Historic Structures

significant structures of the past

The Whipple Bowstring Truss

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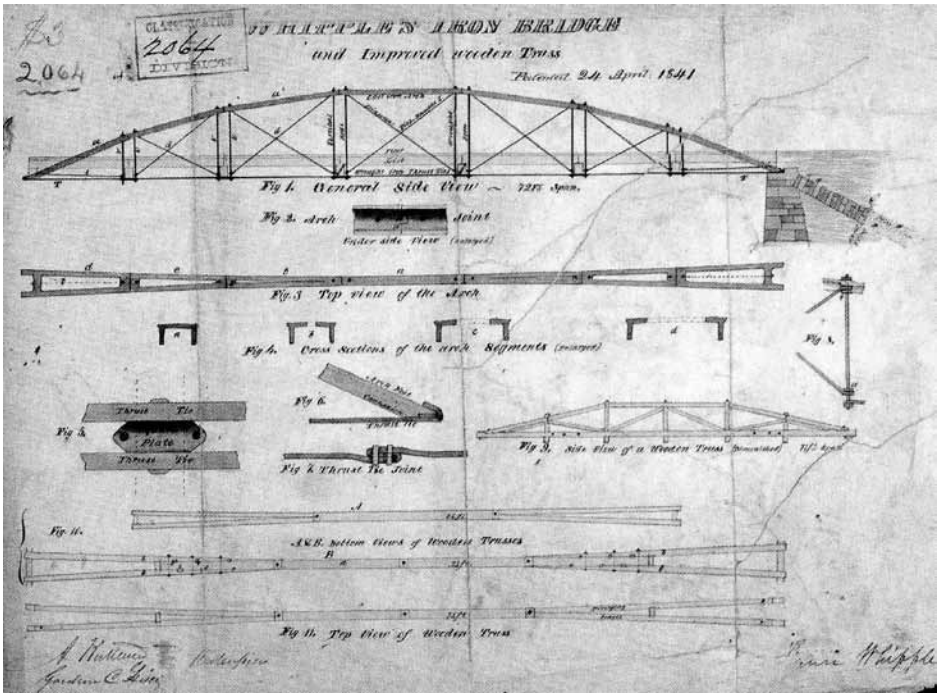
Iron bridges in Great Britain date from 1779 when the cast iron Coalbrookdale Bridge was built across the Severn River. It was followed in 1796 with a bridge by Thomas Telford at Buildwas just upstream from Coalbrookdale. Telford also built several aqueducts of cast iron, as well as two other roadway bridges at Craigellachie in 1814 and Betws-y-Coed in 1815. He even proposed a cast iron bridge with a 600-foot span in 1799 to replace the London Bridge across the Thames River.

In the United States, men like Timothy Palmer, Theodore Burr and Lewis Wernwag built major wood bridges, with Burr and Wernwag using some wrought iron in their bridges. It wasn't until Capt. Richard Delafield built an 80-foot span arch bridge, across Dunlap's Creek near Brownsville, Pennsylvania on the National Road in 1839, that iron was used as a major bridge material. It consisted of five flanged, elliptical tubular arches with the sections bolted together. In 1836 Delafield wrote, "In some one of my communications of last fall I intimated that I had matured in my mind the plan of the Cast Iron Bridge to be constructed over Dunlap's Creek–differing in its principles of construction from any of which I could find a notice by either English or French Engineers..." James Finley also used iron loops in his early suspension bridges. It wasn't until Earl Trumbull built a small bridge at Frankfort, New York that cast and wrought iron were used in a truss like bridge. Trumbull patented his bridge on July 10, 1841. It consisted of 7 cast iron sections with a top and bottom chord and diagonals. The verticals were half cylinders used to bolt the sections together. In addition, wrought iron rods dropped down from the top ends of the truss to the lower chord in a parabolic curve. Trumbull had no idea how to size his cast and wrought iron elements. It was, therefore, a combination of truss and suspension bridge. It fell down shortly after its erection. Even though rebuilt, it never received any fame other than that associated with being the first iron bridge over the canal.

It was into this environment that Squire Whipple (STRUCTURE, September 2005) entered the field of bridge engineering. Since graduating from Union College in 1830, he had worked on the B&O Railroad, the Northern Railroad between Ogdensburg and Lake Champlain and the New York and Erie Railroad before moving to the enlargement of the Erie Canal under Holmes Hutchinson. The canal was being enlarged from a 40-foot width at the surface to a 70-foot width and a depth increase from 4 feet to 7 feet. This required a large number of longer span bridges to cross the 363-mile long canal.

Whipple wrote of his entry into bridge building as follows,

> "(A)t the time when I entered the field as a candidate for the honors and profits of skillful bridge construction, nearly all the principles and feasible general combinations had long been in use. So there was little for me to do but to select the best combinations, best materials, and the proper dimensions and proportions of the several parts and members to secure adequate strength without waste of material or unnecessary expense of labor and workmanship."



Whipple Patent Application Drawing.

After some thought he came up with his bowstring iron truss arch on August 22, 1840. His design and intent were to:

> "...construct an iron truss to be used in connection with a wooden floor system, the truss to have sufficient stability to stand of itself, without any dependence upon the wood, so that the latter could be renewed from time to time as might be required, without disturbance or danger to the iron work. And, as an evidence of the complete success of the effort, it may be mentioned that a single model truss six feet long (scale 1/12 size) sustained without transverse support or assistance of any kind, a load of 900 lbs. (representing 129,600 lbs. upon a full truss) without the least indication of yielding, or want of complete stability."

He submitted his design to the Patent Office, and was awarded Patent No. 2,064 on April 24, 1841.

He was not claiming that he was the inventor of the bowstring truss. He was claiming the use of cast-iron segments in combination with wrought iron diagonal ties or braces to sustain the form of the arch against the effects of unequal loadings. He also claimed the use of thrust ties, the string in the bow and string bridge, to sustain the thrust and spreading of the arch. His last claim was use of a diverging top chord, either in wood or iron, to give the arch or truss lateral stability, hence the *independent* iron arch truss bridge.

Whipple knew the exact role each piece of his truss would play, and how to size the member so that it could play that role. His use of cast iron in compression and wrought iron in tension was based on economic considerations, as wrought iron was only available in small bars or round stock and was very expensive. Therefore, he used the cheaper cast iron for most of his bridge. In practice, Squire ended up using the options to his main proposal rather than the original plan. For instance, he quickly went to single verticals through the joint rather than double verticals offset from the segmental joints. On the "string", he went to wrought iron loops rather than spliced flat bar stock. His proposed wood truss, while interesting, is beyond the scope of this paper. Why he threw in the option of using buttresses to support the lateral thrust of the arch rather than the "string" is not known. He would still have needed some element to tie the suspended verticals and diagonals together. No evidence exists that he ever built one of his bowstrings with buttresses. He actually calculated the loads in his truss members but

Vischer's Ferry Bridge across the Enlarged Erie Canal. Bridge was originally across the Erie Canal at Sprakers and later across Cayadutta Creek in Fonda, New York.

did not publish his method until 1846-47 in his book, *A Work on Bridge Building: Consisting of Two Essays, the One Elementary and General, the Other Giving Original Plans, and Practical Details for Iron and Wooden Bridges*. For this work, A. P. Boller called Whipple "the retiring and modest mathematical instrument maker, who, without precedent or example, evolved the scientific basis of bridge building in America."

He now had a patent and design that he knew, from a life cycle cost standpoint, was superior to any wooden bridge in use. He still had to convince the Canal Commissioners that iron bridges were a good investment and would, over time, more than justify their higher initial cost. What he needed was a customer! He built and tested a six-foot long model of his bridge, but this hadn't convinced the Commissioners that a large-scale bridge, using cast and wrought iron, would act in the same way. What he did would seem rash to many people, but given his options it was probably the only way he could have sold the Commissioners on his idea. He went to his brother-in-law, Oliver Shipman who ran an iron works in Springfield Center, New York, and built a full-size, seventy-two foot span, bowstring truss using $1,000 he had saved. It was a single freestanding bridge on a vacant lot next to the drug store in downtown Utica, New York, inviting people to see and test it. The following item appeared in the *Utica Observer* dated March 9, 1841:

> "I have been shown within a few days past, a structure erected in our city. It is the framework of a bridge made of cast and wrought iron. The inventor is Mr. Whipple, civil engineer of this city. The erection is merely a single frame, of a size adapted to that of the new bridges, over the enlarged Erie Canal, for the purpose of illustrating the plan of Mr. Whipple, to cover all spans, from a single canal crossing to the largest railway aqueducts. It stands opposite to Bushnell's shop on Seneca Street, immediately below the corner of Lafayette Street, where any one may have an opportunity of visiting it and examining its merits."

The commissioners could not avoid seeing the arch, as it was only a block away from the canal near the weigh house at Bleeker Basin. This, his first "experimental" bridge, was later built over the canal at Newville (near Rome) in 1845, his second bridge over the canal. Whipple wrote of this effort, "Look at that experiment, standing idle and useless for some four years, during a part of the time the work of enlargement was suspended, in a public place, exposed to the idle gaze of passers by, most of whom doubtlessly, congratulated themselves on not having been born with a propensity for visionary schemes and experiments; while some probably looked at the thing as not entirely a mere monument of visionary folly, but as a work possessing merits which ought to produce profitable returns to the projector."

Shortly after, when the wooden bridge across the canal at First Street in Utica fell, Whipple contracted to build his first bridge over the canal for the sum of $1,000 in the spring of 1841. He now had something to show the doubters, as his bridge was not only durable but, with its arches, was almost graceful and did point the way to materials of the future. Interestingly enough, this bridge served until September 16, 1922 when the canal was closed and the Barge Canal opened using the Mohawk River.

The Stop Work Law of 1842 slowed the enlargement of the Canal, so few other Whipple Bridges were built until 1848 and then only a few until the 1850s. In 1851, the Commissioners adopted the Whipple Independent Iron Arch for use on the canal. In 1854, they decided to place the entire remainder of the enlargement out to bid at one time, called the *Big Letting*, indicating to all bidders that they would be responsible for paying Whipple's patent fees. Whipple wrote a letter to the Commissioners on September 24, 1854 giving his patent fee as $.50/ft for a bridge with sidewalks and $.40/ft. for a bridge without sidewalks. It wasn't until April 17, 1858 that the Canal Board officially accepted Whipple's proposal, after others had built 30 of his bridges to his patent. In a letter to the Canal Board, he listed the 30 bridges and told them they owed him $2,540.80 in patent fees. The Board agreed they owed him that amount in 1859, but the legislature did not pass any authorization for payment. On March 29, 1862, the Legislature finally agreed to allow the Canal Board to settle with Whipple, which they did for a sum of $1,236.09. In the meantime, Whipple and others had built hundreds of Whipple's bowstring truss across the Canal. Whipple wrote a little ditty as follows,

> "These little bridges I invented, Ratty gets the pay.
> Thus not for self, ye birds your nests do build,
> Thus not for self, ye sheep soft fleeces yield,
> Thus not for self, ye bees your honey stow,
> Thus not for self, ye oxen drag the plow."

He renewed his patent in 1855, extending its life to 1862. The bridges were not only built across the Erie Canal but across rivers using multiple spans. When the Erie Canal was filled in, many of the bridges were relocated to other sites and used for many years. The author has restored Whipple Bowstrings at Vischer's Ferry, Boonville, and Union College, all in New York and is currently part of a team rehabilitating the two span Whipple Bridge, the Shaw Bridge, at Claverack, New York. Other Whipple's are across the Normanskill in Albany, New York and in Newark, Ohio on the Campus of Ohio University (restored by Jim Riddell). A bridge to Whipple's plan is located in Tokyo, Japan called the Old Tojo or Hachiman Bridge.

Whipple's bowstring was the first successful cast and wrought iron bridge built in the United States, and the first bridge with each element sized to carry its load under varying placement of the load on the bridge. It set the stage for the Bollman and Fink Trusses that were to follow. For this, and other reasons, Whipple has been called "The Father of the Iron Truss Bridge."▪