An innovative steel truss strategy delivers a bi-state vertical lift bridge in just 18 months.

A New Way to CONNECT

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THE WORLD WAR I Memorial Bridge has been bringing two states together for nearly a century.

Built in 1923, the bridge was a steel stitch across the Piscataqua River that pulled together the towns of Portsmouth, N.H., and Kittery, Maine. Carrying up to 20,000 vehicles a day, it allowed both communities and states to benefit economically and socially from resources on the opposite bank. In recent years, though, it had to be closed due to structural deterioration.

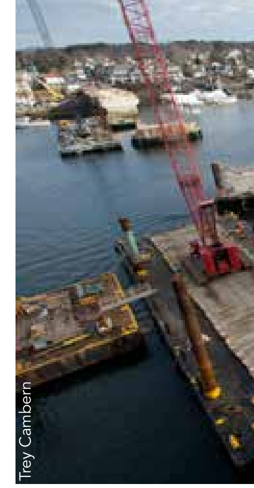
"We tried to keep it functioning as long as we could," said Keith Cota, chief project manager for the New Hampshire Department of Transportation, which shared ownership of the bridge with the Maine Department of Transportation. "We closed it in phases, first to vehicular traffic then eventually to pedestrian and bicycle traffic."

Repairs were made to keep the bridge operational for river traffic while the owners began the process to procure a replacement. To speed up delivery, the bi-state agencies chose design-build procurement and issued a request for proposals. Understanding the hardship and economic impact caused by the bridge's closure, the design-build team of HNTB Corp. and Archer Western Contractors pledged to deliver an innovative vertical lift steel bridge in 19 months—five months faster than other bids that were made. The team was awarded the $90 million project, the largest highway and bridge contract in the history of the New Hampshire Department of Transportation and the state's first design-build job.

The design uses 2,375 tons of 50-ksi steel and features three identical 300-ft through truss spans, a 163-ft lift tower on each of the two flanking spans, two 11-ft through lanes, two 5-ft shoulders for bicyclists, two 6-ft sidewalks inside the truss planes (which eliminate the need for special bridge inspection equipment) and a pedestrian overlook at both flanking spans.

"The proposed structure had to be similar in mass and size to the original bridge so it would not detract from its historic setting," Cota said. "It fits nicely in this location."

Weighing 1,250 tons, the center span of the truss bridge raises to provide 150 ft of clearance during high tide. It is balanced by counterweights of 625 tons each.



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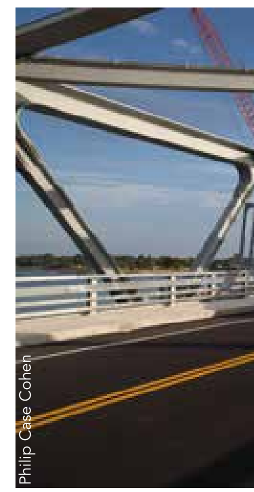

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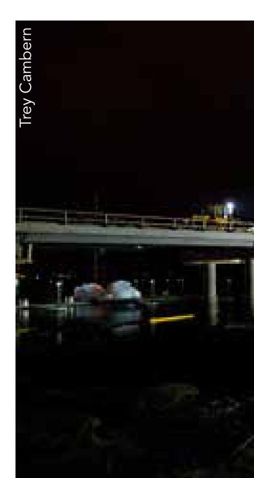
◄ Floating in.



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▲ The bridge uses 2,375 tons of steel.

▼ Ready for traffic.

▲ The center span can raise to provide 150 ft of clearance.

▼ Night work.

As the bridge raises and the ropes slacken, two sets of gigantic chains, typically used for ships' anchor lines, engage as a counterbalance. L-shaped mini cranes on each tower allow operators to add or remove steel plates over the life of the structure to maintain an accurate balance between counterweight and lift spans.

Positioning the mechanical system below deck, a first for vertical lift bridges, helps to create a streamlined appearance and cleaner operations, since elements that require routine maintenance and greasing are below deck. Having the auxiliary drive on one end of the main span and the primary drive system on the other end, connected by a longitudinal cross shaft in the plane of the bottom chord, results in machine rooms that are readily accessible for inspection and maintenance activities without inconvenience to pedestrians or vehicular traffic. A key to this arrangement is that all of the mechanical equipment could be preassembled and the entire machine room hoisted and attached to the bottom chord of the truss, speeding up lift truss assembly.

Facilitating Efficiency and Speed

To bring the bridge together quickly and efficiently revolved around what the design didn't include rather than what it did. For starters, gusset plate connections weren't part of the design. Gusseted truss connections are especially susceptible to deicing salts, which are prevalent in the Northeast. These connections act as pockets where snow, salt and debris collect, causing corrosion and damage to the structural steel. These connections are not only difficult to access for inspection and maintenance but are also nearly impossible to replace without traffic closure and the use of temporary falsework.

The solution was simple: Create a design that eliminates the troublesome connections and instead fabricate the top and bottom chords of the wide-flange sections in much the same way plate girders are fabricated; this offers an immense savings in time. With plate girder-type fabrication, there is little or no penalty for increasing the depth of the bottom chord. The bottom chord acts as a beam in strong axis bending and offers the possibility for true truss redundancy, where the loss of a diagonal can be effectively redistributed in chord bending. Instead of a truss chord depth of 14 in. to 18 in., typical for 30-foot spans, the final design uses 36-in. I-section bottom chord.

With the truss' gusset connections gone, diagonals are connected to the chords via a conventional spliced connection. Rather than the connection being at the node, where the diagonals meet the top and bottom chords, the design moved the splice away from the bottom chord and up the diagonals to enhance fabrication, as well as ease maintenance and inspection.

Splicing the diagonals allowed each flange and the webs to connect to independent plates. This, in turn, permitted piece-by-piece replacement—a significant cost-saving and life-extending advantage over conventional gusset plate design. This configuration also pre-compresses the joint in a highly efficient way. The plates are compact and the bolts are tightly spaced, which helps prevent rust buildup. Overall, the truss design makes the bridge significantly more resistant to corrosion and less costly to maintain.

Designing a deeper bottom chord meant the stringers could be eliminated by using intermediate floorbeams that subject the bottom chord to bending and tension. Thus, the deck system spans longitudinally between floor beams, making the superstructure system easier to fabricate, erect, inspect and maintain.

Bolts were also minimized. Flanges and webs are connected using two sandwich plates, subjecting the bolts to double-shear. Having double-shear connections at every node reduces the number of bolts to half that of a traditional gusset plate connection, saving time and labor costs in both fabrication and installation. Although this truss design uses up

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to 30% more structural steel, the savings in time and labor costs from minimizing the bolts made it extremely cost-competitive with conventional trusses.

While the design strategy for the truss was innovative, in order to reduce risk it had to incorporate as much repetition or uniformity as possible. To speed up fabrication, each of the three spans has identical geometry, with the only variable being exterior flange size (i.e., top flange of the top chord and bottom flange of the bottom chord). All other geometry—webs, interior flanges and diagonals—remained the same.

When it came to coatings, the cost of shop-applied metalizing was about the same as the specified four-coat paint system, but it provided the added benefits of schedule acceleration and life-cycle cost savings. Further, design specifications called for 1/8 in. of sacrificial steel, meaning the trusses had to withstand a certain amount of corrosion without their performance being meaningfully impacted.

For the framing and truss systems, the team used a minimum of 1-in.-wide heavy plates. The heavy metal design yielded a truss bridge that is stronger, safer, more resistant to corrosion and more resilient to potential vessel collisions. Using the same weight in all spans made construction easier as well.

"Metalizing and heavy plates ensure the bridge will easily exceed the required 75-year design life with a 100-year expectancy being much more realistic," Cota said.

Testing Mettle

On paper, the design appeared to accelerate delivery, but its true mettle would be tested during fabrication. Steel fabricator Structal Bridges brought the design to life in its Claremont, N.H., plant. Work orders included the steel bridge superstructure, both 163-ft towers and the three through truss spans.

"Fabrication was the key to achieving the aggressive schedule," Cota said. "This is the first truss bridge to have been built with cold-bent steel flanges. Structal had to develop new weld strategies for the truss chords, particularly for the flange-to-web connections, which incorporate the curved flanges."

Most of the fabrication challenges were resolved on the first truss span. Learning curves on the second and third truss spans were much shorter, which underscored the purpose of the repetitive design.

After the spans were fabricated, Archer Western assembled each one on a barge and floated it out to the construction site. The three floats were timed to coincide with the Piscataqua River's high tide. All three spans were constructed by April 2013 and in place by June 2013. Facing a $25,000-a-day incentive/disincentive, Archer Western crews sometimes worked 20-hour shifts seven days a week to deliver the bridge on time and give the community back its mobility. In the end, the design proved its mettle both in fabrication and construction.

"People come into my office, see the renderings of the proposed bridge and think it is a picture of the actual bridge," laughed Cota. "That's how much the renderings mirror what was built."

"Residents are in love with the bridge," he said. "It immediately resumed its place as the heartbeat of the community." ■

Owners
New Hampshire Department of Transportation
Maine Department of Transportation

General Contractor
Archer Western Contractors

Structural Engineer
HNTB Corporation
HDR, Inc. (Structural Consultant)

Steel Team

Fabricator
Structal Bridges - A Division of Canam Steel Corporation, Claremont, N.H. (AISC Member/NSBA Member/AISC Certified Fabricator)

Detailer
Tenca Steel Detailing, Quebec City, Quebec, Canada (AISC Member)