirect surveys are those conducted from the air, with flown surveys offering a range of photographic, infrared and lidar (light detection and ranging). imaging which can potentially reveal telltale depressions and spoil heaps associated with hidden shafts.

Subsurface perspective can be added by deploying tools from a broad suite of geophysical methods including resistivity, conductivity, magnetometry and microgravity.

Conclusion

Providing tunnel owners with structural and condition information is vital for the safe operation of the rail network into the future. Data providers such as Fugro have proved adept at deploying survey technologies to meet the considerable challenges of the complex tunnel stock relied upon by UK rail users.

Looking ahead, the collection of multi-sensor rapid scanning systems is rapidly evolving and will be delivering systematic, repeatable data streams to measure and map the internal surfaces of rail tunnels in the near future.

Deployed on a routine basis, this exciting development will take asset management forward by identifying change over time, but it will not tell us what lies beyond the surface – for that there will be a need for bespoke geophysics and teams with drills for many years to come.

Tel: 0870 6008050
Email: s.brightwell@fugro.com
Visit: www.fugro.com