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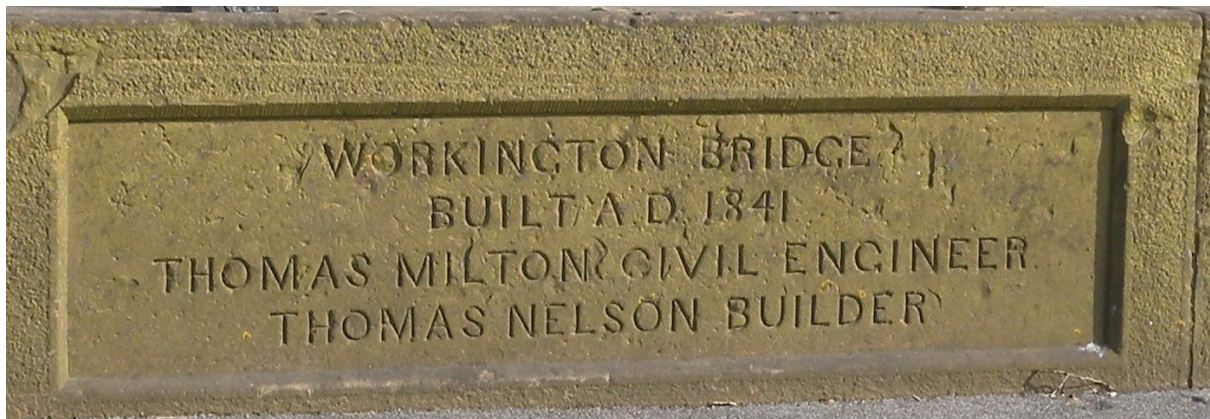
Calva bridge is both magnificent and common in that it is a typical mid 19th century structure. That is to say it is a thoroughly engineered construction. The interest here lies in the fact that its foundations were severely damaged by floods in November 2010. This note is chiefly about how it stood up until the engineers concerned were able to mobilise the effort to repair it. I will say nothing about those repairs because that is for others to describe. I hope they will bring forward a paper on the work.

The bridge is at <http://bit.ly/Calva1> on the river Derwent. The floods of November 2009 were spectacular. Double the flow of any other flood in 100 years. There are lots of pictures at <http://www.visitcumbria.com/workington-floods.htm>.



Here we see a very elegant structure of 3 spans each 48ft. The rise is almost certainly originally 12ft, though a little less now and the shape three centred which means the central radius is 48ft and the ends 9ft. In modern money that is 14.63m span, 3.66m rise and 2.74m end radius. To put this arch into Archie, use the three centred model and set the quarter span rise to 0.218x the span.

The plaque below proclaims the pride of the designer and builder and the date of construction. The material is very good quality old red sandstone with lime mortar.



The bridge was very badly damaged by scour in the flood on 19th-20th November 2009. The interesting thing so far as I am concerned the most interesting issue is how it stood up.

So, lets begin with the damage.



Here is a general view from the downstream side of the bridge with an inset showing the loss of support from the upstream end of the further pier. Look closely and you can also see a drop in the string course over that pier.

During the flood the water reached nearly to the crown of the arch, but it was almost certainly not the general flow that caused the trouble, but rather the cross flow caused by the river trying to change its channel slightly.



Here we can see erosion on the left bank of the river (to the right as it is flowing towards us). So the river came round the bend in the background swept across to the left bank and bouncing off that cut diagonally across the upstream end of the pier as can be seen by the river bed deposits here. The water flowed from right to left of the picture as the flow comes towards us.

So much for the causes. Now to the extent of the damage. The river scoured away its bed from the upstream end of the pier until the bridge was supported on just the downstream end.

Below is the most spectacular view showing the the bottom of the upstream end dropping into the scour hole. I estimate that only about 1/4 of the support remains.

A few more pictures then a look at the engineering.





Looking from the upstream side of the bridge it is obvious that there is damage to the arch as well as to the pier the horizontal split shows the near surface region of the road and the parapet spanning across two spans while the pier section is dropping away below. It seems that this arching action is also contributing considerably to the support of the central section of the right hand arch.

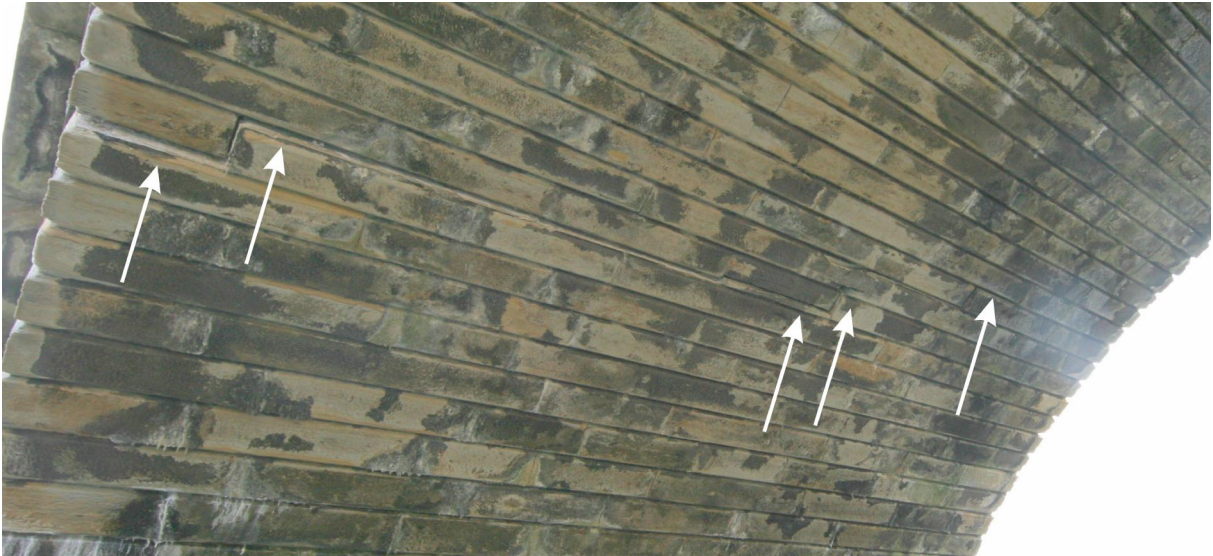
The enlarged view below shows how thrust from the upper elements can be brought to bear on the otherwise unsupported end of the main span section. The point at which the arch has split is a good indication of the extent of solid backing in the arch.



The two pictures below show the parapet lines. Upstream is to the right. The lean on the lamppost, directly over the pier is an indication of the movement that has taken place, but the drop is also evident in the parapet line. Much greater at the upstream side than downstream.

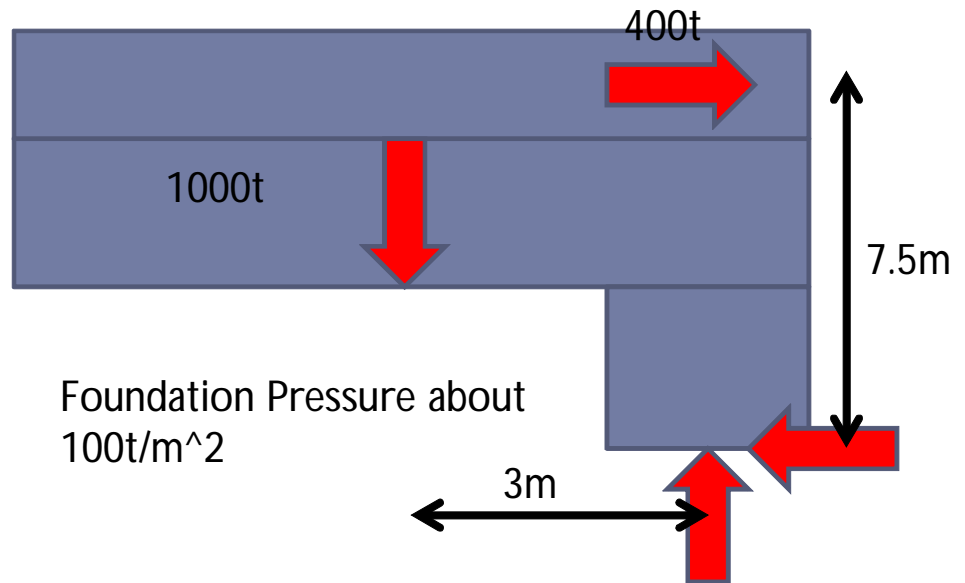


The picture below shows how the split extends across the arch soffit, tapering away to nothing, both in terms of opening and rotation about 1m from the downstream edge



Here we begin to see how the arch holds together and where the forces are transmitted.

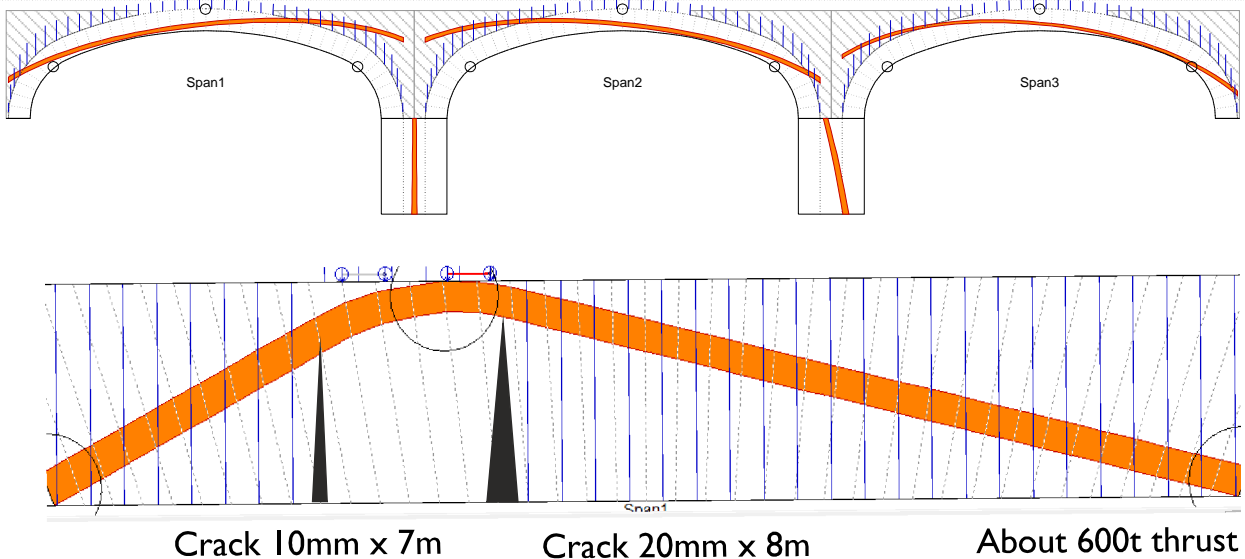
The vertical load on the pier is about 1000 tonnes. It is in the centre of the 30ft (9.14m) width and the only available vertical support is in the centre of the 25% of arch remaining so little more than 1m from the downstream edge. These two forces thus generate a couple of 1000 x say 3m or 3000 tonne metres. The bridge is standing, so it has found something to supply this missing moment. Shear on the river bed can provide one force but the second can only come from the deck arching in plan over three spans.



Here is a view of the cross section showing the forces applied and reactions required. So the question is: Where does the 400 tonnes come from.

The only possibility is arching action in plan and that can be investigated in Archie-M (<http://www.obvis.com>) with a bit of fiddling.

The picture below shows the whole bridge modelled as a flat arch in plan. "Self Weight" has been reduced to zero and the only loads are the four axles providing 100 tonnes each distributed over the width of the solid block of the arch haunches.



The 600tonne thrust is an addition to the basic arch thrust and is concentrated at the bottom corner of the abutment, being carried there by the arch thrust. At the right hand side there is

less need for concentration but at the left it is to be assumed that the abutment moved back plastically before developing this level of resistance. The crack widths are controlled by the eccentricity of the thrust at the edge of the solid pier block. The eccentricity reduces towards the abutments from this point and that ensures that the necessary rotations all occur in or about one joint.

The spalling seen below is caused by high compressive stresses in the parapet where it is arching over a wide gap



News

Archie-M The latest version of can be downloaded from: <http://bit.ly/BillH5>

Seminars and courses. Courses are run as a profit making concern by Bill Harvey Associates and need take £3000 to cover the costs so say 10 people at £300 each. The standard charge for Seminars, run as part of the support for Archie-M is £100 which is intended to cover costs only.

If you would like us to run a course (a full day intensive training) or a seminar (intended as an update on arch studies and Archie plus discussion between users) near you, please let Philip@obvis.com know.

Continuing thoughts about arches and Archie at <http://billharvey.typepad.com>

Moiré Tell Tales: High sensitivity, long range reading. <http://bit.ly/BillH6>