Bridge of the Month 156, February 2024

Yarnton Road Bridge wingwall collapse

Another month, another interesting masonry failure on the railway to write about. The event was a year ago. The trigger is the release of an RAIB investigation report.

On the evening of 10 February 2023, a Great Western Railway train struck debris on the track at Yarnton Road Bridge in the Oxford area. The debris came from the wingwall of the brick masonry over-line bridge.

The RAIB report is available online. Images reproduced here are either Crown Copyright 2024, in which case reproduction permitted, or as otherwise noted where use falls under fair dealing exceptions to copyright. There are further views in a BBC article. Others show remediation work in progress.

There were no injuries. The train was sufficiently damaged that passengers had to be transferred onto another unit.

The report details what I would describe as a story of process over understanding. Sadly, the conclusions don't grapple with that issue, instead recommending minor tweaks and extensions to process. The problems were compounded by inadequate records management.

Two past events are identified in the report as "previous occurrences of a similar character". One is the failure of a parapet above Edge Hill cutting, in which debris also landed on the track, and RAIB investigated. The other, collapse of an abutment at Lochburn Footbridge, I can find no details of. Google only seems to know about it from this report. It was the subject of an internal NR report only. It seems likely, from the little information given that again debris fell on or near the track.

It strikes me as odd that the several other recent masonry failures across the network are not even mentioned as potentially similar. Significant collapses at Carron Water, Nine Elms, and Plessey Viaduct, have been subject to internal NR investigations at most.

It seems that "train hits debris" is (unsurprisingly) a trigger for investigation, but masonry falling from an underline a railway structure isn't, even if it could have resulted in multiple fatalities or life-changing injuries. Is RAIB unconcerned about developing risk to the public around the railway from railway assets? If so, is this a blind spot or an issue of formal remit?

I've wondered about this before, so time to dig a bit deeper. (I get back to the main topic on page 4.) When I last looked I didn't find anything on the RAIB web site, but I can't have looked very hard as there it is at the top of the main page: "Our legislation and regulations".

So we have the Railways and Transport Safety Act 2003 (RTSA), and The Railways (Accident Investigation and Reporting) Regulations 2005, the latter being secondary legislation allowed for in the Act.

RTSA section 7 has that:

> *The Rail Accident Investigation Branch—*
>
> (a) *shall investigate any serious railway accident,*
>
> (b) *may investigate a non-serious railway accident or a railway incident, and*
>
> (c) *shall investigate a non-serious railway accident or a railway incident if required to do so by or in accordance with regulations made by the Secretary of State.*

RTSA section 2 defines railway accident (the "relevant to the operation of the railway" limitation here is interesting):

> *In this Part a reference to a railway accident or railway incident is a reference to an accident or incident which occurs on railway property in so far as it is or may be relevant to the operation of the railway.*

RTSA section 1 defines railway property:

> *"railway" means a railway or tramway within the meaning given by section 67 of the Transport and Works Act 1992 (c. 42), and*
>
> *"railway property" means anything which falls within the definition of "light maintenance depot", "network", "rolling stock", "station" or "track" in section 83 of the Railways Act 1993 (c. 43), or which falls within the equivalent of any those definitions in relation to a tramway.*

And we have to go to the Railways Act 1993 section 83 for the definition of "track":

> *"track" means any land or other property comprising the permanent way of any railway, taken together with the ballast, sleepers and metals laid thereon, whether or not the land or other property is also used for other purposes; and any reference to track includes a reference to—*
>
> (a) *any level crossings, bridges, viaducts, tunnels, culverts, retaining walls, or other structures used or to be used for the support of, or otherwise in connection with, track; and*
>
> (b) *any walls, fences or other structures bounding the railway or bounding any adjacent or adjoining property;*

The definition of "serious" is left to the secondary legislation.

> *(3) "Serious accident" means an accident involving a derailment or collision of rolling stock which has an obvious impact on railway safety regulation or management of safety and includes such an accident that results in—*
>
> (a) *the death of at least one person;*
>
> (b) *serious injuries to five or more persons; or*
>
> (c) *extensive damage to rolling stock, the infrastructure or the environment.*

Where does all that get us? The definition of track is oddly circular (track and any structures used in connection with track) but seems clear enough. The bridges, tunnels, wing walls and retaining walls that we might be interested in, whether under or over the line are certainly "railway property". Under-line structures support track. Over-line structures strangely depend on being used "in connection with" track, but they must count, and in any case will tend to drop masonry on the track so seem more likely to trigger investigations.

The clause "in so far as it is or may be relevant to the operation of the railway" is interesting. It seems to say that some serious accidents occurring on railway property could be excluded from investigation by RAIB as not "relevant to the operation of the railway". What is the test of relevance?

The definition of "serious" is open to interpretation in some senses but actually very narrow in scope. Only "an accident involving a derailment or collision of rolling stock" is included. I guess this is key: RAIB is legally uninterested if there was not or it is not perceived that there was likely to be a derailment or collision of rolling stock.

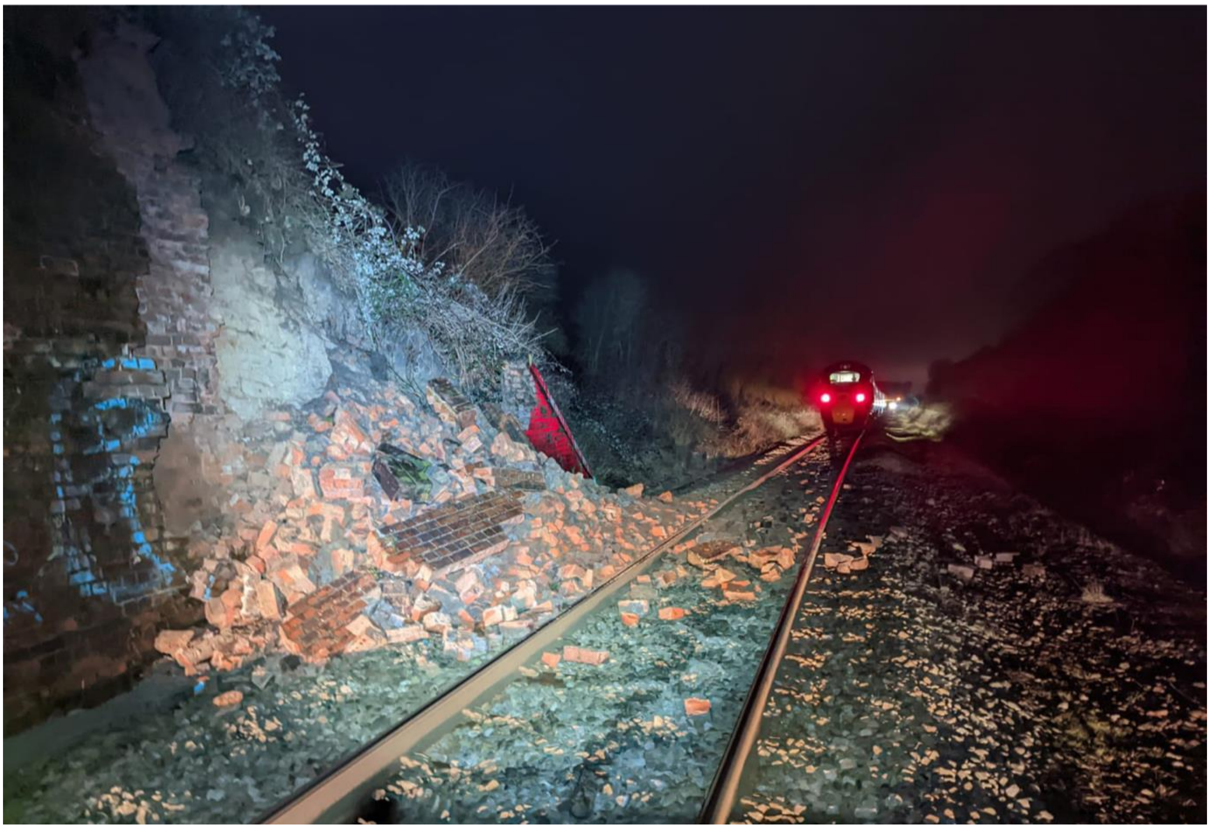
It is surely the case that the collapse of a spandrel wall on an open line, as at Carron Water, could lead to a derailment, so from the above it seems that RAIB could have chosen to investigate, and not doing so was a decision.

The Nine Elms collapse was triggered by construction work when the line was closed. It had an operational impact (delayed re-opening) but wasn't going to cause a derailment or extensive damage to rolling stock. There was certainly extensive damage to infrastructure. There could very easily have been deaths; these would have been of members of the public or construction workers, not passengers or operational workers on the railway.

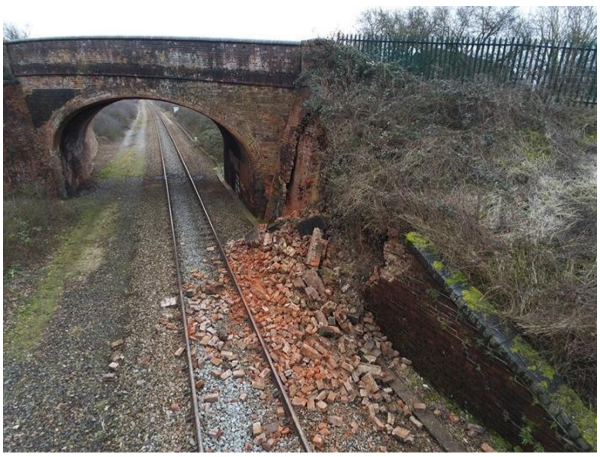
Would there have been an RAIB investigation had there been deaths? That isn't clear to me. If not RAIB, then who? This is the core of what troubles me about all this, and it doesn't trouble me any less after working through the legislation.

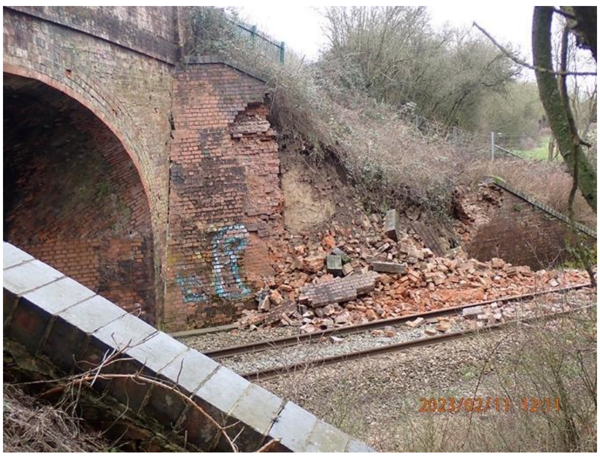
So there we are. The best we can hope for in response to events like collapsing spandrel walls is an internal, unpublished investigation from an organisation with an overriding interest in repairing the damage and re-opening the railway. The event at Yarnton Bridge got RAIB attention because there was an actual impact between rolling stock and the debris.

Back to the matter in hand. The immediate aftermath looked like this (photo credited to Network Rail).



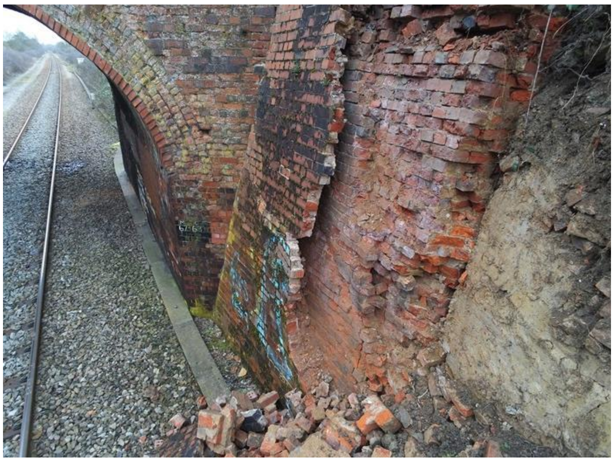
Two views from the following day show interesting features. To the left, a large void is visible between the outer skin of masonry and the wall behind. To the right, there is a very sharp, vertical break, with no remaining masonry to the right. The second of these features doesn't seem to be commented on by RAIB.





The exposed slope where the brick wall has completely collapsed seems to be largely intact. That is confirmed by RAIB, who note that there is no evidence of the collapse being driven by a large slip failure in the embankment.

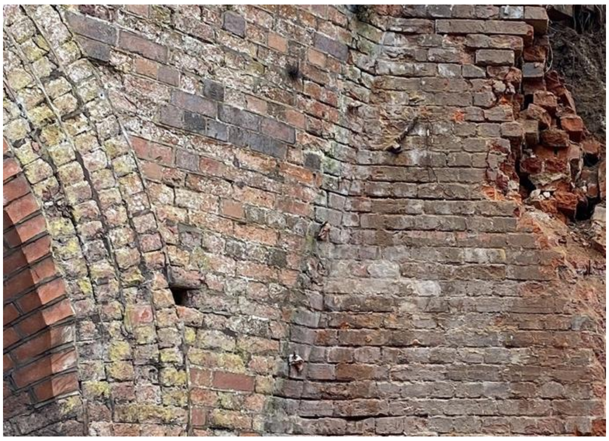
Closer views of the damage shortly after the collapse (below) show the scale of void behind the outer skin. Of course, the collapse itself will have tugged at the remaining masonry, so this void will be exaggerated. What is very clear is that there are only snap headers, and no bond between the half brick skin and the older masonry behind. That may not be the whole story, as the near part of the old wall has lost the top half brick. Whether this came down in this incident or previously is not remarked on; was the rubble properly examined?



It is not absolutely clear, but it seems to me that the thicker wall behind may have terminated at the near edge. The upper part above left looks like a relatively clean end, and seems to project back behind the cutting face in front. A line of deeper damage to the old masonry at the top of the frame needs explaining.

Exam reports recorded a "mitre fracture" between the wing wall and the bridge. This close up from one of the photos above shows the feature. This is clearly not a fracture, but a gap where there has never been any bond. That may have been understood by the examiners, but if so then the word "fracture" should not have been used. Note also the reskinned inner arch ring, with sloping coursing reflecting the substantial skew angle. The older brick ends do not look lozenged, suggesting that only the inner ring was laid in spiral courses, which is not uncommon.

With the remains of the later skin removed, we can see (below right, Network Rail photo) that the original wing wall was neatly bonded to the spandrel wall. There is little sign of a fracture here, though patch repairs may hide earlier damage. This brickwork is a lovely illustration of the attention to detail given to mundane structures at the time.



The exposed slope visible above and more clearly shown in photos of the stabilisation work suggests that the trackbed here is in slight cutting, perhaps into clay. The road presumably rises on made ground over this to clear the railway. It may be that the wing walls were considered only to support the made ground.

RAIB relate that, "Following the collapse of the wing wall, core holes were drilled in the other three wing walls... No other voids were found, but the thickness of the wing walls varied between 0.35 metres and 0.85 metres."

Questions that may have been addressed by the investigation, but probably would have been quoted by RAIB if they had been, include:

- Did the cores also reveal changes in brick, confirming similar two stage construction?
- Were cores taken into apparent headers to check for snap headers?
- Was the thicker masonry near to the bridge elevations, the shorter ones further out? Or was there some other pattern?

Cores into brick should always be converted into 9" brick units (in stone, feet). Those dimensions amount to 3.7 and 1.5 bricks respectively. The 3.7 could be a 3 brick thickness for the original wall, plus a half brick newer skin. The 1.5 could be a half brick skin over a 1 brick wall, or a complete 1.5 brick wall.

Was serious thought given to the questions coring was to address, and the pattern of coring that could do so? Much coring is under-specified, with too many decisions left to the coring contractors. The information obtained often cannot justify the damage done to obtain it.

Were the other wing wall faces of similar vintage to the one that collapsed (ie more recent than the bridge)? Do they all show the lack of bond in the corner indicating a new skin?

Regarding that inner, original section of wall, the part near the spandrel wall of the bridge exposed by the clear up looks quite sound, though the outer/upper parts are in poorer condition. In the last photo above we can see that the original (previously hidden) thick section of wing wall has been broken back. The wide photo taken later in the works shows that it was broken almost back to the spandrel wall. Was this necessary? What did it achieve? The spandrel wall has lost its buttress as a result.

What did the RAIB report conclude?

> *There are no record drawings for this bridge or many other similar bridges, which are of a largely generic and historic design.*

This is presented as fact, without comment on whether any/enough effort was made to locate drawings of this bridge or *of any other overbridge along the line or on other lines by the same engineer or contractor.*

The second part of the statement suggests a view that drawings probably never existed. That is simply false: contract drawings for the bridge type certainly existed. Given the skew, a bridge specific drawing seems likely. These may have been accessible on paper (though not necessarily easy to find) through to the formation of Railtrack. Sadly, at that point the archives were either destroyed or put beyond reach. The archive now consists largely of low-quality scans of bad microfiche copies, still only partially indexed. The cost of this, and the ongoing systematic underinvestment in archiving, is vast.

> *There is no record of repairs prior to 2013. Records post 2013 are also inadequate.*

The second part of that is a paraphrase. RAIB found that a repair undertaken was smaller than that initially proposed, but the change was not recorded.

It is likely that records of repairs were only ever partial, and this can't be corrected retrospectively. Such records as were kept in the past have suffered the same neglect as the original drawings. Archive requests for a bridge will sometimes turn up records of work, but it is extremely patchy.

The continuing failure to systematically archive detail of repairs and interventions to structures (design and as built) is a form of corporate negligence. The same is true of intrusive investigation results. It condemns future engineers to work in the same information vacuum as today's.

> *The wing wall had a hidden defect which meant that brickwork repairs were ineffective. / The [Network Rail] structures team did not understand the internal condition of the wall or the potential implications of deterioration.*

Both of these relate to the fact that the visible surface of the wall postdates the original structure, and some of it at least was a half-brick skin with snap headers, not attached to the older masonry behind.

RAIB state that examiners and engineers *assumed* that the wing wall was a contiguous structure. If true, this is alarming. Unbonded brick with snap headers was universal in brick patching over a significant part of the life of the railways. *Perhaps* things are better now: the NR standard detail for re-skinning indicates that bond should be achieved, but is this checked?

Regardless of current practice, anyone working with brick structures on the railway should be able to identify likely replacement brick, and should be looking for it. When a new brick skin is found the *assumption* should be that the re-skin is 4½ inches thick with no bond to the masonry behind, because this is both the conservative assumption and by far the most likely state.

In fact that this wasn't all re-cased/re-skinned masonry in the normal sense. Some of the new skin was simply built up in front of the existing masonry – without even properly removing the obsolete telegraph wire bracket first. Another part may have been new wall in front of cutting face. Inspection of the rubble could have clarified more but there is no record of this being done.

> *The most recent detailed examination could not be completed because part of the structure was hidden by vegetation.*

Deep sigh. Allowing vegetation to grow in masonry is the model of false economy, a theft from the future. But the resources wasted by examiners going to site only to report that significant parts of a structure could not be inspected (because of vegetation, or failure to arrange access to tenanted spaces, or …) should be a scandal. NCE could devote their FoI attention to this sort of thing rather than silly questions about the age of bridges compared to a modern design life.

> *The role performed by an examining engineer is dependent on the examiner's observations, measurements, and photographs. An examining engineer will often compare the most recent report with earlier reports as part of the review process, but this is made more difficult when photographs are taken from a range of locations and at different angles. Some recent reports include low-resolution photographs which can make fractures difficult to see and interpret.*

RAIB note that NR guidance issued as recently as 2017 *required* that exam report photograph sizes were reduced to below 150kB per photo. This was superseded in 2019 by NR/L3/CIV/006/2A, which does not require that photo quality is decimated, but also *does not require that it isn't.*

Low quality photographs in examination reports are pervasive. The quickest way to improve the value of examinations would be to reject as unfit for purpose exam reports with photographs that are out of focus, badly exposed, or compressed to the point that they contain no information.

> *The defect risk scores assigned in examination reports did not reflect the actual risk.*

This section questions the details of the scoring, but fails to tackle the fundamental issue, which is that risk scoring gives a spurious air of rigour to a deeply subjective process, and absolves asset engineers from making critical decisions. The problem here is not merely that the wrong score was given. It is that risk scoring is intrinsically broken.

The risk scoring process requires that *defects* are given two scores from 1-5: a likelihood and a consequence. The two numbers are then multiplied to produce a single value scale. Scores over a certain value are expected to trigger action; those below are not.

But neither of the component scales are remotely linear, and the result of multiplying them together is meaningless. An outcome that will certainly lead to public complaints is in no way comparable with one that has a low probability of causing fatalities, but these get the same risk score.

It is not defects that should be scored, but outcomes. Defects are symptoms of some underlying cause. Getting from defects, to the cause, to possible outcomes, to probability of occurrence and consequences requires *diagnosis*.

> *Reviewing the guidance for structures examiners so that photographs of masonry fractures included in examination reports are taken from a location*

perpendicular to the surface and that bulges are photographed at an oblique angle and from both sides where it is practical and safe to do so.

Few examination reports contain enough information even to robustly triage structures, let alone to diagnose. Issues with photo quality are discussed above. A deeper problem is that taking photographs that effectively show defects *and allow them to be understood* is near impossible.

Photogrammetry offers a solution to this. Building full, survey controlled photogrammetric models is a specialist activity – well worth it where a structure is showing signs of distress – but examiners should be trained and equipped to capture the photography needed to build local models of areas of concern during examinations. Models built from these photos would give engineers vastly more information than an inspection report. This one of Rugley Bridge was built from handheld photography from the ground and measurement with a laser disto capable of measuring 3D points. The data collection on site took 40 minutes.

Our Reveal 4D software, approaching a first commercial release, is designed to support diagnosis from such models.

Network Rail should develop and implement … a standardised and repeatable method for accurately measuring the shape of bulges in masonry walls that is suitable for use by structures examiners. …

"Measuring the shape of bulges" is the wrong focus. A bulge is rarely an isolated defect, and simply tracking its growth will not lead to a better understanding of the underlying cause or appropriate response. For walls like this where the collection of defects present clearly qualifies as *distress*, the requirement should be to capture the geometry and condition of the area of concern in a form that allows objective tracking of change, whether that is bulging, cracking, subsidence, or anything else visible at the surface.

It is also far from obvious that this should be done by examiners. The requirement is to capture the information that the engineer needs to make decisions about next steps. When there is enough concern about a wing wall to warrant high frequency inspection, it would be more valuable to send a team equipped to capture survey controlled photogrammetry, and get those models onto the engineers desk for review and comparison with earlier models, than to add to the stack of inspection reports.

But do we even need *a* method, or should there be a suite of tools? Can we get objective geometrical data from high throughput data capture, for example train mounted scanning? Perhaps the existing gauge scanning would be enough – sadly the data is locked up by commercial interests, blocking possible innovative applications.

Whatever the solutions look like, detecting structure movement in 2024 should not depend on examiners eyeballing and comparing with inadequate past photographs.

… This method should enable the likelihood of failure to be assessed with greater confidence and should define the actions to be taken in specific circumstances, such as identifying the trigger for additional monitoring.

Here we are again, wanting to reduce everything to a documented process. But the next issue won't fit the new process, and because the process has left no room for understanding, it won't be caught either.

What is monitoring? "Monitor" is used by examiners to mean "check this at each exam and compare with previous exam(s)". That use should be deprecated; it is a comfort blanket, as demonstrated by failures at structures under enhanced examination schedules. Sticking instruments on with the idea that ongoing movement might be detected (and disaster averted) is no better. Such equipment often fails or falls out of use before sufficient movement happens to be detected.

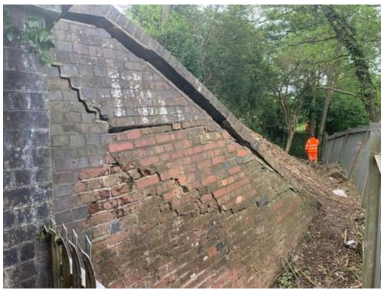
The real value of monitoring is not as an excuse to postpone action, but to *support diagnosis*. Monitoring can be key to distinguishing between different possible interpretations of damage. But to do so it must be deployed as part of a diagnostic process.

It is normal for monitoring contractors to be asked to "monitor this" with no real spec. To qualify as monitoring, there must be a design, and that design must build on a hypothesis of behaviour. The design will include detail of how the results will be visualised and interpreted; time series plots of variables are rarely adequate for interpretation of behaviour.

> *Infrastructure managers and examination contractors are reminded of the value of understanding whether a masonry fracture is stable. This requires a mechanism to accurately determine whether movement is occurring, for example, by installing tabs.*

Monitoring wasn't needed here to establish whether the cracks were stable. What process would result in all that cracking, then stop? Mortar tabs would have delivered nothing of value.

The question of "stability" is badly framed. The important questions are *what is the cause of the crack (or system of cracks and movement)*, and what is the nature and rate of movement. Cyclic or progressive? In which direction? Do we have time to think?



If there is thick mortar *and* an open crack, then movement has been going on for a long time and is ongoing. Why would it stop? As, for example, at Nuneham Viaduct (left, photo posted to LinkedIn several months before the recent emergency closure). How were those cracks interpreted when they were filled up with mortar, before they reopened as movement continued?

Monitoring for non-movement makes sense after a response has been implemented, but the monitoring approach will have to work over a very long timescale.

> *Network Rail should review the training and working practices associated with allocating risk scores and the examination report review process to ensure that defects affecting parts of structures which could present a direct risk to the railway in the event of collapse are given an appropriate defect risk matrix severity factor.*

Note that direct risk to the *public* (as from collapse of spandrel walls of urban under-line viaducts) is not mentioned.

Nor is the validity of the risk scoring approach questioned.

In summary, my big concerns are around what is not mentioned, or apparently considered.

- There is no mention of the safety of operatives undertaking examinations and investigations at structures such as this. For those doing repair work, this *may* be implicit in “consider how repair of masonry which is already in a poor condition is undertaken.”
- The is *no mention of diagnosis* by that or any other name. This is a gaping hole in the whole inspection and assessment system. It is routinely assumed that the appropriate response to cracks is to point or to repair by standard detail. But without diagnosis this is likely to be ineffective or harmful, and the belief that such repairs will be effective is dangerous.
- It is accepted without question that procedural systems like risk scoring and condition marking are effective, while the evidence presented shows them to be actively harmful, stripping out meaningful insight and understanding and replacing them with meaningless and often misleading numbers. The whole process of inspection and care for structures has been reduced to a handle turning procedure. It isn’t working. Fiddling at the edges by tweaking guidance will not solve this.
- Examination reports, including those with photographs of adequate quality, are incredibly low bandwidth. Examining engineers cannot make robust decisions about structures from them.
- Examiners are not generally engineers. The straitjacket of guidance that tries to make examination an objective process (itself an exercise in futility) actively discourages examiners from thinking about the significance of what they see. Examiners should be educated so they can participate in the triage process, not merely trained to record defects.
- Understanding of masonry is weak across the board. Engineering students are taught little if anything about masonry as a material, or how to think about its behaviour, and nothing about how masonry structures were built in the past.
- There is a dearth of diagnostic/forensic engineering skills in the industry. The process of reasoning about existing structures and structural pathology is very different from new building design. These skills are fundamental to good engineering generally, not least because little engineering truly avoids interfacing with existing structures. Yet degree courses do nothing to develop these skills.

This is much too long. As Blaise Pascal famously wrote, “I would have written a shorter letter, but I did not have the time.”

I will try to return to brief explorations of interesting bridges next month!