PROJECT

Preserving a Landmark: Lake Tillery Bridge Rehabilitation

With innovative construction techniques, a historic concrete arch bridge in a North Carolina National Forest was preserved

by Eric Chavez and Colin McCabe, PCL Construction

The Lake Tillery Bridge in the Uwharrie National Forest has been a landmark for North Carolina residents for almost a century. When the superstructure for this historic open-spandrel concrete arch bridge with four arch spans, originally built in 1927, needed to be replaced, the project also needed to accommodate a widened roadway cross section on the west end of the bridge.

Although the bridge was in need of rehabilitation, the City of Albemarle wanted to preserve its unique features. The original arches—an architectural design that was popular in the early 1900s—made the bridge instantly recognizable. So, when the North Carolina Department of Transportation (NCDOT) hired the contractor to rehabilitate the beloved bridge, the contractor knew the project would require a high level of care and attention to detail. The project team needed to rehabilitate the structure to modern standards while still maintaining the original aesthetics and preserving the bridge's importance to the community.


The original James B. Garrison Bridge over Lake Tillery (left) before the rehabilitation and superstructure replacement. The eastbound bridge (right) also required rehabilitation. All Photos and Figures: PCL Construction.

Demolishing the Structure

This project involved two adjacent bridges: the westbound historic concrete arch bridge and the eastbound bridge, which is a newer, steel-girder bridge. For the eastbound bridge, replacement of bearings, expansion joints, approach slab, and a deck overlay was required.

Although the superstructure of the westbound bridge had to be replaced, the original concrete arches of the substructure were in great condition. To replace the structure above the arch while preserving the aesthetics of the iconic piece of infrastructure, the design would need to re-create or preserve the arch ribs so that the final appearance would emulate the characteristics of the original bridge. NCDOT hired an engineer of record for the project to develop this unique design. However, NCDOT and the engineer of record concluded that contractor input was critical to ensuring the the success of the project, so NCDOT let the contract as design-build.

profile

JAMES B. GARRISON BRIDGE (WESTBOUND) / **ALBEMARLE, NORTH CAROLINA.**

OWNER'S BRIDGE DESIGN ENGINEER: AECOM, Raleigh, N.C.

CONTRACTOR'S SPECIALTY ENGINEER: Modjeski & Masters Inc., Mechanicsburg, Pa.

PRIME CONTRACTOR: PCL Construction Inc., Tampa, Fla.

CONCRETE SUPPLIER: Troy Ready Mix Inc., Troy, N.C.

PRECASTERS: Prestressed concrete box beams and deck panels: Eastern Vault Company Inc., Princeton, W.Va.; Precast concrete fascia panels: Ross Prestressed Concrete LLC, Knoxville, Tenn.—both PCI-certified producers

A section of the original bridge deck is removed from span C. Twenty strain gauges were installed in the existing arches to monitor stress and movement during demolition.

Cast-in-place concrete cap construction.

The design-build team began by evaluating the existing concrete arch bridge and original demolition sequence. The team proposed a new demolition sequence that kept the bridge in balance, removed leading-edge safety hazards (that is, worker fall hazards), and eliminated longitudinal saw cutting to prevent concrete slurry from entering the lake. The team collaborated with NCDOT and the engineer of record to come up with a new demolition sequence. The contractor then proceeded with removal of the concrete superstructure while leaving the four arch spans and the original piers intact. Because the original bridge arches were to remain and become the foundation of the new bridge, it was imperative to closely monitor the structure for movement after every step to ensure that the substructure and arches did not exceed allowable stress levels. Twenty strain gauges were installed in the existing arches to monitor the stress and movement during demolition.

The contractor essentially took the structure apart piece by piece, using a 60-in. saw to cut transversely through the concrete sections, while avoiding longitudinal cuts. Taking the complicated geometry and stability of the existing bridge into consideration, the team developed and implemented key alternative construction sequences that maintained the stability of the structure throughout all stages of construction. The strain gauge measurements were diligently and continuously monitored and recorded. The revised sequence and precise demolition methods resulted in stress and movement levels of the arches well below the allowable limits.

Water Work

While taking apart the existing bridge superstructure, the contractor had three floating crane barges on the water and used tugboats to move the barges to facilitate the removal of each piece. The process took about six months from the start of saw cutting the concrete until all

A protective layer of concrete was installed at all existing piers of the arch bridge to protect and reinforce the area most susceptible to erosion from the fluctuating water levels. The cofferdam system provided access for crews to apply the shotcrete protection. The left photo shows the shotcrete application, and the right photo shows the finished product.

NORTH CAROLINA DEPARTMENT OF TRANSPORTATION, OWNER

OTHER MATERIAL SUPPLIERS: Formwork: Doka GmbH Amstetten, Austria; reinforcing steel: Harris Rebar, Stoney Creek, ON, Canada; access systems for work on the concrete arches: Safespan Platform Systems, Tonawanda, N.Y.; bearings: D.S. Brown, North Baltimore, Ohio; specialty fabric formwork: TrapBag, Fort Meyers, Fla.

BRIDGE DESCRIPTION (FOR WESTBOUND BRIDGE): 1060-ft-long, four-arch, open-spandrel, reinforced cast-in-place concrete bridge

STRUCTURAL COMPONENTS: 104 cast-in-place vertical columns, 52 cast-in-place concrete caps, 4154 linear ft of precast concrete spandrel box beams, 21,060 ft^2 of prestressed concrete deck panels, cast-in-place concrete deck slab, 96 architectural precast concrete fascia panels

BRIDGE CONSTRUCTION COST: $21.3 million

AWARDS: Engineering News-Record Southeast: Best Highway/Bridge 2021; Slag Cement Association's 2020 Slag Cement Project of the Year in innovative applications

New precast concrete box beams are erected in span F. Note the continuity reinforcement detail at the beam end, the common bearing under the continuity diaphragm, and the epoxy-coated reinforcement that will be cast into the composite deck.

Prestressed concrete box beams are placed and await the cast-in-place concrete continuity diaphragms.

the pieces were ready to be disassembled. During demolition, NCDOT required that one river channel be left open because Lake Tillery is heavily trafficked by boaters and jet skiers. Maintaining access was a priority throughout the project because it allowed safe boating in the channel.

With tight constraints for accessing the lake, a new bulkhead was identified as the solution for loading the barges with heavy equipment. The bulkhead structure retained fill material so a flat working area could be constructed to load heavy equipment onto the barges. Determining the location of the bulkhead was tricky because it could not encroach into the lake. The contractor worked closely with NCDOT and other stakeholders to develop a solution that would meet permit requirements. The excavation, forming, reinforcement installation, concrete placement, and drilling earth anchors for the bulkhead construction were all performed in an environmentally sensitive area without leaving any environmental impacts.

Both bridges required underwater structural encasements of the existing substructure to extend the life of the piers. A protective layer of concrete was installed on all existing arch bridge piers from the base of new construction to 4 ft below the normal pool waterline to protect and reinforce the area most susceptible to erosion from the fluctuating water levels. This effort required placing concrete 6 ft underwater.

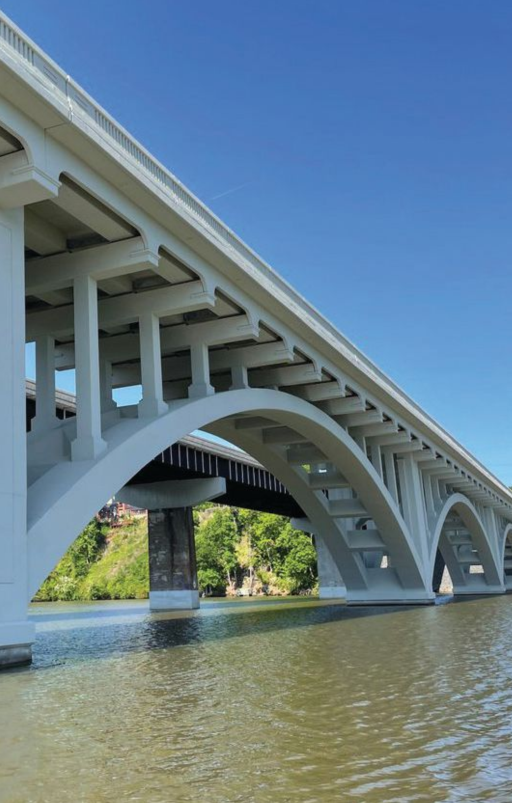
The project team worked together to find an effective installation procedure that would minimize the impact to the waterway. The contractor designed a steel cofferdam that was attached to each pier on both bridges and could be lowered to a level below the area that needed repairs. The cofferdam was sized to allow workers room to install the protection after dewatering. This operation was performed instead of a challenging underwater grouting operation, which would have been difficult to vent adequately given the site's constraints. This revision provided a safer work environment and resulted in a better product when completed. Instead of using traditional concrete formwork, a diving crew used injection ports to construct a sacrificial shotcrete layer within the cofferdam. After pumping out the cofferdam, the crew could work in that space to apply the final shotcrete protection to the piers in the dry.

Slag concrete was used for the substructure repairs below the waterline. Slag cement is a durable solution for protecting the structural integrity of the original bridge arches that is less susceptible to an alkali-silica reaction, which results in flakes falling off into the water over time. Slag cement also held the slump longer, made the mixture more workable, and was easier to place using long boom lines.

Conquering the Unexpected

One significant owner-directed change extended the scope for the concrete repair and epoxy injections. The engineers inspected both bridges during the preconstruction phase to map out all the spalls, areas of delamination, and cracks in the concrete substructure. Once on site, the contractor and its specialty subcontractor performed an independent inspection to verify the project requirements. This uncovered additional

Precast concrete fascia panels were used to preserve the historic aesthetics of the original arch structure.



The completed project maintains the historic character of the original structure while extending the service life of the bridge for many more years.

The parallel bridge required a protective layer of 2-ft-thick reinforced concrete to be cast in place around one pier footing more than 20 ft below the waterline. More than 200 yd^3 of concrete were placed underwater by tremie for this repair—a process that took 16 hours of continuous pumping from the deck of the bridge.

repair areas that were not originally identified due to limited access during the original inspection. NCDOT then approved additional repairs to ensure the structure's integrity.

A 2-ft-thick protective layer of reinforced concrete was designed to be cast in place around the pier footing more than 20 ft below the waterline to address cracking from alkali-silica reactive concrete that was improperly used during the original construction. An innovative solution to accomplish the repair was developed using reinforced geotextile fabric for the formwork; this solution ensured that the project schedule was maintained and access in the waterway was provided (see the Creative Concrete Construction article on page 53 for details).

More than 200 yd^3 of concrete were placed at the pier—a process that took 16 hours of continuous pumping to complete. The sheer quantity of concrete placed, plus the logistics of bringing in all the trucks and pumping the concrete, made this a unique aspect of the project.

Maintaining Architectural Features

The existing superstructure was replaced with prestressed concrete spandrel box beams that were 3 ft × 3 ft and 20-ft 7-in. or 14-ft 10-in. long, depending on the cap spacing. Each beam contained reinforcement that extended from the beam ends, which allowed the beams to be set and connected with a cast-in-place diaphragm to create a continuous beam across the span.

Partial-depth prestressed concrete deck panels were placed to span transversely between the beams. The 3.5-in.-thick panels were 4 ft × 6 ft 8 in. and served as a work surface and formwork for the cast-in-place concrete bridge deck.

Another unique feature of the bridge was the barrier railing, which was designed to preserve the architectural intricacy of the existing structure. The concrete barrier was cast in place using custom barrier wall forms to achieve the exact spacing and appearance of the "church windows" that span the length of the bridge. Because NCDOT specified a Class II surface finish on the concrete barrier, full-time grinding and patching crews were required to ensure the final product met expectations. This surface finish extends the service life and enhances the aesthetics of the bridge, and will minimize required maintenance and patch work in the future.

Continuing the Legacy

Everyone involved in the design and construction of the project is extremely proud of the results for many reasons. The rehabilitation project has won multiple awards, including the 2020 Slag Cement Project of the Year award in innovative applications from the Slag Cement Association, and the *Engineering News-Record* Southeast Best Project in the Bridge and Highway category. The project also demonstrated that the design-build team was willing to go above and beyond for its client, finding innovative solutions for the unexpected challenges that arose. The construction team is incredibly proud that it played a part in preserving the original aesthetics of a bridge that has significant value to the surrounding community. This concrete arch bridge is a great example of what makes concrete structures so remarkable, and this rehabilitation ensures the structure will remain an iconic landmark far into the future.

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