It's a Pratt! It's a Howe! It's a Long! No, It's a Whipple Truss!

Over the last century the nomenclature for certain bridge design elements has been based on error, not fact. It is time that the record be set straight.

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In the 19th century new truss patterns were usually named after the man who received the patent or was its primary builder and proponent. By the 20th century some of these trusses were called by names that do not necessarily accurately reflect their genesis. While engineers have become accustomed to using these names, a good deal of the history involved in the development of these trusses has fallen by the wayside. Many great engineering minds of the 19th century have been been lost to our engineering vocabulary in this manner, almost creating a form of revisionist history. The exact knowledge of the contributions of the original creators of truss patterns — specifically Stephen H. Long, Squire Whipple, Thomas and Caleb Pratt, and William Howe —should remain with us.

Stephen Harriman Long

Stephen H. Long, of the United States Army, was granted his first bridge patent in 1830 and his last in 1858 (see Figure 1). Twenty-four patents dealing with bridges had been granted by the patent office prior to Long's first patent (see Table 1). Not all of these patents, however, dealt with truss bridges. Unfortunately, as a result of a fire at the patent office in 1836, the nature of some of the patents is unknown. Palmer, Burr, Town and Wernwag were the leading wooden bridge builders of the early 19th century. Finley and Templeman were known for their chain bridges and Pope for his "Flying Pendant" cantilever bridge.

Unlike most of his contemporaries in the bridge building business, Long was a college graduate and well versed in mathematics. He graduated from Dartmouth College in 1809 at the age of 24 and taught mathematics at West Point for several years prior to being assigned to the Topographical Engineers. It was during his assignment to the Baltimore and Ohio Railroad from 1827 to 1830 that he became interested in the design and construction of bridges. In his 1829 monograph "Rail Road Manual or a Brief Exposition of Principles Applicable in Tracing the Route of a Rail Road" that was reproduced in part in the *Journal of the Franklin*

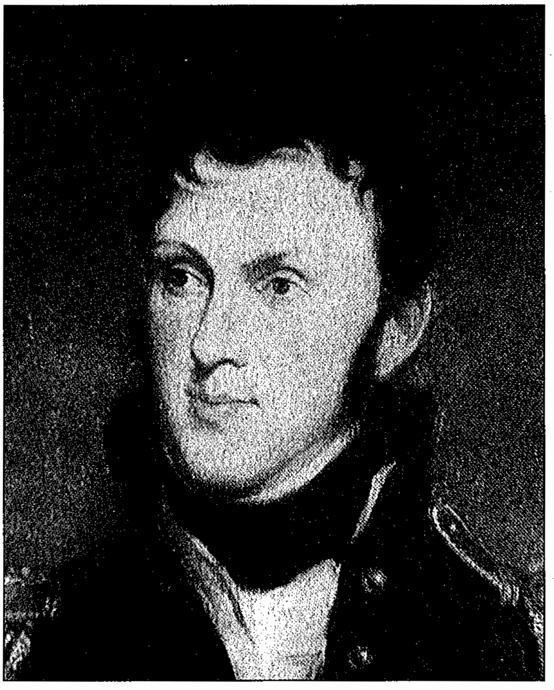

FIGURE 1. Stephen Harriman Long.

Institute, he wrote that "the mode of construction deemed most applicable, is that adopted by Mr. Wernwag, so far as [it] relates to the formation and adjustment of the main arches." At the time of publication he had evidently not given much thought to the topic of bridges. After leaving the railroad, however, he received patents on six bridges (see Table 2).

Long's Jackson Bridge

Long's first patent was for a 109-foot span roadway bridge he built on the Washington road, about two and a quarter miles from Baltimore, where it crossed over the Baltimore & Ohio Railroad. This bridge, named the Jackson Bridge, was a parallel chord, rectangular profile truss with diagonals in compression and verticals in tension (see Figure 2).

To give the truss additional support, he installed two braces (he called them "inferior arch braces") off of the abutments out to the first and second panel points. In addition, he

TABLE 1
Early Bridge Patents

Patent Holder	City	State	Date	Patent Number
W. Peale	Philadelphia	PA	January 2, 1797	NA
C. Fowler	Philadelphia	PA	February 24, 1797	NA
J. Stickney	Worcester	MA	June 3, 1797	NA
T. Palmer	Newburyport	MA	December 17, 1797	NA
T. Burr	Oxford	NY	February 14, 1806	NA
T. Pope	New York	NY	April 18, 1807	NA
J. Finley		PA	June 17, 1808	NA
J. Templeman		MD	August 16, 1808	NA
J. Templeman		MD	March 6, 1810	NA
J. Dyster	Philadelphia	PA	February 23, 1811	NA
J. Jessup	York(town)	PA	July 1, 1811	NA
R. Crosbie	Newark	NJ	February 17, 1812	NA
L. Wernwag	Phoenixville	PA	March 28, 1812	NA
B. Connor	Portsmouth	NH	April 23, 1812	NA
G. Tabb	Martinsburg	VA	February 23, 1816	NA
T. Burr	Burr Haven	PA	April 3, 1817	NA
N. Bishop	Barre	VT	January 11, 1819	NA
J. Bragg		Canada	January 4, 1820	NA
I. Town	Fayetteville	NC	January 20, 1820	NA
M. Lewis	Chenango	NY	April 12, 1820	NA
W. Woomansee		VT	March 6, 1827	NA
G. Wilkinson	White Creek	NY	May 15, 1827	NA
T. Blakewell	Pittsburgh	PA	May 15, 1827	NA
L. Wernwag	Jefferson	VA	December 22, 1829	NA

added "superior arch braces" or "those applied at the top of the truss frames, centrally of the span, and serving to relieve the upper strings of a portion of the thrust to which they are subjected."[1] In his 24-page pamphlet (that included diagrams) published in 1830 entitled "Description of the Jackson Bridge Together With Directions to Builders of Wooden or Framed Bridges," he included two articles that had been published in the *Journal of the Franklin Institute* as well as testimonials and "Directions to the Builders of the Jackson Bridge." In this publication, one of the first to specify actual member sizes for a truss bridge based on a crude knowledge of loads in the members, he presented in two tables the member dimensions for spans of 60 to 300 feet (along with a column of data entitled "load that may be sustained on the bridge"). His string and arch pieces were uniform in size in all panels and consisted of three members, of which the center of the three pieces was approximately 50 percent larger than the two side pieces.

He wrote that "the spaces between the posts (panel lengths) are in all cases equal to two-thirds the height of the bridge between the strings, which is believed to be the best proportion, to be preserved in arranging the relative distances between the upper and lower strings, and the posts."[1] Squire Whipple, to be discussed later, found this ratio to be one to one, or diagonals on a 45-degree angle. Long wrote that "stiffness can only be insured in a braced trestle (truss) by braces and counterbraces"[2] — something else that Whipple was to challenge later. Long considered the posts, main braces, counter braces in his detailed analysis as follows:

TABLE 2
Long's Bridge Patents

Patent Number	Date
NA	March 6, 1830
NA	January 23, 1836
1,397	November 7, 1839
1,398	November 7, 1839
5,366	November 13, 1846
21,203	August 17, 1858

Posts: "The size of the posts for a bridge less than 120 foot span need not exceed 6 inches square for the *quarter* posts, and 6 by 8 inches for those at the center and extremities of the bridge." It is clear from this requirement that he did not have a clear understanding of the load in the verticals that increases under full and most partial loading from the center towards the end of the truss.

Main Braces: "Their dimensions transversely, should be the same as those of the *quarter* posts." The same lack of understanding of forces in the web members is clear.

Counter Braces: "These should be equal in size to the main braces . . ."

Stay Braces: "The stay braces are essential not only to an erect posture, but to the longitudinal stiffness of the bridge; and ought to be introduced not only at each abutment, but

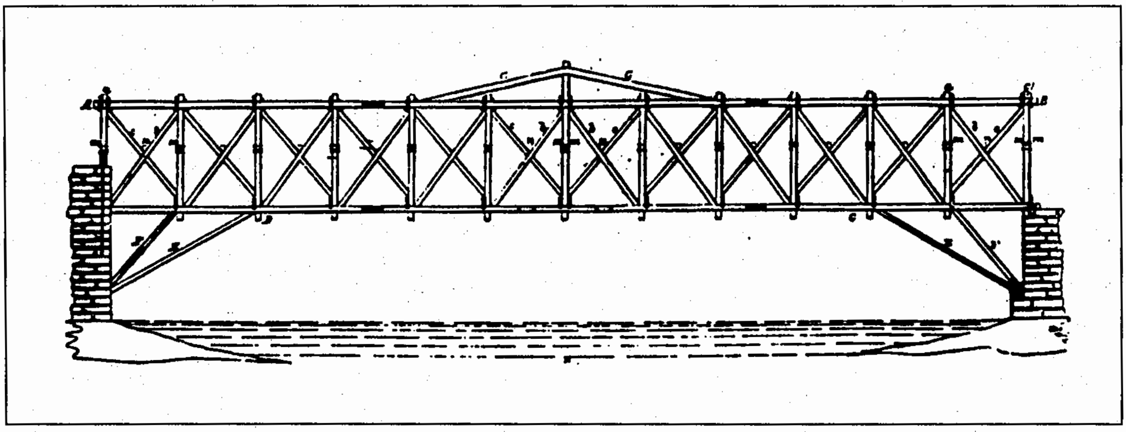

FIGURE 2. Long's 1830 Jackson Bridge.

at every pier of the bridge. They may be made to perform their office either by tension or thrust. In the former case, they may consist of iron rods, extending from the abutment or pier beams, through the posts at the extremity of the span; and to an anchor, or other fastening, in the abutment or pier. If the latter they may be connected to the end or pier posts, at the lower extremity of the transverse braces, or at any other convenient point, and extend to a sill or other suitable fixture in the abutment or pier.... The size of the iron stay brace, need not, in ordinary cases, exceed one and a quarter inches square. . ."[1]

It should be noted that the stay braces are mounted perpendicular to the line of trusses and serve only the function of keeping the trusses vertical, in contrast to stays which in suspension bridges help to carry the vertical loading. Long further claimed that:

"[M]oreover, the principles aimed at in the construction of this bridge, are such, that the strain to which the truss frames are subjected by the heaviest load, that is admissible upon the bridge, is no greater than that exerted upon it, without any load at all. Paradoxical as this may appear, it is, nevertheless, demonstrably the fact, with respect to all parts of the bridge, except the arch braces, and those parts merely, which are in contact with the sleepers or bolsters upon which the bridge is sustained."[1]

He clearly expressed the structural behavior of his truss by writing:

"The system embraced in the Jackson Bridge is such, that the braces all act uniformly in the direction of their axes, and exclusively by *thrust*. Their connexion with the truss frames is such as to preclude any action by *tension*.... A structure possessing these properties cannot fail to recommend itself to the consideration of those who may be interested in the adoption of the most firm and substantial mode of constructing bridges. Nor is the simplicity and economy displayed in the construction of the Jackson Bridge less conspicuous than its firmness and efficiency."[2]

His consideration of span length was also ahead of his time. Using the example of a stream or river crossing (instead of a railway crossing as in his first bridge), Long wrote:

"The extent of the spans of bridges should be regulated by the size of the stream, and especially by the quantity of drift and ice likely to be brought down in times of freshets. In dividing the breadth of a river into spans for a bridge, it will be well to make them as nearly equal as possible, except the exterior spans, or those contiguous to the contemplated abutments, which should have only about three-fourths the extent of the other spans. The reason for this will be obvious from a recurrence to the principle of double action in the strings — as also from the circumstance that the trouble and expense of trussing upon the abutments for the purpose of giving tension to the upper strings may thereby be saved. In conformity to the arrangement here adverted to, the center posts of the truss frames for the exterior span must be located not at the centre of the spans, but at a point distant from the abutment about one-third part of the length of the exterior span."[1]

It is clear that Long was considering making his trusses continuous over the interior spans, thus making the top and bottom chords both tension and compression members depending on the location of the live loads. He also recommended that "the splices should be as remote as possible from the points of greatest tension, *viz:* from a point midway of the lower string, and from points immediately above the piers in the upper strings."[1] In addition, he claimed that:

"However slender the materials of which this bridge is composed and however deficient in strength it may appear, it is crossed daily by stages at full speed, and has actually sustained about eighty beeves, driven across it at once, in close gang, without the least apparent yielding in the truss frames. Agreeably to the most approved rules for computing the strength of similar structures, it will sustain, on every square foot of its floor, in addition to its own weight, at least 120 pounds, or equally distributed over the entire surface of the floor, about one hundred and ten tons weight."[1]

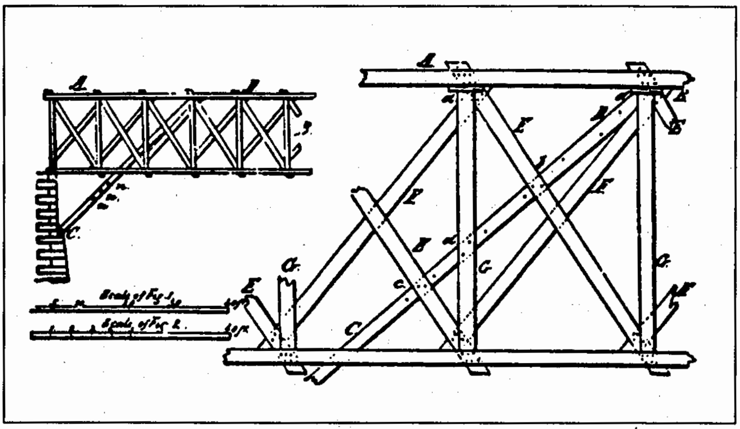

FIGURE 3. Long's 1839 suspension bridge.

To illustrate his design he built a 20-foot-long model of his bridge and presented it to the Franklin Institute at its meeting on June 24, 1830. The pamphlet he published that year was a remarkable publication since it was the first (or at least it was an early) description of a truss that had been designed by a practicing engineer. That pamphlet, along with his two Franklin Institute articles, placed Long in the forefront of early 19th-century bridge engineers. No document was published of such significance until 1842 when Herman Haupt published his "Hints on Bridge Construction."

Long's 1839 Patent

The most significant of Long's patents was his first 1839 patent for a wooden-framed suspension bridge (see Figure 3). In his patent application, and subsequent pamphlet, he stated:

"The suspension bridge is composed of two or more truss frames, together with arch braces, lateral braces, flooring, *etc.*, and is distinguished from other bridges heretofore invented and now in use by reason of the following actions on the posts, main braces and counter braces of this truss frame: to wit, *the posts act by thrust instead of tension, and the main and counter braces by tension instead of thrust,* [emphasis added] as in other bridges. Of course, the relative position occupied by the main and counter braces in the suspension bridge are completely the reverse of those occupied by them in common bridges; and the modes of attachment between the several parts of the truss frame, are materially different from those of other truss frames. . . ."[3,4]

In the same application he indicated his knowledge of structural behavior by demonstrating how his truss could have its panel spacing varied in such a way that the diagonals were under equal tension and, therefore, could be of similar dimensions. He considered a truss with a span of 120 feet and panel lengths varying from 18 feet at mid-span to 5.25 feet at the abutments. If the two double panel counter braces were removed, with the two central panel counter braces left in, the drawing would appear as shown in Figure 4.

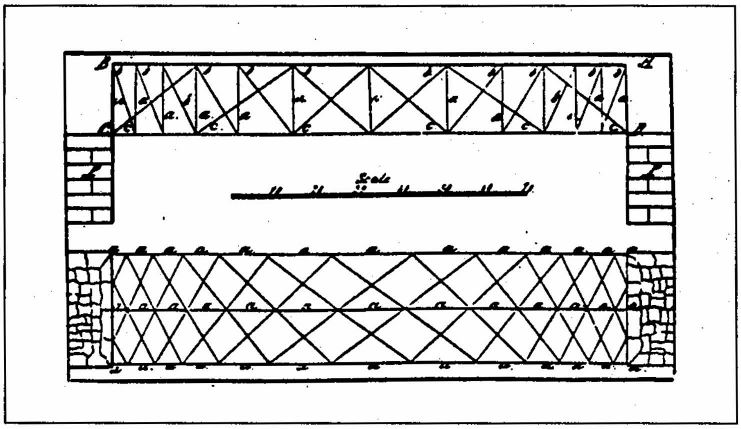

FIGURE 4. Long's truss bridge with equal loading in the diagonals.

He also wrote that his invention was:

"[N]ew and original; not only with respect to construction of wooden bridges, but also with respect to bridges composed of iron, or partly of iron and partly of wood, which may be constructed of similar parts nominally, though these parts may all differ in shape, dimensions, and manner of attachment to each other, all of which may be varied according to circumstances."[3]

In a pamphlet written in 1836, Long expanded on his Jackson Bridge and discussed his new lateral bracing system and a series of movable bridges he had designed.[4] He also gave his procedure for determining the length of spans for a long bridge. He recognized the importance of continuous trusses, introducing the terms *single action* and *double action*. Single action refers to simple span bridges and double action to bridges in which the chords were continuous over the interior supports. His analysis indicated that a bridge could carry twice the load at mid-span if it was continuous rather than simply supported.

In another pamphlet he published in 1839, and which was reprinted in the *Journal of the Franklin Institute*, he finished with the following statement regarding the use of his suspension bridge in iron:

"It is obvious that the arrangements prescribed in reference to the suspension bridge, are not only applicable in wooden structures, but, with slight alterations and appropriated modifications, the same principles are equally applicable in the construction of iron bridges. In this application of the principles, it would be advisable to construct all the parts that are exposed to *tension*, of wrought iron, while those exposed to *thrust*, or compression, may be constructed either of wood or of cast iron. The connexion between the strings, main and counter braces, may be effected by means of key-bolts of suitable size, passing entirely through these parts, and confining them together, the main and counter braces being merely rods or bars of wrought iron with eyes at their extremities, adapted to the reception of the bolts."[5]

In 1839, Long, therefore, had patented a bridge in wood (which would also work in iron), in which the diagonals were in tension and the verticals in compression. He could adjust the camber in the bridge by means of wedges at the ends of its vertical posts. Another patent, issued on the same day, was for a bridge with the same profile but with compression braces and tension/compression counterbraces and verticals in tension. It is clear that he also considered a truss with both diagonals in compression and verticals in tension, in his Jackson Bridge as well as in this 1839 patent, thus predating William Howe's patent by eight months.

That Long knew how loads were resisted by truss diagonals was indicated in an article he published in the *Journal of the Franklin Institute:*

"2nd. The mode of bracing the trestle or frame pier is often defective and inefficient. The braces are frequently arranged in such a manner that the thrust or resistance communicated by them is met by no other counteraction than that imparted by the stiffness or inflexibility of the beam or post with which they are connected. This must be regarded as a defect totally incompatible with firmness of structure, and should be studiously avoided. The remedy is simple and obvious, and is at once suggested by a recurrence to the principle denominated the 'parallelogram of forces.' The action of the brace, whether by thrust or tension, should be communicated to the sides and ends of the parallelogram in such a manner as to resolve itself into, or be counteracted by two forces acting at right angles to each other, and at the same point. A wooden brace should generally act by thrust, consequently the post, and beam, or stile, that receives its action should act by tension. From the principles here adverted to, it may be inferred that stiffness can only be insured in a braced trestle by braces and counterbraces, the heads and feet of which are firmly connected by ties, also that a trestle cannot be rendered firm and unyielding when the braces meet the post, beam or sill, at points unconnected by ties in the manner just explained."[2]

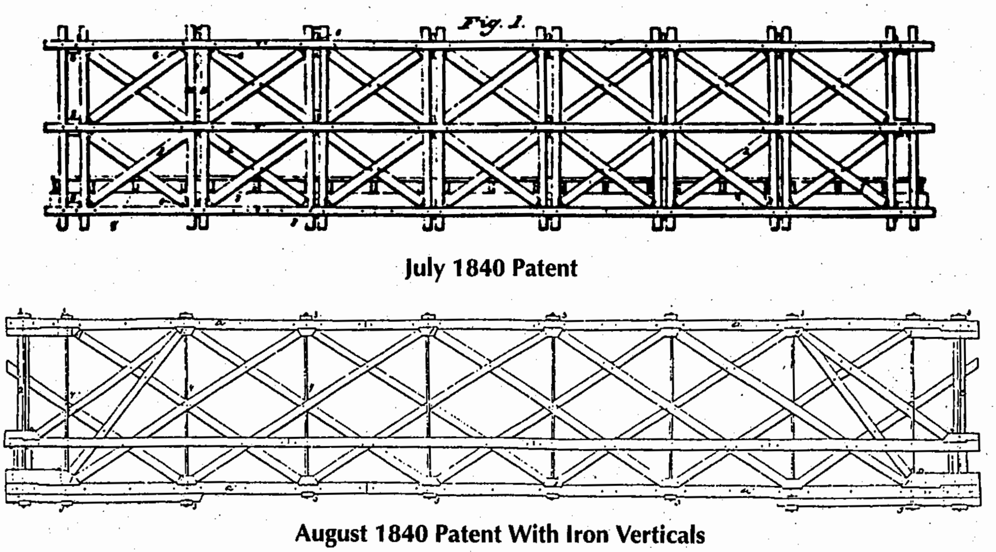

FIGURE 5. Howe's patent for a bridge with a double intersection pattern.

Long never proposed anything other than a truss with a rectangular profile — *i.e.*, the end posts are vertical. His diagonal patterns and characteristic loadings with the diagonals in tension and posts in compression, as well as diagonals in compression and posts in tension, are supposedly the distinguishing characteristics of what are commonly called the Pratt and Howe trusses.

The Howe Truss

In August 1840 William Howe patented a wooden bridge with verticals in iron and with a double intersection pattern of wooden compression diagonals. The previous month Howe had been granted a patent for a similar truss but with wood instead of iron verticals (see Figure 5).[6] It is of interest that Henry Wilton had patented a combination "Town Truss" with a supporting arch that had iron verticals (he called them "suspended braces") in June 1834.[7] He claimed that "the employment of the vertical braces and horizontal bolts" would remove "the difficulty experienced in the construction of the lattice bridge in their twisting and separating which destroys the bridge and which the suspended braces and horizontal bolts above described effectually prevent."

Later, in August 1846, Howe received a patent on a combination truss with wooden diagonals, wooden chords and iron verticals (see Figure 6). The diagonals in this truss only carried over one panel. It included an arch from which he intended to adjust the camber of the truss through "regulating screws that are made to bear on the arch beam."[6] It is not known if he ever built a truss to this patent. It is also not clear whether he could adjust a full-length truss using the regulating screws.

It is strange that the truss shown in Figure 7 that carries Howe's name bears little resemblance to the three patents that were issued to him. His only claim to originality, and that is a weak claim, was the use of iron verticals in tension.

Interestingly enough, Frederick Harbach patented on August 12, 1846, an entirely iron truss in the so-called Howe pattern (no arch) almost two weeks before Howe's last patent.[8] Harbach referred to "Howes patent bridge," which he said consisted of "diagonal braces, abutting blocks and tension rods, the braces act by thrust only." Harbach maintained that the braces "in no respect operate by tension or as suspension braces." Harbach's iron braces and counter braces were connected with iron saddles that, in turn, were connected to the upper and lower iron chords. The top chord was made of cast or wrought iron tubes and the lower chords of riveted wrought iron boiler plate. He

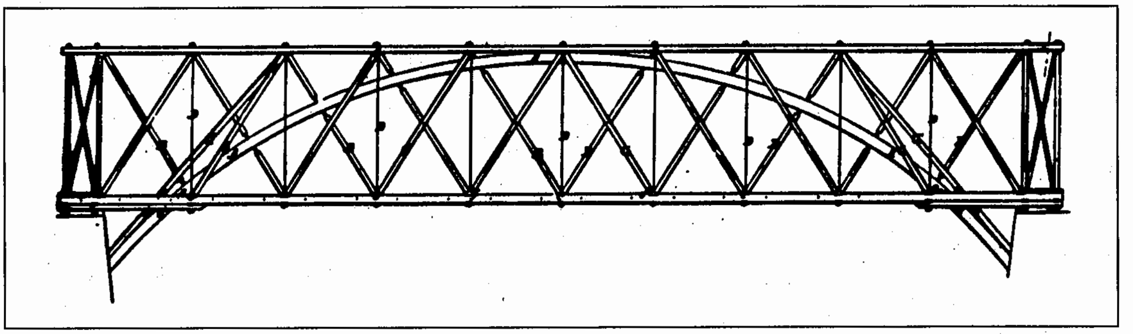

FIGURE 6. Howe's 1846 combination truss bridge.

proudly stated that "by combining with the braces, and counter braces, the toe pieces and with the tension rods the supplementary screws and nuts as above described, I effect a very important improvement in such a bridge truss, as the braces and counterbraces may thus be made to act as suspension or tension, as well as thrust braces, and thus to resist the vertical strains upward as well as downward." In addition, he added nuts on his vertical rods both above and below the upper and lower chord. By so doing his "vertical rods at the same time operate either by tension or thrust.".

Harbach built at least one bridge using his patent on the North Adams Branch of the Boston and Albany Railroad just north of Pittsfield, Massachusetts, in the 1840s, as well as reportedly several others in Ohio.

The Pratt Truss

Thomas and Caleb Pratt in 1844 patented a wooden truss with crossed iron diagonals in each panel and with wooden verticals in compression (see Figure 8). Their patent claim was based on "a 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."[9] They wrote that:

> "[T]*he bracing by means of tension bars extending diagonally across each panel of a bridge truss has been long known and used* [emphasis added]; 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."[9]

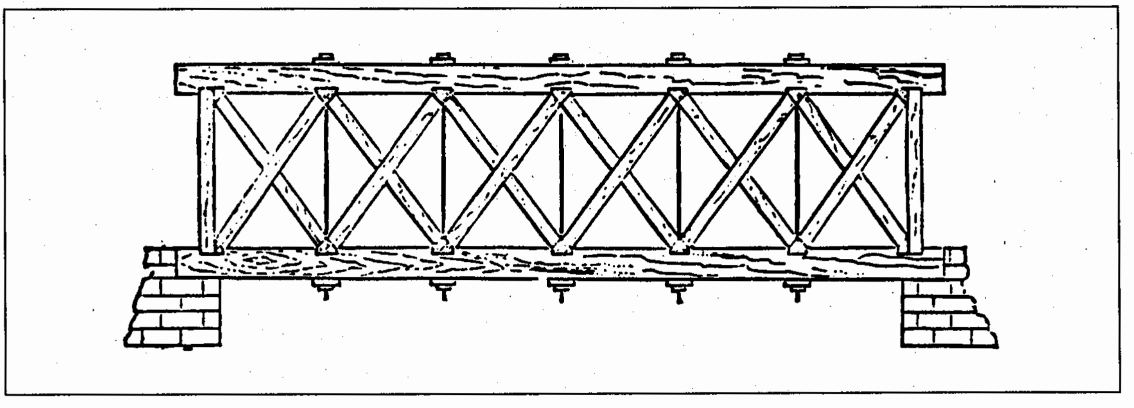

FIGURE 7. The truss commonly referred to as the "Howe truss."

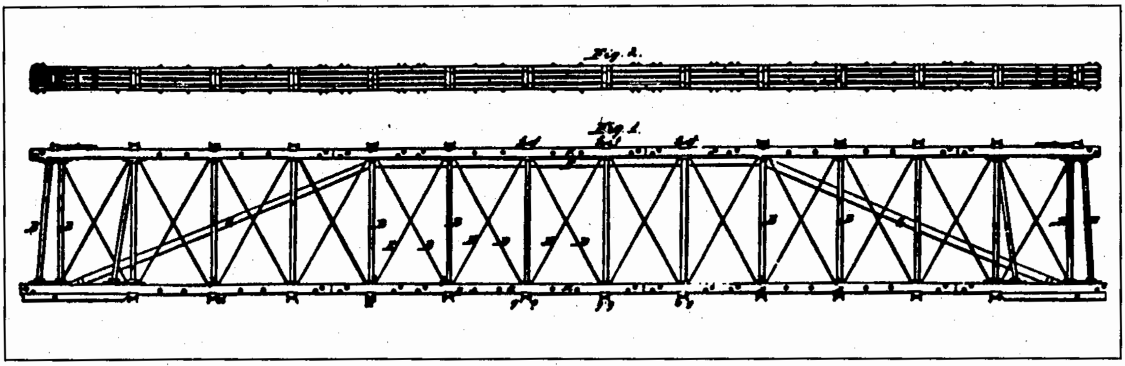

FIGURE 8. Pratt truss patent drawing.

They even wrote that "in some situations where a truss may be employed which has its braces and counterbraces arranged as exhibited in Figure 1 [bottom part of Figure 8 here], the lower stringer may not be requisite as the flooring or whatever is held up by the truss may be depended directly from the lower straining blocks or other convenient parts."[9] This statement shows a complete lack of understanding of the role played by the lower tension chord and was also the reason for the later collapse of several Rider bridges that incorporated this design.

A standard rectangular truss pattern with the end post vertical or near vertical is shown in Figure 8. All of the tension diagonals ran only over one panel. The "arch beam," as it was called, was optional "should it be desirable to increase the strength of the truss."[9]

What then did the Pratts invent? They were wrong about the use of two tension diagonals being new since Long had done the same thing in 1839 (and it will be shown below by Whipple in 1841). Long did use the vertical post to set his camber while the Pratts used nuts on the threaded ends of their iron diagonals, but that is a minor difference. It is also interesting that the so-called Pratt truss that was built later in the century using iron and steel did not have any way in which to adjust the length of the diagonals to maintain the truss in its design configuration without distortion and as such did not use the only new feature of the truss as it was patented.

The Rider Truss

A year and a half later Nathaniel Rider patented a bridge design that reflected, in his words, a "new and useful improvement in bridge-trusses having diagonal braces, all of which are subjected by the forces which usually act upon a bridge to tension strains" (see Figure 9).[10] Rider also did not make any false claims on his application:

> "*I am also aware that in general manner or principle in which the several diagonal tension braces, horizontal top and bottom stringers, and vertical posts are arranged and operate together there is no substantial novelty* [emphasis added]. I do not mean therefore to be understood that my discovery or invention is to be found therein. It is however to a certain extent in an arrangement of the straining power with respect to tension braces and posts, so that it shall not act unequally upon them, or so that the force applied to effect a strain shall apply to two of them at once, and be distributed equally upon each thereof."[10]

Rider had simply taken Long's truss in wood and built it in iron. To Pratt's truss he added a strange cambering device that acted somewhat like Pratt's additional "arch beams" except Pratt's was a compression device under the upper chord while Rider's was a tension device under the lower chord. Notice that Rider also had a truss with a rectangular profile. Rider referenced Pratt's Truss in his application as follows:

> "[T]he tension bars or braces as well as the top and bottom strings . . . I make of wide plate iron, which I refer to rods of iron, such as are used in other bridges of this kind,

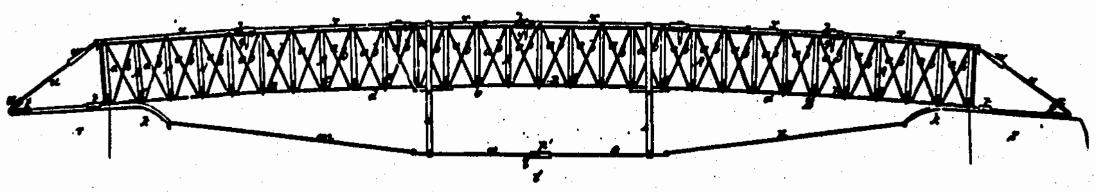

FIGURE 9. Rider truss patent drawing.

particularly in one described in certain Letters Patent numbers 3523 and dated the fourth day of April, A. D. 1844 [Pratt's], my invention being intended as an improvement consisting in wholly dispensing with 'straining blocks,' such as are described in the said Letters Patent."[10]

Long later came to an understanding with Rider in which Rider attributed to Long the original patent idea and apparently made a settlement with him to allow the further construction of Rider bridges. Long (according to Richard S. Allen, a noted wood bridge historian) also went after the Pratts, but with little success since the bridge they designed was never built in wood or iron for some time. The Pratts never pursued Rider even though he had mentioned their patent in his own application.

In late 1846, therefore, Long had laid the basis for diagonals in tension and posts in compression, while Howe introduced iron for posts in tension and wood for diagonals in compression (which was modified to an all-iron truss by Harbach). Long had predated both of them with his 1830 Jackson Bridge. The Pratts had, perhaps unknowingly, taken Long's idea and made their diagonals in iron, which Long had already considered, while Rider used iron for all parts of his truss.

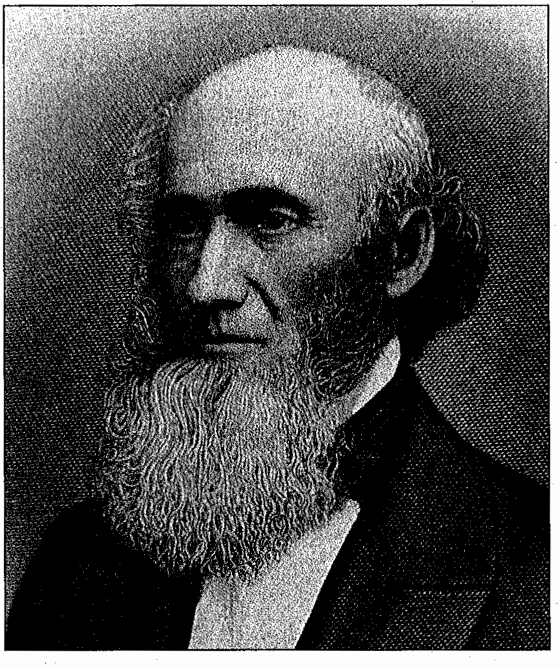

FIGURE 10. Squire Whipple.

Whipple's Bridges

Squire Whipple patented his bowstring arch under the title of "Construction of Iron-Truss Bridges" in April 1841 (see Figure 10). After describing the top chord, thrust tie and verticals for this truss, he wrote that the design would have:

"[D]iagonal ties . . . of wrought iron, or braces of cast iron, in pairs crossing one another between the vertical rods and between the arch and the thrust ties, except under the end segments . . . of the arch where only one tie or brace, Figs. 1 [top in Figure 11 here], and 3 [second from bottom in Figure 11 here], is used extending horizontally from the end of the arch to the foot of the first vertical or from the end, Fig. 5 [lower right-hand corner in Figure 11 here] . . . The vertical rods may be made of round iron, and in all cases should have an aggregate strength sufficient to sustain the floor and any addi-

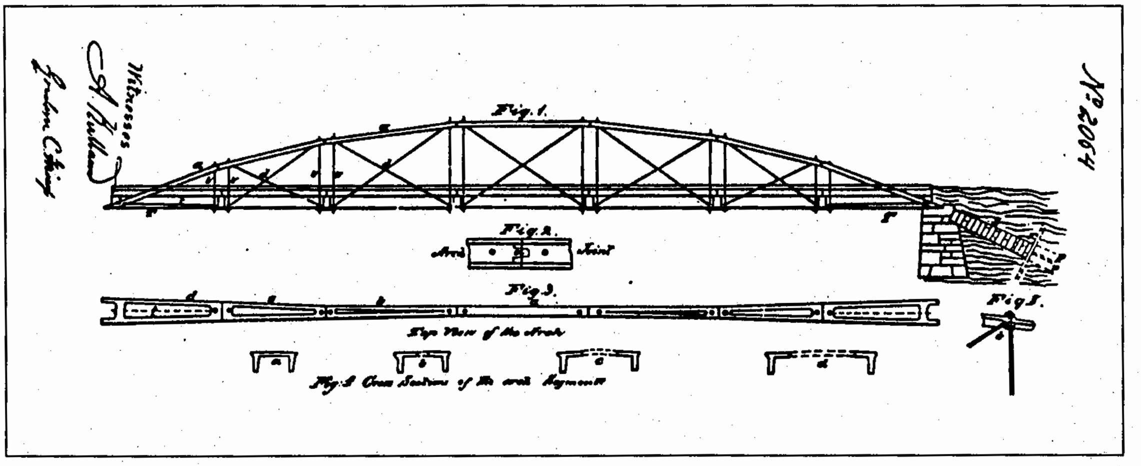

FIGURE 11. Whipple's 1841 patent application drawing.

tional weight that may come thereon, and when the wrought iron diagonal tie is used the vertical rods should have a larger size to give them stiffness as posts.... When the cast iron brace is used instead of the wrought iron diagonal tie, the vertical rod is never subjected to a thrust or negative force and may be of a smaller size and furnished only with a bolt head at one end and a screw-nut at the other, like an ordinary bolt. Otherwise, there may be one or more posts of cast or wrought iron used in conjunction with the wrought iron diagonal ties, in which case the vertical rods may be made smaller, or dispensed with entirely, the diagonal ties being enlarged so as to be adequate to sustain the whole weight."[11]

Whipple's patent, unlike any bridge patent before, showed an understanding of the structural behavior of the diagonals and verticals and the need to size the verticals to handle their loads as either a tension or compression member. Once again, like Long, he had crossing diagonals in each panel (except the end ones) in tension with posts (verticals) in compression. It is not evident that he used cast iron diagonals and, thus, never used verticals in tension. Therefore, like Long, he predated both Pratt and Howe in covering the essentials of the latter two patents.

Whipple analyzed various types of truss forms and suggested that some were more efficient than others. He wrote that:

"[P]rior 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."[12]

His study also indicated that:

"[I]t 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."[12]

In 1846 Whipple wrote an essay in which he set forth the basis of scientific bridge building, much of which had been used in his bowstring truss design. This essay was collected with an-

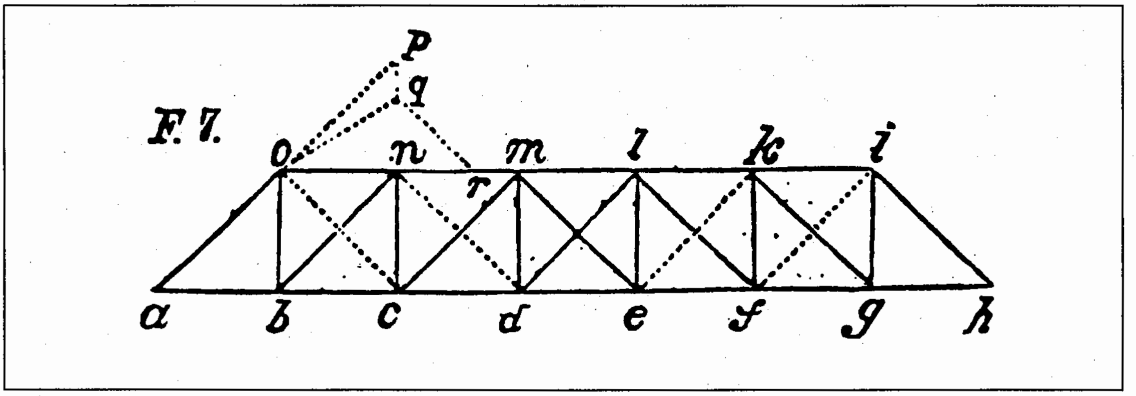

FIGURE 12. The truss Whipple analyzed in his 1847 book.

other into a book the next year. This 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,* was one of the first to set forth the scientific principles of bridge building.[13] He compared his trapezoidal truss with that of Howe and Long (he never mentioned Pratt) as follows:

"[T]hough the general plans and principles of this truss have been extensively used in bridge building, still, for reasons which I will not, in this place, undertake to explain, the principles have never (to my knowledge or belief) been applied with that skill and economy in the proportions of the different parts of the structure, which are necessary to secure the advantages above pointed out as practicable.

"For instance, the bridges built on the plans generally known as Howe's or Long's plans, are essentially the same in their general features.... But instead of being built with each part proportioned to the maximum stress to which it is liable, the upper and lower ribs or stringers have been of the same dimensions throughout, or nearly so; whereas, the stress varies ... some fifty per cent or one-half. The verticals and diagonals have been nearly of the same size throughout, or increased towards the ends to a far less degree than the comparable stress to which they are subjected in those places, demands."[13]

In that manner Whipple dismissed the work of Howe and Long. Whipple's patent was the first to give rules for sizing members and for spelling out details for a typical 60- to 80-foot truss carrying a load of 100 pounds per square foot of deck area. The size of his cast iron top chord (at mid-span) was described as:

"[T]he depth about half the width and the thickness of metal about one-tenth of the width, size, form and proportions to be varied according to circumstances or the taste and views of the engineer ... the remaining segments to be formed and adapted to the preceding in the same manner last described, but increasing in width and divergence to the end of the arch, where the width may be about three times as great as the middle, with the same area in the cross section except at the cross bars connecting the two halves of the segments ... when the rise of the arch above the thrust tie is from one tenth to one eighth of the length of the span, thrust ties having an aggregate cross section of about one square inch for each hundred square feet of bridge floor will be about a suitable size in ordinary cases."[11]

In his book Whipple came to the realization that the trapezoidal form of a truss with a sloping first top chord member (which he called his end brace) was to his surprise more efficient than his bowstring. He was the first to promote this type of truss. In the first essay in the book he analyzed a truss with all the characteristics that were patented later by the Pratts and are now called Pratt trusses (see Figure 12). In an 1855 article in the *American Railroad Journal,* he

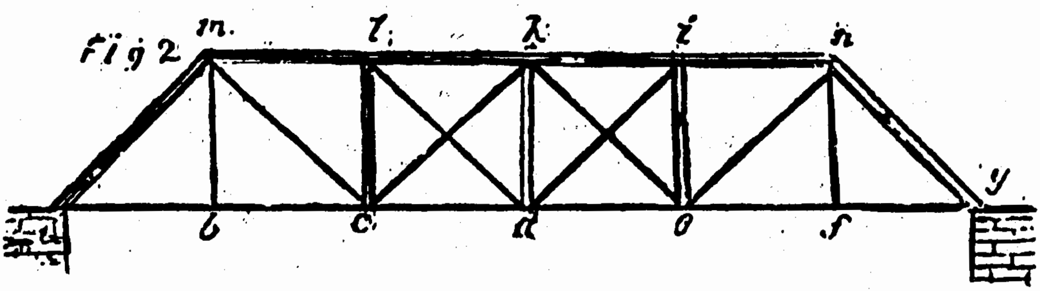

FIGURE 13. The Whipple truss that was shown in the Bollman article.

compared this type of truss (which he said was "arranged and practiced upon by me" and is shown in Figure 13) with the Bollman truss (which he called "a mere fossil of one of Whipple's discarded principles, dug up, and probably considered to be original by Wendell Bollman").[14]

In the January 29 issue of the same journal, Whipple completely analyzed the same truss since he "had been requested by several readers of the Journal to give demonstrations in relation to the maximum strains upon the several parts of the bridge truss."[15] This may have been the first time he had demonstrated, in a journal, the method of analysis he developed in his book.

This truss pattern had single diagonals in tension and counter braces only in the center panels. Whipple had shown in his 1847 book that counter braces only made sense in the panels near the center of the bridge. He wrote (see Figure 12):

> "The counter diagonals *nb, me, lf,* and *lg* can manifestly, only act, when the main diagonals, *cc &c*, to which they are respectively opposed, are relaxed, *i.e., nb* can only act when the tendency of the variable load is to produce a greater action upon this part, than the weight of the structure alone tends to produce on *oc*, and then, will only have an action equal to the excess of the former tendency above the latter . . . . consequently the counter diagonals *nb* and *kg* will usually be of no use in the structure, except for appearance and may be dispensed with. . . . [I]n like manner, the maximum action in *mc* and *lf* will be a negative quantity, and the parts may be dispensed with, especially for common road bridges, which usually are not liable to be exposed to very large variable weights."[13]

This particular type of truss was adopted by John Murphy in the Philadelphia area and became known as the Murphy-Whipple truss (see Figure 14). Murphy, a Rensselaer graduate, worked with Whipple for a short period on the enlarged Erie Canal. Upon moving to Philadelphia, he and a classmate from Rensselaer, George Plympton, built many Whipple trapezoidals and bowstrings in that area giving Whipple his patent fees for the latter and credit for developing the former. Murphy is best known for substituting turned pins for Whipple's loops and cast-iron shoes. He also gradually substituted wrought iron for cast iron in his top chords and verticals. When asked what was the relationship between Murphy and himself, Whipple responded:

> "I first met John W. Murphy about the year 1850 or 1851. I learned that he thought well of my book and my bridges, whence I inferred, of course, that he was a man of discrimination and ability, and as he afterwards talked up iron bridges and Whipple bridges in Pennsylvania, he was of service to the cause and to me. Iron bridges 'took' in Pennsylvania rather better than in New York, and Murphy, with others, formed a partnership for building iron bridges, and purchased my patent (covering the arch

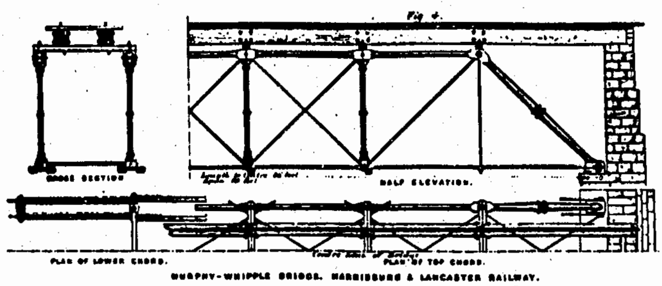

FIGURE 14. The Murphy-Whipple truss as shown in Colburn's paper.

truss only). In the year 1859, or thereabouts, he 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."[16]

Whipple built iron bridges to this pattern on the New York and Erie Railroad in 1848 and 1849, and on the Utica & Black River Railroad at Boonville, New York, in the early 1850s. He was well aware that Murphy had adopted his idea and that Murphy was more successful in finding railroads that wanted to build iron bridges than he was.

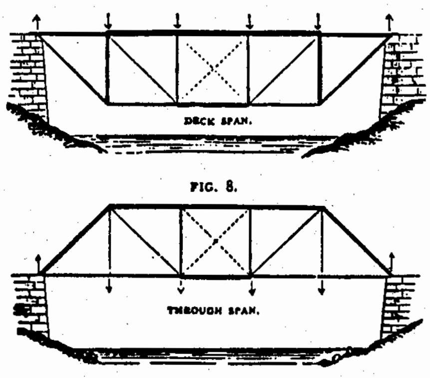

FIGURE 15. Boller's illustrations of Whipple bridges.

Zerah Colburn in his paper on "American Iron Bridges," published in the *Proceedings of the Institution of Civil Engineers*, shows the bridge pattern and calls it a Murphy-Whipple saying that "the Murphy-Whipple Bridge . . . was believed to be the best class known in the States."[17] C. R. Manners in an *Engineering, London* article, reprinted in the *Scientific American Supplement* March 12, 1892, called the pattern a Whipple truss.[18] A. P. Boller in his 1890 book, entitled *Practical Treatise on the Construction of Iron Highway Bridges for the Use of Town Committees*, designated this pattern as a Whipple single cancelled truss, which is the terminology Whipple used in his book (see Figure 15).[19]

Therefore, in the period from 1850 to 1890, most of the technical literature designated this truss pattern as either Whipple or Murphy-Whipple and not a Pratt. Why and when did a Whipple truss, or the Murphy-Whipple truss, become known as a Pratt truss?

The Whipple Double Intersection Truss

In his 1847 book Whipple analyzed a trapezoidal truss for long spans (greater than 120 feet). A long span required a high truss in order to minimize the use of metal. He had shown that the diagonals, to be most effective, should be placed at 45-degree angles. He also knew that if the panel length was too long, the cost of the deck structure would be excessive. In order to meet all these criteria he had his diagonals cross over two panels. This method kept his angle to around 45 degrees. It also kept the panel length down and made the height of truss large.

He presented illustrations of this style of bridge (with verticals for iron trusses and without verticals for wooden trusses), which was similar to one he built across the Mohawk River at Freeman's Ferry near Schenectady, New York

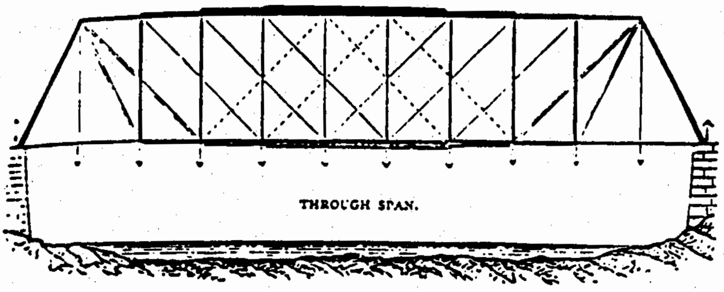

FIGURE 16. The 1847 Whipple double intersection truss.

(see Figure 16). It was a model of this truss in iron that he sent to the American Institute Fair in 1846 and for which he received a silver medal. He also utilized this type of truss for the bridges he built across the enlarged Erie Canal at West Troy and over the Mohawk River at Utica.

Murphy and Jacob H. Linville, like Whipple a Union College graduate, built many bridges to this pattern after the Civil War. In fact, Linville patented the truss (with eye-bar links for the lower chord) in 1862 — over 15 years after Whipple had designed it and over nine years after he had built the West Troy bridge. F. C. Lowthrop had also patented a similar truss pattern. A. P. Boller, George Morison, Charles Macdonald, T. C. Clarke and others built this pattern in steel with spans well over 500 feet. The first American cantilever built by C. Shaler Smith over the Kentucky River in 1876 and the Glasgow Bridge over the Missouri River (the first all-steel bridge) were also built to the Whipple pattern.

Starting around the turn of the century some people began calling the truss pattern a double intersection Pratt. The Pratts never patented, nor built, a truss with a trapezoidal profile. Nor did they ever mention the idea of having tension diagonals span two or more panels. These were all Whipple's ideas, which he had taken and turned into reality by building trusses to the pattern. When did some people start to call this type of truss a double intersection Pratt, and why?

Summary

The Pratts never claimed originality in having crossing diagonals in tension. In their patent application they stated that "the bracing by means of tension bars extending diagonally across each panel of a bridge truss has been long known and used."[9] Long was the first to discuss the use of diagonals in tension and posts in compression in his 1839 patent; Whipple did so later in 1841. Rider paid, or came to some kind of an understanding with, Long for his continued use of trusses with diagonals in tension in the late 1840s. Long also patented a truss with diagonals in compression and posts (verticals) in tension well before Howe received his first patent.

Whipple was the first to propose, analyze, discuss in writing and build a trapezoidal truss in iron with single tension diagonals in each panel and counter braces (ties) only in panels near the center of the truss. He was also the first to design, build and analyze the trapezoidal double intersection truss and recognize its advantages for long spans.

The standard assumption given for calling a truss with a single tension diagonals in each panel with counter braces (ties) in the center panels a Pratt truss is only that Pratt first patented the idea. This assumption is an error. Long was the first and Whipple the second engineer to patent an approach based on this method. Using this rationale, the truss should be called a Long truss.

However, even though Long extended his patent idea to bridges in iron, he never designed or built any bridges in iron, nor did he use single tension diagonals or leave out counter braces (ties) in any panels. In addition, all of his trusses had a rectangular profile.

The only engineer who developed all the characteristics that many people ascribe to Pratt was Whipple. The engineering profession should give credit where credit is due and in the literature designate this type of truss pattern a Whipple trapezoidal truss or a Whipple-Murphy truss for the reasons given.

If the name of Pratt were to be removed from the truss which has borne that name for decades, it would be even easier to remove the name from the double intersection trapezoidal. This truss was uniquely a Whipple design and had its conception as early as 1846. It was used for an actual bridge in wood in 1848 and in iron in 1853.

Merriman and Jacoby, in their textbook *Roofs and Bridges*, wrote:

> "[T]he Whipple truss ... is an instructive instance of a form which was extensively used from 1850 to 1885, even for the longest spans, but which now is no longer built. This has all the advantages of the Pratt type as regards the use of vertical compression members in the web, and also by the double system of webbing the panel points are brought nearer together."[19]

Waddell, in his book *Bridge Engineering*, wrote:

> "[T]his bridge was of the double-intersection Whipple type; and, on account of the improvements introduced by Murphy, it has frequently been known as the Murphy-Whipple Truss."[21]

Carl Condit, in his book *American Building Art — 19th Century*, included a diagram of a double intersection trapezoidal truss of Whipple's and Murphy's usage and called it Whipple's. Condit noted that this type of truss was widely known as a Whipple truss. He added that Murphy made improvements to the truss, which led to its subsequent widespread adoption for long-span railroad bridges.[22]

It appears that one of the main reasons for growing acceptance of the misnaming of this truss was the bridge poster distributed by the *Historic American Engineering Record*, which designated the truss pattern as a double intersection Pratt.

Recommendations

Appropriate credit should be given to Stephen H. Long and Squire Whipple as the premier bridge engineers of the period between 1840 and the start of the Civil War. Long worked entirely in wood, even though he conceived of designs in iron and was 55 years old when he received his most important patents. Whipple was 35 when he received his patent on the bowstring truss (only one year after Long). Whipple worked primarily in iron, although he did build several major wooden bridges. These two men were the first to apply structural theory to the design of their bridges.

The Pratts and Howe were of the old school of bridge designers. They were trained as carpenters, millwrights and architects — without benefit of a sound scientific education. Thomas Pratt, even though he spent some time at Rensselaer, did not have the ability to design members nor did he size members according to the load placed upon them. Both Howe and the Pratts seemed to have introduced iron only as a means to adjust the camber of their wooden bridges.

Whipple and Long, however, not only understood structural behavior, but were able to design and build trusses that were cost effective. Each of them also shared his thoughts and ideas with colleagues in the scientific literature of the day. Most of Long's work was published in pamphlets and the *Journal of the Franklin Institute*. Whipple published in *Van Nostrand's*, the *American Railroad Journal* and *Appleton's*, as well as in his 1847 book on bridge building.

Whipple was also very aware that some people did not always give him credit for his bridge designs even during his lifetime. Several comments by Whipple follow:

> "'Murphy-Whipple bridges,' properly considered, simply means bridges built by Murphy upon plans and principles originated by Whipple."[23]
>
> "[W]hich the author calls the 'Whipple truss,' and another which he designates as the 'Linville truss.' The former contains an important feature, unlike anything ever constructed, recommended, or even tolerated by me; while the latter is in general features

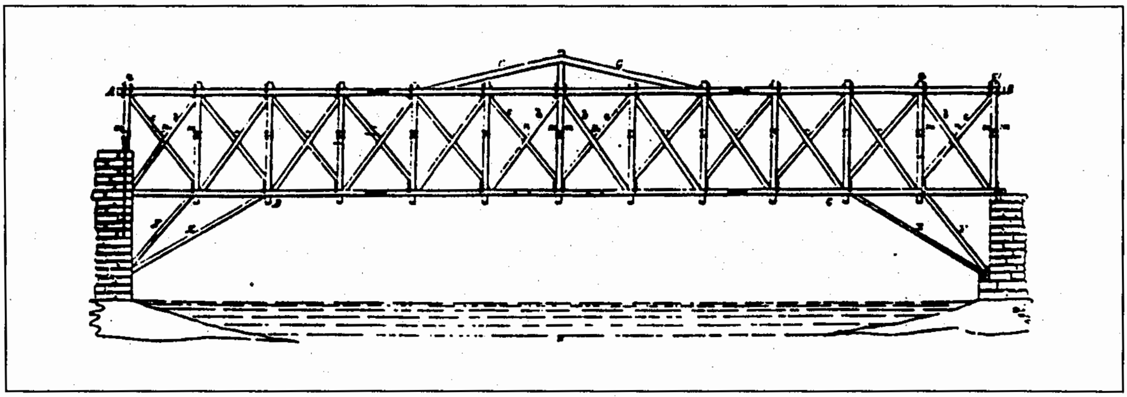

FIGURE 17. The "new" Long truss, replacing the Pratt (rectangular) and Howe trusses.

the same as was used and recommended by me over twenty years ago."[12]

"[T]he isometric and the Post trusses are merely modifications (and not very favorable modifications either) of a type of truss first used and thoroughly discussed by me."[23]

"[A] mere fossil of one of Whipple's discarded principles, dug up, and probably considered to be original by Wendell Bollman."[14]

"The same fate befell three small structures by the same party, of 23 and 26 ft. span, to carry the Newburgh branch over common highways at and near that village. These were wrought-iron skeleton girders upon the triangular plan, such as have since been called Warren girders, and by some regarded as a newly invented combination."[12]

It is clear that Whipple knew that his book and bridges were the basis for many truss patterns that followed. The only recourse he had to receive due credit was by writing occasional letters to the journals of the day. There is also little doubt that he wanted that recognition and felt that he was not treated fairly by his colleagues in this matter. After his death in 1888, it became easier for others to lay claim to his creations and, with the exception of A. P. Boller, few came to his support.

For these reasons, it is well worth examining the historical record to consider whether Whipple and Long have received sufficient credit in the literature for the trusses they developed in the early to mid-19th century. Such an examination might lead one to adopt the following designations of truss types:

- Long truss, replacing the Pratt (rectangular) and Howe trusses (see Figure 17)
- Whipple trapezoidal or Murphy-Whipple truss, replacing the Pratt (see Figure 18)
- Whipple double intersection truss, re-

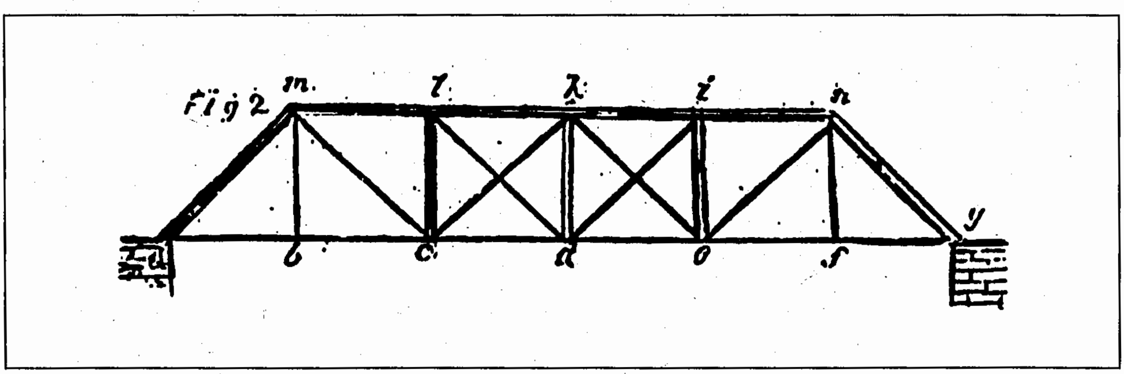

FIGURE 18. The "new" Whipple trapezoidal or Murphy-Whipple truss, replacing the Pratt.

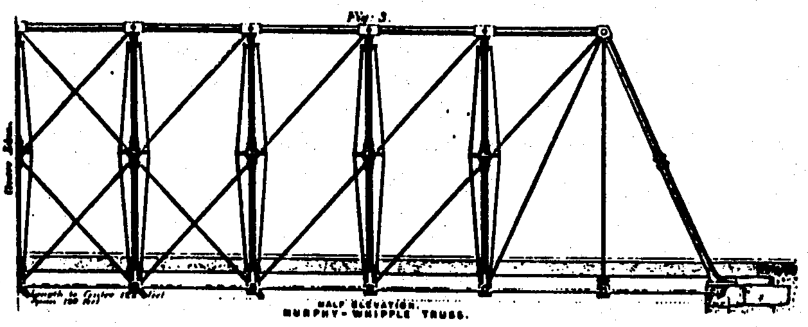

FIGURE 19. The "new" Whipple double intesection truss, replacing the double intersection Pratt.

placing the double intersection Pratt (see Figure 19)

These designations would remove the Pratt and Howe trusses from the roster of truss types in engineering literature. This alteration would be appropriate since their contribution to the field was virtually non-existent. If the Patent Office had examiners with more truss knowledge than they had at the time, they would never have granted patents for work that was not new. This reminds me of a professor who upon returning a student's paper wrote: "Your work is both good and original; unfortunately, the part that is good is not original and the part that is original is not good." Long and Whipple's work was both good and original, and they should be given the recognition they have long deserved. In doing so, a serious lapse in scholarship in the field of history of bridge engineering would be corrected and justice would be done.

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