NEWS ALERT

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# New Severn Bridge Article References use of Vapor phase Inhibitors for Corrosion Control!


MIGRATING CORROSION INHIBITORS
FROM GREY TO GREEN

An article entitled, "Cutting Out Corrosion: Remedial Work is Giving the Severn Bridge Suspension Cables a New Lease of Life," is hot off the press for the January 2017 edition of the New Civil Engineer magazine. This article mentions the use of "vapour phase inhibitor" in the efforts to protect and preserve the Severn Bridge after unacceptable corrosion was found in the main cable in 2006.

Cortec® Case History 390 tells the inside story of this VpCI® application, which was actually the inspiration for the development of PTC Emitters for post-tension cables. A dehumidification system had been installed on the bridge to reduce moisture and prevent further corrosion on the cables. However, dehumidification protection can be imperfect, and the engineers wanted an additional source of corrosion protection that would also serve as backup protection during periods of dehumidification system shutdown.

Since fogging of VpCI® powder or water based inhibitor was not acceptable to the project owner, a new system was created by packaging VpCI® in breathable pouches. These new PTC Emitters were to be placed by fives in each of the simple hatch and crate system units that were part of the main dehumidification pipework. As the dehumidification air is blown through the pipework, it now carries VpCI® along with it to adsorb on the surfaces of the cables and protect them from corrosion.

Protection has been successful. The New Civil Engineer article said that a 2010 follow-up inspection showed cables stabilized, indicating that no further corrosion had occurred. However, because of the original corrosion, a third inspection was performed in 2016. The article explains that the large cables were basically pried apart at eight different points around the circumference and wedged in place for inspection. Workers checked for corrosion on the internal wires in order to perform statistical analysis of cable corrosion and residual strength.

The article states, "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." The article concludes by saying, "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."

Cortec® is proud of the role it has been able to play in protecting the Severn Bridge from deterioration, keeping it safe and extending its service life. Cortec® is also grateful for how unique challenges like the Severn Bridge have led Cortec® to new levels of discovery and product innovation while seeking the best solution for customers.

To read the original case history, please visit the following link:
http://www.corteccasehistories.com/case-histories/ch390.pdf

Technical Excellence

# CUTTING OUT CORROSION

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

BY KATHERINE SMALE

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**

**“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**

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.

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

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.

**“They drive wedges into the cable to inspect a face in the middle. From the top it's relatively easy, from the bottom requires significant manpower**

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

> “The sensors listen all the time and record when they get the right signal, which they have correlated to a wire break

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.

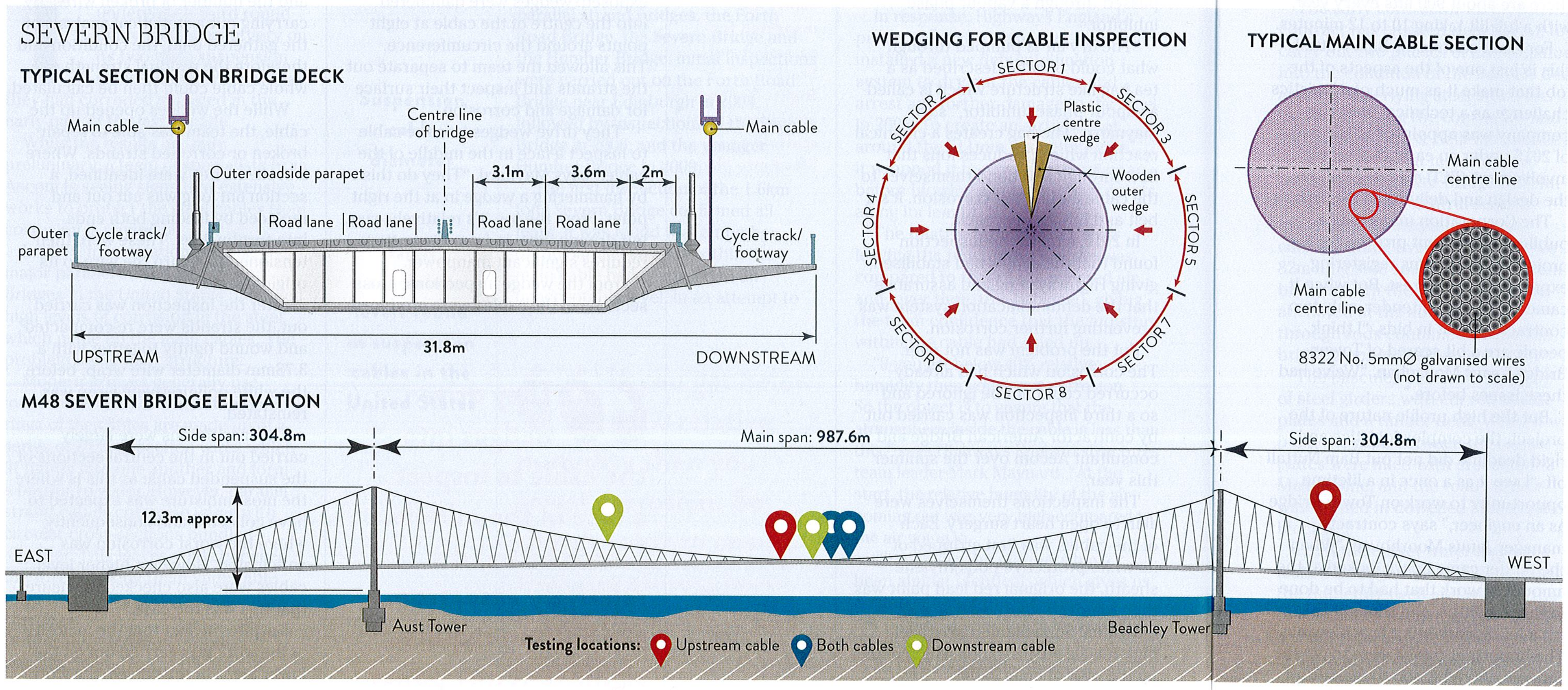
In early 2008 the team also installed an acoustic monitoring system which is sensitive enough to listen out for wire breaks which might occur within the cables. Sensors were placed on every second hanger and then calibrated to pick up the sound of a wire break.

“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. N




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*


# CASE HISTORY

## Suspension Cable Protection

### PROBLEM

The suspension cables on this type of bridge are known to corrode over a long period of time. The 20 inch (508 mm) diameter main cable is constructed from 8322 high tensile galvanized steel wires of 0.196 inches (4.98 mm) in diameter. The total area of the cable is 314 in2 (202,580 mm2) of which approximately 20% is comprised of voids. The cable is wrapped in 0.144 inch (3.66 mm) mild steel galvanized wire. Dehumidification is used to reduce the level of moisture around the cables.

It is known that the dehumidification system does not provide perfect protection. Engineers from Mott MacDonald wanted to find a way to add additional corrosion protection into the system's airflow. Mott MacDonald contacted Lake Chemical to see if Cortec® would have such an inhibitor that could be used this way.

Original thoughts were to fog a VpCI® powder or water based inhibitor into the system but neither of these options was acceptable to the owner. A test rig was built using VpCI® 105 emitters as the source of corrosion inhibitor to see if it would work and to ensure that the inhibitor had no detrimental effect on any of the materials/components of the cable system. The testing proved positive and there were no material incompatibilities noted. The biggest issue was then to find a way to be able to package the inhibitors to ensure that enough of them entered into the airflow and would be distributed around the cables as needed. Cortec's PTC Emitters were developed as a result of this.

### APPLICATION

A simple hatch and crate system that is a part of the main dehumidification pipework was developed. This allowed the inhibitor to be put into the airflow without disrupting the system when the product needed to be changed out. Five (5) PTC Emitters per unit are placed into a basket inside the crate with no special separation or spacing of the individual emitters being required. The dosage rate of 5 PTC Emitters per 10 injection sleeve inputs per month was determined by Mott MacDonald/Lake Chemicals.

### CONCLUSION

The system has now been running for over 2 years and testing was carried out using a newly developed VpCI® sensor solution to confirm the presence of VpCI® inhibitor in and around the cable. Corrosion rate monitoring and relative humidity testing is carried out and as a supplementary precaution, longer term samples will be held in the VpCI® airstream and tested at pre-determined intervals over the operational life of the system. Control samples are being held in one of the existing plant rooms.

**DATE**
July 2007

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