The Pratt Truss

Whipple, Single Canceled, Trapezoidal Truss

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Most bridge historians and bridge textbooks state that a bridge with a single tension diagonal in each panel and a compression vertical with parallel chords and an inclined end post is a Pratt Truss. The usual truss profile is shown in *Figure 1*.

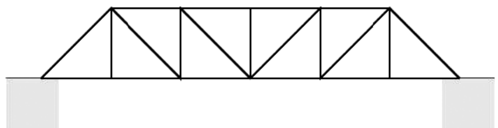

Figure 1. Pratt Truss, even number of panels.

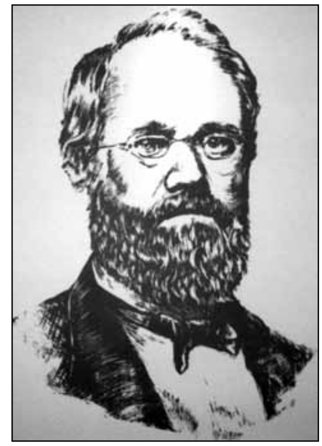

Figure 2. Thomas Willis Pratt.

This, however, is not what Pratt had in mind when he designed his truss in 1843. Thomas Willis (T. W.) Pratt and his father Caleb were well known engineer/architects in New England in the middle of the 19th Century. T. W. attended college in Troy, NY at the Rensselaer Institute, later Rensselaer Polytechnic Institute. He did not graduate, which was not uncommon in those days, as only about a third of those who matriculated graduated. He returned to Massachusetts to work on the Boston and Worcester RR and the Providence & Worcester RR in the mid 1840s under Ellis Chesbrough and James Laurie, later the first president of the Boston Society of Civil Engineers and the American Society of Civil Engineers. There was a need for many bridges to cross the rivers and streams along the routes. At the time of his entry into bridge design, S. H. Long, Elias Towne, and William Howe (STRUCTURE, November 2014) were the primary wood bridge designers for railroads. Long's and Towne's bridges were all wood, even though they indicated they could be built with iron. Howe's, however, replaced the wooden verticals with iron. His diagonals were in compression which, with wedges at both ends, were able to place a small amount of pre-stress in the structure. With nuts on the threaded ends of his verticals, he was able to camber the truss so that, under loading, the deck would approach a horizontal position.

Pratt no doubt had seen Howe's Springfield Bridge, patented in 1840, across the Connecticut River and was aware it was adopted by many railroads replacing the Long and Towne Trusses. The span of the Howe Truss was limited, as the diagonal compression members were susceptible to buckling as their length increased with increase in span. Over time, the wedges came loose requiring frequent adjustment of the tension verticals.

Pratt basically took the Long Truss and replaced the wooden diagonal members with two iron rods with threads and nuts, while keeping wooden verticals in compression, on both ends to make necessary adjustments to obtain the required camber and pre-stress. Since longer spans were possible with the long members in tension, the bridge appeared to correct some of the problems with the Howe Truss.

T.W., along with his father, obtained a patent, #3,523, on April 4, 1844 for a TRUSS FRAME OF BRIDGES (Truss Bridge). There is no evidence that his father had anything to do with the design, and it has been suggested that T. W.

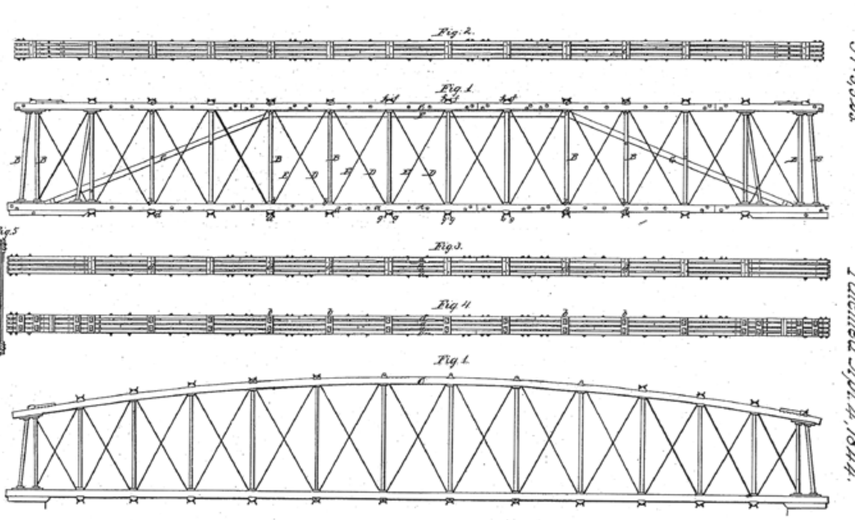

Figure 3. Pratt Patent Drawing.

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****.*

included his father's name as a tribute to his work as an engineer. It will be noticed that Caleb's name is the first name on the patent.

He wrote of the top drawing, "Should it at any time be desirable to increase the strength of the truss beam F, of suitable length, may be arranged centrally and directly under and in contact with the upper stringer, as seen in Figures 1, 5, and from each extremity of this beam an inclined beam, G may extend to the lower stringer into or upon which it maybe stepped in any convenient manner, the said central and side timbers forming what may be termed an arch beam." This form is similar to the Wernwag/Latrobe Truss built at Harper's Ferry for the B&O Railroad (STRUCTURE, August 2014). As to the lower profile he simply wrote, "Figure 6 exhibits a modification of the truss, wherein the upper stringer is crowned or arched." This is similar to the later McCallum Truss patented in 1857. The additional depth at mid-span more closely followed the moment along the truss, resulting in lower section sizes.

Figure 4. Aldrich Change Bridge, originally built 1858.

The main feature of the truss, however, was the placement of crossing iron rod diagonals in each panel. He wrote of this feature,

> *The several iron braces are subjected to a tension strain and being arranged as hereinbefore described, they draw or confine the posts and stringers together. More or less camber may be easily given to the truss by means of the nuts upon the screws of the braces, which on being turned in the requisite direction, lengthen or shorten the distances between the heads and nuts of the braces to such degrees as may be requisite to produce the necessary camber. In the truss represented in Figure 1, the braces of each panel being coupled by means of the straining block, with the counter braces of the succeeding panel, and the counter braces also of the same, being in a similar manner coupled with the braces of the succeeding panel, a connected strain is thus kept on the tension braces, independent of the other-parts of the frame, whereby the tie beam or lower stringer is more or less relieved of a portion of its strain, according to the disposition of the weights producing the said strain. The bracing by means of tension bars extending diagonally across each panel of a bridge truss has been long known and used; but the system of bracing and counterbracing, by means of tension bars crossing each other in each panel, is believed to be new, and not only affords the means of regulating the general camber of a bridge, but allows it to be drawn up, or depressed, in any particular segment, at pleasure, and thus furnishes a means of regulation not derivable from the single tension braces in each panel.*

He concluded his patent application with,

> *The above described method of constructing a truss, that is to say the combination of two diagonal tension braces and straining blocks, in each panel of the truss frame of a bridge by means of which the camber may be regulated so as to increase or to diminish it, either in whole or in sectional part of the bridge, the whole being constructed and operating, substantially as herein before set forth.*

Not many bridges in wood and iron were built to this Patent. When compared to the Howe truss, it was necessary to adjust two rods instead of one, and the fact that the rod ends were inclined made it more difficult to tighten the nuts. In many cases, the tightening also caused the washers to press into the top and bottom chords damaging the wood. George Vose wrote in his 1878 book, Manual for Railroad Engineers and Engineering Students, "the prominent defects of the old fashioned Pratt Truss were the crushing of the top chord between the washer and nut." As a result, most railroads of the time adopted the Howe Truss.

In the 1850s and 1860s, iron started to replace wood as the material of choice by the railroads. (STRUCTURE, January 2015, February 2015 and April 2015). The first man to design and build a truss with a single tension diagonal in each panel was Squire Whipple. In his 1846/47 book on bridges, he analyzed, using the method of joints, all the loads in each member of the truss. He built several change bridges over the Erie Canal in the mid to late 1850s using cast iron for his compression members and wrought iron for his diagonals and lower chord. A change bridge was used when it was necessary to change the tow path from one side of the canal

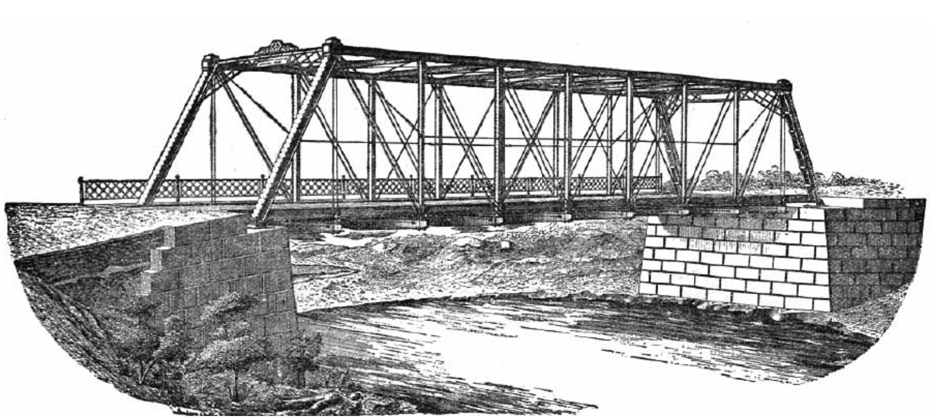

Figure 5. Wrought Iron Pratt Truss with pinned connections and Phoenix Compression Members.

Figure 6. Vicksburg, Fairgrounds Avenue Bridge.

to the other without unhitching the mules. The writer was part of a team that restored an 1858 change bridge that was originally built in Rochester and placed it in a park near Palmyra, New York.

The top chord and inclined end post were cast iron tubes. The cast iron verticals were cast to provide support for cross beams at various heights so that the deck surface would parallel the curved top chord at about the height of mules, so the tow rope would slide easily along the top chord without snagging.

This style truss became a standard design for spans of up to 200 feet. Later in the 1880s, wrought iron replaced Whipple's cast iron compression members. Frequently the top chord, verticals and end diagonals were built up Phoenix sections (by the Phoenix Bridge Company and others) or Keystone sections (by the Keystone Bridge Company), and the diagonals were eyebars and lower chords of wrought iron links. These bridges were prefabricated in shops and easily erected by local craftsmen. They became what was called by some "catalog bridges' in that a local government would simply state the span and number of lanes required, and a bridge company would supply and frequently erect the bridge.

The writer was also part of a team proposing the removal, rehabilitation and relocation of the two-span Fairgrounds Avenue Bridge. It has Keystone, polygonal, compression members connected by cast iron junction blocks and links for the main diagonals, bars for the counter ties and links for the bottom chord. The two spans were originally built as a total of eight approach spans to a bridge across the Mississippi River at Dubuque, Iowa. It was designed by the Keystone Bridge Company under Jacob Hays Linville.

The next stage in the evolution of the truss type was the design of the compression members of built up steel shapes, such as angles and channels. The Waterford Bridge across the Hudson River was built in 1909 by Alfred P. Boller and Henry Hodge to replace Theodore Burr's wooden bridge that was built in 1804 and, after a life of 105 years, was destroyed in a fire.

The top chord was built up with two channels, a solid plate on top and lattice bars connecting the lower flanges of the channels. The verticals are made of two latticed channels, and the diagonals and lower chords are steel links.

This style was replaced with an entirely riveted steel structure of rolled shapes in the late 19th century. This made the truss very rigid and durable, and it was adopted by many leading engineers including J. A. L. Waddell who used it up to spans of 200 feet both with parallel and arched chords. In addition, he made many of his lift spans to the design. An example of its rigidity was when several trusses crossing the Kansas (Kaw) River were pushed off their piers in the Kansas City flood of 1903. They were simply pulled and jacked into place with little or no damage.

According to Turneaure and Kinne's book dated 1916, an "even number of panels were recommended for a riveted structure, while an odd number of panels was best for a pin-connected structure. The even number of panels permits symmetrical joint details and avoids the use of a double set of rigid diagonals in a centre panel. In pin-connected spans, an odd number of panels simplifies the lower chord-bar packing near the centre of the span."

In summary, Pratt never designed a bridge with inclined end posts, with a single tension diagonal in each panel, nor calculated the loads in each of his members, and never built a bridge in iron or steel, and yet the bridge style is called a Pratt Truss. Squire Whipple, however, designed a bridge with inclined end posts, with a single tension member in each panel and calculated the load in each member. In addition, he built several bridges in this style in cast and wrought iron. The author wrote an article entitled, *It's a Pratt! It's a Long! It's a Howe! No It's a Whipple* for Civil Engineering Practice, Journal of the Boston Society of Civil Engineers in 1995 trying to correct this and other misnamed truss styles. Whenever the author gets the chance, he calls a Pratt Truss by its proper name – a Whipple, single cancelled, trapezoidal truss.▪

Figure 7. Waterford, NY, Hudson River Bridge 1909 with built up posts and top chord, pinned links for diagonals.