Linton Bridge in Wharfedale. Photo © Andrew Fletcher / Shutterstock

Stress relief

Tareq Khodabacksh, Graham Smith and Aaron Okorie relate the use of wireless sensors for the remote monitoring of a distressed structure

Linton Bridge is a Grade II listed structure that links the villages of Collingham and Linton over the River Wharfe in West Yorkshire. This historic structure was built of stone in the early to mid-19th century and is a major and iconic feature of the local area.

During 23-24 December 2015, Storm Eva – measuring 84mph –caused massive power cuts and eventually flooding across the area. In the aftermath, cracks appeared on the carriageway of Linton Bridge; there was visible damage to the parapets, and settlement was apparent on the bridge deck. The highways and transportation department at Leeds City Council was asked to go and investigate after concerns were raised by the local police. Upon inspection, a crack was observed on the southern arch. Public access was then suspended and both gas and water services were shut off at both ends of the bridge.

It was identified that one of the piers founded in the river had settled almost 200mm during the storm, causing the arches to crack and the carriageway and parapets to settle. BMM JV (a BAM Nuttall and Mott MacDonald joint venture) were contracted to investigate the flood damage, protect the structure from further damage, and design the repairs in partnership with Leeds City Council.

Assessing the damage

Various types of investigations were conducted to best address the problem of settlement, including a drone survey to enable safe examination of defects above the water more closely. An underwater inspection of the piers pinpointed the extent of the scour to the southern pier. This was followed by a survey to accurately scan the current shape of the arches and the road to help create 3D models of the bridge and plan the repairs. A bathymetric survey was also undertaken remotely to establish the current profile of the river bed in the vicinity of the bridge. Manual levelling was carried out to monitor the movement of the bridge. However, due to safety issues and cost, it was proving difficult to find a way to continuously and effectively monitor the movement of the bridge manually.

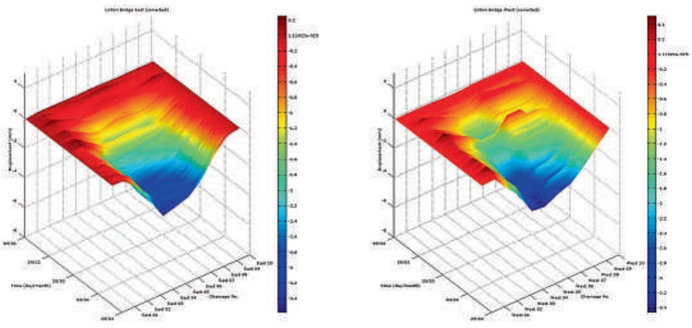
Wireless monitoring

In January 2016, Mott MacDonald contacted Senceive, as it was aware of the application of the company's wireless condition monitoring technology to the remote monitoring of bridge settlement. Already pre-commissioned, the company's stable and robust FlatMesh monitoring system was installed by the BAM team within three hours. Data was immediately available to help the City Council assess the ongoing stability of the arch without putting anyone at unnecessary risk. Data was then accessible 24/7 to users via a secure website.

High accuracy and stable sensors on special interconnected beams that compensated for any temperature variations, ensured the smallest amount of settlement movement could easily be determined.

Although part of the bridge had already settled significantly, it was important to get stable and high resolution data to sub-millimeter resolution to determine the real settlement trends. For this purpose, 10 high-precision tilt sensors, mounted on beams, were mounted on each parapet wall.

Using the FlatMesh wireless system the sensors communicated data to a solar 3G gateway to allow the monitoring to be completely wire and mains power-free throughout the monitoring period. The data could then be accessed remotely using the FlatMesh WebMonitor visualisation software. A video summarising the proposed repair work was posted on Leeds City Council website and the methodology was approved by the Environment Agency.[1]



3D representation of movement over time on both parapets revealing circa 4mm of movement over four months. Sensors are resolved to 0.053mm/m. Images: Senceive

Relieving the pressure

Senceive's wireless monitoring system was also used to determine if the remedial works were successful. The system allowed for quick deployment and the initial monitoring could be compared with the manual measurements undertaken earlier. A complex temporary arch support system was installed to give safe access to the bridge and a temporary piling platform built on both sides of the structure. Steel tubular piles were then filled with concrete and sunk into the river bed.

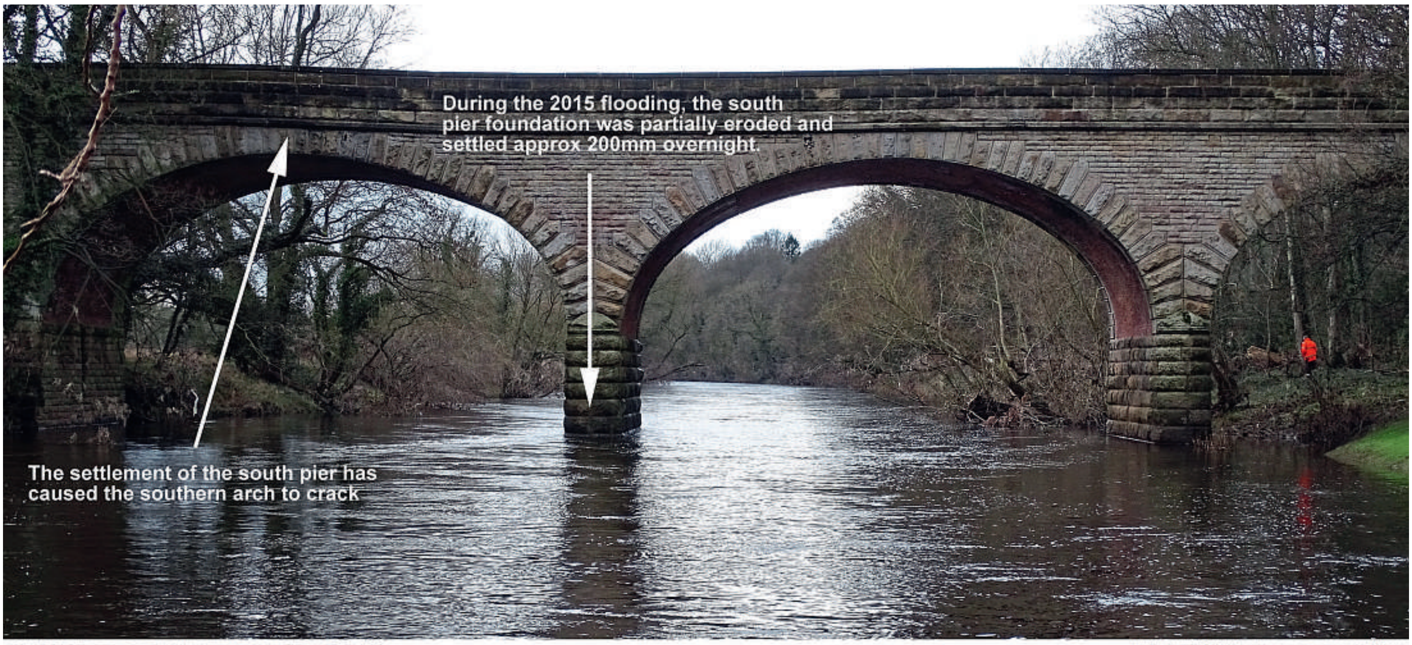
Once the arch support system was installed and work could be safely undertaken beneath the bridge, the cracks in the arches were stitched and grout injected into the ground beneath the south pier. The stitching and grouting works were originally planned to be included in the strengthening works, but it was then decided that this could be incorporated into the stabilising works. This made the bridge safer to work on without adding any time to the overall programme. It would make the bridge robust enough to carry the construction equipment and withstand the vibrations and impacts associated with the implementation of the strengthening works.

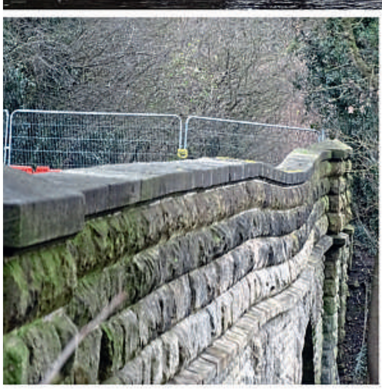
The wireless monitoring was continued for a further period of approximately 8-10 months to assess whether there was any further settlement on the bridge after the stabilisation. The wireless monitoring system was removed during December 2016, one year after Storm Eva.

Currently, the strengthening works are fully underway and the bridge will remain closed for a few more months until completion. Once opened the bridge will continue to be part of day-to-day life for the surrounding villages and local scenery for many years to come.

1. www.leeds.gov.uk/residents/Pages/Linton-Bridge.aspx

Tareq Khodabacksh and Graham Smith are with London-based Senceive, specialists in wireless condition monitoring for civil engineering (www.senceive.com), while Dr. Aaron Okorie is an engineer with the highways and transportation department at Leeds City Council (www.leeds.gov.uk)





Top: Linton Bridge settlement. Below (L-R): A settled parapet; Senceive nodes on beams on both parapets; High-precision wireless sensor; and Solar 3G gateway. Photos: Senceive

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Dealing with a modern problem

So how do you better handle your data and reduce processing time? Andy Beckerson thinks he has a modern solution

At one time, surveyors used to collect the minimum amount of data that was required to complete a task and have some redundancy, 'just in case'. Then, as technology developed and data collection and recording became more and more automated, the amount of data collected increased – it was so quick and simple to do, why wouldn't you!

That's fine for Total Station data – with a bearing, distance and a description. With relatively straightforward computer processing software and a plotter, your drawing was automatically plotted and *Voila!* Need a different scale, then just press the button and watch the pens move up and down and the paper move backwards and forwards. Job done.

But what about imagery and 3D point clouds?

Laser scanners are renowned for delivering huge amounts of data, but immense 3D point clouds slow processing time and can require high performance hardware for users to access, manipulate and process them. For some deliverables, do you really need to collect a 3D point cloud, or might an image and some measurements suffice?

Picture perfect

So what about imagery? How many images do you take of a subject to get that perfect shot, one or ten or even more? With digital cameras it is so easy to do and then you can just delete the photos you don't need. With imagery for surveying you must make sure the overlap is right and it would be nice to have the same lighting conditions. Of course, high resolution is taken for granted in your phone, but what about your Total Station...and what do you do with all those images?

Wouldn't it be a good idea if you could not only make the collection of the field data straightforward, but also all the office processes as well and have some simple way of producing whatever deliverable your customer required? Wouldn't that increase your productivity? If you could combine imagery, point cloud and Total Station measurements, think about the possibility of providing more than your customer required – wouldn't that keep you close to your customer by over delivering?

The concept of a combined Total Station, laser scanner and imaging Total Station has been around for some time. However, the concept has now become a reality with the Trimble SX10 scanning Total Station; add in simple dedicated workflows and your field data collection becomes a job that can be done even faster with fewer distractions!

The Trimble SX10

Calibrated photograph with point cloud fitted on top

From field to office

It follows that your office software needs to be at the same productivity level as your field data collection. If it isn't, then you have just moved your 'problem' from the field to the office and the backlog of processing starts to build. This in turn reduces your ROI on the field hardware and therefore, doesn't it make sense, if you are investing in field hardware with greater capability, to also look at your office survey processing software?

So what should you consider for the office processing? Well you obviously need to process and adjust your optical, levelling, and GNSS data – that's the basic stuff. For the scan data, it would be nice to have some type of point cloud management with automated extraction; for imagery you possibly not only need panoramas but also rectified photographs that you can take photogrammetric measurements from and, of course, the images must colourise the point clouds.

Once the processing is completed, a link to one of the leading CAD and/or GIS packages would give some flexibility in the deliverables made to your clients. Now, if you can combine all these features along with flight data and UAV images, then there is possibly only one question left to answer...

Do you want this on your office PC or hosted in the cloud? But that, as a friend of mine once said, is a question for another day!