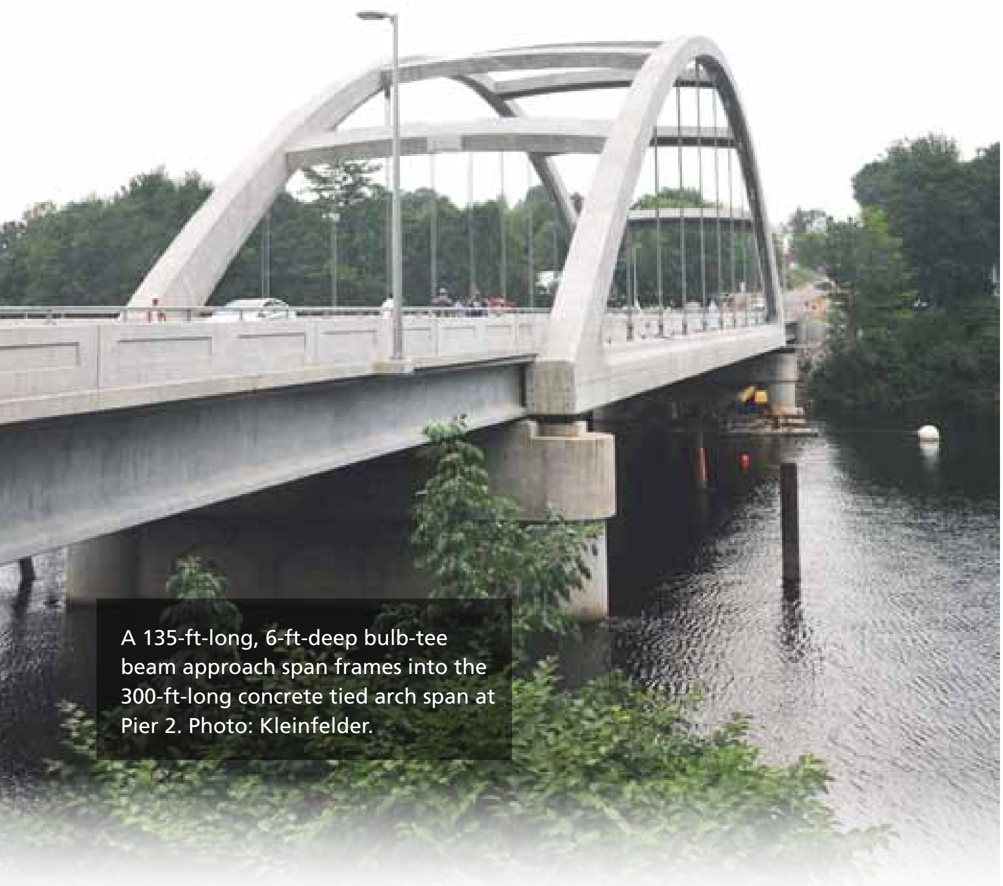
Re-Creating History:
Modern Techniques Preserve Character of Historic Bridge

by Craig Weaver, Kleinfelder



A 135-ft-long, 6-ft-deep bulb-tee beam approach span frames into the 300-ft-long concrete tied arch span at Pier 2. Photo: Kleinfelder.

Early photo of the four consecutive concrete tied arch spans of the Covered Bridge in Norridgewock, Maine, constructed in 1928. Photo: Maine Department of Transportation.

Built in 1928, the 570-ft-long, eight-span, tied-arch Covered Bridge over the Kennebec River in Norridgewock, Maine, was named one of Maine's most significant twentieth century bridges by the Maine Historic Preservation Commission. It was a visible landmark, an integral part of Norridgewock's identity reflected on the town's logo and letterhead—and, unfortunately, it had outlived its service life.

Rehabilitating or replacing the structure divided a community that was proud of the structure's historic significance. It was up to the Maine Department of Transportation (MaineDOT) and its engineering team to come up with a feasible, prudent solution that would satisfy the more than 3000 residents of this community and many others interested in historic preservation.

Community Connections

To ensure community support, the agency formed a 10-person committee to determine the new bridge's look and feel. The committee included the Norridgewock town manager, prominent residents, as well as representatives from the Maine Historic Preservation Commission, the MaineDOT and the Federal Highway Administration.

The committee considered the sentiment attached to the 80-year-old bridge and resolved to build another landmark-type structure. Ultimately, they wanted a "modern" historic bridge that would match the aesthetic and historic appearance of the original bridge with a service life of 100 years and a clearance sufficient for a 50-year flood.

profile

THE COVERED BRIDGE OVER THE KENNEBEC RIVER / NORRIDGEWOCK, MAINE

BRIDGE DESIGN ENGINEER: Kleinfelder, San Diego, Calif.

PRIME CONTRACTOR: Reed & Reed Inc., Woolwich, Maine

CONSTRUCTION ENGINEER: McNary Bergeron & Associates, Broomfield, Colo.

FLOOR BEAM PRECASTER: J.P. Carrara and Sons Inc., Middlebury, Vt., a PCI-certified producer

DECK PANEL PRECASTER: Oldcastle Precast Inc., Auburn, Maine, a PCI-certified producer

BULB-TEE BEAM PRECASTER: Strescon Limited, Bedford, NS, Canada, a PCI-certified producer

CONCRETE SUPPLIER: Mattingly Products Co. Inc., North Anson, Maine

POST-TENSIONING SUPPLIER: VSL, Hanover, Md.

The tie girder reinforcement being installed. The tubes in the foreground will receive the hanger rods from the arch. Photo: Kleinfelder.

To meet the committee's challenge, engineers incorporated key aspects of the old structure, particularly the old bridge's arch design. The new bridge's tied-arch span contains two parallel 300-ft-long arch ribs consisting of cast-in-place concrete with six cast-in-place transverse braces. The arches rise 60 ft above the deck. A 135-ft-long approach span is provided at each end of the arch.

The bridge is 46 ft wide and includes two 12-ft-wide travel lanes. Since the bridge lies along the Interconnected Trail System, a series of snowmobile trails throughout Maine, it includes a 7-ft-wide multi-use lane that will remain unplowed in the winter for snowmobiles and serve horseback riders and bicycles the balance of the year. It has one 4-ft-wide shoulder, one 6-ft-wide shoulder, and a 5-ft-wide sidewalk opposite the side with the multi-use lane.

Into the Bedrock

Once the original crossing and its piers were removed, crews constructed cofferdams for the new piers and abutments to support the arch span and the two 135-ft-long approach spans. Unlike conventional arch bridges that are commonly anchored into bedrock at each end, the Norridgewock Bridge tied arch rests on pile-supported, concrete column piers in the river.

Reinforced, concrete-filled pipe piles are socketed 10 ft into bedrock approximately 40 ft below the riverbed using H-pile tips. The concrete seal measures 70 ft 4 in. by 18 ft 0 in. by 12 ft 0 in. thick. The distribution slab for the piers is 66 ft 4 in. by 14 ft 0 in. by 5 ft 0 in. thick.

There are two 10-ft-diameter columns at each pier. The pier columns are connected by a curtain wall that prevents ice from forming between them, which would impose additional lateral loads on the bridge.

Overarching Demands

After the approach spans and piers were complete, crews began work on the main span, starting with the construction of six cast-in-place concrete end floor beams and four cast-in-place arch end connections. The three floor beams at the ends of the arches are 3 ft 0 in. wide by 5 ft 9 in. deep and form the connection between the arch rib and tie girder. They are post-tensioned to the tie girder. The arch ribs required concrete with a design compressive strength of 5000 psi. Tie girders and arch end connections use 6000 psi concrete.

As seen from below the bridge, precast, prestressed concrete floor beams frame into the edge tie girders, which are, at this stage of construction, supported on temporary intermediate piers. Photo: Kleinfelder.

Design for 100-Year Life

The bridge has no deck joints over its 570-ft length. The new Covered Bridge uses precast concrete floor beams and precast deck panels, at the urging of the MaineDOT. While improving durability, these elements helped speed construction, improve quality, and eased construction. The design allows for easy replacement of the steel cable hangers, when needed, with traffic on the bridge. The hangers are the only primary members of the new structure that are made of steel. Concrete main members were chosen as the primary material in the bridge for durability, consistency with the design elements, and overall aesthetics of the original historic structure. Increased concrete cover on the reinforcement was specified beyond code minimums. Also, reinforcing steel meeting ASTM A1035 was used in the deck and parapet. Elastomeric bearings were used and jacking points provided should replacement of the arch bearings be necessary. The design of the substructure provided for the scour potential of the Kennebec River.

Self-consolidating concrete was used for the anchor zone of the arch end connection due to the congestion of the reinforcement and post-tensioning ducts and anchorages.

The arch ends connect the base of each arch rib to the tie girder. After the arch ends were complete, crews placed six temporary piers in the river approximately 47 ft apart. Temporary piers were used to support the formwork needed to construct the arch ribs and tie girders. The formwork was constructed in such a way as to permit the concrete structure to shorten and camber due to shrinkage and post-tensioning forces.

THREE-SPAN BRIDGE WITH CAST-IN-PLACE CONCRETE TIED-ARCH CENTER SPAN AND PRECAST, PRESTRESSED CONCRETE BULB-TEE BEAM APPROACH SPANS / MAINE DEPARTMENT OF TRANSPORTATION, AUGUSTA, MAINE, OWNER

HANGAR SUPPLIER: WireCo WorldGroup, Kansas City, Mo.

SHORING SYSTEM SUPPLIER: A.H. Harris & Sons, Newington, Conn.

BRIDGE DESCRIPTION: A 570-ft-long by 46-ft-wide, three-span bridge with a 300-ft-long, 60-ft-high arch span and two 135-ft approach spans

STRUCTURAL COMPONENTS: Two parallel 300-ft-long, 60-ft-high, cast-in-place concrete arch ribs; six cast-in-place concrete transverse braces; two longitudinal post-tensioned concrete edge tie girders; 19 precast, prestressed concrete floor beams; precast, prestressed concrete deck panels; two approach spans with 6-ft deep, 135-ft-long bulb-tee beams; replaceable steel cable hangers; and concrete parapet with a steel pedestrian rail

BRIDGE CONSTRUCTION COST: $21.5 million

Formwork and reinforcement are nearly complete for transverse braces No. 2 and 5. Falsework and forms for transverse braces No. 3 and 4 have been removed. There are a total of six braces. Photo: Kleinfelder.

Crews erected 19 intermediate precast, prestressed concrete floor beams, 4 ft 0 in. wide by 3 ft 0 in. deep that were connected and post-tensioned to the base section of the concrete tie girders. The tie girders were supported on the six temporary piers and were post-tensioned longitudinally using eight tendons. Each tendon, with a jacking force between 1200 and 1250 kips, incorporates twenty-seven, 0.6-in.-diameter, 270 ksi strands. Round corrugated high-density polypropylene ducts were used.

Ribs and Braces

The next step was to construct the cast-in-place arch ribs and six transverse braces using arch falsework that extends from the six temporary piers. The arch ribs measure 4 ft square with large chamfers at midspan and increase in size uniformly to 8 ft 6 in. at the arch ends. The transverse braces are shaped as inverted "U"s and are 6 ft 9 in. wide x 2 ft 10 in. deep. The concrete was placed in one continuous operation for each rib. Once the arch ribs were complete, the general contractor installed two steel cable hangers at nine locations on each rib to connect them to the cast-in-place, post-tensioned tie-girders. Construction workers then removed the six temporary piers, beginning with the middle pier and moving outward, and began construction of the deck diaphragms, the top sections of the tie girders, and the deck. The completed tie girders measure 5 ft 2 in. wide by 6 ft 0 in. deep.

The majority of the entire bridge deck is formed with 3.5-in.-thick precast, prestressed concrete panels over which a 4.5-in.-thick composite concrete topping is placed. The precast panels used were 8 ft 0 in. by 5 ft 10¾ in. on the approach spans and 8 ft 0 in. by 10 ft 6½ in. and 7 ft 0 in. by 10 ft 6½ in. on the arch span.

The tie girders' post-tensioning tendons were installed and tensioned in three stages during the construction of the main span. Stage 1 applied 30% of final stressing forces 3 days after the concrete placement in the base section of the tie girders. The full specified forces for the base section were applied after 7 days from concrete placement or when concrete had reached a minimum strength of 5000 psi. Stage 2 tensioning occurred 3 days after the upper portions of the tie girders were placed and Stage 3 tensioning was applied 3 days after the composite topping of the deck was placed.

The two, 135-ft-long approach spans each use six bulb-tee beams, approximately 6 ft deep (NEBT 1800), spaced at 8 ft 10 in. on center.

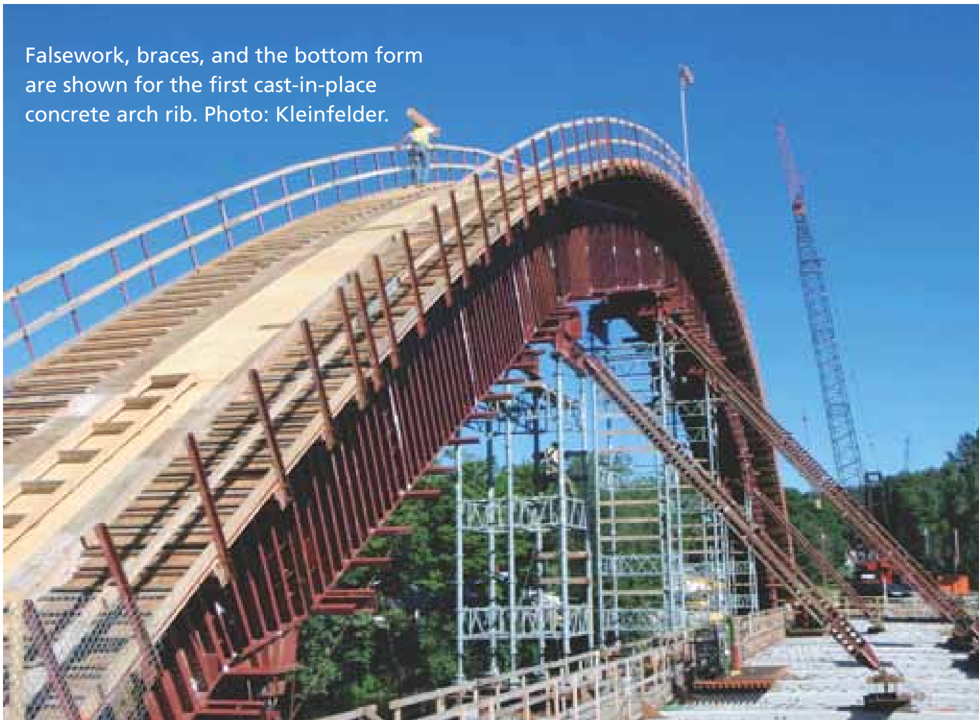
Another innovative feature is that the bridge has no deck joints. To manage the range of thermal expansion and contraction expected from along the arch deck and two approach spans, engineers incorporated durable elastomeric bridge bearings reinforced with steel. Four large 3-ft 6-in. square and 9-in.-tall bearings were located beneath each of the rib ends and atop the piers to support the arch span. Smaller bearings are located under each end of the bulb-tee beams. The bearings will require less maintenance compared to pot or disk bearings.

Opening with Character

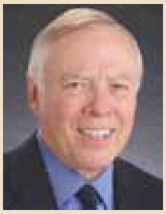
The Covered Bridge opened to traffic July 21, 2011. It is only the second modern concrete tied arch bridge in the United States. The Depot Street Bridge in Oregon is the other. The Covered Bridge is twice the width of the original, with new shoulders and a multi-use lane, and all the modern advancements to help it last for the next 100 years or more—and, according to the community, it looks extraordinary.

Craig Weaver is a project manager with Kleinfelder in Augusta, Maine.

For additional photographs or information on this or other projects, visit www.aspirebridge.org and open Current Issue.



Falsework, braces, and the bottom form are shown for the first cast-in-place concrete arch rib. Photo: Kleinfelder.



AESTHETICS COMMENTARY

by Frederick Gottemoeller

Simplicity is usually a virtue in bridge aesthetics, particularly in a natural environment. At such sites, bridges are usually a small part of a much larger scene. Simple, easily understood shapes make a strong impact where fussy details would be lost in the background. Unfortunately, simplicity can also equal boredom. Those simple shapes must be refined in ways that add interest and grace. The Covered Bridge over the Kennebec River in Norridgewock, Maine, achieves that goal.

The shapes, including the cross bracing, are about as simple as they could be. At the same time, there is a lot of refinement here. The arch ribs taper from their thinnest point at midspan to match the tie girders at deck level. The cross braces have a subtle arch of their own. The dimensions and proportions are so thin that it's hard to believe that this is a concrete bridge. And the concrete allows simplicity at the joints, particularly at the arch rib-tie girder joint, that no other material could match. Finally, the thin cable hangers contrast dramatically with the concrete members of the bridge, giving the whole structure a light and open appearance.

A final refinement is the way the parapets carry in a continuous line across the whole bridge. They are inside the arch but outside the approach girders. Their overhang above the approach girders creates a shadow line that literally underlines the difference.

Concrete tied arches once appeared frequently along American roads. It is great to see that tradition revived with such a straightforward and graceful example.