CASE HISTORY AMERICAN BRIDGES

Wisconsin Ave Bridge Washington D.C.

Strengthening from Within

by Christy Darden and Thomas J. Scott

Seamlessly integrating new and old materials helped strengthen a historic bridge in Washington, DC.

The Chesapeake & Ohio Canal flows under the stone masonry arch of the Wisconsin Avenue Bridge in the busy Georgetown area of Washington, DC. The towpath beside the canal serves as a footpath and recreation resource. The original wrought-iron railing dates back to 1831.

The twin demands of accommodating heavy traffic and ensuring the preservation of the oldest bridge in the Nation's capital proved to be manageable challenges on a recent restoration project in the historic Georgetown area of Washington, DC. When structural analyses showed that the Wisconsin Avenue Bridge over the Chesapeake and Ohio Canal National Historical Park could not adequately support current vehicle loads, transportation officials from the District Department of Transportation (DDOT) and the Eastern Federal Lands Highway Division (EFLHD) of the Federal Highway Administration (FHWA), began exploring alternatives to strengthen the structure.

Adding to the complexity of the project, the National Park Service (NPS) owns the bridge and DDOT is responsible for the maintenance and control of the road through an interagency agreement, so collaboration and cooperation became essential early on--and remained so throughout the project--to ensure that both transportation and historic preservation goals were met.

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Mules on the towpath pull tour boats operated by the National Park Service up and down the canal.

"The strengthening project was necessary because DDOT needed to have a reliable and increased load rating for the structure," says Darcel Collins, the FHWA project engineer, "and much of the masonry and iron railing was in very poor condition and needed restoration."

An innovative reinforcing system embedded entirely within the structure offered a solution that helped the team strengthen the stone arch bridge without visibly altering the appearance of the historic structure. Careful planning kept the heavy city traffic flowing on this key thoroughfare throughout construction. An equally significant accomplishment: multiple agencies with widely diverse missions cooperated to make the project a success. Finally, public coordination and communication were critical to the project and helped immensely, even though construction caused some disruptions to the community.

A Historic Bridge Needs Help

Built in 1831, the High Street Bridge—now called the Wisconsin Avenue Bridge—-lies in the heart of Georgetown, a National Historic Landmark District, just minutes from the White House. When the district was established in 1967, the bridge was identified as a contributing element. Resting in the midst of the restored historic district, office buildings, and modern condominiums, the bridge supports a busy city street used by residents, office workers, tourists, and trucks delivering seafood, vegetables, and meats to stock fashionable Georgetown restaurants.

The single-span arch bridge extends across approximately 16.5 meters (54 feet) over the canal and adjacent towpath. It is constructed of local gneiss (a foliated metamorphic rock, compositionally related to granite), most likely a byproduct of material extracted when the canal was dug, and Aquia sandstone, a building material quarried along the Potomac River during the colonial period. Aquia sandstone was used in numerous historic structures in the DC area such as the U.S. Capitol Building and White House. The original wrought iron picket railing is anchored in large capstones that adorn the top of the spandrel walls and stone wing walls. Large stone end posts topped with ornamental cast-iron spheres stand at each corner of the bridge and at the ends of the railings above the wing walls.

The canal and adjacent towpath historically served as the transportation corridor that carried coal-laden boats, with the aid of mules, into Washington, DC. Today, the towpath under the bridge is a popular resource for pedestrians traversing through the busy office and commercial district and lures recreational hiking, jogging, and bicycling enthusiasts as well. In addition, NPS uses the path to educate new generations through tour boat rides that offer a glimpse into the past, when it was a common sight to see mules towing boats along the canal. Therefore, keeping the path safely open for foot and diverse recreational traffic was an important consideration during the project planning.

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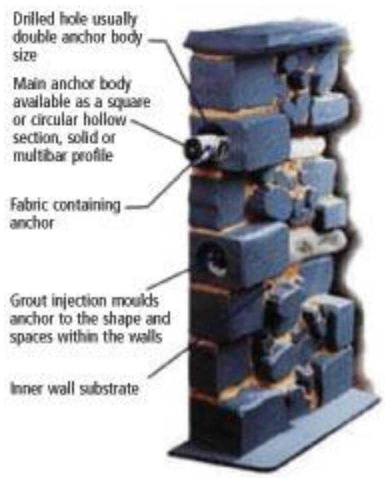

Source: Cintec.

This cutaway model of the Archtec process illustrates how a stainless steel reinforcing rod fits into a slightly permeable fabric sock that is then filled with cementitious grout under pressure.

The bridge was originally designed to carry horse-and-cart trade across the canal. Today the structure carries the heavy loads of a modern urban bridge—9,400 vehicles per day on average. Although the bridge was not "overtly" structurally deficient, its load rating could not be determined accurately. Therefore, in the mid-1990s, the help of a consulting engineering firm was sought to assess the situation.

After an inspection and load rating analysis, the engineering firm determined that the bridge could not support current vehicle loads at the minimum live load of HS20 recommended by the American Association of State Highway and Transportation Officials (AASHTO), which is 32.7 metric tons (36 tons). DDOT asked the engineering firm to investigate alternatives for strengthening the bridge. In 1999, the department sought assistance from FHWA to complete the project, along with several others in the area, and EFLHD entered into a memorandum of agreement with DDOT.

High Expectations

At the beginning, one of the first challenges was to agree on the scope and purpose of the project. Each stakeholder had a different mission, and dozens of meetings were required to work out the compromises and concessions that eventually satisfied the participants.

As owner, NPS initially was reluctant to allow work to be done on the historic structure, and the agency wanted reasonable assurance that the strengthening project was not overdesigning a solution that might compromise the historic integrity of the oldest bridge in Washington, DC. "Our mission is to preserve historic structures as nearly as possible to the original state," says Mike Seibert, exhibits specialist (restoration) and preservation project manager with NPS.

The National Historic Preservation Act of 1966 defines the National Park Service's stewardship of cultural resources within the national parks. The essence of the mandate is to retain the most historic fabric possible and not implement treatments that could damage or adversely affect historic materials. "This includes not using modern materials with old materials without adequate research as to the effect on the cultural resource," Seibert adds. "As preservation professionals, we would seek other alternatives, such as rerouting traffic, before altering the bridge." The capability to carry heavy truckloads on this bridge would turn out to be a big challenge for designers to accommodate.

As the design team—including DDOT, EFLHD, NPS, and their contractors—began to prepare for the project, it also solicited feedback on traffic control choices from the community. Through meetings with Georgetown's various community groups, hotels, restaurants, and other businesses in the corridor, the team learned that the major concerns centered on minimizing the impacts on traffic in the small, already congested area.

A Solution Presents Itself

In April 2001, EFLHD, DDOT, and NPS began exploring possible methods for strengthening and preserving the bridge. Because masonry arch bridges were commonly removed and replaced with modern concrete or steel structures, relatively few stone masonry arch bridges remain in the United States, and very few comparable bridge strengthening projects exist. One method for strengthening would be to build a new, load-bearing bridge over the top of the original bridge, a method called saddling. Neither demolition nor saddling was appropriate given the physical and spatial constraints of the site and the desire to preserve and protect the existing historic structure.

While researching alternative solutions, the team learned about a stone masonry strengthening process that preserves the original structure. The company that developed the process, based in Great Britain, had been involved in a project to restore a multispan bridge in Aldie, VA.

The process, called Archtec™, involves installing a reinforcing system entirely within the fabric of the structure, leaving no visible change to the outward appearance. According to the British company that owns the process, the concept was originally developed in Germany and has evolved to meet the diverse requirements of the civil engineering industry in the fields of strengthening and preservation. In fact, some 70 bridges have been upgraded using this strengthening system in the United States, Australia, and Europe. In addition, the technology has been used in Windsor Castle, Buckingham Palace, the Blair House (part of the White House complex in Washington, DC), and other buildings.

The masonry grout is strained to remove lumps before it is fed into the fabric sleeve.

The system combines simulation software and a reinforcing process. Full-scale arch mockups of a bridge are created and load-tested to failure in the software. To develop a specific treatment, a designer then

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creates a three-dimensional model of a bridge using a computer-aided design (CAD) program. Live loads are then simulated as the bridge model is progressively strengthened. When the simulated reinforcement is in line with the live loading required for the project, the software generates the final design specification.

A representative from the manufacturer describes the reinforcing process as follows. First, holes are drilled into the arch barrel through the road surface using diamond core drills. The drill rod is left in the hole and a stainless steel reinforcement bar, surrounded by a woven polyester sleeve, is then inserted inside the rod. The drill rod is then removed and grout is pumped under low pressure into the sleeve. The sleeve inflates from the bottom up to prevent trapping air bubbles and expands into the profile of the hole, forming a chemical and mechanical bond between the reinforcing bar and the substrate. The sleeve is permeable enough to allow some of the grout milk to seep through to form the mechanical bond, but not so permeable that the grout escapes into cavities in the infill, which potentially could damage the arch. When the process is complete, the only visible evidence of the drilling is a small amount of grout on the surface, which later will be covered during repaving. In other words, the system works by grouting a deformed stainless steel reinforcing rod into holes drilled into the arch. This adds internal reinforcement to the arch bridge so that it acts as a reinforced cohesive unit.

One of the factors that influenced the selection of the strengthening method was that U.S. design specifications did not provide extensive guidance on load rating masonry arch bridges. However, the United Kingdom Highways Agency has developed comprehensive standards for assessing live load capacity on masonry bridges. The standards are incorporated into the agency's *Design Manual for Roads and Bridges: Volume 3*, Section 4, Part 3, BD 21/01, "The Assessment of Highway Bridges and Structures." (For more information, see www.official-documents.co.uk/document/deps/ha/dmrb/vol3/section4.htm.)

The company that owns the strengthening process helped develop the U.K. standards that are now widely accepted throughout the world as the most comprehensive code for assessing masonry arches. With its proprietary software, the company completed a finite element analysis of the structure to approximate the bridge's live load capacity rating and create models to determine the point of failure. Another benefit of using this system is that the entire drilling, coring, and installation operation can take place on the existing roadway surface, without requiring excavation. Utilities do not need to be relocated or otherwise affected during construction.

In addition, the strengthening system takes substantially less time than traditional methods like saddling, and its effect on traffic is minimal. According to the manufacturer, the installed reinforcing rods have been independently age-tested in the United States and Europe, with a predicted long-term durability of at least 120 years.

Design and Construction

A detailed survey of the bridge focused on the road and arch barrel surfaces, and control points were established for setting up the drilling rig during operations. Engineers visually inspected the arch intrados (interior curve of the arch), spandrel and wing walls, and the railings to assess the general condition of the bridge, and took core samples.

Then the designers modeled the properties of the materials and the behavior of the material contacts, and applied loading in accordance with the British standard. Next, they loaded the survey data into the program to generate a three-dimensional CAD model including the road and arch barrel surfaces, the position and length of the reinforcing rods, the angles of insertion, and utilities.

After establishing the optimum design, construction began in September 2004. Workers drilled holes 6.5 centimeters (2.56 inches) in diameter parallel to the roadway and at an angle along the arch. The holes were drilled to the precise angles specified in the design with a small core drill, which operated at a slow enough speed to preclude any potential damage to the structure due to vibration. The drill rig was bolted

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to the road through the paving surface to prevent movement during drilling. After a hole was drilled, the reinforcing rod and fabric sleeve were inserted into the hole, and the drilling rig was then moved to begin the next hole. In all, 26 reinforcing rods (13 on each side of the arch crown) were then inserted into the arch barrel. With two drilling rigs, workers were able to drill two holes a day.

"We had not seen the technology before," says Karyn LeBlanc, communications specialist with DDOT. "This was really an interesting engineering feat. We took other engineers out to view the process as it was going on because it was so innovative."

In the end, workers were able to strengthen the Wisconsin Avenue Bridge in less than 3 weeks—2 days ahead of schedule. The strengthening process cost about $350,000 (construction) plus design. Replacement, which was out of the question because of the historic value of the bridge, would have cost many times that, with greater disruption to the local community and traffic.

Additional improvements planned for 2005 include a new concrete slab over the arch to function as a riding surface, and the restoration of the iron railings, stone work, and sidewalks, further enhancing the safety and beauty of the bridge.

A Smooth Operation

The experiences on the Wisconsin Avenue Bridge project yielded several significant lessons for future projects. First, the innovative strengthening process could be a viable option for dealing with other historic structures and can be considered when addressing the requirements of historic preservation, while also satisfying modern engineering, safety, and environmental requirements. Before the strengthening project, the weight restriction on the bridge was posted at 22.7 metric tons (25 tons), according to an inspection report from February 1997. After the renovation, the rating is HS25, or 40.8 metric tons (45 tons) under AASHTO guidelines.

The project not only improved the safety of the 174-year-old structure but also extended its service life. Traffic continued to utilize the bridge throughout the duration of construction with minimal disruption. Northbound traffic continued to use one lane throughout the process, while southbound traffic was rerouted to a street one block away.

Workers bolt the drilling rig to the pavement on the bridge in preparation for driiling the 26 holes needed for the strengthening project.

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Workers insert the fabric sleeve and stainless steel reinforcing rod into the drilling pipe, which is later removed. In the background, traffic continues to move across the bridge during the work.

Cooperation and communication among multiple stakeholders during the planning and design stages through project completion helped resolve issues before they became problems. Meetings were the preferred method to identify and work through concerns, and FHWA coordinated the meetings to ensure that appropriate decisionmakers were present. Tony Fusco of KCI Technologies, design consultant on the project, describes the process: "We basically began by laying out the design criteria and the level to which we would strengthen the bridge, presenting the pros and cons of each alternative. This established the surface features of the bridge as an extremely important priority to the National Park Service and helped us identify acceptable rehabilitation treatments that would not compromise the structure's purpose or historic character but would minimize or eliminate the cause for the exhibited failure mode."

Once all the concerns were identified, rehabilitation designs could be developed to address each concern and element of the bridge. Each agency played a role in the review during the design phase to ensure that their concerns were being addressed adequately. "If additional concerns were identified during any phase of the design, we would address them and incorporate the solutions into the design for all to consider at the next review stage," Fusco says. "If there were critical elements of the design that could derail or delay the design process, we would make specific interim submissions addressing the concern to the respective agency to gain feedback and agreement before proceeding with the next project review submission. Conducting meetings face to face enabled us to present engineering construction documents and data to nonengineers reviewing the information and provided them the opportunity to question us, so they had a full understanding of the project, details, materials, and intended outcome."

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Historic meets modern. Today, the old Wisconsin Avenue Bridge, shown here looking north up busy Wisconsin Avenue, continues to support a variety of traffic ranging from pedestrians and bicyclists to cars and heavy trucks.

According to DDOT's LeBlanc, involving personnel from all relevant government agencies as well as citizen groups and businesses was key. "Communicate, communicate, communicate," she says. "We sought [community] input, and we worked to come up with a solution acceptable to all the parties involved—the businesses, the taxpayers, and the citizens."

The iterative meetings and frequent communication were well worth the lengthy upfront planning. "It made the actual construction go smoothly and quickly," Fusco adds. "We encountered no surprises, and all participants felt satisfied that their particular requirements were being met. The extensive planning

prevented work interruption by clarifying concerns and negotiating concessions to achieve win-win solutions."

In the end, what began as a potentially contentious aspect of the project—addressing the diverse concerns of multiple stakeholders—turned into one of the most rewarding, according to Mike Seibert of NPS. "We came together skeptical of the other participants' intentions, but before the project concluded, we were working together as a team, with respect for each other's needs," he says. "Really, we will miss working together."

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