Telford's iron bridge mastery

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In 1778, at the time Telford was working as a young stonemason on Langholm Bridge with its three 40 ft (12 m) span masonry arches, there was no alternative to the use of stone for permanent bridges. The longest spans achievable using masonry were about 100 ft (30 m), because of the difficulty in supporting the weight of the arch-stones whilst the arch was being formed. Telford's destiny was to increase bridge spans some six-fold, through his mastery in the innovative use of iron at the limits of practicability to become the 'Pontifex Maximus' of his time.

Three years later, the world's first significant iron bridge, with a span of 100½ ft (30.6 m), was completed at Coalbrookdale, an event which stimulated Telford from 1794-1826, by then a civil engineer, to harness the potential of improved iron technology to his canal and road practice.

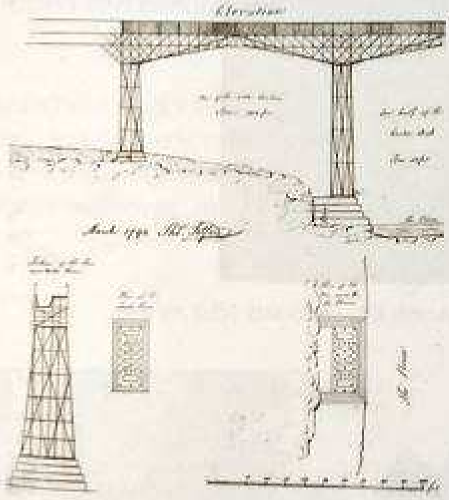


Fig. 1-1 Telford's design for Pontcysyllte Aqueduct in March 1794 [Science Museum Library, London, No. 110, 592/61]

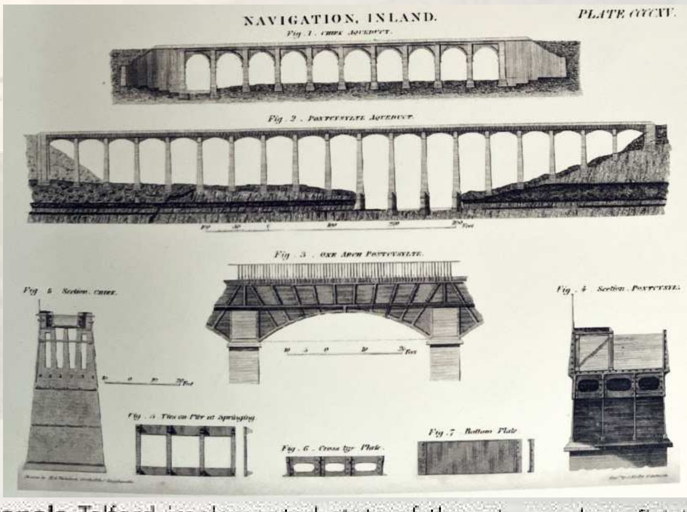


*Fig. 1-2 Pontcysyllte Aqueduct as built. [TELFORD T. 'Navigation Inland'. Edin. Ency., 1830, **XV**, 311, pl. CCCCXV (part). First issue 1821]*

On canals Telford implemented state-of-the-art, user-beneficial, practice. From 1794, to obviate the use of bulky masonry aqueducts and end locks, he used iron to achieve high-level light aqueducts on the Ellesmere Canal. The earliest known iron aqueduct drawing is Telford's 1794 design for crossing the Dee at Pontcysyllte, near Llangollen [Fig 1-1]. Completed in 1805, at about 1,027 ft (313 m) long and up to 126 ft (38 m) high, Pontcysyllte Aqueduct represents the supreme structural engineering achievement of the canal age [Fig. 1-2]. It is still in constant use.

Telford's ironwork design was based on, intuition, experiment, attention to detail and traditional timber practice, combined with invaluable advice and high quality ironwork from ironmasters Wm. Reynolds and Wm. Hazledine. Before Pontcysyllte Aqueduct design was finalised, Telford and Reynolds proved the iron aqueduct concept in use at Longdon-on-Tern on the Shrewsbury Canal in 1796. The structural principle of both was a combination of a U-section beam and arches.

On roads – cast iron bridges. Telford improved on the near semi-circular arch at Coalbrookdale in 1795-96 when, following the destruction by flood of old Buildwas Bridge, he replaced it in iron [Fig. 2-1]. In his design he adopted the Swiss 'Schaffenhausen' timber arch principle, that is, using outer suspending ribs to give extra support to the main bearing ribs with their rise of only 13% of the span. Telford thus achieved a 30% greater span than at Coalbrookdale for half the weight of ironwork, demonstrating that using cast iron enabled a flatter and more economical arch to be achieved. The bridge, opened in June 1796, became the world's longest span cast iron bridge until the completion of Sunderland Bridge soon afterwards.

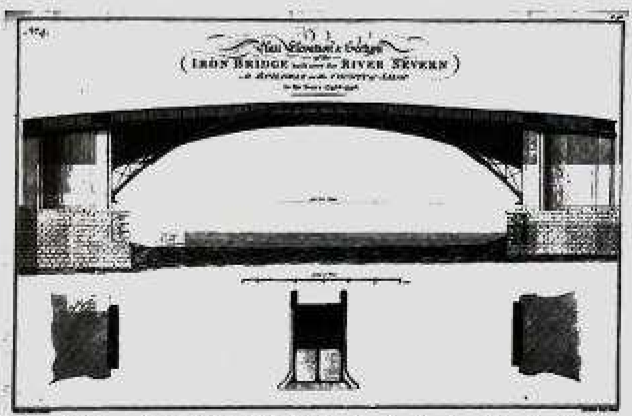


Fig. 2-1 Buildwas Bridge (1796-1905) [Telford's design in Plymley's Shropshire, pl. 4, 1803, and TELFORD T. 'Bridge'. Edin. Ency.,1830, ***IV****, 538-41, pl. XCII. First issue Feb.1812]*

In 1800-01 Telford proposed a bold cast iron arch replacement of 600 ft (183 m) span for old London Bridge [Fig. 2-2]. Although not executed this design contains the embryo of the bracing and rib elevation of his landmark light-weight lozenge lattice bridge type, the first arch of which, of 150 ft (45.7 m) span, was erected at Bonar Bridge over the Kyle of Sutherland in 1811-12.

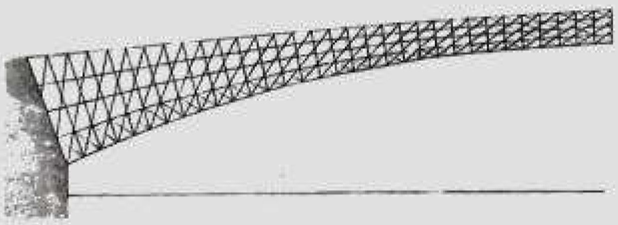


Fig. 2-2 Telford's iron arch proposal for London Bridge [Rep. Sel. Com. on Improvement of Port of London. House of Commons, 3 June 1801]

The innovative light-weight Bonar structure, with the whole arch and superstructure acting as one frame, combined elegance with economy and strength to an unparalleled degree [Fig. 2-3]. Its success encouraged iron bridge-building generally and established Telford and Hazledine's leading reputation in this art. Of the seventeen cast iron road bridges exceeding 32 m span in service by 1830, sixteen were in Britain, of which nine were by Telford, and one each by Rennie and others. Telford also developed a smaller span open-frame radially-oriented iron bridge type.

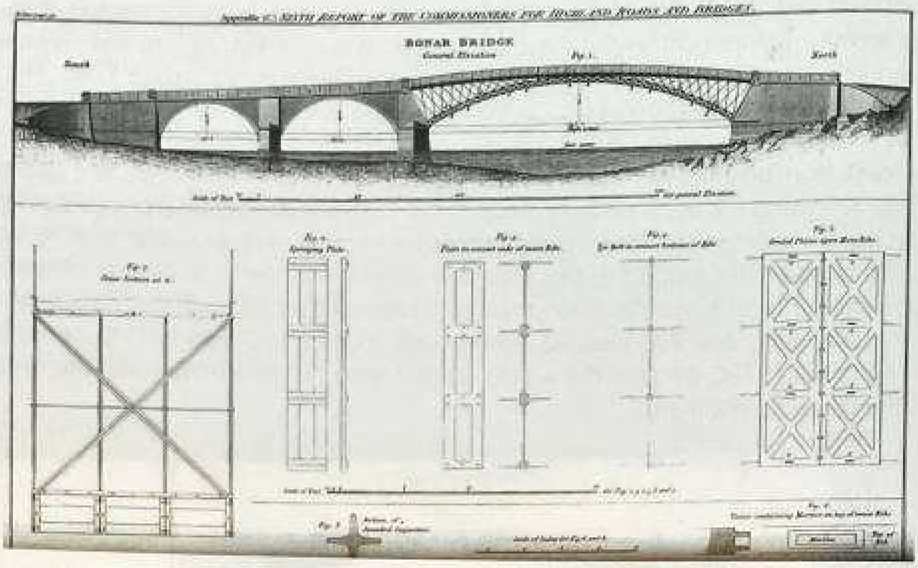


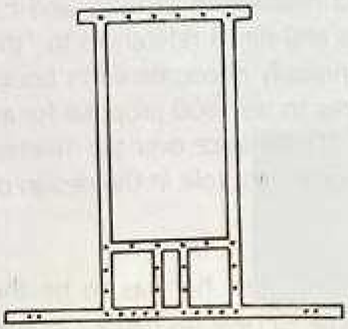
Fig. 2-3 Bonar Bridge (1812–92). [6th Rep. Highland Roads & Bridges, House of Commons, 1813]

Other bridges of the basic Bonar genre erected, mostly of 150 ft (45.7 m) span, included Craigellachie (1814), now Scotland's earliest surviving iron road bridge; Betws-y-coed (1815), carrying the A5 on a 105 ft (32.1 m) span; Esk or 'Metal' Bridge (1822), near Longtown, [Fig. 2-4]; Eaton Hall Estate Bridge (1824), Chester; Mythe Bridge (1826), Tewkesbury, of 170 ft (51.8 m) span, with more structurally efficient vertically orientated lozenges [Fig. 2-5]; Holt Fleet (1827); and Galton Bridge (1829) on the Birmingham Canal, the last of the genre for which Telford was the engineer. All except Bonar and Esk are still in use to varying extents. The lozenge elevation influenced elegance in many later bridges, for example, at St. Nicholas St. Bridge, Newcastle upon Tyne (1848) and Carron Bridge (1863) over the Spey.

Fig. 2-4 Esk or 'Metal' Bridge (1822-1916) on the Glasgow to Carlisle Road [10th Report of Commissioners for Repair of Roads and Bridges in Scotland. House of Commons, 25 March 1824]

Fig. 2-5 Mythe Bridge, Tewkesbury, 1826 © Mike Winney 2004

On roads – suspension bridges. Telford had proposed using wrought iron bars in suspension as early as 1811 to support centring from above for a large cast iron arch at Menai Strait. But it was not until 1814 that he began designing suspension bridges in earnest, conducting more than 200 strength experiments, the results of which were widely disseminated from 1817. Telford also erected and load-tested the first iron wire bridge [Fig. 3-1]. It was a 50 ft (15.2m), one-twentieth scale, model of a 1000 ft (305m) span he was proposing to erect across the Mersey at Runcorn.



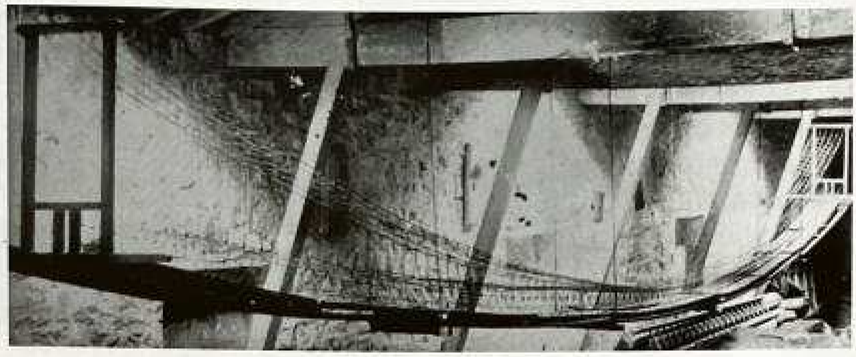


Fig. 3-1 Telford's wire bridge model 1814 preserved at Ellesmere ca. 1906, and cross-section at a support showing 0.1 in (2.5 mm) wire positions [British Waterways Archive, Gloucester Docks, WP 64/53]

Although not executed, work on the Runcorn project, and into the next decade for Menai Bridge, formed part of a more or less continuous design process to the completion of Menai Bridge in 1826. Telford's masterpiece at Menai, the first great suspension bridge, was then the world's longest. It is 1388 ft (423 m) long with a main span of about 580 ft (176 m). In 1940 its deck and ironwork were replaced to cater for modern traffic, with minimal loss of character, under the direction of Sir Alexander Gibb & Partners. The bridge now carries the A5 traffic without weight limit [Fig. 3-2]. Conwy Bridge (1826), of 327 ft (100 m) span created with the same technology, has its original ironwork. It is now is owned by the National Trust and is no longer in vehicular use. For both bridges, 'Merlin' Hazledine was the ironfounder and Telford's key assistants were William Provis and Thomas Rhodes.

Menai Bridge, which combined elegance and functionality to an unprecedented extent, was a landmark in suspension bridge development. Despite wind-induced deck oscillation problems which exercised the skills of Provis and others from 1839, it fundamentally influenced the use and development of the type, and established its role as the most economic means of achieving the longest spans, now exemplified at Akashi Straits Bridge, Japan, with a span eleven times greater.

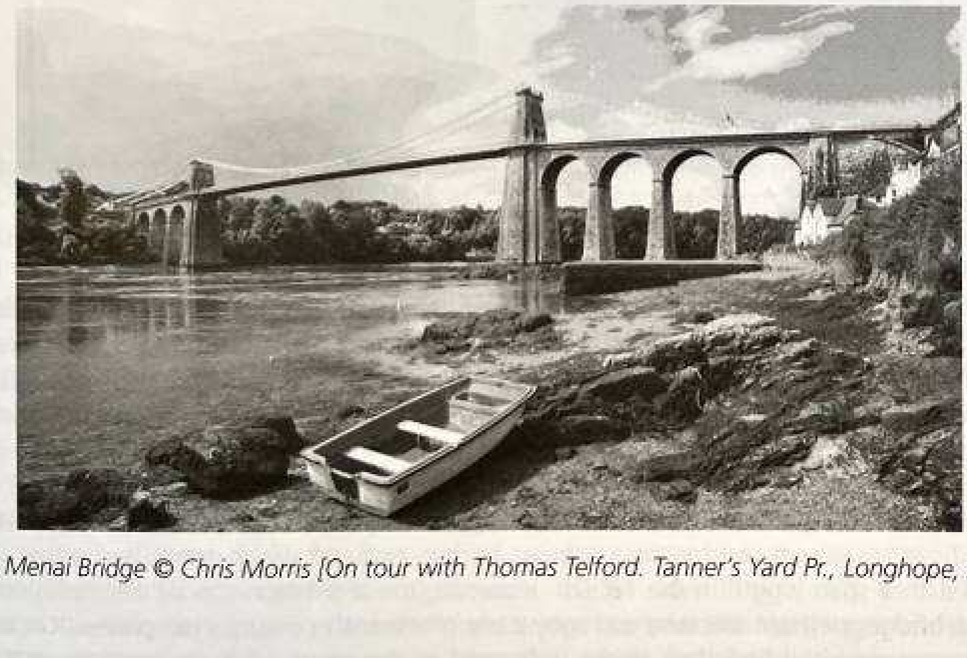


Fig. 3-2 Menai Bridge © Chris Morris [On tour with Thomas Telford. Tanner's Yard Pr., Longhope, 2004]