Burgess & Niple
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TECHNICAL PAPER

Revitalization of an Ohio River Suspension Bridge

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BURGESS & NIPLE
Engineers ■ Architects ■ Planners

Market Street Bridge

Table of **Contents**

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Executive **Summary**

When local community leaders learned that the bridge might be closed, they reacted quickly to contact the state officials who could make decisions to save the bridge.

Divided by the Ohio River, the cities of Follansbee, Wellsburg, and Weirton in Brooke County, West Virginia have long been connected by three bridges to the City of Steubenville in Jefferson County, Ohio. In early 2009, the Ohio Department of Transportation decided to close the Fort Steuben Bridge leaving only two bridges. Although the Veterans Memorial Bridge can handle most of the traffic demand and heavy loads, the Market Street Bridge also serves as a vital link for commuters, light commercial traffic and emergency vehicles.

The Market Street Bridge was originally constructed in 1905 to carry tin mill workers in streetcars from their homes in Ohio to the mill in West Virginia. Surviving for over a century, this cable suspension bridge has been repaired and strengthened on several occasions, including retrofits by D.B. Steinman in 1953. More recently, the West Virginia Department of Transportation (WVDOT) has maintained the bridge and enlisted engineers from Burgess & Niple (B&N) since 1991 to monitor the condition of the delicate structure during annual inspections. As a result of inspection findings, the bridge load posting was reduced to 5 tons. B&N was recommending major rehabilitation to keep the bridge in service when the Fort Steuben Bridge was closed. With discussion of a new Ohio River Bridge being constructed in southern Brooke County, the future of the Market Street Bridge seemed uncertain.

When local community leaders learned that the bridge might be closed, they reacted quickly to contact the state officials who could make decisions to save the bridge. After careful evaluation, the decision was made to invest in a rehabilitation project to preserve the structure at least until a new bridge can be constructed. A team from five Burgess & Niple offices was challenged to evaluate the most critical needs and design repairs

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Executive **Summary** *(Continued)*

Completion of design work for the 107-year old structure was accelerated to position the project to receive American Recovery & Reinvestment Act funding.

to rehabilitate the Market Street Bridge in a very aggressive timeframe. Completion of design work for the 107-year old structure was accelerated to position the project to receive American Recovery & Reinvestment Act funding.

A 3-D model of the bridge was developed using MIDAS software, and the B&N team performed fatigue and structural analyses on the aging structure. The gusset plate connections of the approach truss were load rated. The results confirmed the need for repairs. The analyses also revealed that a few members needed immediate attention, repair plans were developed and repairs were performed by WVDOT personnel. B&N accelerated design of structural steel repairs by using inspection photographs in the plans. Instead of providing line work for the existing members, repair notes and details were superimposed onto the photographs.

Municipality and public involvement included the selection of paint colors through an internet poll on the WVDOT web site. Feedback from the online poll also led to the inclusion of decorative bridge lighting.

Ahern & Associates (Kokosing Construction Co.) was awarded the rehabilitation contract including temporary support of the bridge, eyebar backup rods, rocker post retrofits, cable suspender retrofits, strengthening repairs, painting, and state-of-the-art decorative lighting. As the first major bridge structure in West Virginia to receive a penetrant sealer and calcium sulfonate paint system, this project is leading the way to better coating protection. This paint remains plastic even after it cures to provide ongoing protection against crevice corrosion. A weigh-in-motion device will detect over-weight vehicles that may try to cross the structure.

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Executive **Summary** *(Continued)*

Through innovation and aesthetic enhancement, this project transformed a tired, forgotten structure into an icon for the communities for which it was designed.

A ribbon cutting ceremony was held to celebrate the reopening of the revitalized bridge on December 7, 2011. West Virginia Governor Earl Ray Tomblin was among the state officials and local politicians on hand to commemorate the event. The bridge was closed for almost two years during construction of B&N-designed structural and aesthetic improvements totaling $16 million. The revitalized bridge sports a new color scheme featuring the West Virginia state colors – Mountaineer Blue and Gold.

The Market Street Bridge Rehabilitation is an outstanding achievement in bridge engineering. Through innovation and aesthetic enhancement, this project transformed a tired, forgotten structure into an icon for the communities for which it was designed. The reflection of the lights on the river at night conveys a postcard-like image. Likewise, the community has once again taken pride in the revitalized bridge. This sense of accomplishment provides the public with new hope for economic growth. By lengthening the life of the structure, WVDOT has shown a commitment to preserve history, reduce the use of new materials, and protect the environment.

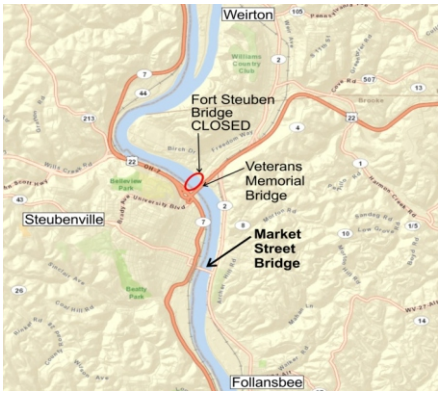

Figure 1 - Location Map

Figure 2 - Market Street Bridge

Figure 3 – Fort Steuben Bridge

Introduction

Situated on the eastern banks of the Ohio River, the cities of Follansbee, Wellsburg, and Weirton in Brooke County, West Virginia are founded in a history of steel and metals production. The City of Steubenville in Jefferson County, Ohio arose from the ashes of Fort Steuben to be an economic hub for industry and business. These communities have long been connected with three bridges over the Ohio River (see Figure 1).

The **Market Street Bridge,** shown in Figure 2, is a cable suspension bridge constructed in 1905 to carry tin mill workers in streetcars from their homes in Ohio to the mill in West Virginia. This southernmost bridge serves local traffic consisting of commuters, light commercial traffic and emergency vehicles.

The **Fort Steuben Bridge,** shown in Figure 3, carried 3,000 vehicles per day on Freedom Way and is the northernmost bridge. This cable suspension bridge was constructed in 1928.

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Introduction *(Continued)*

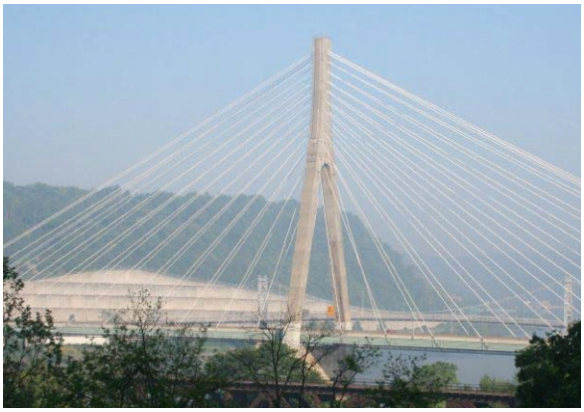

Figure 4 – Veterans Memorial Bridge

The **Veterans Memorial Bridge,** shown in Figure 4, carries US Route 22 with a modern cable stay main span. This bridge was constructed in 1990 and serves over 30,400 vehicles per day.

In early 2009, the Ohio Department of Transportation decided to close the Fort Steuben Bridge leaving only the Veterans Memorial Bridge and the Market Street Bridge. Although the Veterans Memorial Bridge handles most of the traffic demand and heavy loads, the Market Street Bridge also serves as a vital link for commuters in the southern portions of the community. With deterioration of the structural components on the Market Street Bridge, WVDOT was facing a crucial decision: close a structure regarded as a vital link in the public's eye or embark on a multimillion dollar rehabilitation.

Project **Background**

Figure 5 – Elevation View (Before Renovation)

The overall length of the bridge is 1,794 feet. The three cable suspension spans over the river are stiffened by a welded Warren through truss (see Figure 5). The main span is 700 feet long. The west approach consists of two deck girder spans and five spans of the original riveted steel through truss, which is a quadrangular Warren with verticals. The cables are suspended from two steel towers that rise approximately 210 feet from cut stone piers. The substructure consists of cut stone piers, concrete stub abutments, and both concrete and steel bents. The bridge serves two lanes of traffic on an open steel grid deck. A cantilevered sidewalk provides pedestrian access on the downstream side of the trusses. In addition to the river, the bridge spans over railroad tracks on both sides of the river, two city streets, and four lanes of Ohio Route 7.

Surviving for over a century, the bridge has been repaired and strengthened on several occasions, including retrofits by renowned bridge engineer, David B. Steinman, in 1941 and 1953. More recently, engineers from Burgess & Niple (B&N) have monitored the condition of the delicate structure during annual inspections and load rating updates since 1991. As a result, the load posting was reduced from 13 tons to 5 tons. B&N recommended major rehabilitation to keep the bridge in service when the Fort Steuben Bridge was closed.

Figure 6 – Tower Inspection by Rappelling

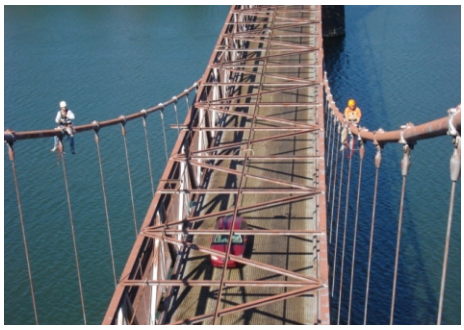

Figure 7 – Inspection without Lane Closures

Figure 8 – Cable Inspection

Inspection **Access & Procedures**

The bridge type and load posting does not permit reasonable use of heavy inspection access equipment such as manlifts and underbridge inspection trucks. B&N uses adapted rock climbing techniques to access the bridge (see Figures 6, 7, & 8). This progressive method allows a hands-on inspection while inspectors are safely supported by ropes or lanyards secured to the bridge components.

Rappelling of the towers and climbing of the cables and trusses allows inspectors access without closing traffic. The suspension spans floor system is equipped with rolling scaffolding.

In addition to the standard inspection procedures, the cables were unwrapped at several locations and the strands were wedged apart as shown in Figure 9 (next page). The tower saddle caps were also removed to reveal the cable condition in this high stress location. Due to the presence of heavy section loss, detailed notes and measurements of each floor system member were documented to determine the remaining capacity.

Condition **Evaluation**

In 2009, the overall condition of the bridge was rated as poor. The towers controlled the load rating. The riveted tower columns are laced and braced with curved gusset plates. Previous strengthening repairs added full height plates on the transverse faces of the towers by stitch welding. Pack rust was causing these plates to bow away from the tower columns and breaking the stitch welds. Various bracing gussets had deteriorated with through holing (Figure 10 on next page) and

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Figure 9 – Strand Inspection

Figure 10 – Typical Tower Bracing

broken lacing bars. The base of the tower columns had isolated areas of section loss.

The suspension system was generally in fair condition; however, a few locations had issues. The stiffening truss connections to the towers, called rocker posts, had expanded into the towers and in one location lost bearing due to pin wear. The main suspension cables each consist of 1,498 parallel No. 8 Birmingham wires, each 0.165" in diameter. The wires are coated with red lead and wrapped perpendicularly with No. 9 soft double galvanized wire. The wrapping is painted with primer and an aluminum top coat. The main cables were in fair condition with only minor loss of section and corrosion mainly in the lower third of the section. The red lead paste was generally in good condition. The cable clamps at the suspenders had deteriorated caulking and corrosion. Pack rust had formed behind many of the eyebar connections to the floorbeams and at isolated locations caused concern for the adequacy of the eyebars, clevises and pins. Uplift anchors and windlocks had advanced loss of section.

Deterioration to the floorsystem, stringers and floorbeams had caused through holing in several locations and reduced capacities near the posting level. The embankment in front of the downstream wingwall at the West Virginia approach had eroded away. Although protected by clearance portals on both approaches, inspectors occasionally noticed violations of the 5 ton posting.

Making the **Decision**

One of the main goals of the Brooke-Hancock-Jefferson Metropolitan Planning Commission was to promote the study and construction of a new Ohio River Bridge in the area. However, progress on this bridge crossing was still in the planning phase, and it was projected to be 10 years before a new bridge would be in service. The future of the Market Street Bridge seemed uncertain. When local community leaders learned that the bridge might be closed, they reacted quickly to contact the state officials who could make decisions to save the bridge.

WVDOT needed to review the options. When engineers from the Federal Highway Administration and WVDOT visited the bridge, reviewing inspection reports and consulting with B&N, the following facts were established:

1) **The construction of a new bridge would cost $125 million dollars, and could face obstacles which would prevent it from becoming a reality in the near future.**
2) **Permanently closing the bridge would lead to congestion and would eliminate the possible detour route if the Veterans Memorial Bridge would need to be temporarily closed.**
3) **Just the cost to demolish the bridge would be a few million dollars.**
4) **The main issues with the bridge could be repaired.**

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Figure 11 – Structural Models

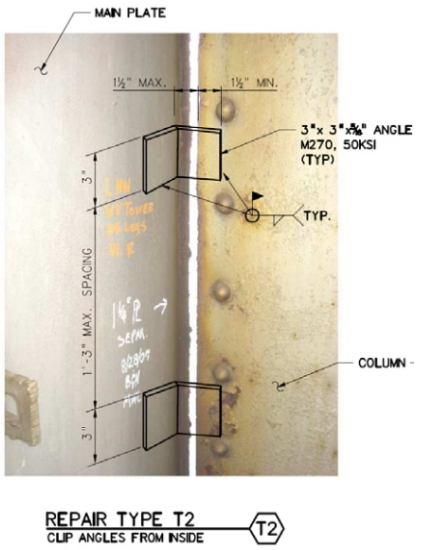

Figure 12 – Tower Repair Detail Overlaid on Inspection Photograph

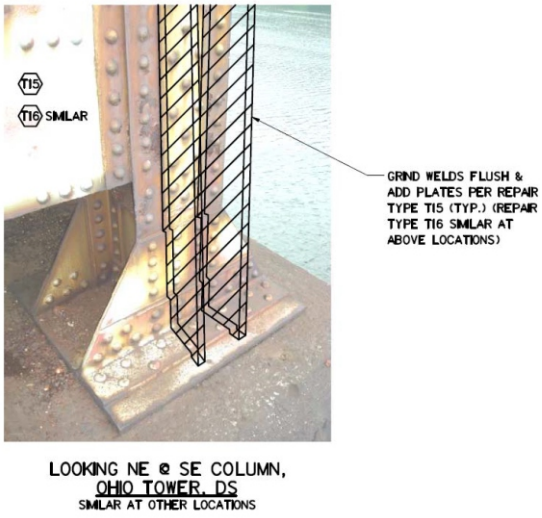

Figure 13 – Column Strengthening Detail Provides 3-D Perspective

Making the **Decision** *(Continued)*

5) **Essential structure repairs and painting for the bridge would cost $10-20 million.**

6) **Federal stimulus funding was available, if the design plans could be complete on time.**

After careful evaluation, the decision was made to invest in a rehabilitation to preserve the structure at least until a new bridge can be constructed. The rehabilitation was to focus on maintaining the structural capacity and safety issues in order to keep the Market Street Bridge in service for an additional 10 years.

Innovation in **Plan Preparation**

A team of employees from five Burgess & Niple offices was challenged to evaluate the most critical needs and design repairs to rehabilitate the Market Street Bridge in a very aggressive timeframe. The B&N team performed fatigue and structural analyses on the aging structure. A 3-D model of the bridge was developed using the computer program MIDAS, which is an acronym for Modeling, Integrated Design & Analysis Software, (see Figure 11).

The gusset plate connections of the approach truss were load rated. The results confirmed the need for repairs. B&N accelerated design of structural steel repairs by using inspection photographs in the plans.

There are several benefits to using photographs in repair plans (see Figures 12 & 13). Instead of providing line work for the

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Innovation in **Plan Preparation** *(Continued)*

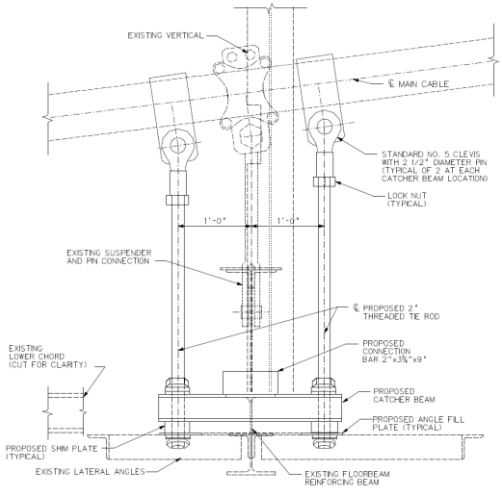

Figure 14 - Suspender Catcher Beam Retrofit

existing members, repair notes and details can be superimposed onto the photographs. The intent of the repair is clearly communicated to the contractor. As compared to traditional line work, it is much easier to understand what is surrounding the member and what location is being defined. The photographs allow for a three-dimensional perspective. After construction is complete, the field engineers can simply re-take the photograph to document the as-built condition.

Many of the details on the project were not conventional to modern bridge engineers. Rather than temporarily supporting the floorbeams to repair the suspender connection, a permanent back-up system was designed (see Figure 14). Replacement of the rocker post required a system that could reuse the existing supports while accommodating the thermal movement of the 700 foot spans. Maintenance free pins were used to eliminate the need to have grease fittings. A system of threaded rods and cables were used to reinforce the tower sway bracing eyebars below the deck.

Pack rust, or crevice corrosion, was a major issue on this bridge. WVDOT had successfully used a penetrant sealer and calcium sulfonate paint system on a smaller project. This paint remains plastic even after it cures to provide ongoing protection against crevice corrosion. The specifications called for commercial blast cleaning for most of the bridge and hand tooling in more delicate areas, such as cables and splays. After cleaning, the sealer was applied to the pack rusted areas and has the capability to wick deep into the crevice before drying. The calcium sulfonate paint can be applied wet-on-wet. This means that the painter does not need to let the paint cure prior to proceeding with the next coat. This speeds construction and reduces costs.

The plans were completed in just 10 weeks – meeting the deadline needed for the ARRA funding.

Municipality & **Public Involvement**

A committee composed of the mayors from Follansbee and Weirton WV, Steubenville OH, Area Metropolitan Planning Organization (MPO), Representatives from WVDOT District Six and Scenic Byways held meetings to select a series of color schemes to be used in a public opinion poll.

The public was involved in selection of paint colors through an online poll on the WVDOT web site (http://www.wva.state.wv.us/wvdot/marketstreetbridge/default.aspx). A total of 25,710 selections were made. The winning color scheme included navy blue towers and cables and a gold colored truss system, representing the West Virginia state colors – Mountaineer Blue and Gold. The public requested WVDOT to consider adding decorative lighting similar to a suspension bridge in Wheeling. WVDOT seized this opportunity to add aesthetic value to the project and build community support and pride.

Construction

WVDOT District 6 bridge repair crews along with Central Heavy Maintenance Detachment performed repairs in the summer of 2009. These urgent repairs were deemed necessary during the design process in order to keep the bridge open and safe for the traveling public while renovations plans were being finalized.

Ahern & Associates, a division of Kokosing Construction Company, submitted the low bid of $14 million in November of 2009. Costs for the cleaning and painting were approximately $7 million. The bridge decorative and navigational lighting came in at $2.6 million. The miscellaneous steel repairs were bid at $20

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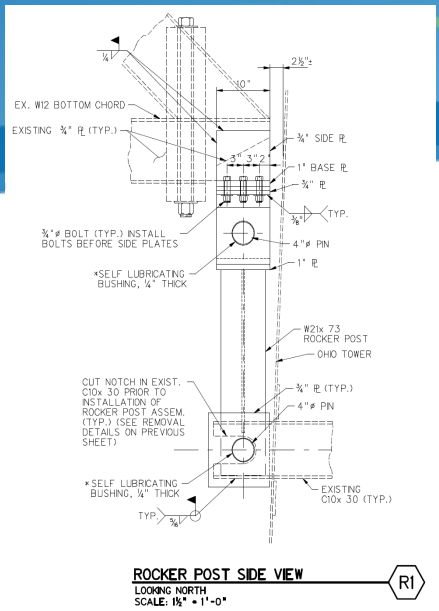

Figure 15 – Rocker Post Retrofit

Figure 16 – Tower Bracing Repair in Progress

Figure 17 – Tower Containment

Construction *(Continued)*

per pound. The rolling scaffolding was replaced for $225,000. The suspender retrofits were bid at a quarter million dollars. The work included temporary support of the bridge while new rocker post truss supports were installed (see Figure 15). Additional plates were welded to the base of the tower columns to maintain their capacity. The main tower stiffening plates were re-welded to the columns. Backup rods were added to supplement the tower sway bracing eyebars. Extensive plating of the tower gussets assured solid bracing between the main compression members (see Figure 16).

Cable suspender retrofits were performed in ten locations where the connection of the suspenders to the floorbeams had corroded. Strengthening repairs for the floorsystem included several stringer and floorbeam replacements as well as plating retrofits. Weak points in the approach trusses were retrofitted by removing rivets one at a time and replacing them with bolts to attach additional sections. The sidewalk plate was treated with a new traction surface, and fencing was added between the traffic and pedestrians.

The cleaning and painting operations cost more than all the other repairs combined. The containment was limited to avoid overloading the bridge members keeping with the 5 ton posting. The towers were completely surrounded by 17 stories of scaffolding and contained (see Figure 17). As the first major bridge structure in West Virginia to receive a penetrant sealer and calcium sulfonate paint system, this project is leading the way to better coating protection.

A weigh-in-motion device installed in the approach pavement will detect overweight vehicles that may try to cross the structure. In addition, the clearance portals were lowered to decrease the vehicle height to 10 feet.

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Construction *(Continued)*

Figure 18 – Decorative Lighting

The state-of-the-art decorative lighting makes the project unique. The catenary lighting delineates the cables with 160 white necklace luminaries. The towers are illuminated by 60 directional floodlights, and a blue LED stripe accentuates the upper chords of the truss. The sidewalk railing was also brightened with 212 fixtures. The lighting scheme provides a striking aesthetic appeal in the night sky.

Opening Day

Figure 19 – Ribbon Cutting Ceremony

A ribbon cutting ceremony was held to celebrate the reopening of the revitalized bridge on December 7, 2011 (see Figure 19). Many state officials and local politicians were on hand to commemorate the event. Among them was West Virginia Governor Earl Ray Tomblin, who said, "The nearly $16 million invested in repairing, painting and lighting the 106-year-old span is worth it because not only is it beautiful, but it will support commerce between the two states and neighboring communities." Tomblin also noted the bridge was built in 1905 by Dohrman J. Sinclair, a Steubenville banker, who believed it would help many Steubenville residents to obtain jobs at the tin mill being developed by the Follansbee Brothers in the community that now bears their name.

Secretary of Transportation Paul Mattox added, "Because of the American Recovery and Reinvestment Act, the Division of Highways was able to keep this historic structure in place by making the repairs necessary to extend its life, preserve its

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Figure 20 – Sidewalk Lighting

Opening Day *(Continued)*

history for future generations, and keep those communities united."

The decorative lighting received great praise when framed photos of the bridge at night were presented to Governor Tomblin and Follansbee Mayor Tony Paesano.

The Revitalized Bridge

Figure 21 – The Revitalized Market Street Bridge over the Ohio River

The Market Street Bridge Rehabilitation is an outstanding achievement in bridge engineering. Through innovation and aesthetic enhancement, this project transformed a tired, forgotten structure into an icon for the communities for which it was designed. The reflection of the lights on the river at night conveys a postcard-like image (see Figure 21). Likewise, the community has once again taken pride in the revitalized bridge. This sense of accomplishment provides the public with new hope for better economic growth. By lengthening the life of the structure, WVDOT has shown a commitment to preserve history, reduce the use of new materials, and protect the environment.

Co-authoring with representatives from WVDOT, Burgess & Niple has been selected to present on this project at the 2012 International Bridge Conference. WVDOT has selected B&N to continue monitoring the bridge with a new six-year inspection contract.

For more than 100 years, Burgess & Niple has led the development of infrastructure in rural and urban regions. Our success is driven by a passion for advancing the built environment with exceptional concern for quality of life, safety and sustainability. Our work spans the world and ranges from complex urban renewal projects to restoration of historic bridges.

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