CUTTING OUT CORROSION

REMEDIAL WORK IS GIVING THE SEVERN BRIDGE SUSPENSION CABLES A NEW LEASE OF LIFE

BY KATHERINE SMALE

Left: Stripped cables are inspected for corrosion and breaks
Right: The high level inspection scaffolding is lifted into place

The 50 year old Severn Bridge has recently undergone a third round of investigative surgery on its two main suspension cables after concerns that they had corroded surfaced in the early part of the last decade.

While the results are only preliminary, a team of specialists from Aecom is seeing signs that extensive works to protect the steel cables from corrosion is paying off.

In 2004, investigations on six major parallel-strand suspension bridges in the United States identified high levels of corrosion in the steel which made up the main cables. The problem lay in their structure.

Modern bridges generally use locked strand coils where the outer rings of the cables are made up of a series of Z cross-section wires which fit tightly into one another and form a barrier to water. However, parallel strand cables comprise wires with circular cross-sections bundled together. This leaves voids between the wires, making them vulnerable to water ingress and consequently corrosion.

After the corrosion problem was discovered in the US, the UK Department for Transport (DfT) started to inspect its own three parallel strand bridges, the Forth Road Bridge, the Severn Bridge and the Humber Bridge. Initial inspections were carried out on the Forth Road Bridge near Edinburgh in 2004, followed by inspections of the Severn Bridge in 2006, and the younger Humber Bridge in 2009.

The first inspection of the 1.6km long Severn Bridge confirmed all fears. It was found that a number of the parallel strands within the main cable had corroded to an unacceptable level. In an attempt to control the situation, weight limits were placed on the bridge.

KEY STATS

511mm
Suspension cable diameter

2004
High corrosion levels found in suspension cables in the United States

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In response, Highways England's predecessor the Highways Agency installed a new dehumidification system to dry out the cables and arrest any further damage to the steel in 2008. To create an airtight seal around the 511mm diameter cable, it wrapped it in a polyurethane wrap before blowing air into five key points along its length.

The relative humidity of the air leaving the polyurethane wrap was compared to that of the injected air and, over time, this balanced, giving the team confidence that the moisture within the cable had dried up.

"If you get below 40% relative humidity then you arrest corrosion. So the object is to ensure that the atmosphere inside the cable is less than this," says Highways England structures team leader Mark Maynard. "At the start, the relative humidity of the air coming out was very high compared to the air going in.

"Since then the numbers have been almost identical, which gives us confidence that the cable is dry as it's not picking up any more moisture in between."

To further the effectiveness of the new system, the dry air was also passed through a vapour phase inhibitor.

"The dry air is pumped through what could only be described as a tea bag-like structure which is called a vapour phase inhibitor," says Maynard. "The bag creates a chemical reaction which produces ions that flow through and bond themselves to the cable and inhibit corrosion. It's a belt and braces approach."

In 2010, a follow up inspection found that the cables had stabilised, giving Highways England assurance that the dehumidification system was preventing further corrosion.

But the problem was not over. The corrosion which had already occurred could not be ignored and so a third inspection was carried out by contractor American Bridge and consultant Aecom over the summer this year.

The inspections themselves were akin to open heart surgery. Each of the cables was first stripped of its white protective polyethylene sheath, the original red lead paint was then removed to expose the 8,322 individual 5mm diameter parallel high-tensile steel strands which make up the overall main cable.

When the individual wires were exposed, wedges were hammered into the centre of the cable at eight points around the circumference. This allowed the team to separate out the strands and inspect their surface for damage and corrosion.

"They drive wedges into the cable to inspect a face in the middle of the cable," says Maynard. "They do this by hammering a wedge in at the right point. From the top it's relatively easy, but driving them in from the bottom requires significant manpower."

From the wedge inspections, cross-sections of the cables were produced, modelling the condition of the cable and the number of broken wires. By carrying out a statistical analysis of the gathered data, the condition and therefore the residual strength of a whole cable could then be calculated.

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While the wedges opened up the cable, the team was able to repair broken or corroded strands. Where a broken wires were identified, a section 6m long was cut out and replaced by feeding both ends into turnbuckles. These were then tensioned to return the wire to its original state.

After the inspection was carried out, the strands were re-compacted and wound tightly together with a 3.78mm diameter wire wrap, before the white polyurethane wrap was reinstated.

The inspections were largely carried out in the central sections of the suspended cable as this is where the most moisture was expected to have collected and consequently where the worst corrosion was anticipated. However, higher level cables were also checked to ensure that this was the case.

Despite the fact that the majority of the work was carried out on the lower areas of the cables, the work

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was complicated as all access to the cables was restricted to the public footpath and cycleway on either side of the bridge deck.

Unlike the Forth Road Bridge, whose deck is supported by a large truss, the Severn Bridge's deck structure is more streamlined. Its main deck is an enclosed steel box girder with a lightweight cantilevered foot and cycle path on either side. The cantilever limited the weight of the scaffolding the team could use to access the work sites.

"The scaffold which we have used for the works might seem simple to build but it's been complicated because it has to withstand the wind loading on the bridge," says Maynard.

"It therefore has to have kentledge on the bridge to hold it down, but that puts the load on a thin cantilever.

"So we can't put the maximum required kentledge to hold it down in all wind conditions because of the effects it would have on the permanent structure."

Because of this, the work was subject to wind restrictions which, if exceeded, meant the scaffolding had to be partially dismantled causing delays in proceeding with the inspection.

To mitigate the risk of a vehicle crashing into the scaffolding, the team closed the outer lanes of the deck to traffic and installed a specialist safety barrier. But even this was not a simple task.

"Because you've got scaffold on the structure, you've got to protect it from the traffic," says Maynard.

"But because of the sensitive nature of the structure and the limited weight capacity of the structure, we had to go for a steel barrier as a concrete one was too heavy.

"Normally steel barriers are bolted down to the ground, but in this case that wasn't possible [to avoid damaging the deck], so as far as we know this was the first example of a Varioguard barrier using a small anchorage, 3t concrete anchors at the ends of it."

Inspecting the cables higher up was also a challenge. Each area has had to be inspected from a 30m long, high level scaffolding system which was hoisted up to wrap around the cable.

In conjunction with the cable inspection work, the team also carried out a detailed analysis of the actual loading on the bridge.

By embedding sensors in the road surface, the team has been able to compare the actual loads on the bridge to the revised capacity of the cables, based on the corrosion of the cables. This helps the team to assess how much traffic can safely pass over the structure.

In early 2008 the team also installed an acoustic monitoring system which is sensitive enough to listen out for wire breaks which might occur within the cables. Sensors were placed on every second hanger and then calibrated to pick up the sound of a wire break.

"The sensors listen all the time and record when they get the right signal, which they have correlated to a wire break," explains Maynard. "When they have a potential wire break, a trained person looks at the signal and will confirm it.

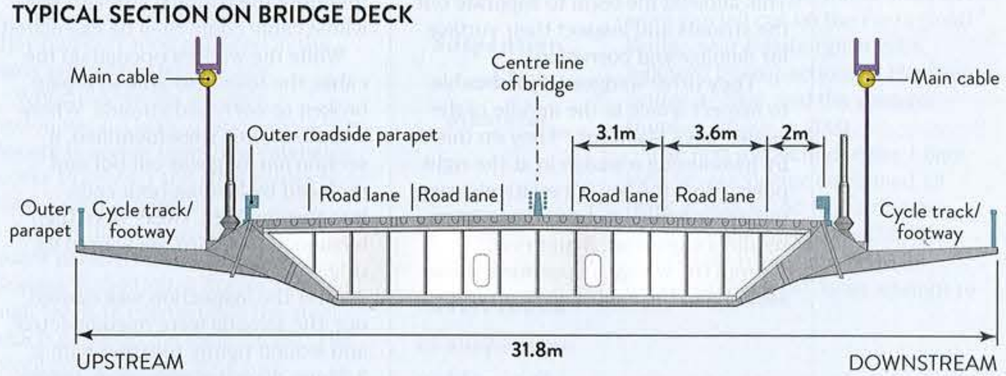
"It's another mechanism by which you can monitor the health of your structure."

To calibrate the system and check the sensors are still working, they are tested on a regular basis by breaking a pencil lead next to them as it produces the same signal as a wire break.

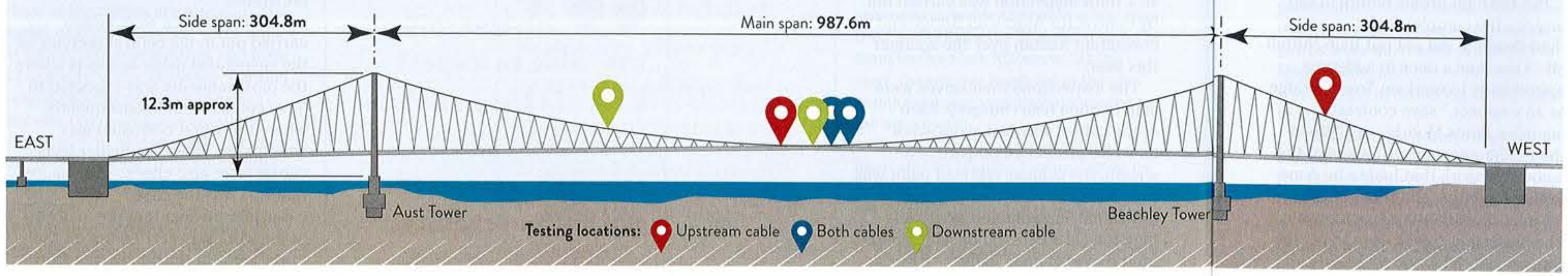
Future inspections will be planned based on the results of most recent tests, but for now, the Severn Bridge has been given a new lease of life, hopefully for decades to come. ■

SEVERN BRIDGE

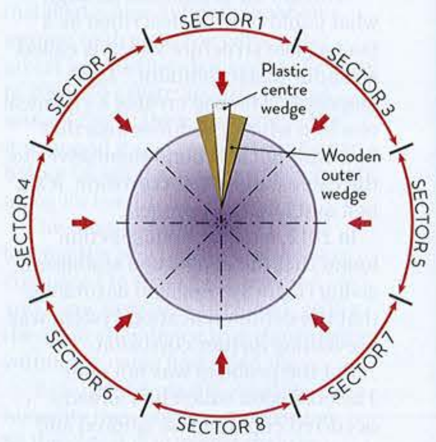
TYPICAL SECTION ON BRIDGE DECK



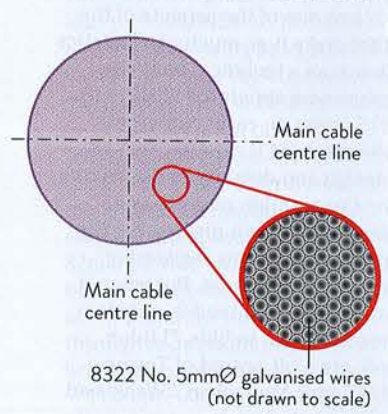
M48 SEVERN BRIDGE ELEVATION



WEDGING FOR CABLE INSPECTION



TYPICAL MAIN CABLE SECTION



SECURITY VIEW

HIGH TECH PROTECTION

Diane Burt

Security at airports has never been tighter. Yet with the demand of increasing global footfall and an ageing population contrasting against the need to make passenger journeys more comfortable, the aviation industry needs to square the circle.

It's not going to be easy, but the sector is already well prepared with good practice, codes, robust security strategies, and a culture that is ingrained to learn the lessons from past incidents.

However, as technology changes at a lightning pace, the sector needs to keep up. Twitter, for example, broke news of the Hudson River plane crash in 2009, and the Boston Marathon bombings in 2013. The trouble with this platform is that it is not location specific. Terrorist incidents tend to be multiple simultaneous events and having detailed information can help those caught up on it to escape, saving lives.

Different approaches are also required for different incidents. For example, when you look at the guidelines for a fire, the general approach is "if it's small try and put it out", and "if it's not, walk calmly to a location and call the fire brigade". However, if there is a bomb threat or if there is somebody shooting, the advice is to run and hide.

Technology's role here could be crucial: If you were hiding and were informed there was another gunman, or the location of a second bomb, you could make an informed decision as to whether to stay or get out of the building.

One way we can use the latest technology to assist passengers is location-specific mapping information, twinned with "big data". Currently the density of phone signal movements mapped over alternative routes helps avoid traffic. By using the layout of a building, a smartphone app and physiological data from wearable technology we could share information to show the fastest (and safest) routes out of a building by mapping passenger flows on foot.

In an incident at your home or office you would typically know the lay of the land. However, at transport hubs the way in is not always the way out. To solve this we could use GPS and piggyback off the use of signage or advertising to help with evacuations.

Elsewhere, baggage scanning technology advances could function rather like the technology you find in shop doorways to security scan people as they walk through. This would provide enhanced security inside terminal buildings and ensure there is no-one roaming around with large parcels land side. This reduces large queues that themselves are targets.

If you have a distributed, automated process, such as bag drops in airport car parks, you wouldn't create such a target. So you are trying to separate an armed person from their weapon at the earliest opportunity and disperse the crowd.

By using a combination of technological advances in scanning equipment to prevent devices becoming close to crowds and use of real time data to respond to an event should it occur, we can look to minimise the impacts and enable us to get from A to B in the fastest, safest way.

● *Diane Burt is WSP Parsons Brinckerhoff aviation director*