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Mainly on the subject of Bridges

Development in Early Iron Bridges. The earliest substantial use of iron in bridges rests with the Chinese in suspension bridges of iron chains, with wooden decks laid directly on the chains. One is recorded as dating from the early days of the Han dynasty (200 BC). However problematical the documentation of such bridges in Asia some of these structures – with as many as twenty chains – certainly deserve the description of 'iron bridges'. Spans are recorded as much as 400 ft, capable of carrying four horsemen abreast.

At the time that wider knowledge of China was filtering through to Europe 'Machinae Novae' (Fausti Verantii c1590) depicted various applications of iron in bridges ,but the real basis of these or any contemporary application is unknown. The Winch footbridge in Durham, 1741, was of the Chinese form but no other 'early' ones have been confirmed in Britain , although an example now exists in Ireland.

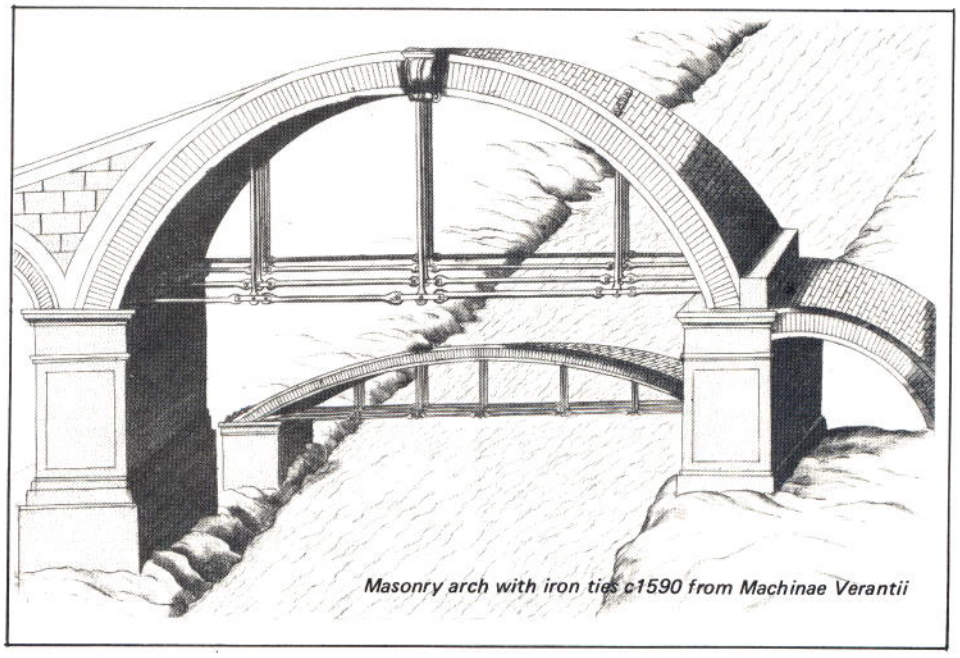
An iron arch bridge was attempted at Lyon in 1755 ,but was apparently abandoned after the casting of one rib as being too expensive. Although there is one reference to there having been several iron bridges before Ironbridge no details were given, and only one record is known, in the ***Leeds Intelligencer*** of 2nd January 1770. This reported on a 72 foot bridge at Kirklees Hall in Yorkshire, and gives the first name which can be associated with anything more than a proposal, in Maurice Tobin, an iron founder of Leeds. This structure has now been given real substance by research[1] which shows the 6' wide arch supported by two posts into the ornamental river which it crosses. These may have been provided to give lateral support to the slender structure rather than to break up the span, but either way it poses many questions as an exercise in ornamental ironwork for the knowledge and experience required in its undertaking.

Within a decade two substantial bridges were under construction, this time by men whose experience was more towards the 'heavy end' of engineering. At Preens Eddy ,not far from the Ironbridge site ,two spans of iron ribs were used to support a wooden deck and the bridge was finished in 1780. Probably the ribs represented the largest units which could be conveniently cast and handled, but at Ironbridge this was not the case. Here the money, knowledge ,and will, came together for the first time under Abraham Darby to provide for an iron bridge that required even the furnaces to be enlarged – and the erection of half ribs weighing nearly six tons.

The development of a design in iron for the Severn span by Thomas Pritchard is now well known, from a segmental iron vault supporting masonry to the multiribbed spandrel structure which is clearly represented in the existing bridge. Pritchard had the better engineering solution in a bridge of relatively low rise, but this was abandoned to provide the stone arch proportions or Ironbridge giving clearance for vessels on the Severn. This form, and its setting, promptly caught the imagination of public and artists, but perhaps inhibited engineers, for the bridge was copied only in a few European examples. Despite this Ironbridge – 'the first built of iron only' as the Coalbrookdale founders described it, with iron baseplates ,iron ribs ,iron connections, iron deckplates and railings and even iron slag for the roadway, was the springing point from which the first stream of iron bridge construction flowed.

A second stream originated with Tom Paine (of the 'Rights of Man' pamphlet). Before succumbing to politics, Paine had produced several models for iron bridges and left his adopted country to obtain backing in England and France. The only results of much original work were a 90 foot arch rib at the Walker family ironworks at Rotherham, and a 100 or 110 foot trial span erected at the Yorkshire Stingo (a pub) in Paddington. Paine's design was a series of short curved wrought iron bars, separated vertically by cast iron connecting pieces, to form arch ribs of very low rise. Had Paine continued to press his ideas there is no doubt that the course of iron bridge construction would have been radically different. His concepts were substantially more advanced than those followed and his arch ribs only slightly removed from girders, while the components of his bridges were small and easily transportable.

There remains of Paine's work his 1788 Patent, and a drawing 'Paine's drawing' in the Science Museum, its provenance not detailed but probably prepared by him in explaining his ideas to the Walkers. A drawing in the Sir John Soane Museum, definitely not by Paine, shows the application of his form of structure to the Wear Bridge site at Sunderland. Before the Ironbridge stream could be carried further by Telford at Buildwas, and Paine's ideas could be reconsidered by Rowland Burdon for the Wear Bridge, a small girder footbridge was built over the Glamorgan Canal at Rhydicar (1794). The 25 foot span beams acted as parapets and supported cross members for the deck at the bottom. This design, which was repeated



Masonry arch with iron ties c1590 from Machinae Verantii

locally, seems to be the earliest iron girder so far noted. 1795 saw the resilient John Nash managing to have an iron bridge of his design fail, and the first of the small bridges cast at Coalbrookdale with circular spandrel infill was completed.

Buildwas and the Wear Bridge were both completed in 1796. The line of development from the Wear Bridge is much shorter than that deriving through Telford and is conveniently dealt with first. At 236 foot span it was only once exceeded by a cast iron arch and when built was exceeded only by the timber bridges at Reichenau and Wettingen (and some suspension bridges in Asia!) Credit for its design has often been accorded to Tom Paine, but he left England hurriedly in 1791 and had no direct part in it. Burdon thoroughly investigated all the possibilities, including masonry. When advised against a 200 foot span in masonry he must have turned to Paine's design, for the Ironbridge solid ribs would have been difficult to apply to a span over twice as long, and he probably had material and models available at the Walkers to study, including the Stingo span.

In the Soane papers there is an account from Mr Foulds (later concerned with the construction of London Bridge) in the sum of five guineas 'To Sunday attendances to meet Dr Hutton and Mr Soane at Lambeth and Scotland Yard to examine the model of a bridge 200 feet span and to give his opinion thereon', dated January 7 1793. Fould did not get paid for eighteen months but a copy report, probably his although not credited reads – 'I shall venture to make some observations on my friend Thos Paine's Patent Iron Bridge' and goes on to criticise the insufficient quantity of iron, the corrosion of wrought iron in a marine environment (!?) recommending cast, and the low rise. These were precisely the measures which were adopted on the Wear Bridge and to facilitate them Burdon determined on a voussoir construction (an invention to which his associate Wilson later confirmed he had no claim). All of these were in fact retrogressive steps, but taken by Burdon apparently on the basis of much expert opinion, and Paine's wrought iron bars which might have contributed to a major step forward were used as strapping for Burdon's voussoirs.[2] Circles were used in the spandrels making the bridge almost a large second generation Coalbrookdale bridge except for the short voussoirs, and lacking the iron deck plates of its predecessor.

Thomas Wilson took up the system, but was singularly unfortunate or inept in his abutments for bridges at Yarm and Staines failed, but an 1810 bridge at Tickford, Newport Pagnell, remains as a testimony to his efforts to establish himself as a bridge engineer.

At Buildwas, Telford adopted the solid rib system from the Coalbrookdale bridge with variations which, unwittingly, brought him closer to the early design by Pritchard. When he later saw these designs Telford realised ,and acknowledged ,the original contribution which they had made. In using a rise which was much less than that at Iron bridge Telford came into disagreement with its founders. He was already moving from dependence on the ironfounders' ideas and for the iron aqueduct at Longdon-on-Tern also in 1796 he employed the Ketley iron works. This was completed only a month after a very similar smaller structure for the Holmes aqueduct near Derby, for which William Jessop was probably the engineer.

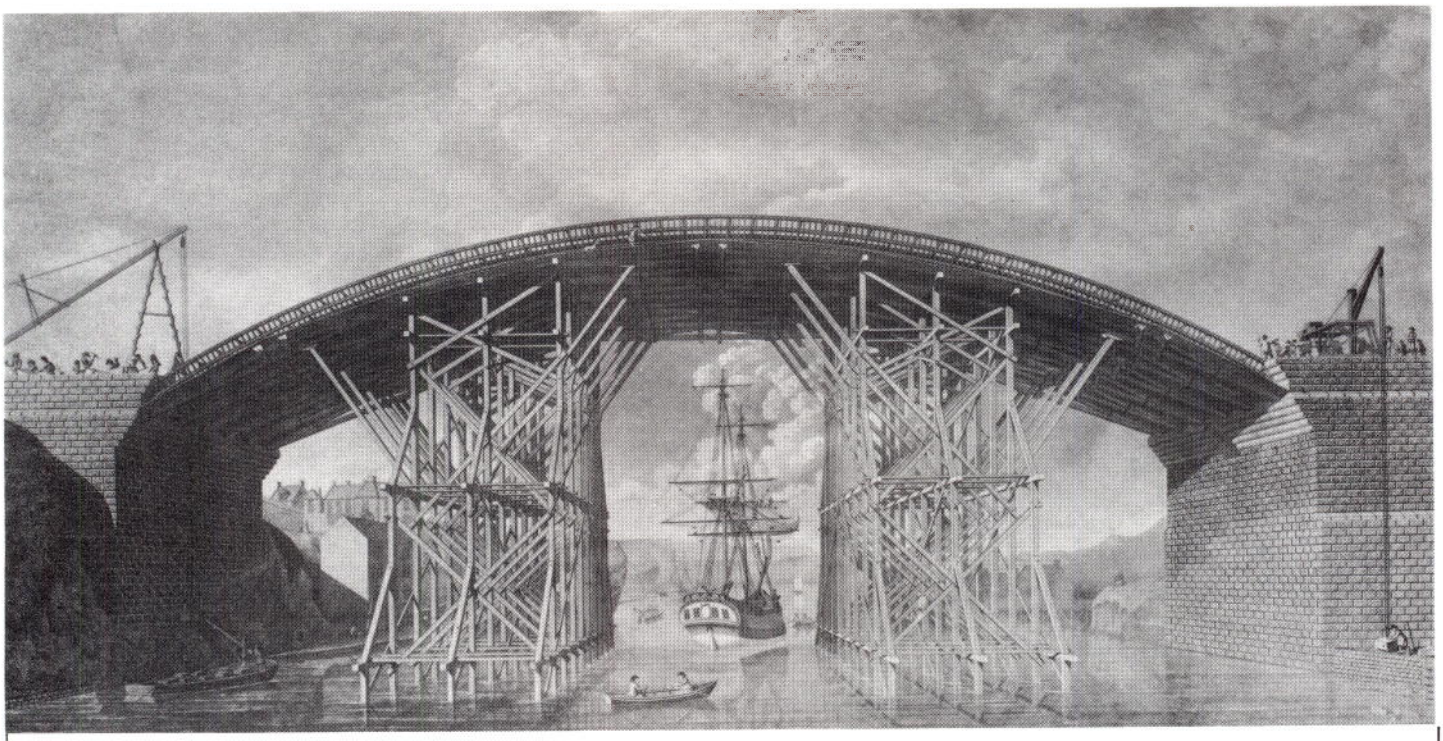
At this time Telford had designed a cast iron structure for Cysylte, remarkably similar to the form of the later railway viaducts. What reasons determined the final form of Cysylte are not known but its 1805 arches for the aqueduct were much in advance of equivalent spans up to that time.

In a second design for the 600 foot span proposal for London Bridge (1801) Telford's fully worked out ideas can be seen. This was the arrangement which typified his later bridges , Bonar Bridge in 1812 being the first of these . The 'lattice' arch ribs were made in units as long as the isolated location allowed. They were braced together not only by diaphragms at the end of each unit, but also by case lattice units across the extrades of the arch. In addition bracing between the spandrels up to the iron deck plates level ensured that the design could have been used with confidence for the spans entertained for London and the Menai Straits.

Thus in 30 years from Ironbridge ,Telford had refined the iron arch virtually as far as it was possible to go. The line of development which was basically through the Walker foundry ceased about the same time. The firm itself was ruined by Rennie's Southwark Bridge (1819) which was in some respects closer to Telford's practice.

The next step involved going back to wrought iron. This had already been taken by Finlay in 1801 in suspension bridges, and the advance to Menai was even more rapid. The use of a suspended deck with an arch was suggested in 1796 (it was also depicted on a Roman medal). It was adopted by George Leather with the Monk Bridge over the River Aire in 1827 allowing the broader application of the arch form.

Only the humble girder bridge had failed to make such progress. Its time was just beginning.



East view of the cast iron bridge over the River Wear at Sunderland 1796

1 Northcliffe D: A preliminary report on the Kirklees Iron Bridge of 1769 and its builder (Yorkshire Archaeological Society 1979).

2 Ruddock, Ted: Arch Bridges and their Builders 1735 – 1835 (Cambridge 1979).

Alan Butcher ***Science Museum***

Paine's 1788 drawing from the Science Museum

Pont-y-Cafnau: the first iron railway bridge and aqueduct? In the modern Merthyr of shopping precincts and car parks remains Pont-y-Cafnau or 'the bridge of troughs' (SO 0376 0713), a delightful and unique combined aqueduct and tramroad bridge of cast-iron set in a secluded site just below the confluence of the Taff and the Taff Fechan. Since surveying and recording the structure in the course of our work on the 'Industrial Survey' of Glamorgan for RCAM we have become aware of its considerable importance in a national context, and since the retirement of Douglas Hague from the Commission, Steve Hughes has continued research into its history and to its influences on better known bridges.

This iron bridge was built between January and June 1793 to carry an edge-railway and a water-channel taking limestone and water-power respectively to the Cyfarthfa Ironworks. A contractor could not be found to build the railroad nor would the Glamorganshire Canal Company agree to do so. It therefore fell unexpectedly on the Cyfarthfa Works management under Richard Crawshay to construct this overdue line. To carry this over the River Taff, Watkin George, the chief works engineer, seems to have adapted a king-post roof truss design. The main frame cradling the possibly secondary water-trough is held together entirely by the use of mortice and tenon and dovetail joints (Watkin George was a former carpenter). The bridge span of 14.2 metres (47 feet) is identical to that of the long gone 'old forge' roof at Cyfarthfa that Watkin George probably reconstructed at the same time.

A second stage of the 'old forge' reconstruction was roofed by cast-iron trusses with a central circular bracing fulfilling the function of a king-post over arched cast-iron collar-beams. The influence of its design can still be seen in the 7.5 metres (24'5") span of the arcades supporting the roof of the Crawshays' Treforest Tinplate Works Blacksmiths' Shop (ST 0877 8800) of 1833.

The Shropshire ironmaster William Reynolds sketched Pont-y-Cafnau in 1794 and in March 1795 Telford records with reference to Longdon-on-Tern Aqueduct that its 'Principles of construction and the manner in which it should be executed were referred to Mr William Reynolds' and himself. In the same month Reynolds was testing to destruction what appears to have been an erection of iron-beams based on the form of Pont-y-Cafnau. The design of Longdon-on-Tern Iron Aqueduct was basically of (mock-) timber inclined supports as observed on Pont-y-Cafnau supporting a flat (mock-) masonry arch composed of wedge-shaped sections (voussoirs). This was entirely appropriate as the deck was designed by Thomas Telford the mason, and the supports seem to be based on the earlier design by Watkin George the carpenter. Longdon-on-Tern was of course to be the prototype for the spectacular Pont-Cysyllte aqueduct near Llangollen..

In 1795 the railroad carried over Pont-y-Cafnau was extended twice more over the Taff on a line from the main Cyfarthfa Works site to the Glamorganshire Canal. A second bridge was cast from the Pont-y-Cafnau patterns and erected over the Taff at the main works site. (It is particularly poignant that this may have been demolished as late as the 1960s.) A third bridge then carried the railroad back over the Taff to the canal basin on the lower Cyfarthfa Works site. A sketch of 1798 shows this third span to have been a slender cast-iron arch both supporting and suspending a deck (ie a 'through-arch' bridge) in the manner of Telford's more elaborate Buildwas Bridge. This arch spanned about 16.5 metres (54 feet) and the reason a third set of Pont-y-Cafnau castings was not used may have been because the bridge already existed to give access to ironworks land acquired in 1783.

Watkin George may also have been responsible for the 7.3 metres (24 feet) span (ST 0489 0520) with mortice and tenon joints that until recently stood over the dry bed of the Glamorganshire Canal at Rhyd-y-Car in Merthyr. A bridge at this point was erected to link Cyfarthfa Ironworks land sometime between 1790 and 1814. The Crawshays were by a large margin the biggest shareholders on the canal and by 1800 Watkin George was already associated with the canal's engineering. The open parapets of Rhyd-y-Car each form a rectangular truss internally divided into a triangular framework by struts anchoring the frame to an integral segmental arch. This bears a family resemblance to the parapet-trusses (with through-arches) on the lower Cyfarthfa Works site. By 1813 a bridge somewhat resembling the Rhyd-y-Car Bridge also existed over the narrower Morlais Brook.

The fish-bellied deck-beams and a section of one of the parapet-trusses of Rhyd-y-Car Bridge were recently smashed by heavy lorries despite its being a 'listed' monument. Fortunately John Owen, the manager of British Steel's Dowlais (Merthyr) Foundry has now rescued this bridge and hopes to re-cast the missing sections.

Watkin George's 'Old Iron Bridge' (SO 0472 0616) was a road bridge over the River Taff in Merthyr town and was built in 1799-1800 with funding provided by Richard Crawshay. Despite many protests and its status as a Scheduled Ancient Monument, this bridge was broken up in 1960 and its incomplete remains rest in at

Pont-y-Cafnau 1793