Bridge of the Month No4 April 2011
Telfords bridge at Over, Gloucester

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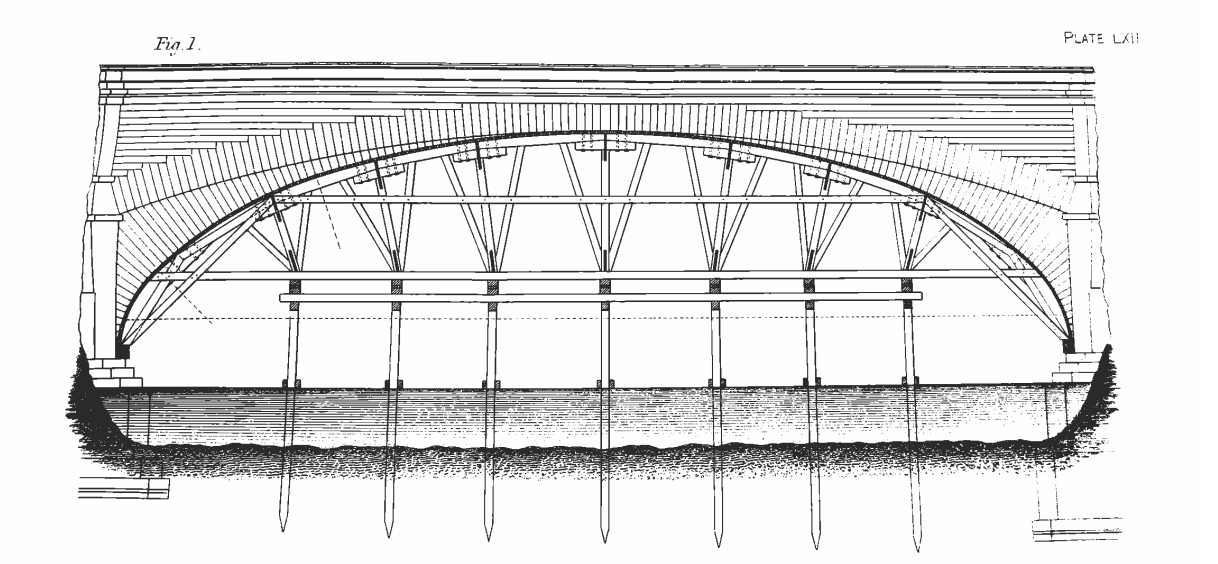
Telford's bridge over the Severn at Over, Gloucester.

There is a story that one abutment of this bridge moved dramatically when it was decentred, requiring a lot of expensive remedial work. Even in this wide angle shot the sag is visible so it seems likely that the story is true, but where did I see it. I had it down for Ted Ruddock's book (Arch Bridges and their Builders 1735 to 1835) but it is not there so I will need to turn to Rolt, I think. And then I found Telford's own account which says not so...
Anyway, the bridge is at: http://bit.ly/OverBridge.

The initial dimensions of the bridge were 150ft span and 35ft rise (45.72m span, 10.67m rise). The basic arch is described as semi elliptical (but see below), but the face is cut back from a flat circular curve of 13ft rise. This is a style used by Perronet in 1768 which Telford knew, at least, from his copy of Perronet's book (Construire des Ponts au XVIIIe Ciecle) which still resides in the ICE library. (Copies can be had for about £4500 or a Facsimile was produced by the Ponts et Chaussées, so my copy cost me £45).
Telford's centre is very simple and rigid provided the piles didn't sink. Note that this drawing shows two inclined dashed lines at the left which indicate a 5 centred arch!



It is recorded that the crown of the arch dropped 10" (250mm) on decentring. Telford declared this to be a result of penny pinching on the abutments and the evidence of movement there is very obvious. The picture below shows the downstream, left hand wing wall which has sunk considerably and been made up to level in several tapered layers, especially at the top.

The core of this bridge is hollow, like the Dean Bridge in Edinburgh built a few years later, or the rather earlier Dunkeld bridge. There would, however, have been a solid masonry backing perhaps to the level of the second radius change from the end. Any settlement due to abutment spread would then be concentrated in the length between these points.Tthe photograph along the parapet line suggest that is the case.

And having written all that I find that the ICE Virtual Library has Telford's engineering autobiography scanned and available for download with a full description of the bridge. He describes it as semi-elliptical so perhaps he is right. What is rather wonderful, though is a letter from his contractor in which he describes in detail how he made and erected the centres. I will copy that below and then return to the main construction.

CENTERING FOR GLOUCESTER OVER BRIDGE.
EXTRACT of LETTER from Mr. *Cargill* to Mr. *Telford,* dated Gloucester, March 26, 1832.

In constructing the centering (*see* Plate 63) for this bridge, I first laid a platform perfectly level and a little larger than the centering which was to be made; I then struck it out the full size upon this platform, firmly fixing centres to the different radii. The timber was Dantzic, being much harder and of larger dimensions than Memel, and mostly fifteen inches square. The iron straps were also of the best iron. The piles upon which the centre was to stand were then driven ; they were of Memel timber, with wrought-iron shoes, and caps framed upon their tops to the proper height; upon these caps were laid another tier of beams lengthways of the centre one under each rib; upon these beams were fixed

the wedges, which were of three thicknesses; the bottom one being bolted down to these beams, the tongue (or driving piece in the middle) being of oak and well hooped at the driving end, the top side of the upper piece was laid perfectly level and strait, both transverse and longitudinally; the wedges were rubbed with soft soap and black lead before they were laid upon each other. Each rib of the centre was then brought and put together upon a scaffold made upon the top of these wedge-pieces, and lifted up whole by means of two barges in the river and two cranes on shore. The scaffold was extended thirty feet, beyond the striking end of the wedges to lay the last ribs upon previous to raising, also to stand upon for finally striking. After the ribs were properly braced, they were covered with the four-inch sheeting piles which had been used in the cofferdams. That this centre was well suited to the purpose is known by its not sinking more than one inch when we keyed the arch. My greatest dread was the coal-boats which trade on the Ledbury Canal, forced adrift by floods in the Severn, and striking against the centre before we could close the arch. To prevent mischief of this kind, I drove the piles for extending the up-stream side of the scaffold (or rather of the platform on which it was originally constructed) very firmly into the clay, so that they might resist the stroke of a boat before she could touch any of the supports of the centering.

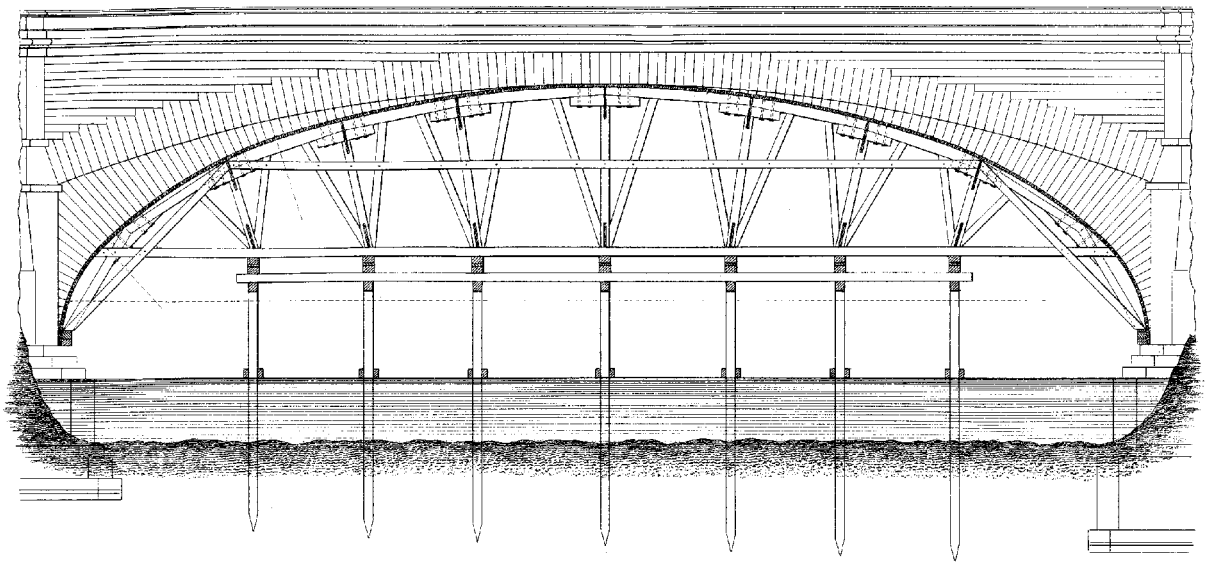
In the month of December, when within twenty feet of closing the arch, a very high flood being in the Severn, two of these boats loaded with coal came, adrift, struck the outside piles, which were Memel logs, broke two of them, then sunk against the main hearing piles which supported the centre, one boat upon the top of the other. These boats, being seventy feet long, raised a considerable head of water over them, and lay there until the flood subsided, which was many weeks; had not these upper guard-piles weakened the shock, I believe the whole centre and arch would have been destroyed.

When the spandril-walls were built up to two courses below the crown of the arch, and the internal brick walls to the same height,—we struck the centre, which was done by placing beams upon the top of the work, directly over the. ends of the wedges; to these beams successively was fixed a tackle, to which (at the lower end) was slung the heavy ram (with which we drove the piles) with tail-ropes fixed to it, and slung exactly, so as to strike in its swinging (when pulled back) the driving end of the tongue piece of the wedge. This ram of 12 cwt., when pulled back by eight men, and two men to pull it forward, gave a most tremendous blow, yet twenty or thirty blows were requisite before we could perceive the wedges to move; but after they once moved, they slid themselves, and we put in pieces to stop them going farther than was required. The whole time of striking, I think, did not exceed three hours, although we had the ram to remove and the tackle to refix at every set of wedges. I was much afraid that no force we could bring against these wedges would move them under such a weight as the entire arch, they being themselves a heavy body, and it was no small joy to see this effected so easily.

I am persuaded no wedges placed in the usual way could have been disengaged, as no force could be brought to act upon them sufficient for that purpose. We then disengaged the covering, (which it will be remembered was composed of sleeting piles from the cofferdam), and let down the ribs as they were put up, took them to pieces and carried them ashore. The whole of the bearing piles were then drawn by two levers (each made of two forty-feet logs) and strong chains; every pile was drawn, and although the expense was considerable, they paid well for the labour.

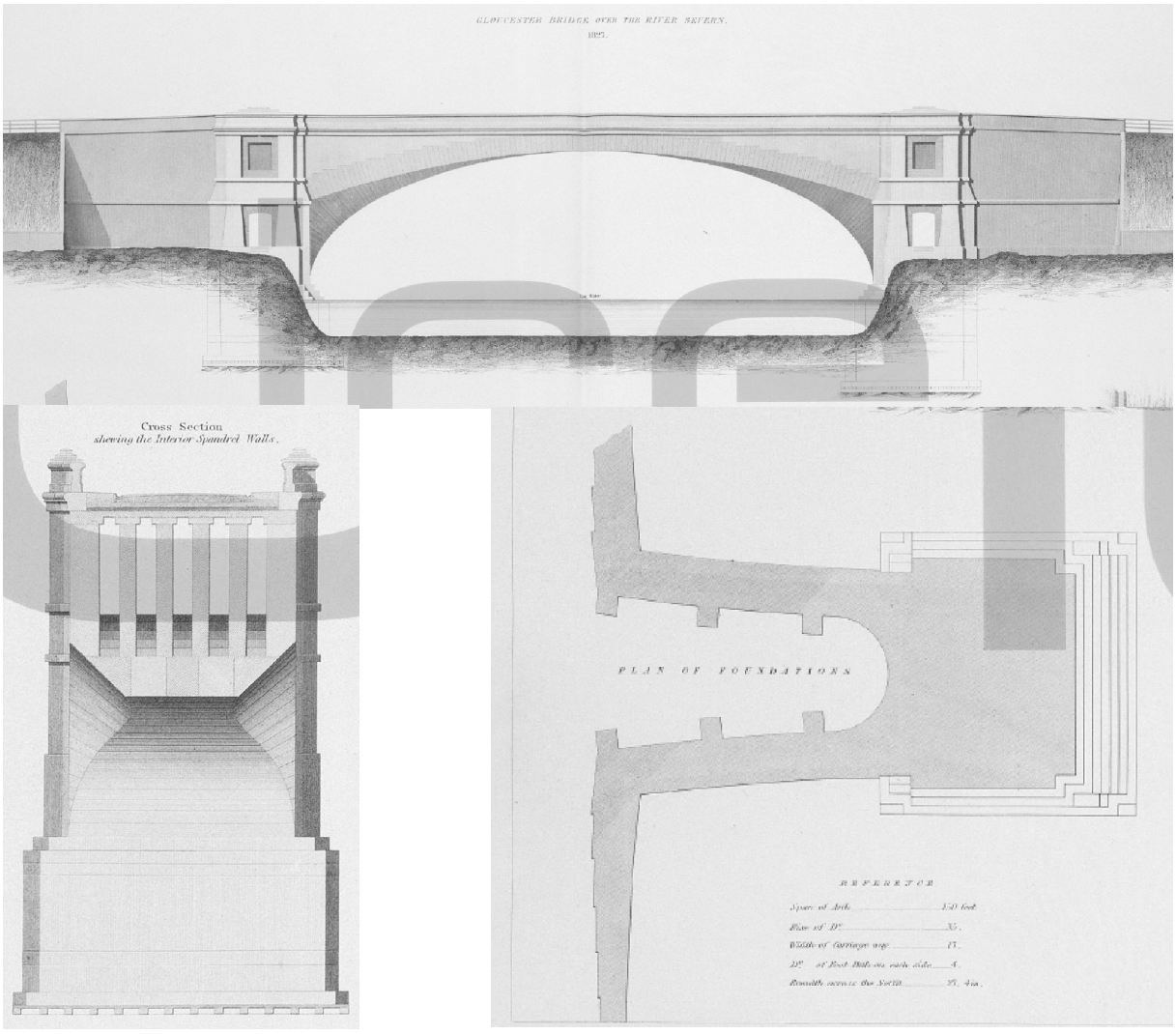
And now back to the bridge itself. In the volume, Telford describes the construction with spandril walls 3ft6in (1066mm) and four internal walls of 2ft (609mm) The over all width is 27ft 4in (8331mm) so the five voids are each just under 2ft 6in which is a very strange dimension but probably results from its relation to other aspects of the geometry. Telford's own drawings, taken from the ICE scan, are shown overleaf.

Fig. 1.



Centring of Over Bridge Gloucester.

This drawing of the centre is taken from The Modern Carpenter and Joiner rather tha Telford's drawing.



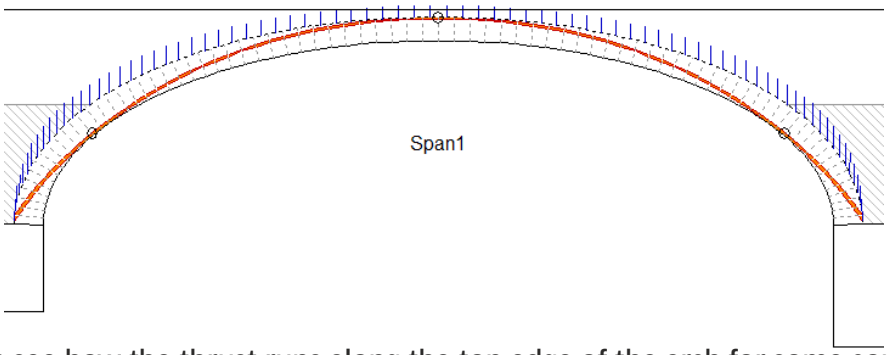
Of the abutment movement and arch sag, Telford said:

When the centering was removed, and the whole weight of the arch left to press against the abutments, its crown sunk about two inches, and afterwards, from the before-mentioned receding of the eastern wing-walls, the arch suffered a further depression of eight inches, making, in the whole, 10 inches. The arches of the Neuilly Bridge, of only 128 English feet, sunk 13 inches when the centering was lowered, and afterwards 10$_{1/2}$ inches more, making 23$_{1/2}$ inches; and that the sinking of Gloucester arch of 150 feet span took place from the pressure upon the upper part of the eastern abutment, when deprived of the resistance of the wing-walls, is evident from the front not having sunk, and the courses of the stone feeing towards the river remaining quite level. On the western side of the river, the abutment and walls, being upon firmer ground, remain unmoved.

This picture suggests rather more than 250mm sag. As does the elevation on page 1.

A close look at the arch near the crown shows longitudinal splitting of the voussoirs. This is the result of a high concentration of compressive stress along a long run of the extrados. The arch, as the abutment spread, tended to open at every joint. The top edge then tended to

become close to uniformly stressed (plastic stress levels) with zero stress below and the voussoirs split along the division. The thrust picture from Archie, below, shows



Here we can see how the thrust runs along the top edge of the arch for some considerable distance. This means that there is little out of balance moment across the width of a voussoir and the arch will bend by small cracks in each joint rather than one big one in the centre. As you can see in the photogaph, the split in the voussoirs near mid span corresponds closely to the area where the thrust line runs parallel to the extrados.

In all of this, perhaps the most interesting thing is the description of the construction and striking of the centring, not least the size of the timbers available in the days when there were still forests of pitch pine in Northern Europe and Scandinavia.

As a footnote, though, given the trouble that ensued from abutment movement, it is interesting to see that when the bridge was bypassed, the embankment behind the east abutment was cut back short leaving it much less well supported than originally. I wonder what the factor of safety is now?

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.

Dates:

· York Seminar 10th May

Book at http://bit.ly/BillH4

Lectures also in Zurich 19th May and Vienna 23rd.

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

Bill is also giving seminars in Zurich, Vienna and Munich in late May and talking to the local ICE branch in Cheltenham on 22nd March