THE IRON BRIDGE
Miles Lewis
12 September 2018

iron rib arch bridges

The earliest iron bridge designers did not know whether to design using cast iron jn the manner of timber or of stone, and the first iron bridge at Coalbrookdale, England, was an unsatisfactory compromise. The French, although they did not have the industrial capacity of the British, tended at this stage to be better engineers, and J-B Rondelet criticised the illogical design of Coalbrookdale.

iron voussoir bridges

The next generation of iron bridges reflected an understanding that cast iron was strong in compression like stone, and should be designed in the form of an arch made up of voussoirs. But the leading example, at Sunderland, had circles in the spandrels reflecting the circular openings used to relieve flood pressure in stone bridges. This was a completely inappropriate way of supportiing the road deck off the structural arch, and this bridge design was again criticised by Rondelet. The Austerlitz Bridge in Paris was more rational.

Telford's arches

Thomas Telford was the first British engineer to design rational cast iron arch bridges, including a proposal for a giant bridge over the Thames in London, which did not go ahead.

suspension bridges

Telford was also responsible for the first major suspension bridge, over the Menai Straits in Wales, for which he used wrought iron chains. In France cables were preferred, as in the bridge at Cubzac.

stiffened suspension bridges

Many designers felt uneasy about the flexibility of suspension bridges, and they were not well suited to a single moving load like a railway train. One possibility was to make the deck more rigid, and another was to replace the vertical hangers with angled stays (in modern terms a cable stayed bridge). James Dredge's patent taper bridge did both, and it was followed by other forms of stiffened suspension bridge.

self-contained spans

Whereas the arch bridge pushed outwards against its abutments, and the suspension bridge pulled inwards from its anchorages, the self-contained span did neither but (given proper end conditions) exerted only vertical load, just like a simple beam. Two types were the lenticular, or lens-shaped, and the bowstring, or tied arch.

beam bridges

The simple beam was not used at first because it was difficult to cast large sizes, but William Fairbairn developed the technique of building up plate wrought iron into girders and box girders, which were commonly used for bridges, while Robert Stephenson built the Britannia Bridge - a box so large that the trains travelled inside it.

the lattice or town truss

The American architect Ithiel town developed a timber girder with a diagonal latticework like a trellis, and when converted into iron this was a particularly useful railway bridge.

the warren girder

The Warren girder, with diagonals zig-zagging thorough it at 60° angles, was in some ways similar to the lattice truss, and similarly suitable for railway use. But there was a major difference in that it could be scientifically designed. It was the first parallel-chorded girder for which techniques of analysis were developed. It was much used for British railway bridges in India, together with a modified version in which vertical members were added, making it structurally redundant and being of little obvious benefit.

howe and pratt trusses

The Howe and Pratt trusses, both favoured in the United States for railway purposes, were at first timber and iron combinations, but later all iron or steel. The interesting aspect of them is that they are essentially the same configuration, a series of rectangular panels with criss-cross diagonals. Only the choice of materials indicates whether the verticals are intended to be in compression and some of the diagonals in tension (Pratt), or the verticals in tension and some of the diagonals in compression (Howe).

other american trusses

The Americans were less conservative than the British, and tended be designing for lighter loads over longer spans, and they developed a series of truss types varying from innovative to crazy. The Bollman truss was like a Pratt truss overlaid with a cable-stayed span, and massively redundant. The Fink truss was a spidery-looking construction but was in principle structurally logical, and economical of material.

french fabricators

There were two major French fabricators of bridges for export, mainly to the French colonies and to Latin America. Eiffel & Cie was the better-known, and in some ways the more innovative, but Schneider & Cie of Le Creusot was the largest and their work included the Viaducto del Malleco in Chile.

steel bridges

Steel was introduced by the American James Eads in his bridge over the Mississippi at St Louis in 1868-74, and was then used for a complete bridge over the same river in 1879. Steel bridges exported from the USA included the Simon Bolivar Bridge at Arequipa, Peru, fabricated by the Phoenix Iron Co of Philadelphia, and completed in 1882.

cantilever bridges

The principle of two cantilevers like clothes hangers, with a simple span connecting them, was used for the Lansdowne Bridge over the Sukkur at Rohri, Pakistan, in 1887-9, and at Poughkeepsie in the USA, in 1888, but far the grandest example was the Forth Bridge in Scotland of 1888-90. This was on an enormous scale and was made up of giant tubes, which were possible only because of the development of mechanical rivetting.

the vierendeel girder

The Belgian engineer Arthur Vierendel introduced the structural girder and the bridge using rigid joints which transmitted bending moment, hence eliminating the need for diagonal bracing, It was the equivalent of the portal frame in conventional building construction.

portable bridges

The need for standardised small bridges which could be used when required, without much site preparation, was recognised by Andrew Handyside & Co of Derby, England, by the 1870s, and in the 1880s Gustave Eiffel developed rather similar bridges for use mainly in colonies like Vietnam. Eiffel also developed a larger girder bridge which could be brought to the site by rail and launched across a gap by counterweighting the back end. The same principle was used in the Marcille bridge, made by Schneider and Co. The most successful portable bridge of the twentieth century was the Bailey bridge, made up of easily transported square panels assembled in a single row to create a lattice girder, or if necessary doubled in width and doubled or tripled in height to make a girder of much larger capacity.