Steven H. Long

First American Structural Engineer

By Dr. Frank Griggs, Jr. P.E. P.L.S.

S.H. Long 1784-1864

Long was born December 30, 1784 in the small New Hampshire town of Hopkinton, one of ten children of Moses and Lucy Harriman Long. At the age of 21, Long entered nearby Dartmouth College and graduated in 1809. After teaching in New Hampshire and Pennsylvania for several years, he attracted the attention of General Joseph Swift then Chief of Engineers for the United States Army. In 1815, Swift convinced Long to join the Army as a Second Lieutenant. After teaching mathematics at West Point for a year, he was appointed Major in the Topographical Engineers.

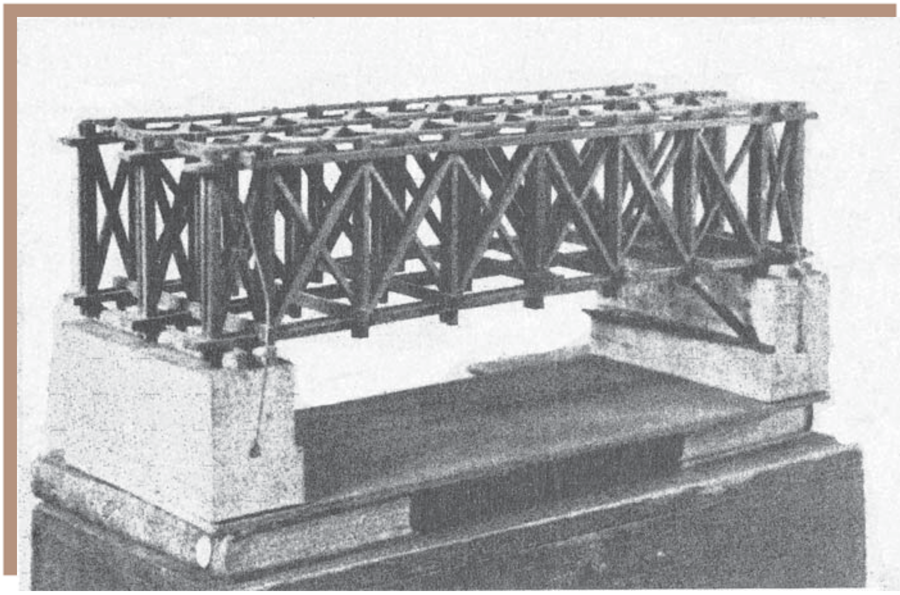
During the next ten years, he led five major expeditions in the west including those to the Rocky Mountains and Yellowstone area. In 1824, Congress passed an Act making Army engineers available to assist in private railroad and canal projects throughout the country. In 1827, Long was assigned to the Baltimore and Ohio Railroad which was just chartered. He, as much as anyone in the United States, was prepared by education and experience to become one of the Chief Engineers of the railroad along with Jonathan Knight. His initial responsibility was surveying the route the line should take to the West. During this period, he found the time to write a "Railroad Manual or a Brief Exposition of Principles and Deductions Applicable in Tracing the Route of a Railroad" in 1829. This manual was printed in part in the *Journal of the Franklin Institute* in 1830.

In 1829 Long, of necessity, became interested in bridge building and proposed to the Directors of the railroad that bridges on the line be built of wood, as they were not sure of the future success or development of the railroad. Wooden bridges could be either scrapped or upgraded as events transpired. Timothy Palmer's and Theodore Burr's bridges were well known, but Long indicated that the wooden bridges built by Lewis Wernwag could be adapted to meet the needs of the line. Other members of the engineering staff, who toured England in 1829 to observe the railroads built by George and Robert Stephenson, wanted to build bridges out of stone. Structures like the Carrollton Viaduct were built in stone as the railroad moved westerly towards the Monocacy River and still serve railroad traffic today, 175 years after their construction.

Long, however, was given approval to build a bridge to carry the Baltimore and Washington Turnpike over the railroad just outside Baltimore. He patented this bridge, named the Jackson Bridge after President Andrew Jackson, in 1830 and described it in articles in the *Journal of the Franklin Institute*. More importantly, however, he also wrote a pamphlet entitled "Description of the Jackson Bridge together with Directions to Builders of Wooden or Frame Bridges." Long's pamphlet enabled builders around the country to build a bridge to his patent. In 1836, he updated and expanded his pamphlet to 73 pages, calling it "Description of Col. Long's Bridges together with series of directions to bridge builders" (*See Figure A on pg. 52*). Because of this pamphlet, and his patent and articles in the *Journal of the Franklin Institute*, Long began to make his mark as the first structural engineer in the United States.

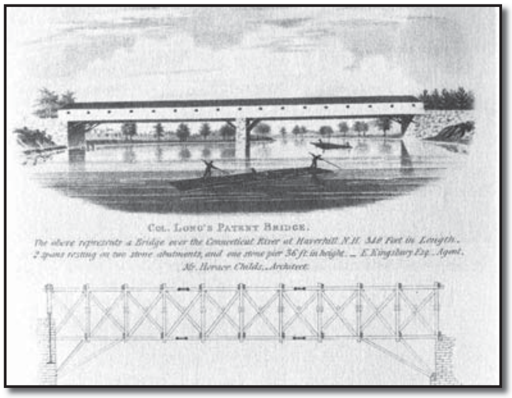
Unlike Palmer, Burr and Wernwag before him, Long was not a bridge builder. He was more interested in the design of truss bridges, patenting them, and then through a formal network of brothers, cousins, etc. receiving patent fees for the construction of his bridges.

His first patent application was lost in the patent office fire in 1836, so no official record exists other than that shown in his pamphlet and *Journal of the Franklin Institute* articles. His 1830 article, however, gives the span of the bridge as 109 feet, width 24 feet and height 14 feet. He gives the size, generally 6x6-inches, of the strings (upper and lower chords), braces, posts, counterbraces stating that the bridge had cost only $1,100 and was built in six weeks. He wrote that "however slender the materials of which this bridge is composed, and however deficient in



Model of Long's 1830 Patent Jackson Bridge as used by his agents

great achievements



Long's Bridge over Connectient River at Haver Hill, NH 1834

strength it may appear, it is crossed daily by stages at high 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." He concluded his remarks with "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 its floor, about one hundred and ten tons weight." Framing was of much smaller members than any bridges built by Palmer, Burr or Wernwag, as it appears that he was actually able to size some of his members to carry the load they would experience in use. This was the first time in the United States that an engineer used anything other than rule of thumb or model testing to design a bridge.

Unfortunately, he did not describe those "approved rules." He used parallel chords with bracing and cross bracing in each panel, as well as struts off the abutments and/or piers similar to the Schaffhausen Bridge of the mid 18th century. He also added a small king post truss on top of his bridge at mid span. It is clear he did not rely on arch action as did Burr and Wernwag, instead relying on pure truss action, with assistance from his struts.

His knowledge of truss action is clear, as he was the first engineer to write about the advantages of pre-loading a truss in order to achieve additional stiffness and the use of the parallelogram of forces to size his members and describe how loads were transferred from member to member and thence to the abutments and piers. In his Jackson Bridge, the timbers of the verticals were passed between the members of the top and bottom chords and were treenailed (a treenail was a wooden dowel), so that they could sustain either tension or compression loads. His diagonals, braces and counter braces were simply wedged into place at the intersection of the chords and verticals. They could, therefore, sustain only compressive forces. He built a statically determinate bridge in a cambered position with his chords, verticals and main braces erected on falsework. He then dropped his falsework and loaded the bridge with a uniform design load (120 psf). At this time, his main braces would be in compression. With the bridge under its design load, he carefully inserted his counterbraces so they were a snug fit, using wedges as necessary. He then unloaded his truss. As the truss tried to rebound, it threw compressive loads into the counterbraces and unloaded his main braces so that they carried less compression. When the bridge was next loaded by traffic, both his brace and counterbrace would remain in compression.

After 1831, he also started to sell his patent rights to railroad companies and many of the first wooden RR bridges were built to his plan. Three Bridges with spans of 70- to 100-feet were built for the Baltimore and Susquehanna RR in 1832-33, and several on the Boston and Providence RR and Boston and Worchester RR with spans up to 120 feet in the same time period. To upgrade his Jackson Bridge member sizes for RR loadings, he took the same table stating that if the builder wanted to build the bridge to carry RR traffic he should go into his table with the span length desired and then move down the table between four or five steps and use the sizes of the longer span. In other words,

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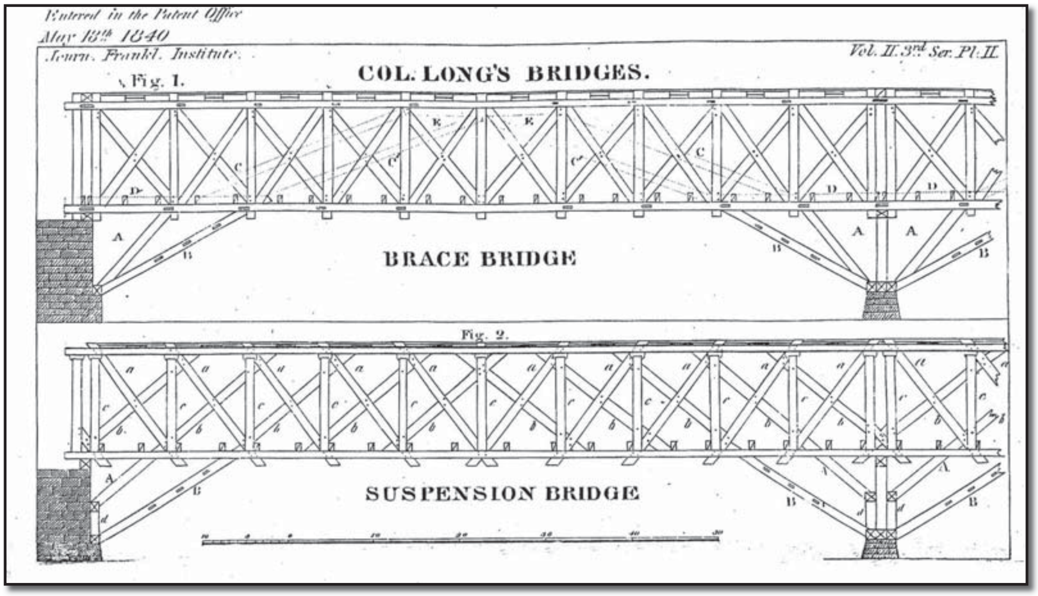


Figure A: Long's Brace and Suspension Bridge Patent #1.397 and 1.398 - November 7, 1839

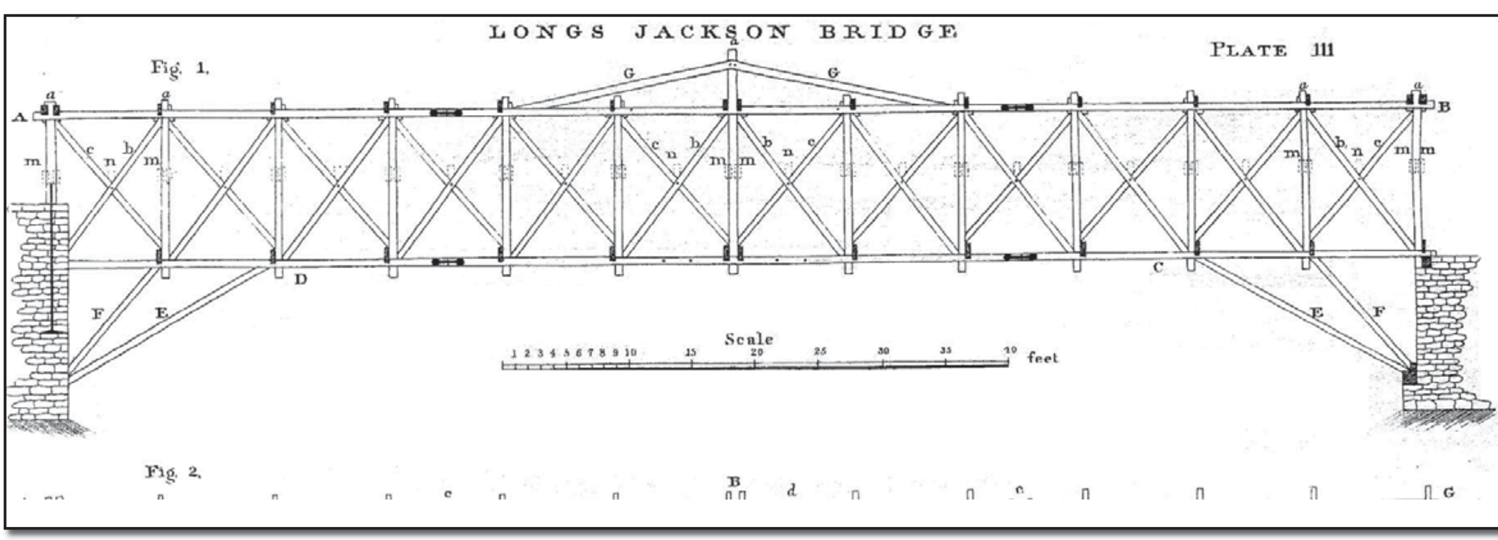
a railroad bridge of 100-foot span would use the same size members as a roadway bridge of 140-foot span.

In his "Directions," he gave two tables of values for the size of every member of his truss for spans of up to 300 feet. He maintained top and bottom chords the same size throughout for simplicity. He recommended the panel lengths of his truss be varied to enable the use of equal size timber and equal to ⅔ the depth of the truss near the piers or abutments, and about equal to the depth of truss near mid-span It remained for Squire Whipple in 1847 to determine that the most efficient ratio was 1 to 1.

He was the first American Bridge builder to talk about the importance of continuity in bridge construction, and the reduction in member sizes and increase in stiffness that could be derived. He considered the subject of the strings (chords), stating that the upper and lower strings "should be equal to each other in their transverse dimensions and *initial* strength…by rendering the upper strings continuous, over the piers and abutments, in such a manner that a degree of tension may be exerted at those points equal to that exerted by the lower string, at points intermediate to the spans, and *vice versa*…" He continued "the reciprocity of the actions of the upper and lower strings, here adverted to should be aimed at in all bridges whose spans exceed 120 or 130 feet; but need not be particularly regarded in bridges of less extent: inasmuch, as the tension in the lower, and the thrust in the upper strings, may be effectually counteracted without increasing the dimensions of the pieces to an unwieldy size."

He arrived at these equal forces in the upper and lower chords by varying the spans of bridges "dividing the breath of a river into spans for a bridge, except the exterior spans, or those contiguous to the contemplated abutments, which should have only about three-fourths the extent of the other spans." In an 1838 pamphlet, he described in more detail how he arrived at this proportion. It was a very reasonable value based upon an analysis which would not be developed for another 27 years, but later engineers usually maintained equal span lengths.

He was issued a second patent on January 23, 1836, (no number), and two more patents on November 7, 1839, one for a brace bridge and another for a suspension bridge. The brace bridge dealt mostly with modifications of member connections, with the basic truss pattern being the same as the Jackson Bridge. The suspension bridge, however, was "new and original." This truss contained, for the first time, diagonals in tension and verticals in compression; what would later be the claim of the Pratt Truss. As can be seen in *Figure A*, the diagonals sloping down and to the right (on the left end of the span) were passed through openings between the upper and lower strings and treenailed into place. The counter-ties were also treenailed to the posts and ties but did not pass between the strings. He noted "The suspension bridge … is distinguished from other bridges heretofore … to wit, the posts act by thrust instead of tension, and the main and counter braces by tension instead of thrust, 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, .." This is just the opposite of the Jackson Bridge in which all the braces act uniformly in the direction of their axes, and exclusively by *thrust*.



Long's Jackson Bridge 1830

Although Long worked primarily in wood he knew his suspension bridge would lend itself well to construction in iron. He wrote:

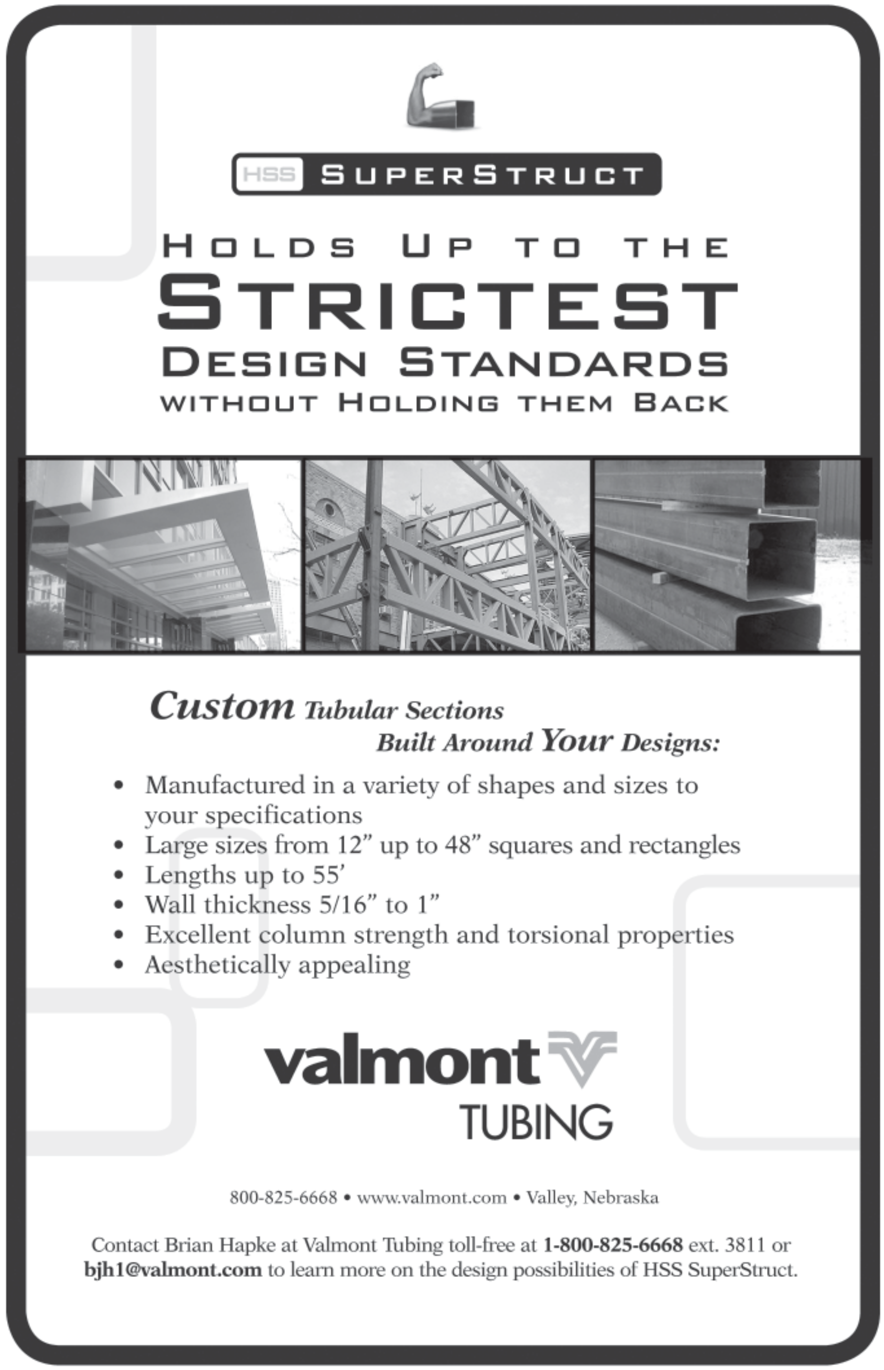
> "It is obvious that the arrangements prescribed in reference to the suspension bridge, are not only applicable in wooden structures, but, with slight alterations and appropriated modifications, the same principles are equally applicable in the construction of iron bridges. In this application of the 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 main and counter braces being merely rods or bars of wrought iron with eyes at their extremities, adapted to the reception of the bolts."

His brace bridge was a precursor to the Howe truss, with its compression diagonals and tension posts and his suspension bridge a precursor to Pratt's Truss with its tension diagonals and compression posts. The brace bridge was also a successor to the bridges of Timothy Palmer 40 years earlier.

He received another patent on July 20, 1841 (#34) which was a reissue of his Brace Bridge patent of 1839. His next patent was issued November 13, 1847 (#5,366) and his last on August 17, 1858 (#21,203), but these added little to the design and construction of wooden bridges and were not built.

He died in 1864 at the age of 80, shortly after retiring from the Army during the Civil War. He was a giant of the mid 19th century as an explorer, railroad engineer, bridge designer and river navigation engineer. The publication of his work in the *Journal of the Franklin Institute*, and in pamphlets, helped to create the development of railroading and bridge building profession in the United States. He was the first American who could be called a structural engineer, as he combined computation with intuition to advance the art of bridge building.▪

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.



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