Bridge of the Month No71, November 2016
Moco Farm accommodation bridge 2

I'm a little late this month. My month of "holiday" in New Zealand turned out to be exceptionally busy. Flew into Heathrow on 30th Nov to freezing temperatures, straight from 23 degrees in Auckland. There will be things from that trip soon but in the meantime, back to Moco Farm and the real lift.

I note that last month's was also riddled with typos and I will try to go back and correct those in the archive version.

Other News

In my haste before going away I missed a few links from this section last month so here is a proper version.

Please note that we now have an email list for Archie users. If you make any use of Archie, please sign up to this and let any other users (and IT support) know too.

Following considerable discussion with Bill Smollett of Aecom and then with Katalin Andrasi of Mott MacDonald, there is a new, thoroughly tested SV load file for Archie and a note detailing how it was put together. Click the links to download those.

Zoltan is working on Version 2.6 of Archie (2.5.1 was a bug fix issued a couple of months ago). Hamish and Keith are working on version 3 when they get time between panic projects on monitoring. Version 3 has major improvements in functionality.

Hamish presented on hidden defects in masonry bridges at the BD&E Hidden Defects 2016 conference in Birmingham. We've put together a note covering the same ground.

Moco Farm Bridge Lift

So, what is involved in lifting an arch. The first task for me was to dispel misconceptions. The biggest of which is the all too common statement that *Arch bridges are brittle*. That is **JUST NOT TRUE** yet I see it and hear it so often. It does a real disservice to the bridges and to all the young engineers who work on them.

Prof Evans, who was on the point of retirement when he taught me in 1965/6 was at great pains that we should understand the way ductile structures could (and MUST) be built from the brittle concrete that was the universal structural material at that time. The same rules apply to masonry, though reinforcing is not the issue here but redundancy and plasticity.

Masonry is brittle in tension, but properly built it is much less so in compression because the softer mortar allows articulation without serious concentration of stress. Like this.

Masonry bridges are also thoroughly three-dimensional structures and can develop load paths that are very difficult to foresee but which, through plasticity, provide massive security. See for example BoM No 6 from 2011 on Calva Bridge.

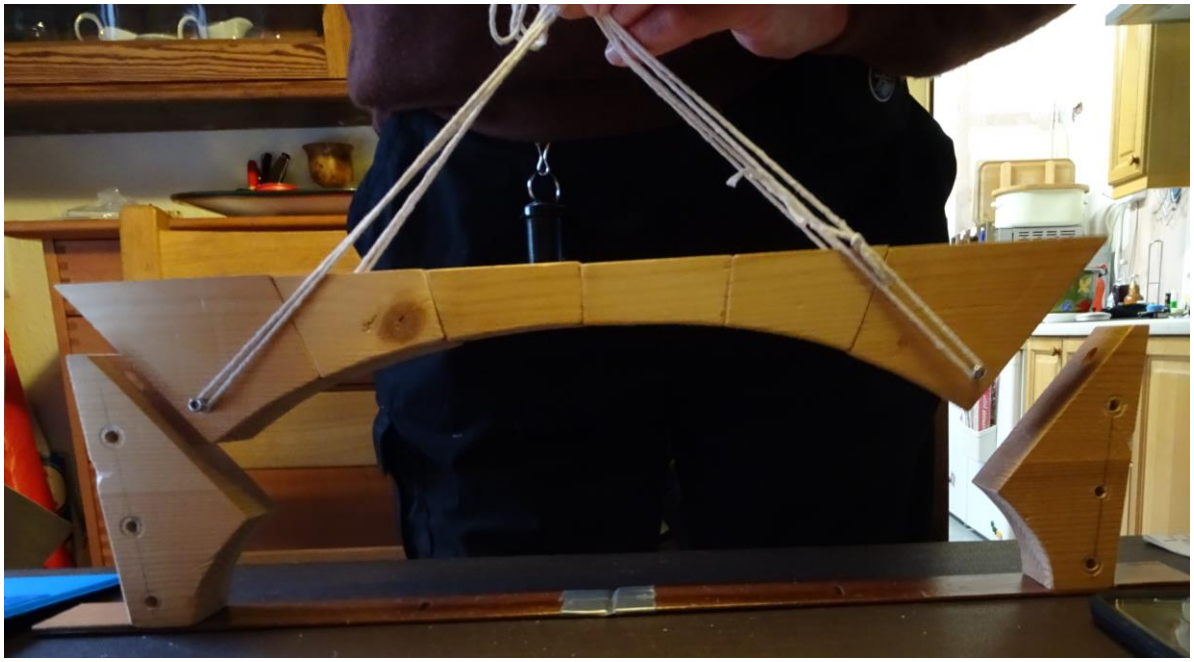
Of course, I also had to convince someone to do it. Freyssinet took that on and I am eternally grateful

The second major issue is the suggestion, repeated here, that the bridge (usually, wrongly, considered to be the arch) is desperately keen to resolve itself into component parts. Even very weak mortar has a tensile strength of perhaps 0.1MPa so suspending a material of 20kN/m3 from a mortar bed gives and allowable height of 5m if there are no stress concentrations. Mostly we are worried about odd bricks, perhaps 75mm thick, falling out, in which case only about 1/67 of the area of mortar need be sound. Of course that is not to say that entropy doesn't rule all. Building a bridge requires the input of energy ad as the energy leaks away the bridge turns back to dust, so it is NECESSARY to keep putting energy back in by way of maintenance.

Then there is the idea that any of the analyses in use today, from MEXE (which is pure, indefensible mumbo jumbo) to discrete element analysis (which requires data that is never available), have anything to tell us about behaviour in the conditions we are meeting here. See below for more thoughts about that.

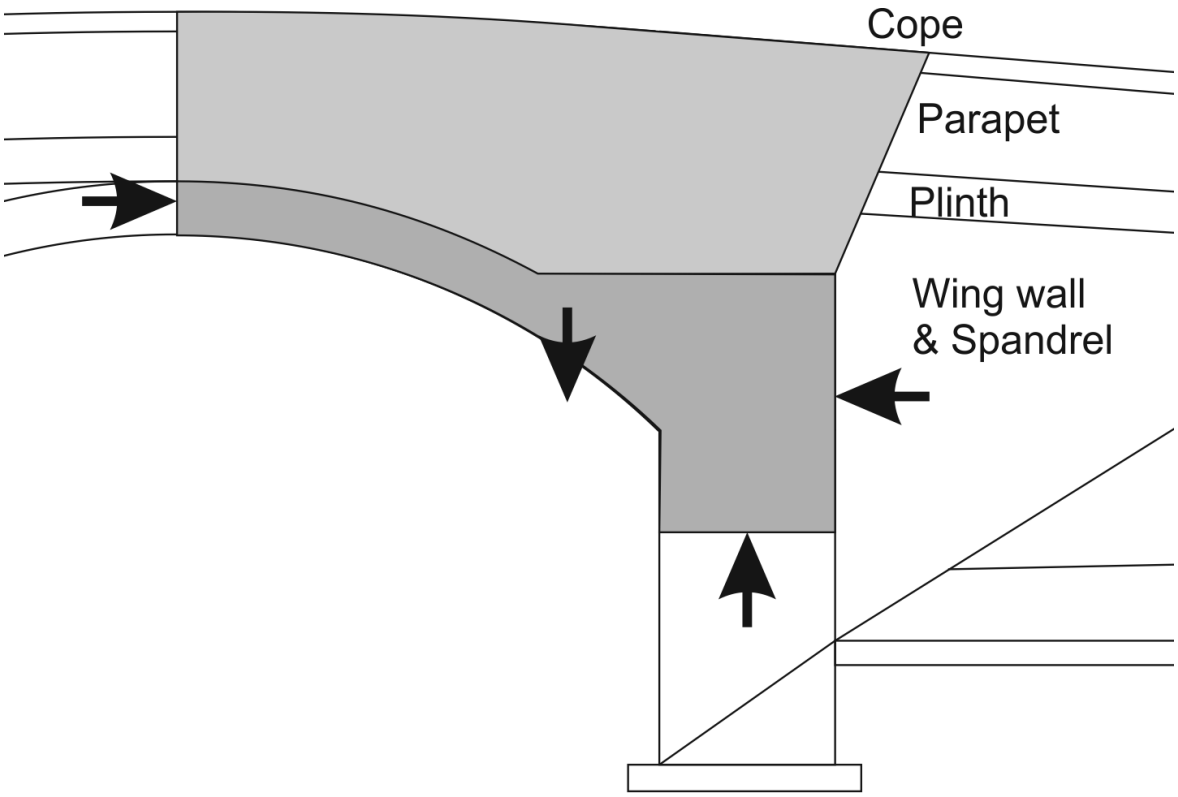
Basic analysis

This all began with a simple model showing that the arch is in stable equilibrium if lifted with ties in the right place and direction.



We cannot do effective 3D analysis but we can think logically about the processes involved and make reasonable engineering judgements. We began with the drawing, considered where we would cut the arch free and then looked at overall stability. That can be done in a very simple way because there are a limited number of points of potential failure. The question we need to answer is “for what range of vertical and horizontal reaction positions is the bridge stable?” Actually, there is one more factor in that system. The vertical reaction is fixed by gravity but the horizontal force can have a range of values for any position because the thrust at the arch crown has to stay in the arch but can be anywhere in the depth. So, we can do a simple calculation of stability based on a given set of positions of vertical reaction, horizontal reaction at the back of the abutment and horizontal force at the crown.

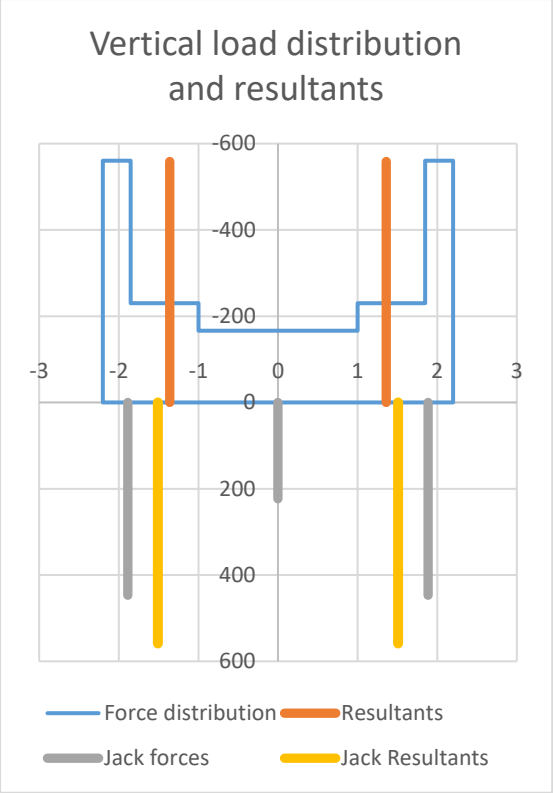
The unknowns in the system are considerable, though. If you look back to the cross section shown last month you will see that the edges of the arch have a raised section looking rather like a kerb, with a parapet sitting on top of that. The parapet and kerb certainly add weight to the system but what about structural stiffness and strength. And the answer to that is an engineering one. The parapet might disconnect by shear along a mortar bed but the weight will still have to be carried. If the split doesn’t occur (and we can show it to be unlikely) the result will be an increase in the range of horizontal thrust that can be applied at a given position, so we can put it in our back pocket as an additional safety factor and ignore it in the calculations. The extreme possible values are illustrated below.



Having done that basic calculation for the whole cut out section it is necessary to consider other directions.

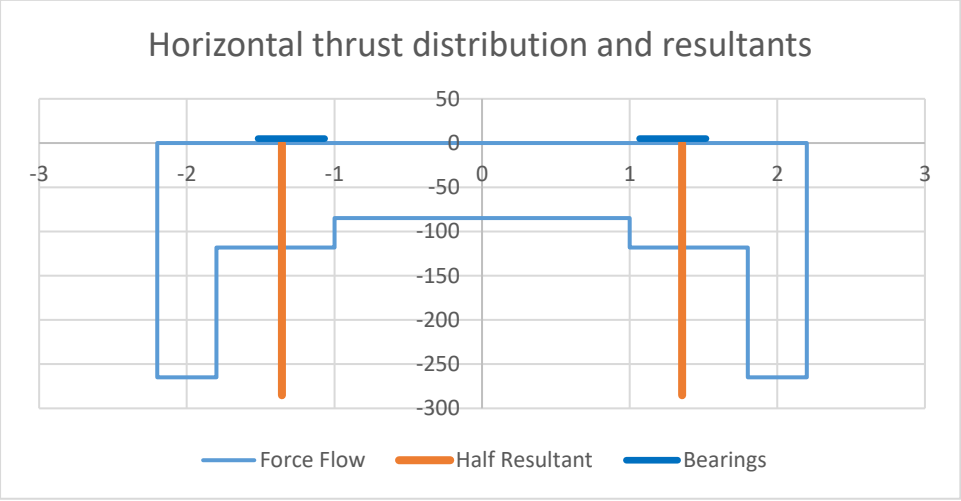
Looking first at vertical forces, they are to be supported on 5 jacks, two near each end of the abutment and one in the centre. The aim is to have identical loads on each. The distribution of forces is then presented here.

The distribution of the weight of the lifted part is concentrated towards the edges as shown below. The resultant of the forces in half the arch is shown, as is the jack positions and the resultant forces from the jacks. Forces in kN, distribution in kN/m width



A little transverse prestress was thought desirable to provide for the concentration of distributed load and the possibility of jack failures. That calculation was done based on the whole load sitting on any four jacks.

Then the horizontal forces are also distributed in a similar fashion.



Again, a little prestress allows the masonry to transfer the distributed load to concentrate on the bearings.

Cutting

The jacks and bearings need pockets and they were provided by coring.

These jacks are a new design from Enerpac, designed to be used for staged lifts. For the loads concerned, they could lift from the base plate by pushing the ram down, Ekki timber packs are then inserted under the plates, the ram retracted and itself packed then away it goes again.

Here are the vertical bearings in their cored slot. The aluminium is part of a monitoring system.

Then the large faces of masonry were cut through with a wire saw.

Lifting

The jacks are controlled by a computer system that balances load and travel. Each lift of 120mm took about 5 minutes followed by a little longer inserting the packers. For demonstration purposes, the suspended part was lifted 900mm before being set down at its 435mm final level. Here we see the bridge at nearly 800mm.

And to finish for this month here is a pic of the bridge set high above its abutments.

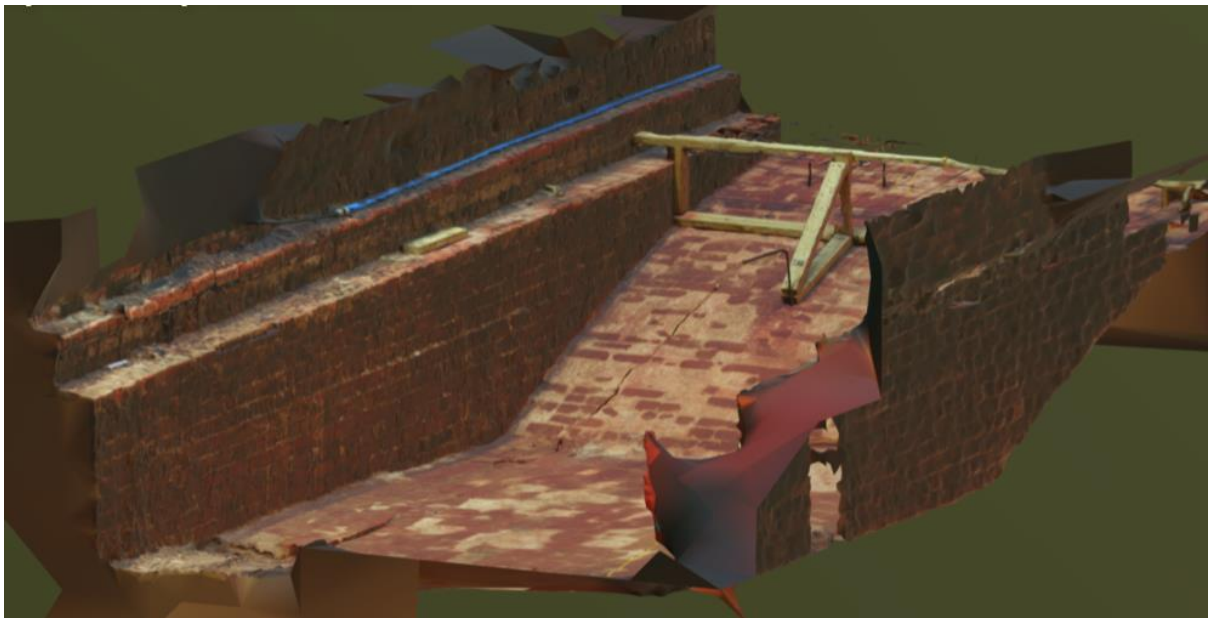
Next month I will look at the monitoring system and at some of the many lessons learned about masonry bridge construction. In the meantime you might be interested in the models here:

http://www.billharveyassociates.com/model-moco-farm-bridge

shows the whole bridge and is a 3D model which can be rotated, panned and zoomed. Here is a still.

And there is a detailed look at the corner cracks here

http://www.billharveyassociates.com/model-moco-farm-crack



These might not work in Chrome but seem fine in IE and Firefox, Oh and Safari and even Chrome on a phone??!