NEW STEEL, Vintage Feel

BY TYLER J. BARILE, CHRISTOPHER J. MENNA, PE,
JAMES B. MILLER, PE, CHRISTOPHER J. RENFRO
AND MICHAEL J. SCHICKLING

New steel supports an old bridge over a busy transit line in Philadelphia.

PHILADELPHIA IS A CITY STEEPED in history, and its bridges are no exception.

The existing Willow Grove Avenue Bridge over Southeastern Pennsylvania Transportation Authority (SEPTA) tracks was a three-span, simply supported, shallow-depth, steel stringer bridge with asphalt deck. The bridge was rehabilitated in 1962 and incorporated the original stone masonry abutments and wing walls that dated to 1884. Located in the Chestnut Hill neighborhood of northwest Philadelphia, the original iron channel and timber superstructure was built by the Edge Moor Bridge Works for the Pennsylvania Railroad—and designed for a live load of horse and carriage.

Built during the industrial revolution, the structure was created to provide grade separation for a street crossing in a very affluent, new neighborhood in Philadelphia. Both the original and rehabilitated bridges featured materials appropriate for the area: timber, metal and Wissahickon Schist stone. Though decidedly inelegant, the structure provided a practical solution to challenging geography in the form of a short hump crest vertical curve nestled between two driveways. Originally spanning over two main-line tracks and a rail siding track to access an ice house, the updated bridge spanned over two electrified tracks between the piers.

◄ "Buddy beams" were installed to strengthen the weakened center-span stringers.

▼ Installation of the sidewalk utility bay.

Images courtesy of City of Philadelphia

Emergency Repairs

Prior to 1994, the bridge was on a regular five-year inspection cycle, per Federal Highway Administration (FHWA) standards. However, due to suspected flaws in the 1962 replacement steel (specifically excessive chemical impurities and poor batch casting) along with the constant infiltration of water and snow salts through the asphalt deck, inspection crews discovered in 1995 that deterioration had accelerated aggressively. Strengthening repairs were required, and inspection reporting was increased to a two-year inspection cycle. For the repairs, the City's Bridge Section performed in-depth inspections to develop rehabilitation and reconstruction strategies. The major findings were as follows:

1. Severely corroded steel, including the pier steel bent frames
2. Seized and malfunctioning bearings and expansion dams
3. Abutment and wing wall stonework in need of repointing and/or rebuilding

Tyler Barile is an engineering specialist, **Christopher Renfro** is an engineering supervisor and **Michael Schickling** is a civil engineer, all with the City of Philadelphia, Streets Department, Bridge Section. **Christopher Menna** is an engineer of design with Jacobs Engineering Group (and was previously with the City of Philadelphia, Bridge Section) and **James Miller** is director of engineering with Michael Baker International.

▲ The completed bridge, from below.

➤ Construction bracing.

▼ The completed bridge, at street level.

4. Moderate spalling of the asphalt deck
5. Failure of the superstructure steel coating system
6. Moderate deterioration of the non-composite deck stay-in-place forms

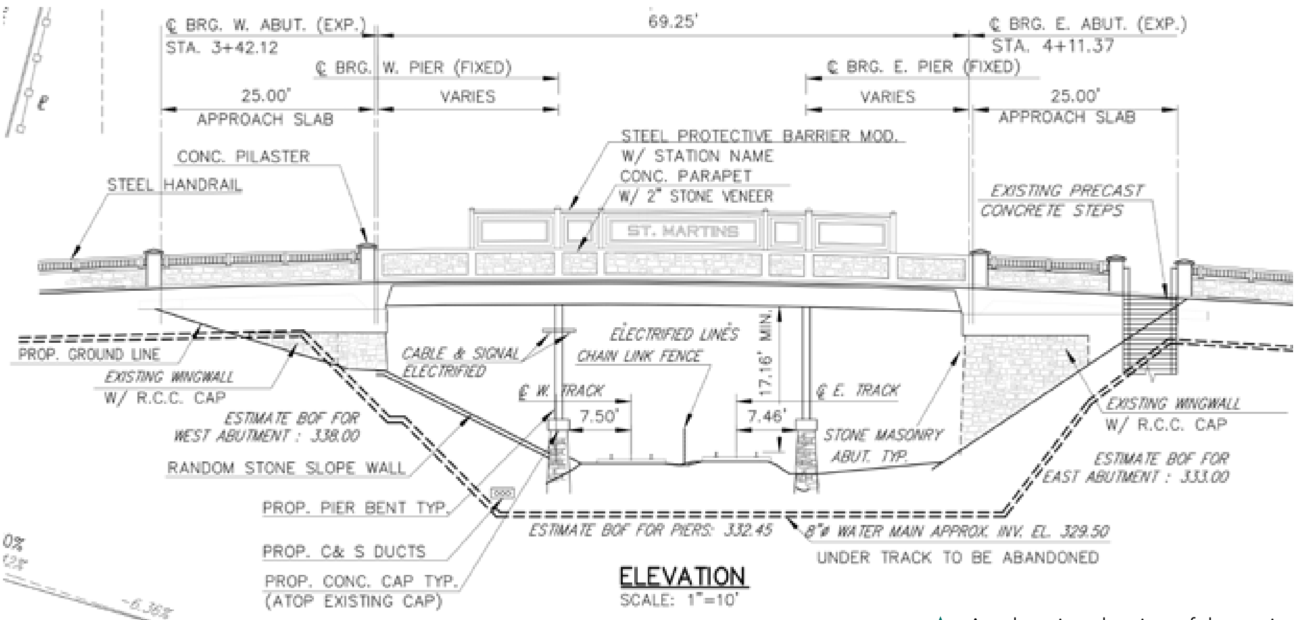
Due to severe steel deterioration under the sidewalk bays, elevated wood boardwalks were furnished and installed temporarily by the City's Bridge Maintenance Unit in 2006 to span weakened areas and provide safe passage of pedestrians. Concrete median barriers were also installed at the curb lines to keep vehicles off the sidewalk, and a truck detour was instituted around the bridge to remain in effect until full reconstruction could take place.

In 2013, the condition and section loss of the stringers became so significant that another emergency repair was performed. Due to deterioration and/or section loss of up to 100% in some places, the bridge was posted for "3 Tons/No Trucks," the minimum allowed by state law. Bridge closure and replacement was imminent unless remedial action was taken. Additional adjacent "buddy beams" were installed to strengthen the weakened center-span stringers, allowing the bridge to remain in service for one more winter without closure and major impact to the commuter rail traffic below. At this point, the structure became the primary design priority for the City's design unit.

New and Improved

The design scope included removal and replacement of the entire superstructure, stabilization and adaptive reuse of the substructure, roadway approach work, reconstruction of a portion of the train station platform stairway and utility work. The engineering and logistical challenges involved with replacing a severely deteriorated, weight-posted, structurally deficient bridge—that was also integrated into an existing SEPTA commuter rail station—were apparent. Moreover, very little information by way of existing plans was available, necessitating extensive survey and substructure probing to verify site conditions. Prior to construction, Verizon, Comcast, City Street Lighting and Philadelphia Electric Company utilities were relocated, and SEPTA Electrical Traction power cables at the west pier were detached. Bridge work would be coordinated with SEPTA, Verizon, Philadelphia Water Department and Philadelphia Gas Works.

Due to the uniqueness and historic setting of this bridge, the design team faced numerous challenges on top of those typically involved with working in a densely populated environment. One of the key questions that had to be answered early on was whether the existing substructure could be reused for a third time. Michael Baker International was contracted as part of the design team, with two main substructure tasks: Verify the existing substructure conditions and formulate an adaptive reuse design plan.



An elevation drawing of the project.

In order to preserve the existing horizontal clearance of the rail, the existing stone masonry piers were maintained. The existing pier foundations consisted of open joint masonry stone walls founded on stepped stone footing. These existing foundations were stabilized by placing a 1-ft.-thick Class C concrete collar around the perimeter to lock in the foundation and solidify the foundation for reuse. The existing stone masonry piers were cleaned and entirely repointed, and a new concrete cap was doweled into the existing stone cap to support new HP12×84 steel columns.

To stabilize the existing abutments and wing walls, existing backfill was carefully removed to the bottom of the existing walls and replaced with Class A concrete immediately behind the masonry structure to form a new gravity abutment, a concept that essentially knit the "old" and "new" structures together. This was done while the existing walls were monitored for excessive movement. The stone masonry of the abutments and wing walls were cleaned, and new caps were provided on each abutment to serve as a seat for the new steel beams.

With the substructure modification plan in place, focus was shifted to stringer design. Numerous beam design runs were performed and compared to the limited available superstructure depth envelope. The design team opted against using plate girders in this application because of the shallow depth available for the new structure. Additionally, the team had committed to providing at least three additional inches of vertical clearance over the electrified railroad. Still, a Public Utility Commission design exception for substandard vertical railroad clearance was required.

The design scheme mimicked the existing configuration of very shallow, closely spaced stringers; however, the existing structure load distribution was improved by converting the arrangement to a three-span continuous structure. Rolled sections, 12 in. deep, were proposed, except for at the fascia, where deeper rolled sections were required in order to accommodate the size and additional weight of utilities. Additional live load deflection calculations were required to gain PennDOT approval of this design scheme. The design team also had to demonstrate that cambering could be done for such a shallow rolled section held down at four points. Cambering feasibility was verified by local fabricators, who noted that the cold cambering method could be successfully implemented in this case.

Due to the bridge's location in the Chestnut Hill Historic District, additional historic requirements had to be met as well. For instance, rivets were used in the existing barrier ironwork that was removed, so the barriers had to be replaced with an historic-looking bolt. Therefore, acorn nuts were selected as the fasteners on the proposed barrier due to their rounded heads that perpetuate the rivet-head appearance. Historic-looking punch rivets were also used for the handrail; when hammered into place, the rivet head went smooth and expanded the bolt to secure the railing.

The project also included multiple interesting construction challenges, which the City's Construction Unit and the contractor, Loftus Construction Company, worked through together. One of the biggest challenges was constructing a bridge over an active operating railroad. Though only the middle span was over active tracks, the bridge's entire footprint had overlapping right-of-way with SEPTA. Much of the work over the tracks could only occur during track and power outages, which were permitted exclusively at night and lasted just three to four hours on average. Numerous night shift outages were needed to complete the demolition and deck reconstruction phases of the project.

Because the bridge was in very poor condition, contract documents included weight restrictions and equipment placement limitations. This challenged the contractor to devise creative means and methods for the demolition phase, mainly using small equipment. The existing deck and sidewalks were removed almost entirely through the use of demolition saws, hand tools and a single mini-excavator, with constant monitoring of the structure for instability. With demolition taking place at night in a residential area, and considering the poor existing condition, hammering of the existing superstructure was prohibited.

Stairs from street level down to the SEPTA tracks.

The design scheme mimicked the existing configuration of very shallow, closely spaced stringers.

Numerous beam design runs were performed and compared to the limited available superstructure depth envelope.

Due to the shallow interior beams and presence of utilities in the fascia bays, standard diaphragms could not be used. Therefore, the utility supports functioned as braces between the girders. However, the location of the utility supports fell on the bottom portion of the fascia girder, which left the top portion of the fascia girder unbraced. This caused stability issues for the fascia girder during construction due to the exterior overhang support system. To prevent excessive overturning force on the exterior girder, WT sections were bolted to the top of the interior girder at regular intervals. Double angles were then extended between the WT section and the exterior girder to provide sufficient bracing to allow construction operations.

Given the numerous project constraints, this bridge rehabilitation was only possible with the use of structural steel. This versatile material enabled the use of girders shallow enough to provide an additional three inches of vertical railroad clearance while satisfying the necessary roadway vertical curve sight distances and load-carrying requirements. The use of steel girders, protective barriers and pier columns preserved the historical aesthetics of the bridge as well. Overall, the project was a sound investment in the Chestnut Hill neighborhood. The project appropriately restored a bridge, fitting it properly to the area's historical context, and set the standard for future projects in historic areas. This exercise was lauded as an excellent example of context-sensitive design by the community and critics alike, and the design team helped restore grandeur and functionality to a prominent structure. ■

Owner
City of Philadelphia

General Contractor
Loftus Construction Inc., Cinnaminson, N.J.

Structural Engineers
City of Philadelphia, Department of Streets, Bridge Section
Michael Baker International, Philadelphia

Bridge Architecture
KSK Architects Planners Historians, Inc., Philadelphia

Steel Fabricator
Michelman Steel Enterprises, LLC, Allentown, Pa.

Camber Fabricator
Greiner Industries, Inc., Mount Joy, Pa.