Repeating History

by Christopher D. Baker, VHB-Vanasse Hangen Brustlin Inc.

One of America's earliest open-spandrel arch bridges is replaced while maintaining the bridge's original appearance

The original bridge built in 1913 was substantially rehabilitated in 1940 shown here and 1991.

The original Lime Kiln Bridge was the only open-spandrel, concrete arch bridge in Vermont and one of the first built in the United States. Since 1913, it stood as an architectural and scenic gem, spanning the majestic Winooski River Gorge. Ordinarily, replacing a 300-ft-long bridge would not require an elaborate design—but the Lime Kiln Bridge clearly was not ordinary. Constructing the new structure involved a challenging design, a challenging site, and a challenging process.

Officials at the Vermont Agency of Transportation (VTrans) sought to update the irreparably deteriorated structure with an efficient crossing while preserving the original's architectural and historic integrity. And, of course, the work had to be done in as short of a time frame as possible using the most cost-effective techniques.

The bridge connects South Burlington and Colchester by spanning a 100-ft-deep gorge cut by the Winooski River. The original design featured reinforced concrete arches and tee beams, which were substantially rehabilitated in 1940 and 1991. To recreate that look while meeting the variety of contemporary needs, VTrans and VHB held numerous meetings over a 3-year period to consider construction options and receive input from all stakeholders, including the Vermont Division for Historic Preservation.

Aerial Photography: Fli-Rite Aviation, Burlington, Vt.

profile

LIME KILN BRIDGE / WINOOSKI RIVER GORGE, VT.

ENGINEER: VHB-Vanasse Hangen Brustlin Inc., Bedford, N.H.

GEOTECHNICAL ENGINEER: Golder Associates, Manchester, N.H.

PRIME CONTRACTOR: Kubricky Construction Co., Glen Falls, N.Y.

PRECASTER: J.P. Carrara & Sons, Middlebury, Vt., a PCI-certified producer

Ultimately, the decision was made to create a structure combining precast, prestressed concrete box beams and slabs with cast-in-place concrete arches. This combination replicated the original bridge's decorative geometrical features and ornamental railings while allowing sidewalks and travel ways to be widened. Street lighting and architecturally treated abutments and retaining walls also were added.

Many Options Considered

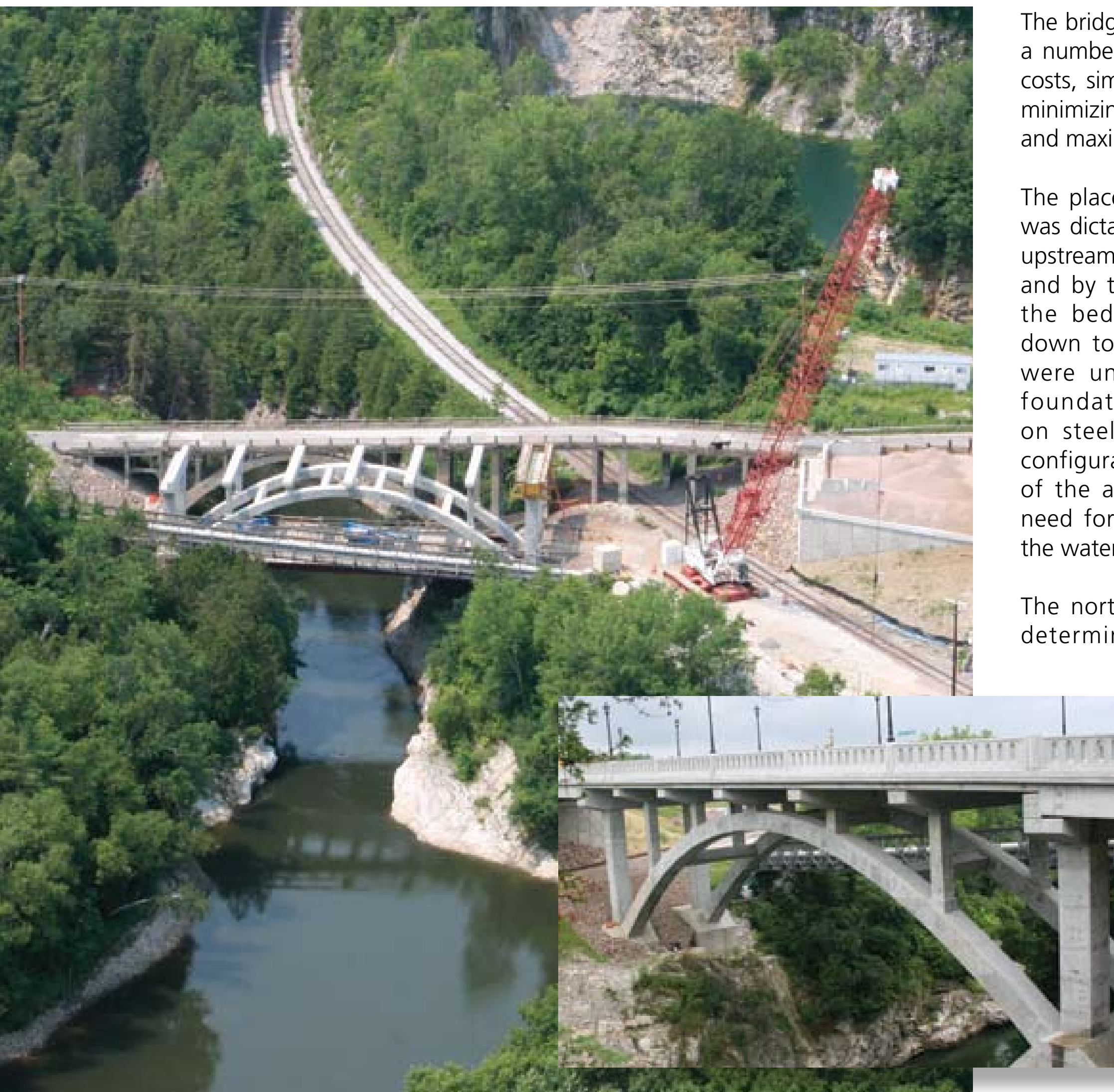
A number of alternatives were considered before the final selection was made. The considerations included rehabilitation possibilities, but it was ultimately decided that they would provide no more than 20 years of service life, and more was desired. A conventional steel-girder replacement bridge also was deemed incompatible with the goal of maintaining the sense of aesthetics, history, and pride of place that the original bridge created.

As a result, VHB and VTrans developed several concrete arch bridge concepts. Finding the best option required meeting specific geometric criteria, and the review process for each submission phase was much more intense than for a typical project. Fortunately, completely filling one of the two quarries that squeezed the site's perimeter allowed improved alignment options during the conceptual stages. These changes provided the opportunity to improve the project and avoid significant impacts to the local environment.

The bridge's ultimate geometry balanced a number of factors, including reducing costs, simplifying geotechnical solutions, minimizing the number of joint locations, and maximizing the service life.

The placement of the south abutment was dictated by a utility bridge, located upstream from the existing arch bridge, and by the depth of the fill overlying the bedrock, which sloped steeply down to the gorge. Soils in this area were unsuitable for spread-footing foundations, so a stub abutment on steel H-piles was selected. This configuration minimized the footprint of the abutment and eliminated the need for deep excavation adjacent to the water.

The north abutment's placement was determined by several restrictions,



The new Lime Kiln Bridge replicates the look of the original bridge, which was one of the first open-spandrel, concrete arch bridges in the United States and the first in Vermont.

CONCRETE ARCH / COLCHESTER AND SOUTH BURLINGTON, VT., OWNERS

BRIDGE DESCRIPTION: Open-spandrel arch crossing a 100-ft-deep gorge using 80 precast, prestressed concrete beams and cast-in-place arches, piers, floor beams, and deck

CONCRETE SUPPLIER: S.T. Griswold, South Burlington, Vt.

BRIDGE CONSTRUCTION COST: $6 million

The 300-ft-long bridge features precast, prestressed concrete box beams and slabs with cast-in-place concrete arches, piers, floor beams, and deck. The arch supports six intermediate 22-ft-long spans that used 1-ft-deep precast concrete solid slabs.

comprising a railroad track to the north and limited horizontal clearances from the centerline of the track to the abutment's face. The abutment was placed to allow excavation for the abutment footing without requiring temporary support of the railroad track. Other restrictions included a minimum 23 ft vertical clearance, span-length limitations, and the varying fill over the bedrock. The abutment was founded on a mechanically stabilized earth backfill because of its suitability to the height, soil conditions, and cost.

Arches Resemble Polygons

The two arches were designed with reinforced, cast-in-place concrete to closely match the shape of an equilibrium polygon under full dead load. The arch spring line was placed at equal elevations for each arch foundation. The clear distance between the arch footings was about 121 ft with the bottom of the arch rising to about 28 ft above the spring line. In section, each arch is 4.5 ft wide and varies in depth from 4 ft at the spring line to 3.25 ft at the arch's midspan.

Footings for the arches were designed to be about 12 ft wide and 22 ft long to accommodate the proposed arch and pier geometry, as well as the design loads. Information from soil borings and geological survey helped set the bottom elevations for both foundations, ensuring they were seated in bedrock for at least half of the footing's height at the back. This placement ensured

Remote-controlled, steerable dollies were used to maneuver the 104-ft-long precast concrete box beams. Photo: J.P. Carrara & Sons

sufficient resistance against the arch thrust and overturning moments.

Precast Extends Design Life

The arches support six 22-ft-long intermediate spans consisting of 1-ft-deep precast, prestressed concrete solid slabs that were transversely post-tensioned after placement. Precast concrete units were used rather than cast-in-place options to minimize formwork over the gorge and increase the deck service life. The slabs are supported by elastomeric bearings on cast-in-place floorbeams at the spandrel arch columns and pier columns.

The end spans of 59 ft and 103 ft use precast, prestressed concrete adjacent box beams that were transversely post-tensioned after placement. The box beams provided a number of benefits, including reducing costs through the use of repetitive construction for the bearings, beams, concrete overlay, and joints for live-load continuity. The relatively shallow depth of the beams provided the required vertical clearance over the railroad, while their appearance from underneath the structure is more uniform, contributing to its aesthetic appeal.

The precast concrete beams also will simplify construction phasing for future deck rehabilitation, since traffic phasing could be easily accommodated due to the continuous support provided by the underlying transversely post-tensioned beams. The box beams are supported on elastomeric bearings. Bearing connections were detailed so that the superstructure was fixed at each pier bent column with expansion accommodated at each abutment.

Aesthetics

Designers paid particular attention to aesthetics in shaping the bridge's profile. The arch was symmetrical, with concrete columns for the intermediate spans transmitting superstructure loads vertically to the arch. Aesthetic considerations included the visual depth of the approach spans, the depth of the intermediate spans, and the post spacing for the concrete bridge railings.

To aid the bridge's appearance, approach-span depths on each end were maintained at 3.5 ft, although the depths for the south approach could have been reduced to 2.25 ft. Designers decided that a uniform look provided better aesthetics and cut costs by allowing repetitive fabrication and erection procedures for both spans. The minor premium for the deeper beams was more than offset by the savings in

The end spans feature precast, prestressed concrete butted box beams that were transversely post-tensioned after placement.

Street lighting and architecturally treated abutments and retaining walls also were added, as well as historical background on the original bridge.

efficiencies and the fewer prestressing strands required in the shorter span.

For the intermediate spans over the arches, the floor beams were tapered to match the approach-span box-beam depths at the fascia. Visually, this helped tie together the intermediate and approach-span superstructure.

The cast-in-place concrete deck had a minimum thickness of 5 in., with a heat-applied waterproofing membrane and 3 in. of bituminous concrete. Texas classic traffic railing type T411 with decorative lighting attached was installed for security and to add to the bridge's aesthetics. The railing posts over the floorbeams and columns provided visual continuity between the superstructure and the supporting-arch structure and substructures.

The completed bridge spans the majestic Winooski River Gorge just as elegantly as did its venerable predecessor. Most important, all parties to this long, complex, process-heavy project were pleased with the result. Innovation, collaboration, patience, persistence, and constant advancement in the state-of-the-art use of concrete materials, combined with pure will on the part of the entire construction team, made this bridge possible. Contemporary materials blended with a respect for the past helped preserve the bridge's architectural and historic integrity.

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