historic **STRUCTURES**

"Here…is the gateway to Springfield and the towns to the east for almost an entire nation," proclaimed Massachusetts Governor Channing Cox on August 2, 1922. It was Dedication Day for the new Hampden County Memorial Bridge, which spans the Connecticut River between the City of Springfield and Town of West Springfield in Western Massachusetts. Boston engineers Fay, Spofford & Thorndike, with architects Haven & Hoyt, designed the bridge, deemed a "finely-engineered example of a rare self-supporting arch rib reinforcement technique derived from the Melan tradition" [HAER Ma-114]. Builder H. P. Converse & Co. of Boston completed the bridge ahead of schedule on July 31, 1922, after 28 months of construction. At 1,515 feet long and 80 feet wide, it was designed to support pedestrian, vehicular, street rail, and heavy armament traffic. A bridge big in size and cost ($4 million) for its time, it remains the longest reinforced concrete deck arch span in Massachusetts.

Looking east, showing piers and arches. Retrieved from the Library of Congress.

Springfield's Great Bridge Salutes History

By Beth McGinnis-Cavanaugh, MSCE

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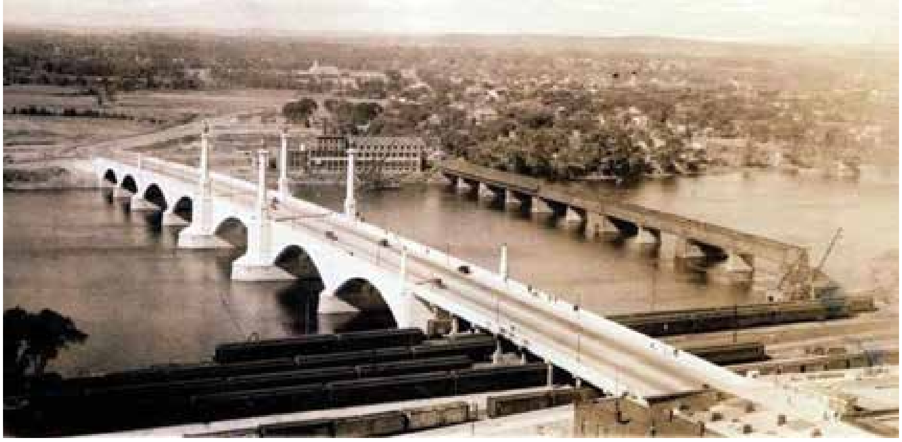
The Memorial Bridge sits at the nexus of three rivers: the 410-mile north-south Connecticut River, New England's longest, and major east and west tributaries Chicopee and Westfield Rivers. With river access to New York and Canada and the rich soil of the Connecticut River Valley, Springfield was founded as a trading and farming community when Puritan William Pynchon purchased land from the Agawam Indians in 1636. The river was not bridged until 1805 when a wooden toll bridge was built. A covered wooden toll bridge followed in 1816, but the motorized cars and trucks of the 20th century and a burgeoning Springfield population made a new bridge imperative in the early 1900s.



Hampden County Memorial Bridge looking west from Springfield, August 1922. Springfield viaduct in the foreground. 1816 covered wooden toll bridge upstream, in the process of deconstruction. A segment of railroad bridge is visible beyond. Courtesy of the Lyman and Merrie Wood Museum of Springfield History.

Years of dispute forced the Commonwealth to appoint an independent commission to finalize its design and location. The Connecticut's soft riverbed precluded solid concrete and masonry structures, and exposed steel arches were deemed unpleasing for what principal Charles M. Spofford called "this important new artery of commerce spanning a great New England river." In 1919, commissioners selected a reinforced concrete deck arch bridge named to honor "those who had died as pioneers, and soldiers in the Revolutionary, Civil and Foreign Wars." The bridge, designed in the Beaux-Arts style, boasted seven parabolic concreted rib arches on six piers and two abutments that spanned 1,200 feet across the river. A nine-span viaduct of 314 feet over railroad tracks on the Springfield (east) side formed the Springfield approach. The bridge was located 400 feet downstream of the 1816 covered bridge at right angles to the river – just north of the river's widest point.

The Memorial Bridge opened to great fanfare in 1922, "beautiful in the sweep of its lines, the last word in engineering science…a symbol of that progressiveness that has been characteristic of the valley" [*Springfield Republican*, July 1922]. Springfield had shed its colonial past, surpassing neighboring Hartford in size and status and emerging as a hub of industry, innovation, and intellect. General George Washington had established the Springfield Armory in 1777, where the first American musket and famous Springfield rifle were produced. After the War of 1812, the Armory pioneered the use of interchangeable parts and assembly line production, making Springfield the nation's epicenter of precision manufacturing – the "Silicon Valley of the 19th century." This catalyzed industry of all types. Springfield was the birthplace of the Duryea car, America's first gas-powered automobile, and the Indian motorcycle. The "City of Firsts" was home to Knox fire engines, Wason railroad cars, Goodyear vulcanized rubber, Rolls Royce automobiles, Smith and Wesson firearms, and Merriam-Webster's dictionary, among many other firsts. Naismith's game of basketball, Milton Bradley board games, four Carnegie libraries, renowned museums, and a young Dr. Seuss also called Springfield home in 1922.

Thus, upon its opening, the Memorial Bridge was more than it appeared – much more than just a river crossing. It was an announcement. The frontispiece of a confident city, the bridge exuded strength, permanence, and promise. It was the very embodiment of Springfield in 1922. Like the City, it was "practically imperishable" according to H. P. Converse, who stated, "I can't think of anything that will prevent the bridge from standing as firmly 500 or a thousand years from now as it does today" [*Springfield Republican*, July 1922].

The Melan System

The introduction of the Melan system spurred the construction of reinforced concrete bridges in the U.S. in the late 1800s and early 1900s. The system called for parallel, self-supporting steel arch ribs – curved I-beams – encased in concrete to support traditionally reinforced superstructures. Ribs were placed along the centerline of the arches, not where tensile stresses occurred as would be typical with traditional reinforced concrete. Steel and concrete were used in parallel to support loads but did not act as a composite material. By 1924, over 5,000 Melan or Melan-style bridges had been built in the U.S.

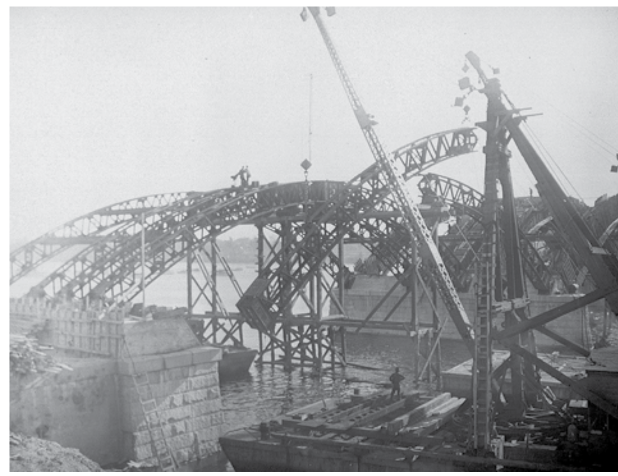
Patented by Austrian engineer Josef Melan (1854-1941) in 1893 in the U.S., the Melan system was originally a design for suspended floors and roofs in warehouses and other large span buildings. Melan, a renowned bridge engineer and professor of structural mechanics, adapted it for bridge use after testing showed that it was 3 to 4 times stronger than other bridge designs, including those using Monier's wire mesh. The system was championed in the U.S. by former Melan student Fritz von Emperger, who patented several variations, including the use of lighter latticed (trussed) ribs instead of I-beams.

Longer and wider spans, greater loads, ease and speed of construction, and economy made the Melan system popular in the U.S. The use of steel arch ribs minimized the use of concrete or masonry as in barrel arches, which reduced dead load. Concreting of the ribs added strength and stiffness. This permitted longer spans with fewer piers, and greater live loads. Further, the use of ribs to support formwork and concrete induced stresses in the ribs that allowed the more efficient use of the steel and maximized the steel's strength. With traditional reinforcement, the capacity of the steel was limited by the concrete modulus, which was typically 10 to 15 times less than that of steel.

The Melan system promoted ease and speed of construction, which meant fewer laborers, less skilled labor, and less time. Unlike concrete or masonry arches that could not be prefabricated or labor-intensive bar reinforcement, arch ribs were delivered in two or four sections ready for erection. The ribs were stable during erection with minimal support and equipment and designed to support the formwork for concrete, which was hung on the ribs. This eliminated vast amounts of falsework, which minimized the use of timber and simplified construction over terrain that threatened the stability of the falsework. Further, the system allowed multiple facets of construction to be done simultaneously; for example, ribs in one span could be concreted while ribs in another span were erected.

As spans lengthened and live loads increased due to the growth of vehicular and street rail traffic, larger rib sections were required. To reduce increasing amounts of steel and dead load as well as pier size, I-beams were replaced with lighter latticed or trussed hinged ribs. Often, these ribs were reinforced with hoops and traditional bars. The use of hinges minimized bending

Bridge construction. Concrete hoisting tower (130 feet) shown. Concrete was transported from mixing plant on West Springfield side along a temporary wood trestle 70 feet upstream. Courtesy of the Lyman and Merrie Wood Museum of Springfield History.



Arch erection in span 7, Springfield side. Courtesy of the Lyman and Merrie Wood Museum of Springfield History.

stresses, temperature stresses, and stresses due to shrinkage of concrete, and made for more straightforward analysis. Crown hinges were fixed during concreting, reducing deflections of the arches.

The Melan system was an alternative to traditional reinforcement and the prevailing uncertainty about composite action, concrete quality, and construction methods. Swiss bridge engineer Robert Maillart criticized the system because the design could not rely on the bond between concrete and ribs. Maillart believed the lack of bonding would lead to separation and ultimate corrosion of steel. Moreover, as Melan bridges were overbuilt to inspire confidence, the system was surely an affront to the efficiency and elegance of Maillart's three-hinged deck-stiffened concrete arches. Also problematic was the concrete encasement of the steel, which prevented proper drainage and led to corrosion.

The Bridge

"No other bridge in the country is just like it…" boasted the bridge souvenir edition of the *Springfield Republican* in July 1922, adding "the structure will long be of interest to engineers." The bridge was "structurally and architecturally significant" and the engineering "sophisticated" [HAER MA-114].

A total of 10,500 pine piles, 20 to 40 feet in height and spaced 20 feet on center on hard clay, form the foundation for six river piers and two abutments. Under the channel span piers, there are 2,263 piles; under the smallest pier on the West Springfield (west) shore, there are 700. An average of 110 piles per day were placed with two steam-powered pile drivers. Concrete piles were used for the viaduct spans.

The hollow concrete piers support 5 arches per span. The piers, constructed using cofferdams, vary in size. The channel span piers, designed to accommodate a potential draw span per order of the Army Corps of Engineers, are the largest at 65 feet by 179 feet. Each pier has ten skewbacks – two for each arch – and does not extend above the springing. All are faced with 10 courses of cut granite from just below the water level that protects the piers from river current and winter ice flows. Dredging was done to maintain the natural flow of the river.

The arch span lengths vary from 110 to 209 feet; the span rises from 19.1 to 29.7 feet. Marked by four 80-foot beacon towers, the channel span is 176 feet in width and 40 feet above low water over 60 feet, "fixed in accordance with the requirements of the War Department" [ENR 88, 13] for all "navigation necessities" [ENR 88, 13]. The bridge is asymmetric on the river to follow deep water; that is, the channel span is the third span from the Springfield side. The two spans that flank the channel span on either side, 154 feet and 146 feet in length, are sized to give the bridge symmetry. Smaller beacon towers embellish these spans, which furthers the illusion of symmetry. The remaining two smaller spans on the West Springfield side balance the Springfield viaduct. The nine viaduct spans are equal in width.

In all arch spans, there are five parallel arches: two exterior and three interior arches, which are centered under the critical street rail load in the middle of the road deck. Each arch is a steel arched Warren truss rib encased in concrete. All arches are 5.5 feet wide but vary in height with span length, ranging from 4 feet 9 inches to 7 feet. The arches support a traditionally reinforced concrete deck on reinforced columns. The inner arches are not filled, and exterior spandrel walls hide the arches and columns to give the bridge the appearance of solid masonry.

All of the 35 steel arch ribs, each weighing between 20 and 70 tons, were initially three-hinged, transported in four sections. They were erected in only 10 days with an erection sequence designed to ensure the stability of the piers. Falsework was used to support the arches at the crowns and quarter points on the four larger spans during erection. The ribs were encased in 593 psi concrete, as compared to a working stress of 16,000 psi for the rib steel. The crown hinges were fixed after concreting, leaving the ribs as two-hinged. On the outer arches, the crown hinges were fixed before concreting; the interior crown hinges were fixed after the roadway deck was placed to offset deformations due to dead load and shrinkage. Within each span, the ribs are connected with wind bracing and reinforced with traditional bars along the arch and hoops around the rib.

Conclusion

The Melan system fell out of favor in part as steel became more expensive and less available. More so, a better understanding of cement and concrete technologies, composite behavior, and the development of uniform codes and construction methods moved structures towards more efficient and economical bar reinforcement. The system experienced a rebirth in the 1970s which continues in Japan and China, where self-supporting arches are used to construct bridge spans in mountainous regions.

As a structure, then, the Memorial Bridge was technically obsolete almost upon its execution – a harbinger of things to come for Springfield. Alterations to the bridge were made in 1950 and 1966, and it was obfuscated by the opening of an elevated viaduct in 1970. A complete rebuilding of the superstructure was completed in 1996 after extensive corrosion was discovered. An EF3 tornado rendered it unscathed in 2011, yet the recent construction of a downtown casino has cast further shadow. But the bridge will not be denied. Transcendent, it remains a vital channel and landmark in Western Massachusetts. As it nears its 100th year, it continues a touchstone for a City struggling to reclaim itself and persists in bearing witness to Springfield's illustrious past.▪