Bridge of the Month 144 December 2022

Rugley

AKC/99 Rugley Railway Bridge is part of the Historical Railways Estate, a collection of structures on disused railways now managed by National Highways, and subject of considerable press coverage in the last year or so. I was visiting friends near Rothbury in the Christmas holiday and took the opportunity to take a look.

The bridge is near Alnwick. The railway here runs in a cutting through rock. The cutting is only wide enough for a single track, but the bridge is wider, first impression is that it was built to allow twin track, perhaps because a modest additional cost kept the option of later widening open.

Following the winding course of the line away from Alnwick, we come to Edlingham viaduct, which in Google Maps measures around 14ft between parapets. So there were limits to the amounts the railway were prepared to pay for this future option.

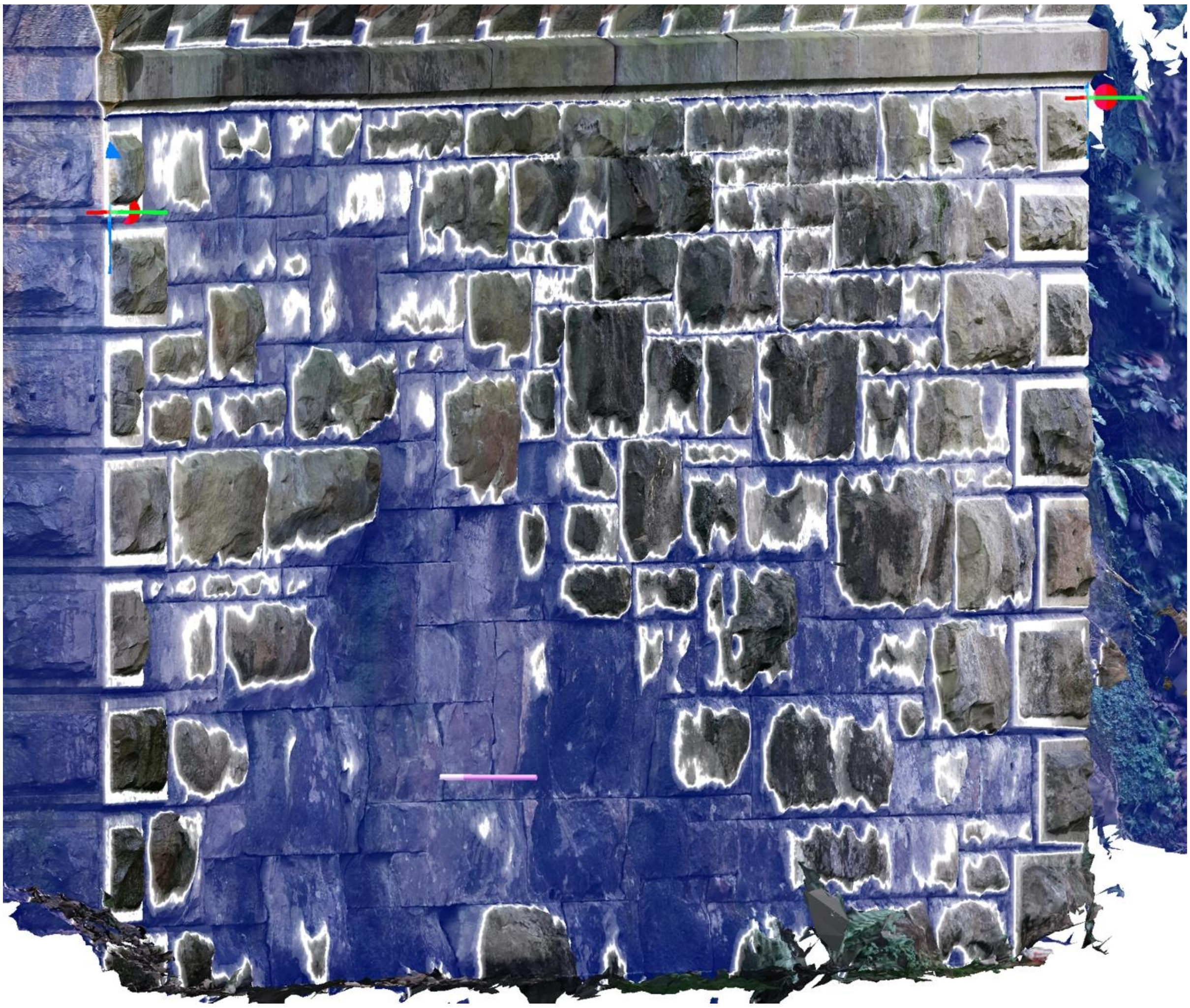
The bridge is well built from a mix of local sandstone and brick. The barrel is of a yellowish brick, presumably of good quality as it has suffered little surface deterioration. The barrel edges, abutments, spandrel walls and parapets are sandstone. Most of the stone is rusticated; the edge voussoirs and abutment quoins stand proud (of the brick ring, especially), and have dressed edges. The acute corners of the bridge are cut back, avoiding the otherwise sharp angles.

The wing walls are very small, as the bridge is built in rock cutting. It is interesting that, rather than springing from rock, the cutting was widened enough at the bridge site to build abutments. I wonder how thick the masonry is here, and how the gap from the rough cutting faces is filled?

It seems most likely that the backing is rubble concrete using material from the cutting. There is no clear evidence of backing level, but it isn't credible that there is none.

There is no sign of live load damage, and little sign of deterioration. The only visible area of damage is in the south abutment, where stones have spalled. It would be comforting to know why this has happened, but none of the fracture surfaces look fresh, the damage has not propagated into the arch ring.

Placing a plane across the south abutment face highlights the missing material. Perhaps a slight inward bow brought the front edges of the stone into bearing and caused the spalling.



An assessment report, commissioned by the council, has been made available by National Highways (the assessment was commissioned by the council). This report says “date unknown”, but we can correct that easily. The invaluable railway codes website tells us that AKC is the Alnwick and Cornhill Line. Googling for “Railway Alnwick Cornhill” indicates that this was also known as the “Cornhill Branch”, was a North Eastern Railway line. It was authorised by Parliament in 1882, construction started in 1884, and it opened in 1887. The road is present in the 1864 OS 6 inch map, and the bridge clearly present in the 1896 25 inch map, so the bridge was surely built with the railway in the mid 1880s.

The assessment concluded that the capacity was 3 tonnes ALL. The lane is no doubt lightly used, but it is certainly used by farm traffic. It has “not suitable for HGVs” signs at both ends, but no weight limit. The bridge will carry occasional axles over 3 tonnes. Given the condition, the capacity is evidently greater than 3 tonnes. That apparent anomaly was a motivation for this visit.

The geometry in the assessment report doesn’t stack up. The skew span is given as 11.05m (36.25ft), skew 11 degrees, and square span 10.8m (35.4ft). Neither span is likely as original geometry. Spans are typically whole feet. A half foot is conceivable, a quarter foot much less so. In any case, viewing on site it is clear that the geometry is circular in the square direction, so it is this span that should be sensible in feet.

Measuring on site I got 11.06m skew and 9.1m square. So where did the 10.8 come from? 11.05*cos(11 degrees)=10.84, so perhaps it was calculated, but since we agreed on the skew span, why is the measured square span so different? Measuring a square span exactly isn't easy, but any error in direction results in over-estimation not under. The 11 degree skew angle didn't seem right on site. An upward facing photo at the corner makes this clear. Measuring the angle in the photo says around 35 degrees. 11.05*cos(35 degrees)=9.05m, which is much closer to the measured span.

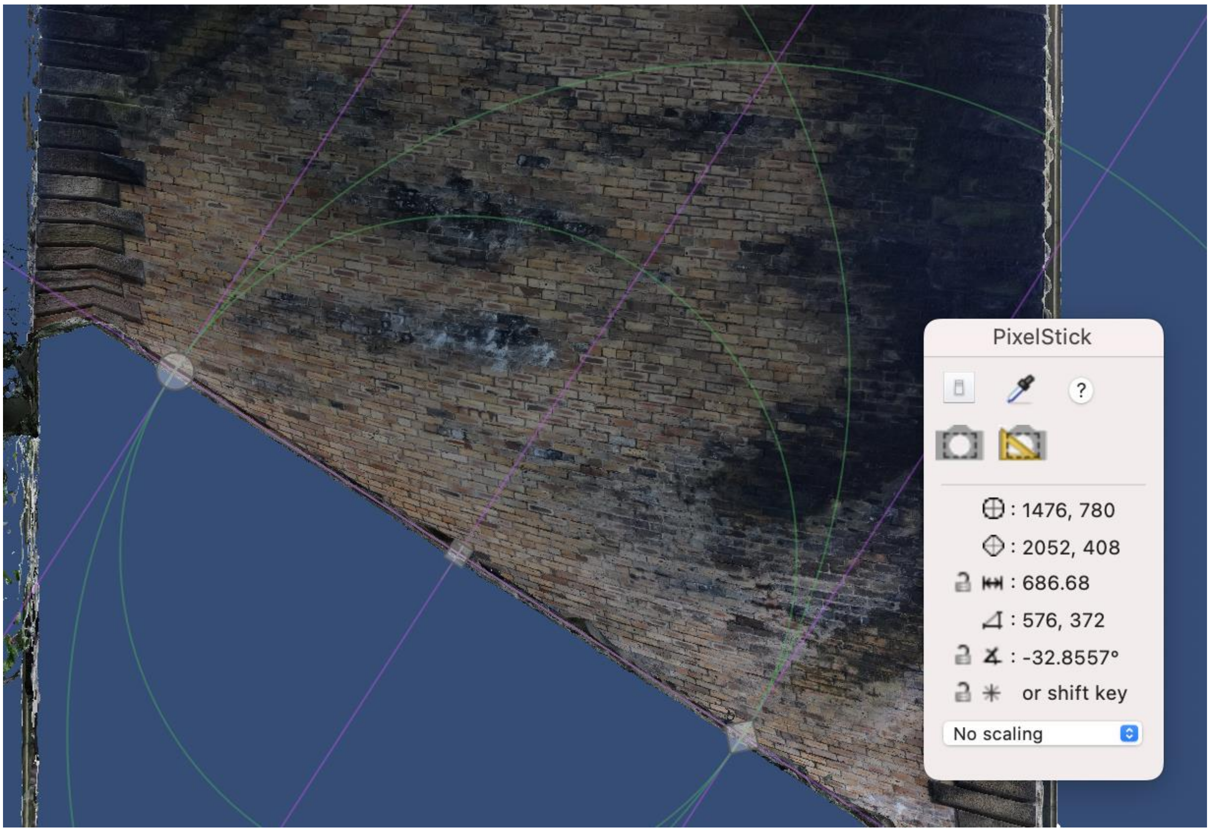
40 minutes on site was enough to collect the data required to build to a scaled 3D model of the soffit and abutments. That consists of 260 overlapping photos and seven 3D point measurements.

Photo quality beneath the bridge wasn't ideal as light was poor. Cover of the elevations was extremely limited. A fallen tree obscures one side, and all photos were looking up from ground level. Use of a pole camera would have allowed the elevation to be modelled, but light was fading, and the weather was too cold to ask family and friends to stand around while I did that.

The 3D point measurements were taken with a Leica disto S910, which functions like a low grade but much more portable total station. A few photos of the disto dot at each location allows the point coordinates to be fed in to control the 3D model. We can then take dimensions from the model with confidence.

The result is a good record, far better than any set of photographs could provide, and one that can answer a lot of questions. Find a version of the model, without the interrogation tools available in our Reveal 4D software, on Sketchfab.

From this we can resolve the geometry properly. First, the skew. Measuring in an upward orthographic view (I use the PixelStick app on the Mac for this), or aligning a vertical plane with the elevation and calculating the angle from the plane normal both give a skew angle of about 33 degrees.


PixelStick

: 1476, 780

: 2052, 408

: 686.68

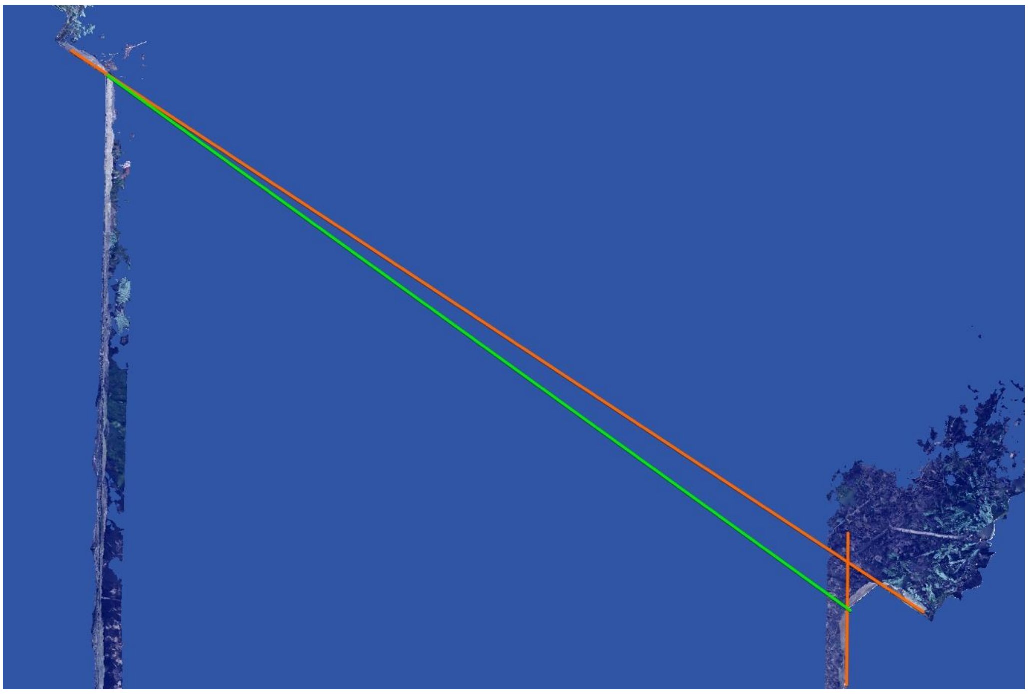
: 576, 372

: -32.8557°

or shift key

No scaling

The cross section square to the abutments looks like a circular section. The skew shape is confused by the chamfered corners. In fact, I realised at this point that these corners also confuse measurement of the skew span on site, both I and the inspectors had made a non-trivial error here. 11.05m is the measurement from the obtuse corner, to the *inner* corner of the chamfer. The true corner has been cut off, and the skew means that the error isn't negligible.



So even with the right skew, calculating the square span from this measurement won't get the right result.

In the model, the square span measures just shy of 30 feet. The rise measures slightly over 9 feet. 30ft span, 9ft rise gives a radius of 17ft, a nice round set of numbers, pretty convincing. The deviations are interesting, we would normally expect a rise slightly below design, and a span very slightly above, as the arch sags slightly on decentering. A 30ft (9.14m) span at 33 degrees skew gives a skew span of 10.90m.

Regarding the arch shape, the report states that the arch has a circular profile. This can only be true in one direction. It is crucial when taking dimensions from a skew bridge to determine whether the profile is circular on the skew or square lines. For over-line railway bridges, it was normal to use the same centres everywhere, set perpendicular to the track bed, and to build skew over these. This ensured the same loading gauge everywhere along the line with only one set of centres needed. As a result, we would expect a circular section square to the abutments.

A 2000 inspection reported a rise of 2.64m and quarter span rise of 2.25m. A 2008 inspection measured 2.76m and 2.19m, these latter measurements being used in the assessment. (It is neither possible nor useful to measure masonry to the nearest millimetre.)

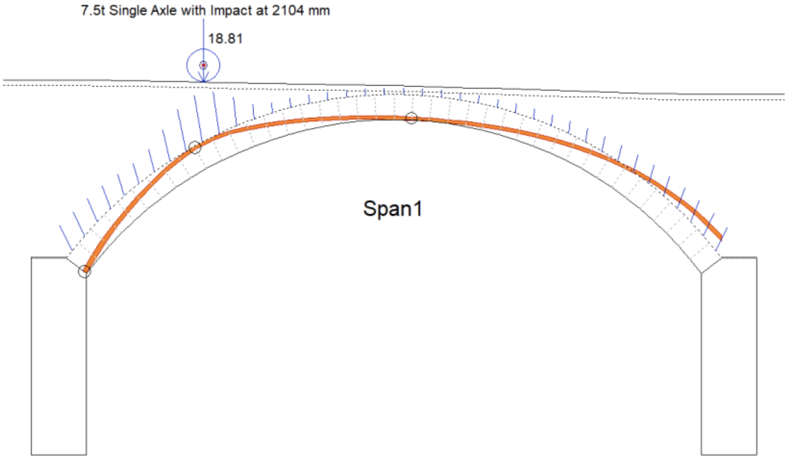
Rise in general, and quarter span rise in particular, is very difficult to measure in the field. It is often calculated. A reasonable approach if we know the geometry is segmental, but as we already found with the span measurements, we need some way of checking. Just taking the minimum number of measurements and calculating the rest isn't adequate.

Here, we find that *if we assume a segmental curve*, a span of 11.05m and rise of 2.76m gives a quarter span rise of 2.18m. But 11.05m is supposed to be the *skew* span – and isn't right, as discussed above. If we take the 30ft/9ft/17ft geometry, the quarter span rise would be 2.21m.

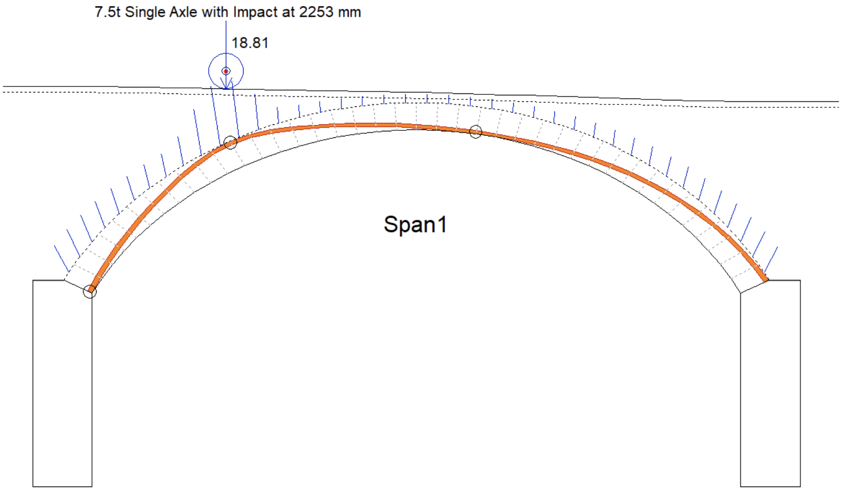
These corrections have a minor impact on the MEXE result, producing a very slightly lower provisional axle load. As always with MEXE, the result is dominated by the factors, to the point that the assessor can choose the result. The deprecation of MEXE in the new CIRIA C800 guidance is overdue.

But this assessment produced a lower result from Archie-M than from MEXE. It did that by assuming *no backing*. The conclusions note that using a "higher" level of backing would increase the capacity, but the rationale for choosing a backing height of zero is not given.

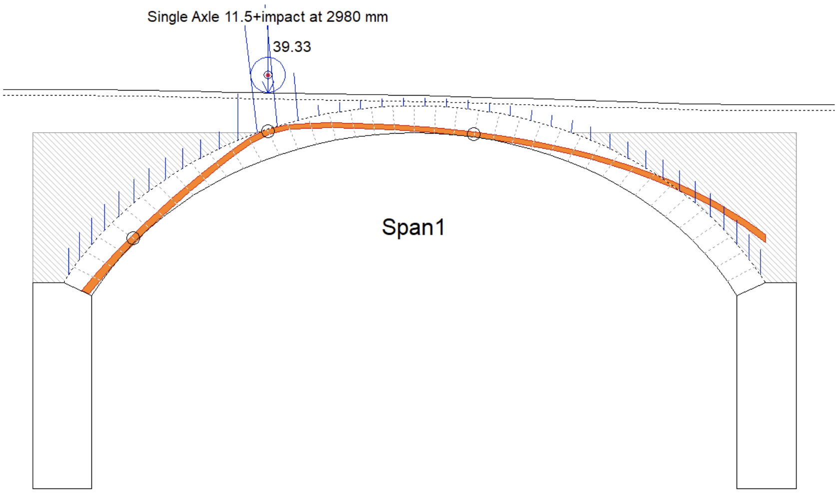
In general, single axles are the most onerous loads for masonry bridges. With geometry as used in the assessment, and no backing, the thrust from a 7.5tonne GVW single axle cannot be contained in the masonry. This is the case that led to a 3tonne GVW capacity.



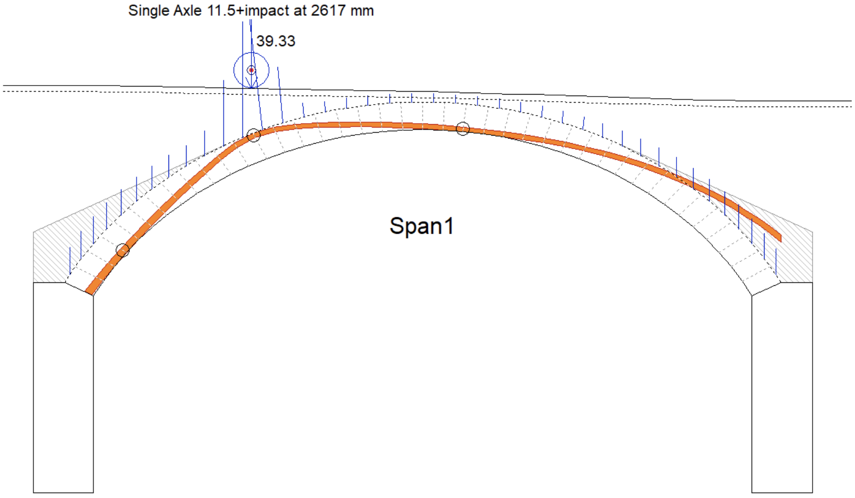
However, if we use closer to the correct geometry, the result is already different. Giving the square geometry of 9140mm span, 2740mm rise, circular segment, and asking Archie-M to apply the 33degree skew, we find that the thrust from the same 7.5tonne GVW load fits in the masonry of the ring.



The idea that there is no backing is not credible. If we add flat top backing to intrados crown level – one of the most common patterns – we see that even an 11.5tonne axle with impact is carried with the thrust in masonry. Rubble concrete backing would provide a stiff load path to the rock of the cutting.



Tangential backing, even implausibly steep, would still contain the thrust.



BD21/CS454 rules, sensibly applied, would probably pass this bridge for 44tonne lorries. Were it to experience frequent 11.5tonne axles, it might well start to show cumulative damage, but that would be a result of mechanisms not considered in the assessment code and models.

This is a fine bridge, well built and lightly used. It is clearly handling the traffic it carries with aplomb, and there is no reason to expect that traffic or the bridge's response to change.

Sensible calculation with correct geometry and reasonable assumptions also shows the capacity to be ample. Any "strengthening" would cause more harm than good. "In filling" would be pointless at best, harmful at worst, and a reckless waste of money and resources. Doing that with crushed virgin rock and cement is outrageous on several fronts, especially carbon.

The weaknesses in the treatment of geometry are very common. So too are unreasonably conservative assumptions about (the lack of) backing. This can't be blamed on the junior engineers doing the work, but it raises serious questions about the training of assessors and the purpose of checking.