MAINTENANCE, REPAIR, and REHABILITATION OF CONCRETE BRIDGES

To perform efficient and cost-effective repairs on bridge abutments, the Ohio Department of Transportation places activated-zinc anode strips (in red) parallel to epoxy-coated reinforcement (green) after the delaminated concrete is removed. The anodes provide global protection for the abutment reinforcement and extend the abutments' service life. The project shown is the Kirkwood Bridge in Sydney, Ohio.

Minimizing **REPAIR IMPACT**

by Craig A. Shutt

Repairing deteriorating bridges without causing considerable impact to users creates a difficult balancing act. The Ohio Department of Transportation has found a solution for its abutment repairs by using activated-zinc anode strips distributed throughout a new reinforced concrete facing. Compared to previous repair methods, the galvanic encasement combination extends the bridge's service life and provides global protection to the abutment in a quick and economical way rather than protection only to the patched area.

The department's designs for cast-in-place concrete, continuous, slab bridges typically have a construction joint located over the abutment. This exposes the abutment to chloride penetration from deicing salts and subsequent corrosion of the abutment reinforcement. Typically, the slabs remain in good condition, with only the abutment under the joint deteriorating.

Previously, to repair the damage, temporary shoring would be placed under the slab and the abutments would be replaced. This required either complete bridge closure or phased construction. Both of these created traffic delays and disruptions. But the other options of doing nothing or replacing the bridge were not feasible either for safety or economic reasons.

Ohio began using discrete activated-zinc anodes several years ago, first as a localized repair. The puck-sized anode units, supplied by Vector Corrosion Technologies, Tampa, Fla., attach to the exposed reinforcement using integral tie wires, and consist of a zinc core surrounded by a highly alkaline cementitious matrix. The zinc has a higher corrosion potential than the reinforcing steel, allowing the anode to corrode rather than the steel.

Providing this galvanic protection allowed isolated patch repairs to be accomplished quickly, with minimal impact on traffic and at a low cost. However, the localized benefit provided by the discrete zinc anodes assured protection only around the patch to mitigate the "halo" effect. This effect involves the area around the patch that begins to corrode at an accelerated rate.

To provide extra protection for the entire abutment face, the department has completed several projects that now supply global protection through the use of activated distributed zinc "strip" anodes. In this process, the delaminated concrete is removed, and the new reinforcing steel is installed along the face of the exposed concrete. Zinc anode strips are placed parallel with the epoxy-coated reinforcement and are connected back to the reinforcing steel in the existing abutment. Then a monolithic concrete placement encases the anodes and fills in the repaired areas.

This solution has been used for several years and offers several advantages, including the short time required for this comprehensive repair and future protection. Monitored locations indicate that the anode strips will provide over 20 years of protection, but this can be adjusted by changing the amount of zinc provided or the anode spacing.

This approach also provides an inexpensive repair method. At the time of repair of the Kirkwood Bridge, located near Sidney, Ohio, rehabilitating the abutment with anode strips cost approximately $319,000. To replace the abutment and provide temporary shoring cost about $427,000, while replacing the entire structure cost about $4.5 million.

The program has worked so well that it has been extended to other concrete structures. The anode strips have been used in eight bridge deck overlays in a Lake County, Ohio, project, as well as to protect columns with reinforced concrete jackets, pier-cap repairs, and pile protection in marine structures. The Ohio DOT projects continue to be monitored to ensure the repairs are performing as expected.

This article is based on a presentation produced by Brad Lightle, director of Planning for District 7 of the Ohio Department of Transportation, and Chris Ball, vice president of Vector Corrosion Technologies, Tampa, Fla.

Fabric Repairs
HISTORIC ARCHES

by Stacie L. Dovalovsky, Clark Dietz Inc.

As the City of Kankakee, Ill., has grown, so too has its need for improved infrastructure to handle the increased traffic. Updating the Station Street Bridge, built in 1924, required careful consideration and planning to ensure its historic appearance was not altered. To achieve this goal, E-glass reinforcing fabric was used to confine the concrete in the bridge's arches and to provide protection from the weather.

The 379-ft-long bridge, listed on the Illinois Historic Bridge List and eligible for the National Register of Historic Places, crosses the Kankakee River with five cast-in-place concrete, open-spandrel arches. Built to carry 1920s-era vehicles and streetcar tracks, it now carries nearly 7000 vehicles every day. The bridge's historic status limited the options for repairing the substructure and superstructure to meet today's needs.

The deck and spandrel columns had been replaced in 1978, but the arches had received little attention and were in dire need of repair. City officials had three key goals: bringing the project in on time, on budget, and with little disruption to the bridge's appearance. The use of fiber-reinforced polymer composite wrappings for the arches helped to achieve all these goals.

The 379-ft-long Station Street Bridge in Kankakee, Ill., had its five cast-in-place concrete, open-spandrel arches repaired with fiber-reinforced polymer composite wrappings. The repair was accomplished for less than original cost estimates.

After careful consideration of options and selection of the best type of wrappings, a detailed analysis of the arches was performed to determine the potential construction sequence. Before the arches could be wrapped, deteriorated concrete had to be removed and replaced. But if too much of the cross-section of the arch was removed, it could fail under the weight of the superstructure's dead load.

Conventionally formed concrete and shotcrete were used for repairs, after which the arches were wrapped with the fiber-reinforced polymer composite. They were then painted to protect the composites and to give the repaired concrete a like-new appearance. To provide a consistent look to the entire bridge, the existing concrete not wrapped was painted to match the repaired substructure. All work on the bridge was performed under the direction of the prime contractor, Kankakee Valley Construction, Kankakee, Ill.

The fabric had been used in Illinois to strengthen existing columns in high-seismic areas, but it had not been used before to strengthen a spandrel arch bridge. Initially, engineering estimates had limited the project to wrapping only the two exterior arches, which were significantly more deteriorated. However, the low bid also allowed the center arch to be wrapped and the project to be completed for $1.9 million or $600,000 below the original estimate.

The reinforcing fabric improves the structural integrity of the arches by confining the concrete, providing protection from the weather, and preventing future spalling. Most importantly, this approach preserved the bridge's historic appearance. It gives the city a virtually maintenance-free structure for the next 20 to 25 years. Much of the material used on the project was supplied by Sika Corp., Lyndhurst, N.J.

To further enhance the project's history, the existing IDOT-standard light poles placed on the sidewalks during the 1978 repairs were replaced with historical period lighting. The new light poles were located on the back of the parapets and out of the sidewalks. Special cantilever pedestals were designed for the new lighting; thereby, improving driver and pedestrian safety. The lighting ties into the city's master lighting plan and allows for future expansion of the period lighting throughout the neighborhood.

Planning for the future is a key goal throughout Kankakee, especially for its infrastructure needs. This project provides a new way to meet those needs while retaining the city's historic charm and improving safety at the same time.

More detail can be found in the article, "Station Street Repair" published in ICRI Concrete Repair Bulletin*, July/August 2008.*

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The arches on the bridge, which is listed on the Illinois Historic Bridge List and eligible for the National Register of Historic Places, needed to be repaired so that its historic nature was not disturbed.

The contractor's low bid on the project allowed city officials to extend the wrapping work to include the center arch and still have the total cost come in below the original engineering estimate.

The historic Rainbow Bridge near Smiths Ferry, Idaho, had its deteriorating rails replaced with precast concrete units that were match-cast in color and texture to provide a consistent look for the entire structure.

A PERFECT MATCH

by John Hinman, CH2M Hill

The Rainbow Bridge near Smiths Ferry, Idaho, was built in 1933 as a cast-in-place arched structure. Its design has made it a statewide landmark and led to its listing on the National Register of Historic Places. But its condition had become less noteworthy, leading to the need for delicate repairs that would not tarnish its historic nature. To accomplish this, new precast concrete rails were installed, with all pieces cast using color and texture to match the existing pieces.

The bridge required significant work, because its rails and decorative features were disintegrating, and corrosion was occurring in the reinforcement of the stringer ends, bents, and spandrel columns. Under ideal conditions, the bridge could have been closed and cast-in-place concrete could have been used to replicate the original design, giving the contractor full access. Unfortunately, this wasn't feasible, as the bridge had to remain open at all times.

Initially, work focused on the substructure, stabilizing corrosion in the arches and columns with electrochemical chloride extraction (ECE), repairing stringers, and performing other patching incorporating galvanic anodes and replacement work. Analysis showed that the concrete had retained its strength, but needed to be upgraded to control the corrosion deterioration caused by significant chloride contamination from deicing chemicals.

The main focus at the deck level was replacing 841 ft of rail using precast concrete sections. This approach was taken to ensure the bridge could remain open avoiding traffic next to an unprotected edge. The key to success was finding the proper concrete mixture to ensure the new components would exactly match the shape, color, and texture of the original rails.

On the assumption that the original concrete mix comprised local aggregates, considerable scouting was done to find suitable sources. Concrete cores were taken from the existing bridge, and these were compared to cores taken from new samples cast with different aggregates. Tinting wasn't an option, as it would begin to weather and create a disparity. It was determined that some local aggregates were totally unsuitable, but ultimately a close match was created. The new concrete is expected to weather over the next few years to closely match the existing components.

Casting and erecting the precast concrete rails created additional challenges, as each piece was unique due to the grades, superelevations, and curves. The complexity was immense, with a lot of individual customization needed for most of the components. Expanded polystyrene pieces were carved using computer-controlled cutters to create the forms for each piece.

The bridge's arches and main piers around the joints underwent an electrochemical chloride-extraction process, while galvanic anodes were embedded in the concrete-patch repairs in other areas.

The precast concrete rails were cast in forms created with expanded polystyrene pieces that were carved using computer-controlled cutters. Each railing piece is unique, owing to the grades, superelevations, and curves.

The resulting forms were coated with plastic to achieve a smooth and durable surface. The surface quality of each cast component still required close attention. The work was overseen by general contractor Mowat Construction Co. in Woodinville, Wash., with the precast concrete components produced by Central Pre-Mix Prestress Co. in Eagle, Idaho.

Officials at the Idaho Department of Transportation also implemented a corrosion-mitigation program to prevent further deterioration. After considering various options, they decided on the ECE method in the arches and main piers around the joints and the embedment of galvanic anodes in the concrete-patch repairs in the non-ECE-treated areas.

The ECE treatment reduces the amount of chloride ions in the concrete and generates higher alkalinity around the reinforcing steel, reinstating the passivity of steel reinforcement. It directly addresses the cause of the corrosion from the concrete, with no permanent system left in place to be operated, maintained, and monitored. Approximately 8000 ft^2 of concrete surface was treated in less than two months. The ECE treatment was designed by Corrosion Control Technologies in Sandy, Utah. Vector Corrosion Technologies in Wesley Chapel, Fla., supplied the galvanic anodes and executed the ECE work as a subcontractor to Mowat.

The result of this careful attention to detail is a design that perfectly blends new and old. The proof is in the enthusiastic response from drivers, who had to crawl past the construction and wait for traffic when only one lane was open. While many times such situations create ill will against the construction crews; in this case, drivers were rolling down their windows to compliment the contractor on how good the bridge was looking. And, with a comprehensive corrosion-mitigation strategy in place, the bridge is expected to perform for years to come.

This bridge was named the 2007 Project of the Year by the International Concrete Repair Institute; for more details on the project, see ICRI's November/December 2007 issue of *Concrete Repair Bulletin*, or visit http://www.icri.org/AWARDS/2007/rainbowbridge.asp.

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