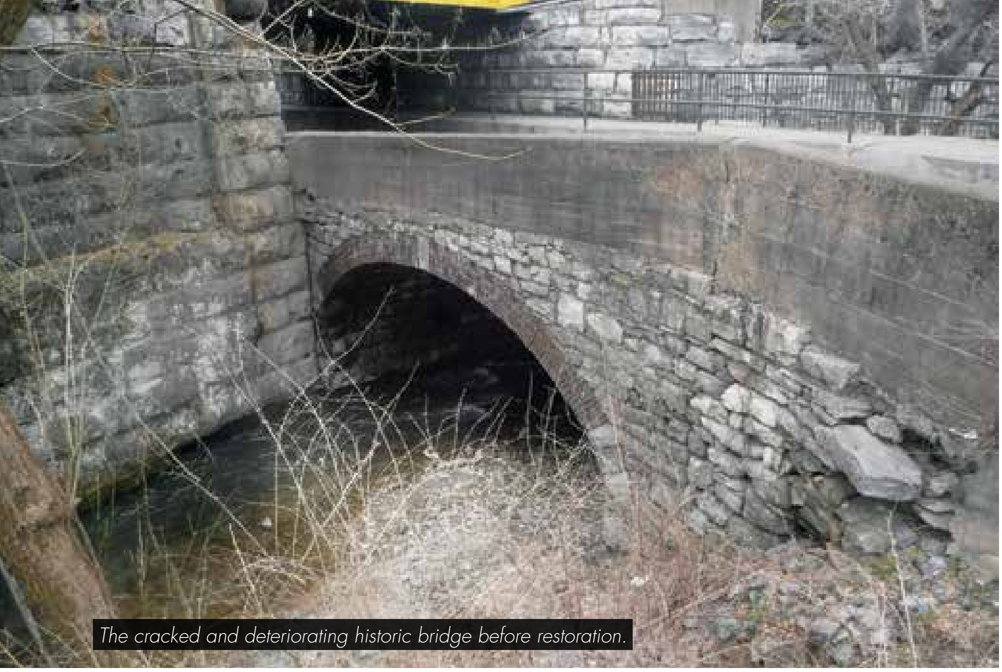


The cracked and deteriorating historic bridge before restoration.

Historic Stone Arch Requires Modern Approach

By Matt Lewellyn, P.E.

The East Burke Street Bridge is an important vehicular and pedestrian connection between downtown Martinsburg, West Virginia, and neighboring residential areas. Equally important as the bridge's function is its rich history dating back to the Civil War. Believed to be originally constructed in 1861, the bridge survived a Confederate attack that destroyed an adjacent bridge and other buildings.

Structural deficiencies, including unstable wingwalls, loss of mortar, sidewalk settlement, and missing, cracking, or loose stones were identified in 2010. As a result, the City of Martinsburg and the West Virginia Department of Transportation (WVDOT) sought a solution that would increase load capacity while retaining the historic aspects of the structure. This required a phased and tailored approach that allowed the team to work around the delicate condition of the historic parts of the bridge.

The City and WVDOT worked with design engineers Burgess & Niple using a multi-phased approach. The first phase included survey, mapping, geotechnical borings, condition inspection, hydraulic analysis, and preparation of a bridge renovation study. The initial study included document research to identify the bridge's historic significance and indicated that the structure was most likely built in the 1860s. This information was used to compare alternatives for renovating and replacing the structure.

The inspection determined that the arch barrel of the bridge was the only portion of the structure that was suitable to preserve. It had been repaired in the 1900s with brick rings, and a keystone was inscribed with that date. Five alternative project approaches were presented, ranging from a minimal renovation to a complete replacement with a pre-cast concrete arch. Ultimately, the bridge owners opted for a major renovation with reinforced concrete to strengthen the historic arch. The phase that followed included both preliminary and final design of the recommended alternative and preparation of right-of-way plans.

Preserving the Stone Arch

The project team's goal was to maintain the existing stone arch while providing an alternate structural system to carry traffic loads. A rigid frame was constructed in direct contact above the stone arch to accomplish this. The rigid frame system consists of a concrete rib that follows the existing arch line and a concrete slab that functions as the roadway surface for the bridge. The new frame was constructed by installing falsework under the existing arch barrel, removing the wearing surface and earth fill, and then constructing the new frame on top of the existing arch.

The contractor's falsework was a series of steel W16 beams, couplers, and posts with diagonal bracing, which supported 3-inch-thick timber planking placed just below the stonework. After mats of epoxy coated rebar were tied into place, the arch rib was formed and poured directly on top of the existing stone barrel. The concrete rib was bonded to the stone using an epoxy bonding agent, applied before the pour. Next, gravel fill was installed to fill the voids within the concrete frame, and the concrete slab was constructed on top

A new reinforced concrete arch was designed and placed over the top of the existing arch to provide full live load capacity.

of the fill, with the midspan portion constructed integrally with the arch rib.

Like a new bridge, this hidden structural system provided durability and increased load capacity.

The MIDAS Touch

The rigid frame support system was analyzed using a MIDAS finite element model that considered construction staging and the effects of soil-structure interaction on the behavior of the frame. The keyed construction joints at the base of the concrete rib were considered classical hinges for the analysis model and were treated as pin supports. The rib and slab elements intersected at a reinforced “knuckle” region and were modeled as moment-continuous. The ends of the slab elements are supported by bearing walls at the abutments and were modeled as pin supports.

The compressive capacity of the existing stone arch was neglected in the analysis, and the existing stonework was included only as dead load. Forces extracted from the model were used to perform design computations for the frame. The frame was designed for the interaction of axial and bending loads, with particular attention given to the reinforcing details in the knuckle regions to control stress concentrations. Support reactions from the model were used to design the micropile foundations. Load combinations producing maximum vertical load, thrust, and overturning effects were identified to determine the controlling design condition.

Use of Micropiles

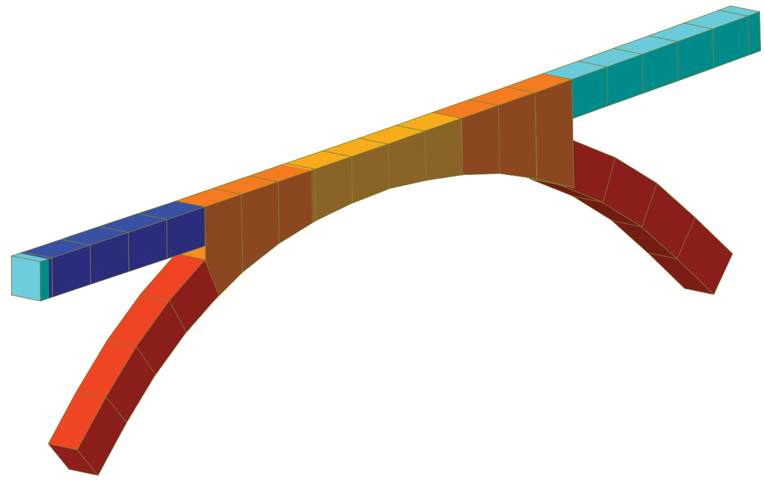
Sensitive ground conditions, steeply sloped bedrock, and adjacent structures made micropiles a good option for the East Burke Street Bridge. A total of 41 micropiles support the forward abutment and parallel wingwalls. Load testing was performed to confirm that the maximum factored axial load of 154,000 pounds per pile would be adequately developed. The rear abutment is founded on a spread footing placed directly on the bedrock.

Several of the 7⅝-inch-diameter micropiles were installed at an angle to accommodate both axial and lateral loads. The outer casing pipe and drill rods advance through overburdened soils to rock and continue to pile tip elevation. Drill rods and casing were added in 5- or 10-foot lengths. Drill cuttings travel up the inside of the casing using air and water and are discharged through a swivel on the drill head. The piles penetrate 10 feet into bedrock to provide the bond zone for the grout, which is placed through a 1-inch high-density polyethylene (HDPE) tremie pipe to the bottom of the hole. A single number 11 reinforcing all-thread bar (Grade 75) was placed in the middle of the micropile.

The micropiles provided a strong foundation without using a more traditional driven steel H-pile that could have shaken the ground and caused damage to the stone arch barrel, which would be temporarily supported but still vulnerable to heavy vibration.

Technology Helps Preserve History

A high-definition survey scan provided a detailed point cloud of existing geometry for stone mapping. The scan was used to



East Burke Street Bridge MIDAS model.

Burgess & Niple designed the bridge with micropiles instead of hammer-driven piles to reduce vibrations adjacent to the existing stone masonry.

The refurbished bridge used stone facing over the wingwalls and black metal fencing to create a similar aesthetic

The East Burke Street Bridge arch as it is unearthed.

assess the condition of the material and arch structure and helped preserve as much of the viable stonework as possible. As a result, the arch barrel was cleaned and repaired with a lime mortar mix, cracked stones were repaired, and missing or damaged stones and bricks were replaced. In addition, the new concrete spandrel walls, wingwalls, and barriers were faced with stone masonry, some of which were reused from the existing walls. Thus, using the scan helped sustain as much of the bridge's history and character as possible.

Project Challenges

The project team faced several challenges during the construction phase of the project. One of the most significant was the location of the bridge approach under a railroad. To allow the railroad to remain operational during the rehabilitation, the contractor had to provide pre-construction photographs and video of the over-passing railroad abutments and walls. During excavations, survey monitoring was performed to confirm there was no movement of the railroad structure. In addition, inspections were conducted following the excavation of each stone masonry course to ensure there was no distress caused to the railroad. If issues were observed, a corrective action plan was in place with materials and equipment on hand to immediately restore stability to the railroad. In the end, the action plan was not needed, which confirmed the assumption that the railroad bridge was structurally independent of the arch and supported directly on bedrock.

Another challenge was the amount of rain that fell during construction, causing the Tuscarora Creek that passes under the bridge to rise, resulting in delays. High water resulting from above-average rainfall totals conflicted with the placement of the temporary support structure. To resolve this, the construction team rerouted a portion of the flow around the structure's footprint by excavating an alternate relief channel in the east approach.

As the arch was unearthed, additional issues were discovered. Predictions made about the width of the existing foundation stones were not accurate. The stones were much larger and conflicted with the placement of the concrete foundation as designed. Trimming the stones was discussed, but the team decided not to risk disturbing the arch. Instead, Burgess and Niple adjusted the structural model to account for thrust of the larger span, and revised plans were issued to keep the project moving. This required three additional micropiles and additional battering of the piles.

History Preserved. Safety Restored

Through this rehabilitation project, the City of Martinsburg preserved parts of the bridge's history while increasing safety and load capacity for travelers. This intricate rehabilitation was achieved with several innovative strategies, such as the use of micropiles and high-definition survey software to address design and construction complexities. In addition to the project team's approach to obstacles, including the proximity of the active railroad and weather-related disruptions, these strategies made this award-winning project a success.▪

Matt Lewellyn is a Project Manager in the Burgess & Niple Parkersburg, West Virginia office. He is a national leader in bridge inspection, load rating, preservation, and rehabilitation. (matt.lewellyn@burgessniple.com)

Project Team

Owner: City of Martinsburg, West Virginia
Project Administration: West Virginia Department of Transportation
Design Engineer: Burgess and Niple, Inc.
Geotechnical Engineer: Terracon, Inc.
General Contractor: Orders Construction Co., Inc.
Micropile Contractor: Coastal Drilling East, LLC

The East Burke Street Bridge following the renovation.