Bridge of the Month 153, "September" 2023

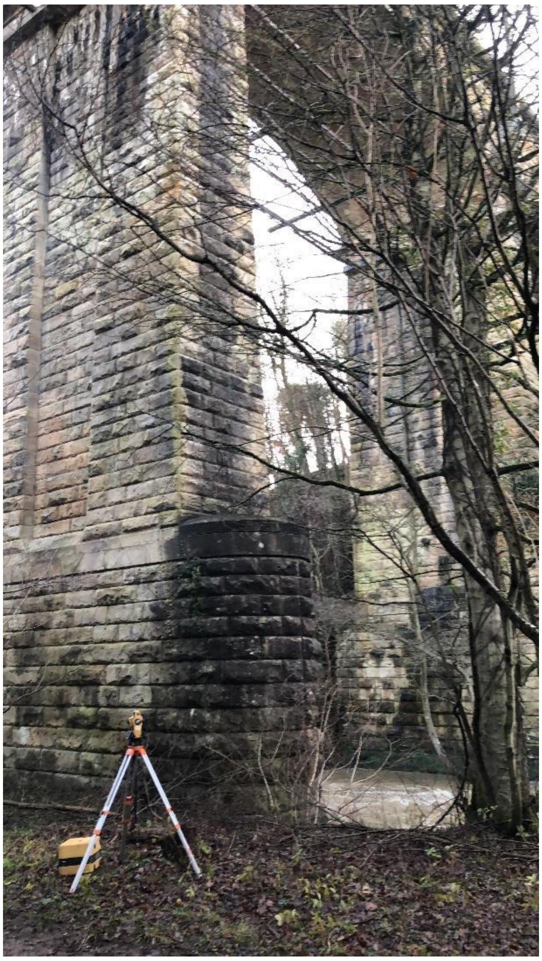
Plessey Viaduct, Northumberland

Over the weekend of 7-8 October 2023, a section of wing and spandrel wall collapsed at Plessey Viaduct. This is a very serious issue, and it seems reasonable to devote the overdue September Bridge of the Month newsletter to it.

The photographs included were either posted on twitter, in which case links are provided to the source, or sent to me privately. None were taken by me.

The photo left was circulating by the evening of Sunday 8th.

The viaduct does not lend itself to general photography, except perhaps from the air, as it crosses a steep wooded valley. The photo below gives an idea of scale.



Before going further, a question of ethics. Is it acceptable to examine and discuss events like this from limited available evidence?

When there are serious incidents on the railway, speculation inevitably follows. In these hyper connected times, this speculation can happen in public. One person's "maybe" becomes another's fact. Where there are casualties, and there is a formal process of investigation and reporting, armchair investigation based on limited evidence will fuel speculation and is unhelpful, for many reasons. Perhaps most importantly it has the potential to add to the trauma experienced by those close to the incident.

In those cases, by the time we have heard about it, the RAIB and possibly HSE will be mobilising, and reports will follow. Conclusions, actions and enforcement will be public. That system is not perfect, but there is a serious process, in which effort has been made to avoid conflicts of interest.

In the case of Plessey Viaduct there were, thankfully, no casualties. There are important issues here that go beyond the specifics of this case. The aftermath of a non-fatal incident seems the best available time to discuss them.

This is the latest in a series of events with some similarities.

- In 2016, a wing wall of an over-line bridge at Barrow-on-Soar collapsed onto live tracks.
- On Christmas Day 2020, during track work on a viaduct at Nine Elms in London, construction plant movement triggered a spandrel wall collapse that propagated 70 metres before it stopped.
- Only a couple of weeks later, on 15 January 2021, a length of parapet fell off the Carron Water bridge near Stonehaven.

And now this.

There were some comments on social media stating an expectation that RAIB, or HSE, will investigate. I will be surprised if they do, as they did not investigate Nine Elms or at Carron Water. There has been no suggestion from Network Rail that they see this case differently. RAIB have not commented publicly to indicate any consideration (it may not be their practice to do so).

Barrow-on-Soar did get an RAIB investigation. Perhaps that is because the material fell onto live rail. But if risk to live rail is the criterion Carron Water would surely qualify too, as the failure there was first detected by a train driver, who reported it as an embankment failure. How many trains ran between the failure and that report?

After Nine Elms, I understand there was an NR internal investigation, but the findings have not been made public. Some ORR annual reports refer to the event, but only in odd bullet points. One notes that, “These incidents illustrate the importance of carrying out high quality evaluations of structures examinations so that risks can be identified, and appropriate mitigations implemented.” Absent serious consideration of whether there were shortcomings in that system of inspection and mitigation in this case, what they were, and what might be done about that, that comment is worthless.

Two others imply that Nine Elms was due to a failure of vegetation management. Now the failure to manage vegetation on structures across the network is resulting in significant damage and undermining inspection value, and the vegetation on Nine Elms viaduct was far too extensive and mature, as shown by the Google Street View images above and below from shortly before the event.

That vegetation may have made a contribution to what happened, but I am far from convinced that it was a primary cause, let alone apparently the only noteworthy cause. And if it was – has vegetation management changed as a result?

I've been sidetracked! The point is that all of these events, up to and including this most recent, are clearly *near misses*. It is by chance that there were no casualties. The more similar events take place, the sooner that luck will run out. Nine Elms had the potential to be a mass casualty event.

Let's have a look at Plessey Viaduct and the failure then come back to the question of what an appropriate response might look like.

The structure was designed by Robert Stephenson and completed in 1850. Stephenson's Royal Border Bridge was completed in that same year, as no doubt were other structures on this line.

It is grade II listed. I have seen comments suggesting that it, and others like it, should be de-listed to free Network Rail from the constraints that listing imposes, with the unsupported implication that these constraints contributed to the failure. There were also, inevitably, comments about "Victorian infrastructure". This is Victorian, certainly, but masonry structures *do not* routinely become unserviceable with age.

There is clear evidence of past concerns, in the form of interventions. These including a rather slender reinforced concrete under-ring, and longitudinal ties.

The under-ring is quite common. The reasons for its installation are quite possibly lost, but it seems likely that the condition of the original arch barrel within the width was considered inadequate.

The ties (the longitudinal rails are obviously too slender to act in compression) from bull-head rail, are more interesting, because they are less common. Are they contemporary with the under-ring or from a different cycle of treatment? The transverse rails and hangers are only there to support the self weight of the ties and stop those sagging.

Have these interventions made any difference? I'd wager no-one knows. The under-ring probably hid some ugly cracks, but has it changed the behaviour that led to them, and stopped them getting worse? Are the ties stiff enough to actually modify the behaviour of the stiff masonry? The only way to answer those questions is by careful measurement of behaviour before and after intervention, which is done approximately never, and often can't be done retrospectively. I was delighted to hear others making the case for *proving* interventions at a recent workshop on masonry bridges organised by the ERMABI project; I'd be even more delighted to help with the sort of testing that could do so.

A slightly different view shows a bit more of that system. Chunky turnbuckles to tension the tie system. I wonder what the anchor in the abutment is, and what is hidden within the transverse concrete element.

The top of spandrel wall here is littered with survey targets (red flags, just visible in the photo right). Installing those targets and measuring them enough times to provide any useful data is not cheap. This photo was taken in 2020; there had evidently been concern of some sort – not necessarily related to the recent damage – before that.

The photo below (again from 2020) is, I believe, the end where the damage has occurred. The nearest target is torn, and looks distinctly grubby, placing the start of this monitoring considerably earlier. There is no obvious tilt here at the near end, but a pronounced dip, the low point I think over the nearest pier. Perhaps the monitoring was related to that.

The near masonry is not really a spandrel wall, but wing wall over the abutment. Notice two sections of the string course stand forward. These areas mark the positions of two buttresses in the wall below.

There was little if any tilt to this wall in 2020. Fast forward last weekend, and by Sunday night a stretch of spandrel wall has dropped to the ground below (first photo above).

On Monday morning, Network Rail said, "During planned engineering work over the weekend, Network Rail teams discovered that the parapet, a safety feature installed on the bridge, had moved. Work was stopped and specialist structural teams attended the site to assess options to repair the bridge."

That's quite an interesting statement for several reasons. Well before it was published, the parapet (in this case, a row of precast concrete units with a steel tube handrail attached) *along with a section of the spandrel wall below* had "moved" all the way to the ground below. And note that it says the specialist engineers came not to establish what had happened (or rather to collect the evidence that would be needed to do so), but to think about repairs.

LNER also put out a notice, understandably vague, saying only that some structural damage had been found. The interesting bit of the LNER announcement was that it included photos, clearly taken earlier than the one from the start of this piece, showing the parapet (and spandrel wall) definitely "moved" but still attached.

Twitter user Random Railways reposted a photo taken some time between (right), when the movement was worse but the full collapse was yet to happen.

Looking at the photo above from outside the wall, we can see a concentrated hinge, well down the wall. Below, the wall is tilted little if at all. Above it has tilted as a unit. The view from inside seems to show ballast dropping into a gap left as the wall moved away.

The concrete walkway is narrower than the string course. The string course masonry is clearly visible into the distance in the LNER-shared photo. In the Random Railways photo it is not clear in the middle distance. Did the masonry rotate out ahead of the concrete? There could be some influence here from the buttresses – if the wall hinges at the face of the buttresses, the masonry between would rise out of contact.

Going back to the photo at the top after the collapse, it looks as if the concrete walkway units were tied down into the masonry with steel bars, perhaps resin anchored into the masonry at the base. Odd stones have been left hanging on the bars. Their presence would encourage the observed rotation of the upper masonry as a unit. A likely point of rotation is just below the end of those bars.

The movement must have been detected when work on lifting the track was well progressed. The wording used by network rail presumably relates to the situation when the damage was first detected. That may be as shown in the photo from LNER, or before.

The movement as first detected certainly must have developed since 2020, as it is not detectable in photos taken then. It seems likely that it developed entirely during the work that was ongoing when it was detected. In other words, that the *proximate* cause is related to the construction work itself, as at Nine Elms, though the details are no doubt different.

To produce this outcome would require both a sufficient load to initiate movement, and a substantial follow through to reach a point of instability.

The underlying causes here may well differ from those at Nine Elms, particularly as the collapse appears to have started over the abutment, so certain types of pre-existing damage that are common in viaducts (vertical cracks behind the spandrel walls over arches and piers) would not be expected.

So what is an appropriate response to an event like this? There are four key points I'd like to make.

1) Whether there are casualties or no should make very little difference to the way the event is handled.

If something happens that might have killed or seriously injured someone and that could do so if repeated – whether public, passengers, train crew, or site operatives – then the incident should be treated with the same seriousness as if it did so.

Near misses are a gift, and it is vital that we learn as much from them as we can. They should also provide the opportunity for specialists to practice and develop techniques.

2) Forensic engineering is key to learning from failures.

Forensic engineering is the application of the scientific method to determining causes of failure of (in our case) structures. Forensic science is often defined as something like, "The application of scientific methods and techniques to the investigation of crime", but that misses the point. It is the application of the scientific *method* that is key, the *methods* come along with that.

The core of that is constructing hypotheses *and rigorously testing them*. It is not enough to think of a possible cause - a hypothesis - that seems to fit what you can see. We need to establish confidence (we should be very suspicious of certainty) in the validity of the hypothesis. We do that by working out what we would expect to find if the hypothesis were true, and testing for that. We might well find that the hypothesis fails those tests and we have to replace or revise it. That might happen several times before we reach adequate confidence to draw conclusions.

All of this requires not just techniques. The most important requirement is a forensic *mindset*.

Degree courses don't teach forensic engineering. Not only that, but they contrive – however unintentionally – to teach students that engineering is a subject of definite answers.

3) Evidence collection is fundamental and must take priority over re-opening the railway or and planning repairs.

Just as in forensic science in criminal investigation, evidence collection is fundamental. Part of this is time critical: there is evidence that will be destroyed as soon as any sort of clean up or repair begins. Collecting this evidence must take priority over everything else except immediate safety.

If that means keeping the railway closed, or part closed, for longer, the railway must remain closed. There is a direct conflict of interest between effective initial investigation and the severe pressure on the infrastructure body to avoid disruption.

It is wholly unreasonable to ask engineers answerable to the financial hierarchy of the operational organisation to decide when evidence collection is complete.

On the other hand - and just as with a crime scene - it is clearly not possible to cordon off a failed structure for the duration of an open-ended investigation. So evidence collection has to be rapid and detailed, and largely complete while only initial hypotheses have been formed.

This requires development and refinement of techniques and skills. Photogrammetric capture should certainly be a standard element of that, as it allows large areas to be captured in detail in a way that simple photographs do not.

Someone must actually be responsible for evidence collection. It troubles me greatly that NR's stated purpose for "specialist engineers" attending site on the morning after the incident at Plessey was *to consider possible repairs*, rather than first and foremost careful collection of the evidence needed to establish as much detail as possible about what happened.

4) Responsibility for investigation, and especially evidence collection, ***must*** *lie outside the infrastructure operator.*

An investigation by the same organisation responsible for everything that led up to the incident is fundamentally unserious. The lack of casualties *this time* does not change that. The conflicts of interest are clear and insurmountable; that during evidence collection is only the most acute.

There is very much more to be said, but this is already quite long enough.

As a prize for those who make it this far, Keith McMahon took (and kindly posted) a video from a train crossing the viaduct on 11 October.