Volume 6, Number 1
March 2019

Historic Bridge Bulletin

Historic Bridge Foundation

In This Issue:

The Spey Viaduct in Garmouth, Scotland, was built in 1885 and features an impressive 350 foot main span. The former railway bridge has been converted for pedestrian use on a trail system. *Photo by Nathan Holth.*

This historical photo of the Ozark Mill area shows the ca. 1865 covered bridge in the foreground, and a railroad bridge in the background. The covered bridge was replaced by a pin-connected metal truss bridge in 1909.

Saving Ozark's Historic Riverside Bridge

By Historic Bridge Foundation

The Riverside Bridge carries Riverside Drive over Finley Creek in Christian County, Missouri. The bridge consists of two 100 foot, 6-panel steel pin-connected Pratt through truss main spans and two steel stringer approach spans. The bridge's substructure consists of concrete abutments, wingwalls, and piers. The current deck surface is concrete over a corrugated steel deck supported by steel deck stringers. The bridge's historic trusses retain a remarkably high degree of historic integrity.

The two truss spans of the bridge were originally constructed in a nearby location over Finley Creek in 1909 by the Canton Bridge Company of Canton, Ohio, on what is today West McCracken Street next to the Ozark Mill. The 1909 bridge replaced a former ca. 1865 wooden covered bridge at the location, which had been destroyed by flooding. The cost of the new bridge was $3,648.00. The location of this bridge proved to be a popular crossing, which saw increased traffic in a short period of time. In 1922, the Missouri State Highway Department decided to route US-65 along McCracken Street. A larger, heavy-duty bridge was needed for a US highway, and thus after just only a decade of service, the pin-connected truss bridge found itself being replaced. The 1922 highway bridge built by the department (which remains in

A historical elevation photo of the pin-connected truss bridge at Ozark Mill.

This historical photo shows the Ozark Mill with the pin-connected truss bridge in the lower left of the photo.

The Ozark Mill Bridge at McCracken Street as seen today. This bridge replaced the bridge that was moved to Riverside Drive. *Photo by Nathan Holth.*

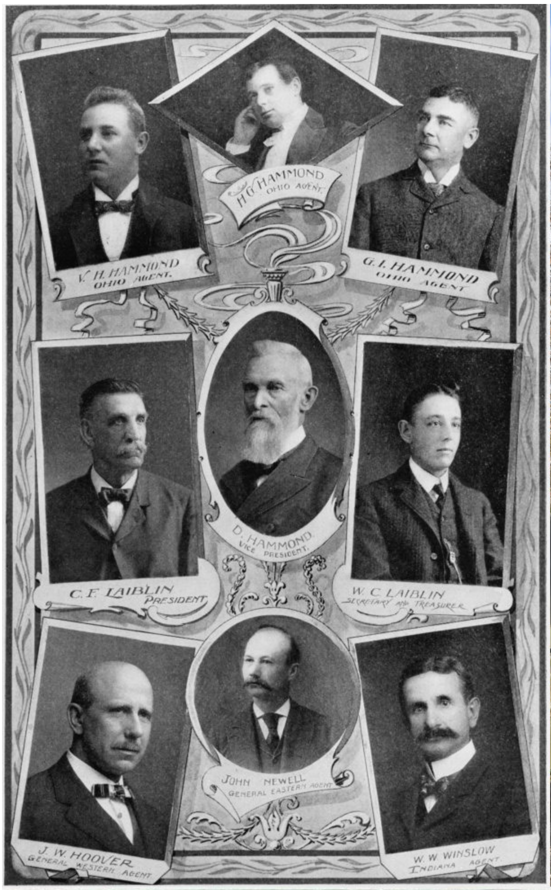
An elevation view of the Ozark Mill Bridge at McCracken Street as seen in 2016. The building visible behind the bridge is the Ozark Mill. *Photo by Nathan Holth.*

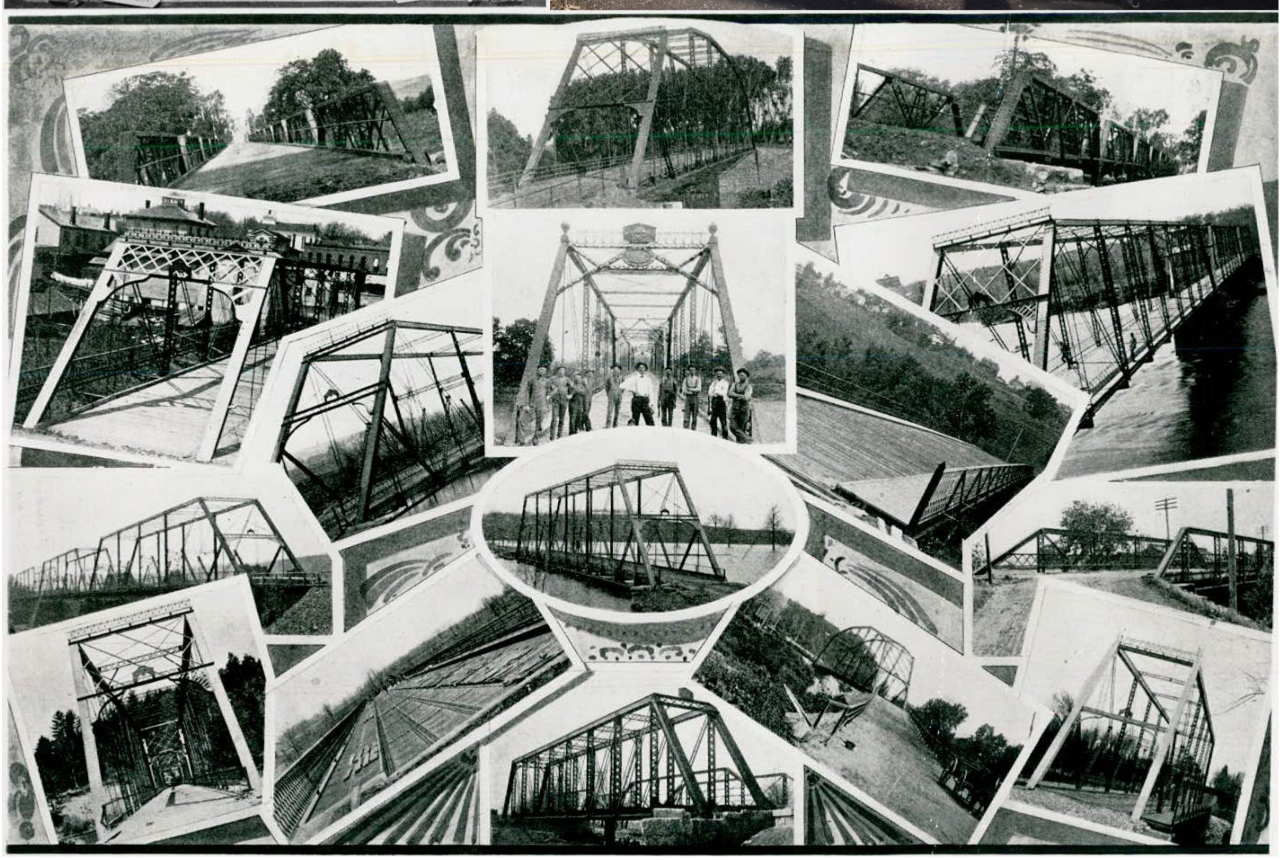
use today) is a rivet-connected Baltimore through truss bridge. Since the pin-connected Pratt bridge that was replaced was not very old and still in very good condition, the county decided to relocate the 1909 bridge to a nearby crossing known as Biers Ford, which today is Riverside Drive over Finley River. The bridge opened to traffic in its new location in 1924.

Riverside Bridge was built by the Canton Bridge Company of Canton, Ohio, a prolific builder of metal bridges in the late 1800s and early 1900s. David Hammond, who created the Canton Bridge Company, was also the creator of an older and more famous company, the Wrought Iron Bridge Company of Canton, Ohio, which was the largest pre-1900 builder of metal bridges in the United States. Hammond held a number of patents on metal bridges and was instrumental in the advancement of metal bridge construction in the United States. His Wrought Iron Bridge Company was a leader in successfully building standardized designs of truss bridges in large quantities. Hammond lead the Wrought Iron Bridge Company for about a decade as president, followed by about nine years as sales agent and other roles at the company, until 1890 when he resigned from the company and withdrew his stock with the intent of retiring. However, his son Vinton and son-in-law John Reed talked him into starting another bridge company, the Canton Bridge Company, in 1891. A success in its own right, Hammond was president of this second company from 1893 to 1897, and vice president until 1905, when he died. Unlike the Wrought Iron Bridge Company, the Canton Bridge Company escaped being absorbed into the American Bridge Company which had formed in 1900, buying out many of the leading 19th Century bridge companies. Even after Hammond's death, the Canton Bridge Company continued to have success constructing many bridges, including the Riverside Bridge in 1909. Indeed, the company appears to have developed positive relationships and "brand loyalty" with agencies and owners such as Christian County, building numerous other truss bridges for Christian County as well.

Riverside Bridge is historically and technologically significant as an outstanding, unaltered example of a metal pin-connected Pratt through truss bridge, a once-common structure type that has become increasingly rare nationally, statewide, and locally, as these bridges have been replaced at a staggering rate nationwide. The Riverside Bridge is an excellent surviving representative example of this bridge type.

A view beside the Riverside Bridge as seen in 2010. *Photo by Daniel Shortt.*





Above left: Page from historical company literature showing the officers of Canton Bridge Company. Despite being listed as vice president, original founder David Hammond is shown prominently in the center. Above right: Photo of the Riverside Bridge taken November 14, 2016. Bottom: Page from historical company literature showing bridges built by the Canton Bridge Company.

The builder plaque on the Riverside Bridge. *Photo by Nathan Holth.*

Its longer, two-span configuration also sets it ahead of shorter single-span examples, which are more numerous.

Including the Riverside Bridge, there are only five truss bridges of any kind remaining in Christian County. Only one bridge other than the Riverside Bridge is a pin-connected through truss, and this other bridge is a single span structure instead of two spans. In 1992, there were nine metal truss bridges remaining in Christian County. Four of those have been demolished. This is a significant local decline in truss bridges, and is a reflection of national trends. Because of the demolition of other truss bridges in the county, the Riverside Bridge is today distinguished as the oldest metal truss bridge in Christian County, and the only multi-span pin-connected through truss.

The portal bracing of the Riverside Bridge, which includes distinctive lacing bar frills and the unusual pin connection to the truss are common features of bridges built by the Canton Bridge Company. *Photo by Nathan Holth.*

Metal pin-connected truss bridges were the most common type of bridge from the 1880s and into the first decade of the 20th Century. The Pratt truss configuration was the most common type of truss employed. Pin-connected truss bridges were favored during this period because they were sturdy, reliable, and made efficient use of materials. They also could be fabricated in a factory, shipped to a site, and easily erected by local labor. Pinned connections rapidly fell from favor in the first years of the 20th Century when it became feasible to fashion rigid riveted connections for truss bridges in the field. Truss bridges themselves saw a gradual decline in popularity throughout the 20th Century as simpler structure types became feasible to construct, such as the steel stringer (beam) bridge, concrete t-beam bridge, and pre-stressed concrete bridges. As such, the Riverside Bridge not only exhibits distinctive designs and engineering techniques of a period in history, it also highlights designs that have not been in use for decades.

The Riverside Bridge also displays historic metal fabrication methods and techniques in its original

The start of the Riverside Bridge relocation project is shown here, with the deck of the bridge removed. *Photo by Daniel Shortt.*

Looking up at the Riverside Bridge, with the deck removed in preparation for its relocation. *Photo by Daniel Shortt.*

At least some of the steel on the bridge was rolled by Cambria Iron Company as shown by the name Cambria on this vertical member channel. *Photo by Nathan Holth.*

material, which is also a record of the craftsmen who fabricated it. The Riverside Bridge displays these features clearly because of the lack of alteration to the original material and design of the truss. Features including rivets, built-up beams with v-lacing, loop-forged eyebars, and rolled American Standard Beam I-beams are all examples of historic metal fabrication methods and designs. These features have not been seen in bridge design for decades.

Starting in 2010, the Riverside Bridge found itself facing an uncertain future when the county proposed demolishing and replacing the bridge. Fortunately for the bridge, a number of local residents were unhappy with the prospect of losing the bridge, including Kris Dyer, who spearheaded an effort to organize community support for the bridge and to seek out assistance from organizations (including the Historic Bridge Foundation), in hope to find a preservation solution for the bridge. The path toward preservation was not easy and involved discussions with multiple agencies including Christian County, the Ozark Special Road District, the city of Ozark, FEMA, and MoDOT. The proposed project resulted in a Section 106 review, which ultimately led to an effort to market the bridge for relocation and reuse by a third party. The effort to market the bridge was a success, with two proposals for reuse being submitted. The winning proposal is a unique one, which involves relocating the bridge to a location next to the bridge's original location at the historic Ozark Mill, where the bridge will serve non-motorized traffic on a trail system. The relocation of the bridge is part of a larger project to restore and preserve the historic Ozark Mill itself. This project is being undertaken and funded by Bass Pro Shops under the direction of Megan Morris, who is the daughter of Johnny Morris, founder of Bass Pro Shops.

As of the writing of this article, the Riverside Bridge has been lifted off its substructure and dismantled. The bridge will now be repaired and eventually erected on a new substructure at the Ozark Mill site.

Rehabilitating the Split Rock Stone Arch Bridge

By Sara L. Nelson, P.E. and Steve Olson, P.E.

An arch consists of two weaknesses which, leaning one against the other, make a strength.
-------- Leonardo da Vinci

Pipestone County is home to and the owner of the longest stone arch bridge in Minnesota that still carries vehicular traffic. It is a single span bridge with a span of 50 feet. The Split Rock Bridge was built in 1937-1938 as part of the Works Progress Administration Program and was listed on the National Register of Historic Places in 1989.

The nomination form stated that "In addition to displaying the largest stone-arch span of any active highway bridge in the state, the structure is an outstanding example of an ornamental park bridge, achieving its aesthetic effect through the purity of its form and the beauty of its random-ashlar masonry". The Sioux quartzite stone used to build the bridge is

East elevation of the Split Rock Bridge. Heavy efflorescence can be seen on the arch barrel and abutment wall. *Photo by Gemini Research.*

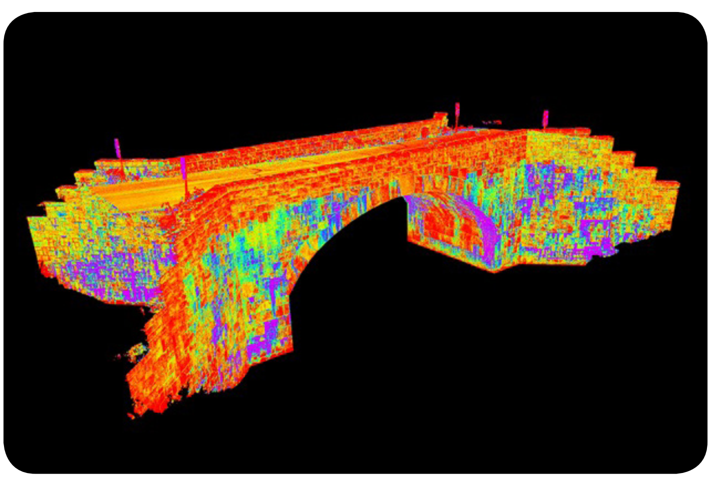
Construction of the Split Rock Bridge. *Photo from Minnesota Historical Society.*

from a quarry just 4 miles from the bridge, which is still active.

The 80-year-old bridge is showing signs of its age. For several years the County had been measuring the distortion in the railings on each side of the bridge. In 2016 the inspection report contained the following note:

MONITOR bowing out of center of both rails 4-18-12. Measured by string line deflection outward of both rails in 2012 & 2014. 0.4' measured along both east and west rails. [2012-2014] A loose stone exists on the inside of the rails on all 4 ends. [2014-2016] 0.5' measured along both east and west rails. [2016]

One of the first things we did was meet on site to inspect and evaluate the bridge. At that time, we also performed a laser scan of the bridge. The laser scan provided invaluable information. First, we were able to quickly determine that the railings were not bowing outward as assumed. Simple section cuts in the scan showed the railings over the middle of the bridge were plumb, but railings were actually tilting inward at the ends of the bridge and on the wingwalls. We could also determine that the wingwalls and headwalls were plumb and the arch was not distorted. This information allowed us to recommend reconstruction of only the railing using the in-place stone.



Laser scan from the east side of the bridge. This data confirmed the inward bow of the railing and plumbness of the headwall and wingwalls.

We were tasked with load rating the stone arch bridge. In 2012 this bridge was rated via a physical inspection rating (PIR) form. After reviewing the structure in the field, the engineer provides a rating based on engineering judgement.

Another way to rate this bridge would be using finite element analysis with soil-structure interaction. Without question, finite-element analysis is a powerful tool for bridge engineers to use. However, at times it can be a time intensive task. Soil-structure analysis is complicated by the fact that soil is non-linear in its structural response. Active earth pressures, at-rest earth pressures, and passive earth pressures applied to a structure typically require some simplifying assumptions when incorporated into a finite element analysis. We were hoping to utilize an analysis method somewhat more refined that "engineering judgement" and less intensive than a soil-structure finite element model.

We did a little research and found that the British use a relatively simple method (modified MEXE) to assess the load capacity of their masonry arch bridges. Great Britain has a lot of masonry arch bridges which were built long before modern trucks were traveling over them. The modified MEXE method provides an allowable axle load, in tonnes (metric tons), based on vehicles listed in their Road Vehicle Regulations. The required input includes span length, rise of the arch barrel at the crown and quarter points, thickness of the arch barrel, average depth of fill, type of arch barrel material, type of construction of the barrel (courses or random), condition of the barrel, and deformation of the barrel. This input is placed in equations to determine an allowable axle load or truck size to safely cross the bridge.

The allowable axle load was then compared to the load rating used in the United States (AASHTO HL-93) to determine if the bridge should be posted. The modified MEXE method indicated that the capacity of the bridge was much higher than the value assigned to the bridge in 2012 by engineering judgement. The HS-17 value assigned to the bridge in 2012 corresponds to a semi-truck with a gross weight of 61,000 pounds. The MEXE method indicated the bridge had the capacity to safely carry a semi-truck with a gross weight of over 100,000 pounds.

This method only rates the arch barrel; it should be noted that the rating could be controlled by the headwalls, wingwalls, or other members. This method cannot be used for flat or significantly deformed arches. They also state it can be used for arches up to a 60-foot span, but it does become more conservative once the span is greater than 40 feet. The method is described in detail in the "Design Manual for Roads and Bridges, Volume 3 Highway Structures: Inspection and Maintenance, Section 4: Assessment."

Once we confirmed the bridge did not need to be strengthened as part of the rehabilitation, we looked at addressing its deficiencies. The bridge abutments, wingwalls, and underside of the arch showed significant signs of water infiltration, resulting in major efflorescence. The mortar joints are also cracked and missing in places and the arch has loose stones.

Because the bridge has a large amount of thick efflorescence, our team decided to test different methods to remove the efflorescence. We assumed the method to remove efflorescence should not damage the stone and be gentle, better to under clean than overclean, and we knew that the bridge would be completely repointed. We found dry

Condition of stone and mortar joint after washing the stone with 300 psi water pressure. *Photo by Gemini Research.*

cleaning methods didn't work. We also found the typical water pressure range between 300 and 500 psi did not work. Knowing that the bridge will be completely repointed and the quartzite stone is an extremely hard metamorphic rock, the testers increased the water pressure incrementally by 300 psi. The results found a tip with zero-degree fan, 2100 psi pressure, applied for 1.5 minutes slowly knocked off the efflorescence with some pitting to the mortar joints and no damage to the stone. We also tried 2500 psi and saw similar results as using a pressure of 2100 psi. Because we wanted the gentlest method, our specifications state to use a pressure up to 2100 psi.

Why do you speak to me of the stones? It is only the arch that matters to me.
-------- Kublai Khan, 13th Century AD

With loose stones in the arch, we knew the mortar was completely missing in some joint locations. As engineers we desire complete bearing along the arch stone face which requires mortar along the entire joint. Given the fiscal constraints of our project it is not practical to dismantle the arch and rebuild it. It's also not feasible for repointing to reach areas 2 feet inside the arch soffit. We turned to supplemental grouting techniques. If mortar is present, but not sound, more than 6 inches from the face of the stone, grout will be used in the arch barrel. If the mortar is missing for more than 6 inches from the face of the stone, low shrink grout under low pressure (less than 400 psi) will be placed into the void until grout begins

Condition of stone and mortar joint after washing the stone with 2100 psi water pressure. *Photo by Gemini Research.*

to fill the joint. No less than 4 inches from the face of the stone will be filled with repointing mortar. The contractor will estimate the amount of grout to fill the void prior to starting the grout application. If they use more than 2 times the grout, they will be instructed to consult with the engineer.

Beyond reconstructing the railing, cleaning and repointing the structure, and adding grout where required, the top face of the arch barrel, non-exposed faces of the headwalls and wingwalls will be waterproofed to better protect the structure from water infiltration. These construction activities will extend the useful life of the 80-year-old structure for residents and visitors of Pipestone County.

In summary, the Split Rock Stone Arch Bridge is a beautiful structure. Fieldwork (which included laser-scanning) indicated that most of the bridge's components are not distorted after 80 years of service. However, there is extensive efflorescence and the mortar joints are in poor condition.

The modified MEXE arch analysis indicated that the bridge has a load capacity much larger than would be assigned with "engineering judgement".

Dry and wet cleaning techniques were tested on the bridge stone to remove the efflorescence. The strength of the stone was impressive. Cleaning with water pressures as high as 2500 psi did not damage the stone.

The County is looking for funding to execute the project. After rehabilitation the bridge is expected to be a focal point for visitors to Pipestone County for decades into the future.

The consulting design team was led by Bolton & Menk, with Olson & Nesvold Engineers working on the arch, and Gemini Research serving as the project historians.

References

Hess, Jeffrey A. "Split Rock Bridge." National Register of Historic Places Registration Form. Aug. 1988.

Design Manual for Roads and Bridges, Volume 3 Highway Structures: Inspection and Maintenance, Section 4: Assessment. Part 4 BA 16/97 November 1997

Sara is a Senior Project Engineer at Olson & Nesvold Engineers with almost 20 years of structural engineering experience with the last 8 years emphasizing on historic structure rehabilitation. She has participated in several studies that evaluated bridge rehabilitation alternatives considering cost, service life, geometric and load capacity improvements. Sara has also designed and detailed structural repairs for concrete bridge structures and steel truss bridges, while also determining their load capacity ratings.

Steve is Principal Bridge Engineer at Olson & Nesvold Engineers. He has over 30 years of design, inspection and analysis experience with both fixed and movable bridges, which includes project experience with dozens of bridges listed in the National Register of Historic Places. For 13 years he taught Bridge Management, Maintenance, and Rehabilitation at the University of Minnesota. He is also an instructor for the National Preservation Institute.

A view beside the Split Rock Bridge, taken in 2014, prior to the rehabilitation project. *Photo by Minnesota Department of Transportation.*

Frankford Avenue Bridge:
Rehabilitation of the Oldest Bridge in America

By Margaret Sherman, PE and Monica Harrower

Unbeknownst to many, a three span, closed spandrel, stone masonry arch bridge that crosses Pennypack Creek along Frankford Avenue, in the northeast section of Philadelphia, Pennsylvania, is the oldest continuously used roadway bridge in America. This stone masonry bridge is estimated to have been constructed in 1697 and remains true to its original form, even after undergoing many construction and repair campaigns during the last three centuries. The Frankford Avenue Bridge, also called the Pennypack Creek Bridge, is significant for its engineering and transportation history and was listed on the National Register of Historic Places in 1988.

The Pennsylvania Department of Transportation, Engineering District 6-0 (District 6-0), has a strong historic bridge rehabilitation program – they view their historic bridges as irreplaceable assets and make every effort to rehabilitate and preserve them. Leading this effort are Chuck Davies, the Assistant District Executive for Design, and Henry Berman, the District Bridge Engineer. They are committed to the consideration of historic bridges in project planning.

District 6-0 and TranSystems developed a rehabilitation program to address continued deterioration and recent collision damage to preserve the Frankford Avenue Bridge. The intent of the program was to sensitively address the bridge's structural deficiencies while maintaining its historic character and context, and was accomplished by partially dismantling and reconstructing in-kind the stone masonry while using as much existing material as possible and maintaining existing dimensions. The program also includes rehabilitation of a stone masonry culvert over a former mill race, located adjacent to the bridge. The program follows The Secretary of the Interior's Standards for the Treatment of Historic Properties with Guidelines for Rehabilitating Historic Buildings and PennDOT Engineering District 6-0's Stone Arch Bridge Management Plan and the Stone Arch Bridge Maintenance Manual.

The Frankford Avenue Bridge was built along what was originally a Native American trail that was later incorporated into the King's Highway. The King's Highway became a regularly traveled route between Philadelphia and Frankford by 1725 and extended to Boston by the end of the eighteenth century. The King's Highway ultimately connected the colonies

Frankford Avenue Bridge, Circa 1900.

North elevation of Frankford Avenue Bridge prior to rehabilitation.

North elevation of Frankford Avenue Bridge after the 2018 rehabilitation.

from New England to the Carolinas. The bridge has two 25-foot spans and one 12-foot-9-inch span for a total length of 73 feet. In 1803, the Frankford and Bristol Turnpike Company paved across the Frankford Avenue Bridge as part of a toll road that extended from Philadelphia to Morrisville, Pennsylvania. Due to phenomenal population growth extending into northern Philadelphia, the bridge was widened in 1893 to accommodate a trolley line.

The 1893 widening of the bridge included increasing the out-to-out width from 22 feet to 44 feet by widening the bridge to the south, raising the roadway profile, rebuilding the parapet walls with crenellated caps, and widening the culvert over the mill race. In the twentieth century, the crenellated parapets were removed from over the creek and replaced with overhanging sidewalks with decorative pedestrian railings, and reinforced concrete arch

South elevation of Frankford Avenue Bridge prior to rehabilitation. *Photo by Nathan Holth.*

liners were constructed under the original portion of each arch barrel (north side).

The recently completed rehabilitation program scope of work included in-kind reconstruction of the spandrel walls and wingwalls, in particular the north spandrel wall that exhibited bulging and the portions of the wall that sustained collision damage. The architectural features that were present on the bridge prior to rebuilding were maintained. Cleaning, repairing and repointing of the stone masonry occurred throughout. The earth fill between the two spandrel walls and beneath the roadway was replaced with lightweight concrete fill. The sidewalks were reconstructed in-kind and a new crashworthy roadway barrier was installed between the sidewalk and the roadway. The new roadway barrier is mounted to 12-inch thick reinforced concrete moment slabs that sit on top of the lightweight concrete fill. The existing decorative pedestrian railing was salvaged, repaired, painted brown and reinstalled on the new sidewalk overhangs. The concrete arch liners were repaired and coated with a sealant. Scour protection measures (rock) were placed around the abutments and piers. Extensive utility work was conducted during the bridge rehabilitation, which included relocating several utility lines to the center of the roadway, where gravel fill was placed instead of lightweight concrete fill, allowing for future access by the utility companies. Roadway work included milling and resurfacing the approaches, approach sidewalk replacement, and inlet repair. A bituminous overlay was placed from curb to curb. The scope of work for the adjacent culvert included stone masonry cleaning

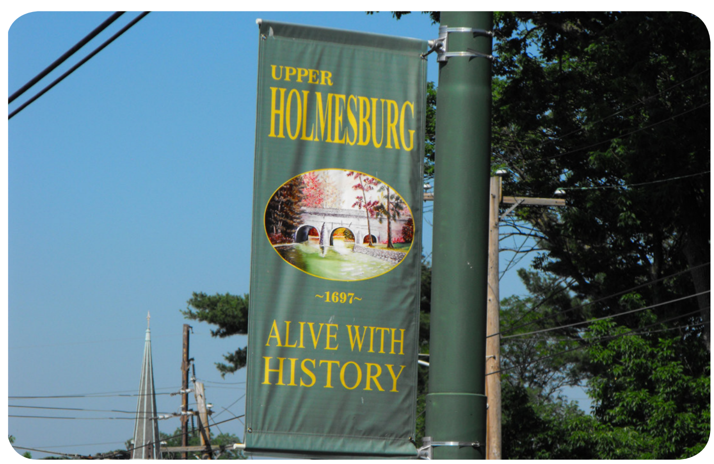
South elevation of Frankford Avenue Bridge after the 2018 rehabilitation.

and repointing and in-kind reconstruction of a portion of the wall end that sustained collision damage.

The Frankford Avenue Bridge rehabilitation project is part of a program that includes seven (7) stone arch bridge rehabilitations and was the first bridge of the group to be completed. The contract was awarded to Loftus Construction, Inc. of Cinnaminson, New Jersey. Construction began in March of 2018 under a full detour. Excavation of the earth fill provided a glimpse into the history of this very old bridge. A portion of the original south spandrel wall was exposed and the width of the 1697 bridge could finally be verified. There were also unexpected site conditions uncovered during excavation including a large volume of concrete on top of all three spans on the south side of the bridge. The date that the concrete was placed is unknown, but it contributed to preserving the stone masonry arches on the south side that were constructed in 1893 as part of the widening project. These portions of the arches are still visible today and were cleaned and repointed as part of the rehabilitation. The bridge rehabilitation was completed and reopened to traffic on September 7, 2018. The Frankford Avenue Bridge was another successful stone arch rehabilitation completed by PennDOT Engineering District 6-0 that will allow the bridge to continue to be an engineering landmark present in Philadelphia.

Margaret Sherman is a Senior Engineer and Project Manager with TranSystems in Philadelphia. Margaret has managed and contributed to many bridge design, rehabilitation, and inspection projects, particularly those involving historic bridges.

Monica Harrower is a Cultural Resource Professional with the Pennsylvania Department of Transportation, Engineering District 6-0 (Greater Philadelphia). Monica is responsible for managing and ensuring that transportation projects comply with Section 106 of the National Historic Preservation Act and other relevant preservation laws and regulations.



The Frankford Avenue Bridge was featured on this street banner in the Philadelphia neighborhood of Upper Holmesburg, where the bridge is located. *Photo by Nathan Holth.*