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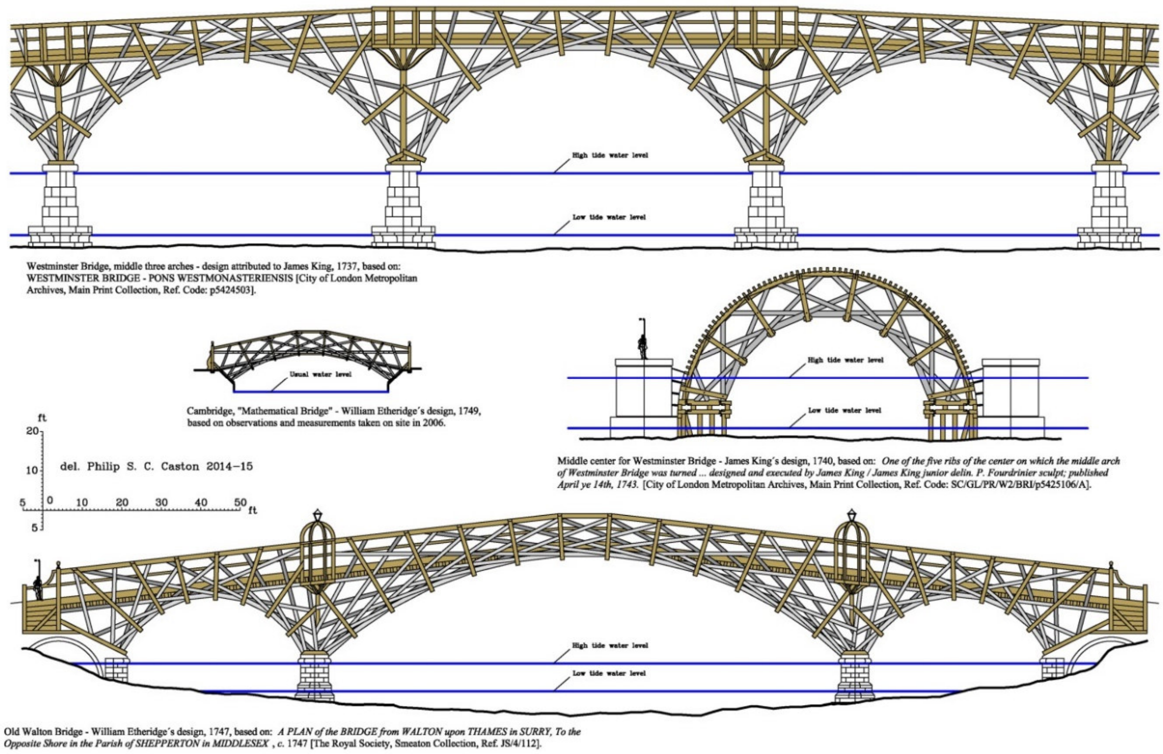
Mathematical Bridges

“*Mathematical Bridge*” over the river Cam at Queens’ College, Cambridge University, England (Image Copyright: Caston).

The construction of mathematical bridges is based on an underlying geometrical pattern. The term is generally applied to wooden bridges with criss-crossing structural elements in their main supporting frames as can be seen in the small foot bridge at Queens’ College, Cambridge. This principle was also applied to some centring in the 18th C. The geometry of these structures is based upon a circle, which is divided up radially from the centre point into sectors. Beams laid out along the edges of the sectors are called “*radials*” as they radiate out from the centre. The other defining element of this construction is the remaining beams which all touch theoretical circles based on the same single radial centre point and match their slopes (i.e. are tangents). These are called “*tangents*” and are aligned to sector centre lines. The resultant intertwining mass of beams are thus geometrically ordered and repeat the same junctions/connections around the circle.

There are limits to this web of radials and tangents which form an inner circular boundary and an outer boundary where the tangents cannot cross each other anymore. Mathematical bridge frames use the inner boundary, where the beams are closest together, as the underside to form a solid arch. James King (d. 1744) and William Etheridge (b. 1709 – d. 1776) used the idea of weaving the tangents in their mathematical bridge designs.



Design for the *Westminster Bridge*, London; *Mathematical Bridge*, Cambridge and the Old Walton Bridge, Surrey/Middlesex all used woven tangents (Image Copyright: Caston).

The tangents are woven together to form a truss, but as the timbers are not flexible enough to be pulled through the truss's flat plane another way of assembly had to be found. The solution chosen involves splitting the weave along the plane to form two layers. The tangents are broken up along their length in to sections that are either in one plane or the other. Where the tangent changes layer sections on either side overlap and are joined together with dowels. In this way the sections can be attached to the whole from one side or the other. When the dowels are in place the sections lockup to form a woven tangent.

Each tangent section is not entirely on "its side" of the plane. A quarter of its thickness lies on the other side. At the overlaps the two adjoining sections therefore physically intersect by one half thickness allowing for a stepped or tabled joint.

What are the challenges of actually building this design? Without the resources to build a mathematical bridge as a full-scale physical replica, we looked at two possible avenues to understand the problems involved. The first was a digital 3D-Model, which had the advantage being able to see all the complex joints, but had the disadvantage of being detached from the real world. The second was to build a scaled model out of a physical material and experiment directly with it. Having completed a model of the "Mathematical Bridge" at Queens College in 2013, we have now moved on to the "Old Walton Bridge", which we started in 2017 and is still under construction.

Old Walton Bridge. Model at a scale of 1:20 in the model workshop. To help stabilise the two main trusses during assembly, temporary supports have been added under the apex of each arch. Even so it is only the mortice-and-tenon-joints that stop then from tipping over. This problem will only be resolved when the arch cross beams connect the two main trusses with the central spine in the final stages of the erection. Did the framers experience that problem as well and did they plan their supports in advance for it? (Image Copyright Caston).

Articles related to mathematical bridges

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