Historic Structures

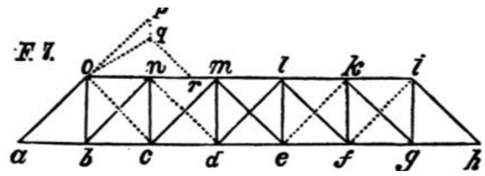
significant structures of the past

Whipple Double Intersection Cast and Wrought Iron Truss

By Frank Griggs, Jr., Dist. M.ASCE, D. Eng., P.E., P.L.S.

Squire Whipple (STRUCTURE, September 2005 and December 2014) patented his bowstring truss in 1841 and built them across the Erie and other Canals and rivers. These were generally for wagons and carriages. In 1846/47, he wrote his *A work on Bridge Building Consisting of two essays, The One Elementary and General, the other showing Original Plans and Practical Details for Iron and Wooden Bridges*. In it he gave the first correct method of determining the load in every member of his truss by the method of joints, and even utilized a graphical method of determining these loads. He studied all the standard trusses to prove that his Bowstring Truss was the most efficient. He determined, much to his surprise, "prior to 1846, or thereabouts, I had regarded the arch formed truss as probably, if not self evidently, the most economical that could be adopted; and at about that time I undertook some investigations and computations with the expectation of being able to demonstrate such to be the fact, but on the contrary the result convinced me that the trapezoidal form, with parallel chords and diagonal members, either with or without verticals, was theoretically more economical *without than with* vertical members – there being shown a less *amount of action* (sum of maximum strains into lengths of respective long members) under a given load," and "it was apparent that each of the three forms – the arch, and the trapezoidal with and without verticals – possessed certain practical advantages entitling each to preference in respective cases, and, no other forms or combinations presenting themselves which seemed capable of competing successfully with these, they were assumed by me as those which would be the prevailing forms which coming practice would adopt." He also determined that the most efficient angle for his diagonals was 45°.

Near the end of his first essay, he got into the use of iron bridges for railroads. He designed them for a load of 2,000 pounds per foot, using an allowable tensile strength of wrought iron of 10,000 pounds per square inch and 10,000 pounds per square inch for cast iron in compression. In his

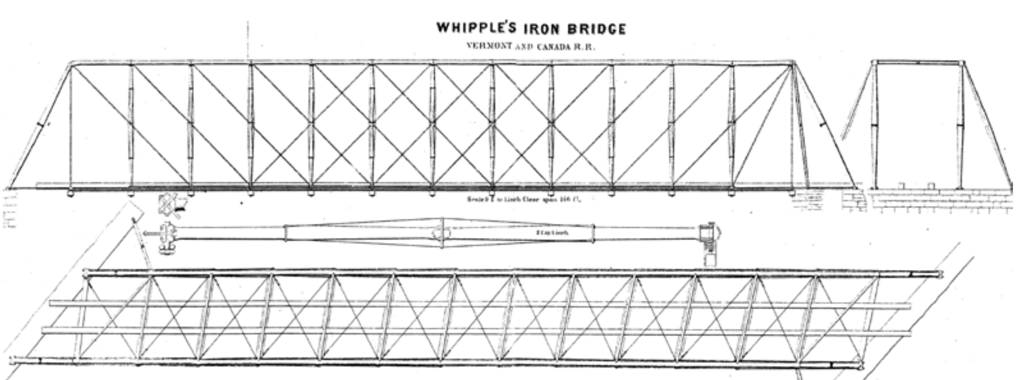


Whipple Single Intersection Truss, from book.

second essay, he described various trusses, including his bowstring truss, which he followed with his *Cancelled Truss Bridge*. He wrote, "if rightly proportioned is from 5 to 10 per cent cheaper than an arched bridge of the same strength, and for railroad bridges, is *generally* to be preferred," and "it is decidedly preferable when the track may be placed on a level with the top of the trusses." He wrote, "this plan, with the single cancel as in Figure 7, is good, perhaps the best, for any span under 75." Spans "from 70 or 80, to 160 feet stretches, should be made with double cancels, or two crossings of diagonals."

He built several short span iron bridges, single cancel and bowstring, for the Newburgh Branch of New York & Erie Railroad in the late 1840s. Even though successful, they were removed after a failure of an iron bridge by Nathaniel Rider on the Harlem River Railroad. Wendell Bollman (STRUCTURE, February 2014 and February 2006) had built several of his iron trusses for the B&O Railroad, including the Winchester & Potomac span (STRUCTURE, February 2015) of the Harper's Ferry Bridge with a span of 124 feet. Albert Fink (STRUCTURE, May 2006) also built his Monongahela River Bridge for the B&O in 1852 with three spans of 205 feet (STRUCTURE, March 2015). Up to 1853, however, Whipple had never built one of his Double Cancelled Bridges, later called Double Intersection or Trapezoidal Bridges. It wasn't until 1852 that he designed a bridge, on a skew of 44°, for the Vermont & Canada Railroad north of Watervliet, New York (West Troy) over the enlarged Erie Canal. Whipple himself described the bridge as follows,

continued on next page



West Troy or Vermont and Canada Railroad Bridge, note skew.

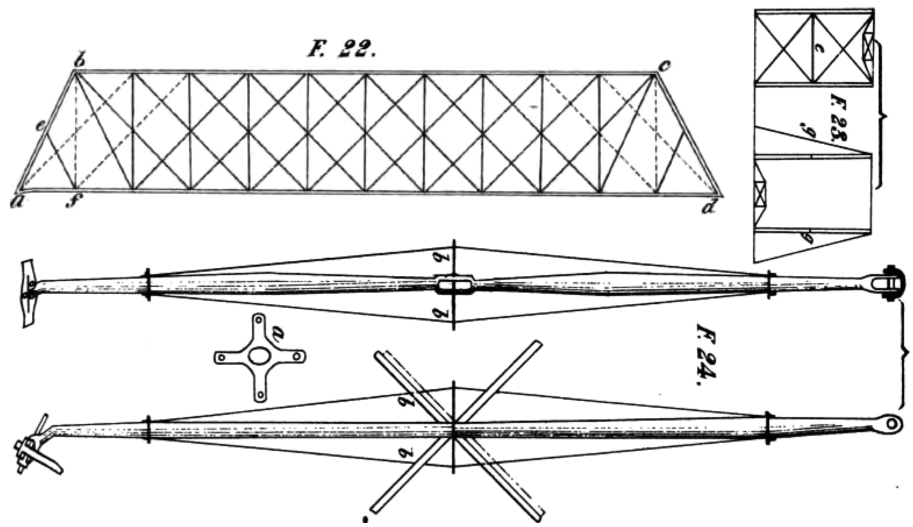
*Dr. Griggs specializes in the restoration of historic bridges, having restored many 19th Century cast and wrought iron bridges. He was formerly Director of Historic Bridge Programs for Clough, Harbour & Associates LLP in Albany, NY, and is now an independent Consulting Engineer. Dr. Griggs can be reached at **fgriggs@nycap.rr.com**.*

"The bridge was built in 1852 and 1853, and put in use in the spring of the latter year. It was 150 feet in length (146 feet clear span), of the Whipple trapezoidal plan, with vertical posts and pin connections, proportioned for a maximum load of one ton per lineal foot, and contained (exclusive of beams and track stringers, which were of wood), in round numbers, 32,000 lbs. of wrought and 43,000 lbs. of cast iron, *being probably the lightest iron R. R. bridge of equal span ever constructed.* [Emphasis Added]

The lower chord was composed of links formed of round bars 2⅜ inches in diameter in the center and diminishing, according to diminution of strain towards the ends of the truss. The links were connected in pairs by cast-iron connecting blocks or pins, 18 to 20 inches in length of a square form and pierced with holes for diagonal members to pass through; these being secured and adjusted by nuts upon the ends. The block had also upon the upper side a bevel seat for the lower end of the post.

The upper chords were composed of cast iron hollow cylinders, about 9 inches in diameter, ½ inch to ⅝ inch thick, and 10 feet 8 inches long; the diameter being swelled out for 3 or 4 inches from the ends, giving about one inch in thickness at the abutting surface. There was an opening in the under side at the ends, to admit the ends of the verticle and diagonal members; the former forked and having semi-circular notches in the ends of the prongs for the connecting pins to rest upon. The abutting ends of the chord cylinders also having semi-circular notches, forming when together round holes horizontally through for connecting pins.

The posts (21 feet 4 inches long between centers of chords), were each composed of four hollow tapering cast-iron pieces, the two middle ones about 5 feet 10 inches, and the two endmost about 4 feet 6 inches long, all about 6-inch in diameter at the smaller and 7 inches to 8 inches at the larger ends. The upper most pieces being forked at the smaller ends connecting with the upper chords before explained, and having a stout flange of a square form at the other end to meet the large end of the adjacent piece. The lower end piece, the same as the upper, with the exception of having a plain square end resting upon the seat formed, as before stated, upon the connecting block of the lower chord. The two middle pieces were alike, being forked at the smaller ends, where they met in the center of the post, thus affording an opening for the passage of the diagonals, the larger ends meeting and abutting against the flanges of the end pieces. The four pieces thus described, placed end to end were secured together by four ⅝ or ¾ inch rods (according to the relative strains of the several parts), extending from the flange of the upper to that of the lower piece, with heads at the upper end and nuts at the lower ends of the rods, and with a stretcher at the center, spreading the rods at that point to a distance of 9 inches or 10 inches from center of the post, thus stiffening and supporting the members against tendency to deflect under longitudinal compression. The stretcher was so formed as to hold the abutting rods of the middle pieces in place, and had also an opening in the center for diagonals to pass through."



Whipple Double Cancelled, Intersection, Trapezoidal Truss, from book.

The reason for making it a double intersection was that, as the span length increased, the depth of the truss had to get deeper and with a normal panel length the diagonals would have been too steep. He wrote, "Now in trusses of considerable length, and, consequently, depth, it becomes expedient, in order to avoid too great a width of panel (horizontally), or an inclination of diagonals too steep for economy of material in those members, to extend them horizontally across two or more panels, or spaces between consecutive nodes of the chords. In such cases, the truss may be called double or treble cancelated, according as the diagonals cross two or three panels."

If he wanted to keep his truss statically determinate, his diagonals had to cross the verticals without being connected to them. This made it possible to separate the truss into two statically determinate trusses, sometimes called Pratt Trusses as the diagonals are in tension. He later built similar trusses at Utica and Boonville, New York. Many people believed the trusses were too frail to carry railroad loading. The Railroad Commissioners of New York State had James Laurie, then President of the ASCE, examine all three bridges. He concluded, "While therefore, I cannot say that the bridge is unsafe, neither can I say that it is beyond question. I certainly consider it as being of too light construction for the passage of the loads at the speeds mentioned in the law establishing the Board of Railroad Commissioners, and although these may somewhat exceed what is required in ordinary practice, it is at all times desirable to have surplus strength, and the more especially when the plan of the bridge is of a new or novel construction." In other words they, while safe, may not have been safe enough for Laurie. When the bridge was removed in 1883, Whipple himself wrote a letter to *Engineering News* stating, "On disconnecting the parts of the bridge after 30 years of usage, the cast-iron portion, without exception, were found to be in a sound and perfect condition as also the wrought iron, with the exception of the rod that broke a few months before the taking down of the bridge, with a suspicious looking fracture leaving, however, sufficient stamina in the remaining parts to prevent a collapse of the structure, although the broken piece was one of a pair of the most important diagonals, and whether the result was due to the original defect of the metal, or to deterioration consequent upon usage, is not quite patent, and the case might be worthy of investigation by those interested in the further construction and use of railroad bridges containing wrought iron in like condition of exposure." The Utica Bridge, built in 1854 with a span of 123 feet, even though taken out in a flood on St. Patrick's Day 1865 and rebuilt shortly after using the same materials, lasted even longer. *Engineering News* wrote on July 18, 1891, "Its existence and capacity for useful work at the present day is creditable alike to its designer and to its builder. Even with modern engine and car loads, which are about double what they were when the bridge was designed, the maximum strain in a web member is 13,165 pounds per square inch, and the greatest strain in the lower chords is 12, 566 pounds. It was an experiment in bridge building, and aroused much discussion at the time, and was roundly condemned by some engineers; and, as was quite natural under these conditions, it was a made a little too strong for the work then to be performed and almost strong enough for the increased traffic of another and succeeding generation. But in consideration of the rapidly increasing load put upon it in the last few years, the board recommends that it be replaced by a more modern type of bridge. It should be preserved somewhere as the work of a pioneer in a type of iron bridge that has since made American bridge engineers famous."

Whipple built many others, sometimes called Whipple Patent Bridges, even though he never patented the style, for roadways throughout New York. In 1859, John W. Murphy who worked with Whipple on the Erie Canal picked up the design and replaced the cast iron junction blocks along with the lower chords with pins and links in place of Whipple loops. He built many of these for railroads in Pennsylvania, and they became known locally as Murphy-Whipple Bridges. Whipple wrote, "In the year 1859, or thereabouts, he [Murphy] built a few bridges, which they were pleased to designate as Murphy-Whipple bridges, to which I made no objections, though it has perhaps been the means of disseminating false impressions. 'Murphy-Whipple bridges,' properly considered, simply means bridges built by Murphy upon plans and principles originated by Whipple. My relations with Mr. Murphy were most friendly, and he conceded to me all my claims to originality in the bridge question."

The next man to pick up the design and improve on it was Jacob Hays Linville of the Keystone Bridge Company. He maintained Murphy's pins and lower chord, but built the top chords and verticals with wrought iron Keystone Column shapes. He built many spans on bridges across the Ohio River, with his longest at Cincinnati with a span of 420 feet. This was followed by several bridges across the Mississippi and other rivers. George Morison picked up the design in the many bridges he built across the Missouri, Mississippi, Snake and other rivers. Over time, Morison replaced the wrought iron with steel.

From the mid-1850s to about 1890, the Whipple Double Intersection Bridge was the most common truss used by railroads. Alfred P. Boller wrote, "the Whipple type (often erroneously called the Pratt) excepting for small spans, has been universally adopted throughout the country as the most economical and constructively the simplest..." The longest bridge built by George Morison was across the Ohio River at Cairo, where he used two Whipple Double Intersection through trusses with two spans of 518 feet (the longest of the type ever built), seven of 400-foot, and three deck spans of 240 feet for a total length of steel bridge plus 38 spans of steel viaduct, making it the longest bridge in the United States at the time.

Whipple, in addition to his Bowstring and Double Intersection Trusses in cast and wrought iron, also designed and built the first successful vertical lift bridge across the Erie Canal in 1874. These bridges, in addition to his books, inspired Boller to write, "Squire Whipple, who is justly entitled to be called the father of the American trapezoidal iron truss bridge, built his first iron bridge in 1840. In 1847, he published his first work on 'Bridge Building,' in which he gave correct rules and formulas for computing the maximum strains from fixed and moving loads, in the various members of a truss; and recommended the now common form with inclined end posts, with link bars for tension members, which finally developed into our present eye-bars and pin-connections..." and that Whipple, "the retiring and modest mathematical instrument maker who, without precedent or example, evolved the scientific basis of bridge building in America." It was appropriate then that ASCE, after its resurrection in 1867, named Whipple its First Honorary Member.■