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The American Metal Lattice-Truss Bridge and the Hilton Truss

Part 2

By David Guise

Part 1 of this article (August 2011, STRUCTURE®) traced the early development of the lattice bridge-truss design, culminating with Hilton's riveted wrought-iron configuration. Part 2 addresses the rationale behind the lattice design and examines the many specialized variations.

The terms *lattice* and *Multi-Warren* have been used interchangeably. Double and triple intersecting configurations are more commonly referred to as double and triple (*Figure 13*) intersecting Warren trusses, while quadruple (and beyond) intersecting configurations are interchangeably referred to either as lattice trusses or multi-Warrens. The quadruple-Warren was the most common "lattice" through-truss configuration used by the railroad lines. The NY Central built a substantial number of these trusses, most of them for relatively short spans. The distinguishing feature of the quadruple-intersecting *Hilton lattice* design is the 45 degree slope of its web diagonals and the vertical tension hanger at their hip joints (*Figure 14*).

Due to the geometry of its configuration, the panel points of a lattice truss are more tightly spaced along the horizontal span of a bridge than those of the other, more common modest span truss configurations such as the Pratt and Howe. The shorter spacing between panel points permitted the bridge deck to carry the increasingly heavy loads produced by ever larger locomotives, and thus made its design particularly appropriate for railroad crossings. Double and triple Warren configurations were more commonly used for wagon traffic, as the wagon loads were lighter than the trains and the wagon truss construction could also be lighter.

Howard Carroll, George Gray (who was New York Central's chief engineer during Carroll's early years), and Carroll's successor, Charles Hilton, all believed that the large number of rigid joints in a lattice truss provided an advantage over the more flexible pin-jointed alternative truss choices, as the riveted construction rendered the truss more rigid and thus less subject to damage due to vibrations. They also believed that the redundancy provided a margin of safety if one of the truss members became damaged.

*Figure 13 (continued from figures shown in the August article): A Triple Warren Union Pacific Railroad Bridge over the Blue River near Manhattan, Kansas. Courtesy of James Baughn, webmaster at **bridgehunter.com**.*

Figure 14: A Hilton, riveted, wrought-iron lattice truss over the James River near Redfield, South Dakota. Note the vertical truss member at the hip joint. Author's post card collection.

Others adopted Hilton's unpatented lattice truss configuration, often pushing the spans beyond those of the New York Central's. For example, The Rice Farm Road Bridge over the West River near Dummerston VT has a 198-foot span. While this structure is not a railroad bridge, it was built to carry the heavy granite blocks quarried by the Lyon Granite Co. and thus the reasoning for selecting a lattice configuration was similar. Since a lattice design requires more material per foot of span than the Pratt truss, it could not compete successfully on long-span crossings with the sub-divided variations of the Pratt, such as the Pennsylvania and Baltimore trusses which were capable of four and five hundred foot spans.

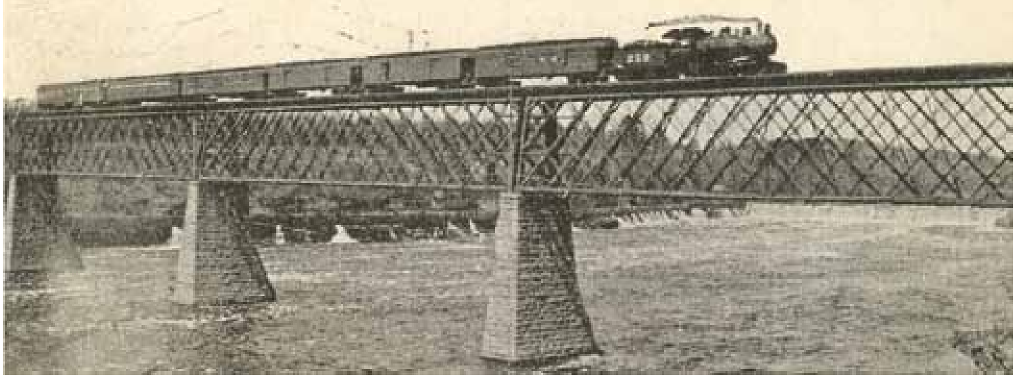

Figure 15: Railroad, Deck Lattice Bridge, over the Chippewa River, Eau Clare, Wisconsin. Author's post card collection.

*David Guise retired after 40 years of private practice as principal of his architectural firm and is Professor Emeritus at City College of New York. He can be reached at **davidguise@myfairpoint.net**.*

Engineers viewed lattice trusses as a composite group of separate overlapping Warren trusses, and analyzed each overlapping arrangement as a separate triangular bracing system. Thus, a quadruple-Warren would be treated as four separate trusses. A moving load causes each of the individual triangular web systems to work in successive order, with the contiguous members of each individual Warren system alternately resisting tensile and compressive stresses. Since the diagonals in the web were actually connected to each other at their intersections, an accurate calculation of the stresses on any individual web member was beyond the capacity of the engineers that built them. However, the overall solution erred slightly on the conservative side.

Although many engineers derided the redundancy of the lattice configurations, others took comfort in the knowledge that if a derailed train, projecting load, or other catastrophe took out a web member of the truss, the redundancy could prevent the bridge from failing. Additionally, the tensile diagonals were also capable of handling some compressive stress by default, because the securing of the diagonals at their crossing points with the compression diagonals subdivided their lengths into several short segments. Each resulting shortened section was then less subject to buckling.

While the majority of the metal lattice-truss bridges may have been through-trusses, lattice deck trusses were erected when clearance beneath them permitted (*Figure 15*).

At least one lattice truss was built with a curved top chord (*Figure 16*).

Figure 16: Willis Avenue Bridge. Over the East River. New York City, 1901. Courtesy of David Guise.

And, of course, there is almost always a one-of-a kind solution. This particular lattice truss needed some additional rather unique help, perhaps added as an afterthought when the locomotive and train loads became greater (*Figure 17, page 32*).

Why a small number of through lattice trusses were constructed with vertical ends remains somewhat of a mystery. No engineering documents have been found indicating a justification for designing a through lattice with a vertical end, which uses additional material without providing any structural advantage (*Figure 18, page 32*).

Perhaps some engineers felt the vertical-end connection details were easier to make. Possibly the earlier (1864) vertical-end Canastota Bridge over the Erie Canal influenced the engineers, L. F. Thayer & E. A. Fisher, who designed the 1877 North End crossing of the Connecticut River at Springfield, Massachusetts, built by the Leighton Bridge & Iron Works (*Figure 19, page 32*).

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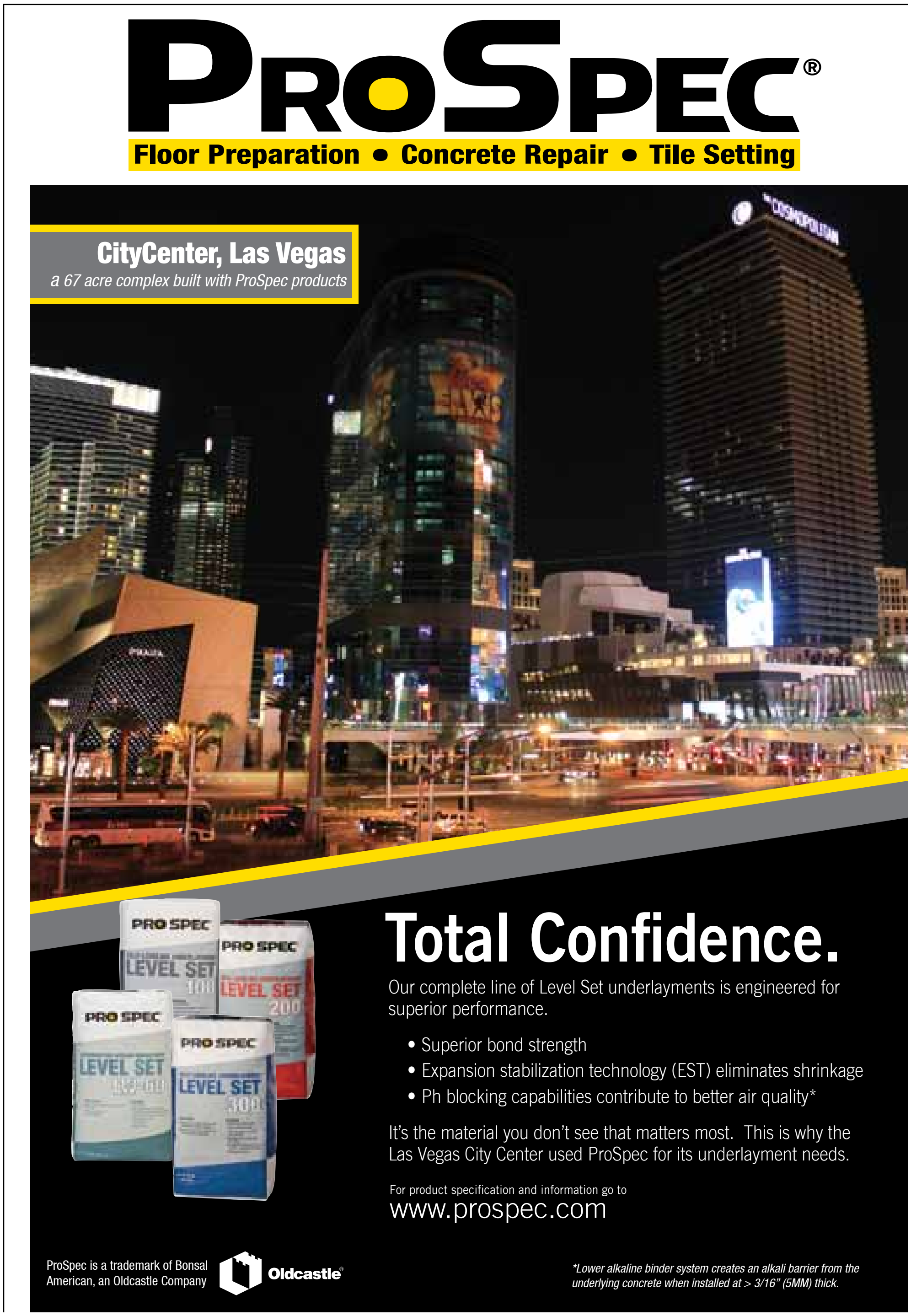

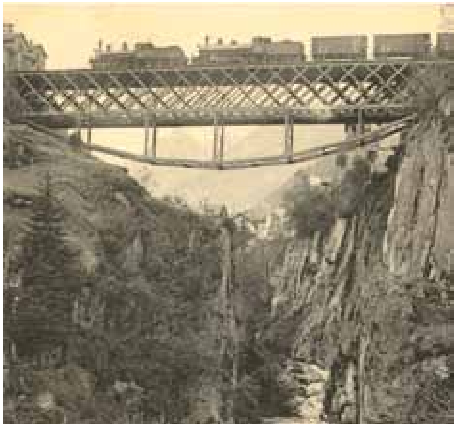

Figure 17: Lattice Truss, Goeschenen, Switzerland. Author's post card collection.

Possibly some thought a vertical portal (especially in the case of a wagon bridge that served as an entry to a town, and thus became a symbol of local pride) presented a more majestic image. However, the clear majority of the through lattice trusses were constructed with more efficient inclined ends (*Figure 20*).

The lattice truss's often muscular image evoked a similar sense of power as the steam locomotives that crossed them, and became part of the railroading image of their time.

Figure 18: Canadian Pacific Railroad Bridge near Cody, New Brunswick, Canada. Courtesy of Richard Cook, The Beauty of Railroad Bridges.

Figure 19: 1877 Lattice truss over the Connecticut River. Springfield Massachusetts. Courtesy of Springfield Museum. Provided by Cliff McCarthy.

Figure 20: Norfolk and Southern Railroad Hilton Lattice Truss, over Seeley Creek, near Elmira, New York. Courtesy of Nathan Holth at ***historicbridges.org***.

Figure 21: Lattice Railroad Trusses. Hillburn, New York. Courtesy of David Guise.

Inevitably, their rugged silhouettes continue to be supplanted by mundane, steel plate-girders that are now used for spanning modest railroad crossings. Fortunately a small handfull of theses old trusses remain to remind us of the earlier, innovative nation-building days of railroading and the bridges that were built (*Figure 21*).▪

References

More than a dozen Pennsylvania trusses had spans in excess of 500. One, at St. Louis, had a 668 foot span. Merriman & Jacoby *Roofs and Bridges*, Long Span Simple Bridges Chart pp. 226-7

The Institution of Civil Engineers, Selected and Abstracted Papers, Vol LXXIII, p.365. London 1883.

MacNeill's first lattice bridge was an 84-foot span footbridge over the Dublin and Drogheda Railway at Raheny near Dublin. J. G. James, *The Evolution of Iron Bridge Trusses to 1850*, p.17.

The viaduct over the Boyne River estuary was built between 1851 and 1855 by the Dublin and Belfast Railway linking the Dublin and Drogheda Railway with the Ulster Railway. R. Cox and M. Gould, *Ireland*, p.75.

Thomson in *Discussion*, Gray's *Notes on Early Practice in Bridge Building*. Transactions, ASCE, June 1897.

A diagram of Carroll's Mohawk River crossing, along with a table showing the size of all its members, is contained in the *Report of the New York State Railroad Commissioners of the State of New York*, 1891. pp.857-860

George Thomson served as chief engineer for the New York Central Railroad for a period of 21 years. *Memoir of George Thomson*, Syracuse Chapter ASCE, 1910. Thus he had full access to their records.

A diagram of the Tonawanda Creek bridge, along with a table showing the size of all its members, is contained in the *Report of the New York State Railroad Commissioners of the State of New York*, 1891. pp.989-991