PENNSYLVANIA'S FIRST EXODERMIC DECK: ACCELERATED DECK REPLACEMENT & REHABILITATION OF THE LIBERTY BRIDGE

Roger Eaton, PE
Associate Vice President
HDR

Jason Zang, PE
Assistant District Executive – Construction
Pennsylvania Department of Transportation - District 11-0

BIOGRAPHY

Roger Eaton served as technical advisor for Liberty Bridge Rehabilitation project. Roger is a Senior Project Manager and Senior Bridge Engineer experienced in all aspects of complex bridge analysis, design, and construction. He is the technical advisor on our Pennsylvania projects and was the lead bridge designer on complex bridge projects I-579 Urban Open Space Cap, Allegheny County, Pennsylvania; Charleroi-Monessen Bridge Replacement, Washington County, Pennsylvania; Hoover Dam Bypass, Colorado River Bridge, Clark County, Nevada; Mon-Fayette Expressway, Uniontown to Brownsville, Section 51A, Fayette County, Pennsylvania

Jason Zang served as the client project manager for the Liberty Bridge Rehabilitation project. He has held various positions at PennDOT since joining the department in 1999, including Assistant Bridge Engineer, Senior Project Manager, Structure Control Engineer, Allegheny County Maintenance Manager, and is currently the Assistant District Executive for Construction. Jason held key roles on several emergency repair projects at District 11-0, such as a failing retaining wall Supporting the Parkway East, the Birmingham Bridge Rocker Bearing Failure, and most recently, the Liberty Bridge construction fire repair. Jason received his B.S from the University of Pittsburgh.

SUMMARY

The Liberty Bridge has been a landmark structure and Pittsburgh icon since it opened in 1928. It created the modern suburbs, quadrupled property values south of Pittsburgh, and opened with a parade five miles long. However, by 2014, the bridge carrying 55,000 vehicles per day was in poor condition. It could no longer carry trucks and had become a poster-child for America's infrastructure crisis. Sixty Minutes, profiling America's neglected infrastructure, highlighted the bridge. Referring to Liberty Bridge and others like it, Ray LaHood, United States Secretary of Transportation, stated plainly: "Our infrastructure is on life support right now."
PennDOT and HDR responded with a rehabilitation project that preserves the structure and meets current engineering and accessibility standards, using innovations including:
•Accelerated bridge construction techniques to replace a bridge deck the size of three football fields while minimizing traffic impacts
•A new Exodermic deck - the first ever used in Pennsylvania to provide a stiff, lightweight replacement for the failing grid deck
Thanks to innovative solutions, today Liberty Bridge is off life support. The new bridge will support life in Pittsburgh for generations, with an ADA accessible sidewalk permitting all people to enjoy crossing this historic structure.

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BRIDGE HISTORY

The Liberty Bridge is a 2,600 foot long deck truss bridge that crosses the Monongahela River in downtown Pittsburgh. The bridge has provided a vital link for commuters to the South Hills of Pittsburgh since it was constructed in 1928 (Fig. 1).

Figure 1: Historic Photograph of the Liberty Bridge

At the time of construction, which occurred 4 years after the Liberty Tunnels were opened, the Liberty Bridge was the largest and most expensive bridge ever built in Allegheny County. At 2,663 feet, the bridge cost $3.7 million to build. However, this is not what makes the bridge historically significant.

The bridge (and tunnels), are one of the largest contributing factors to the development of Pittsburgh's "South Hills", as well as some of the first "suburban" communities in the U.S. Dedicated in 1928, the commemorating parade was 5 miles long, also the largest in Allegheny County History. Property values in the South Hills quadrupled after opening of the bridge. The last major rehabilitation of the bridge occurred in 1982, at a cost of $31.5 million.

BRIDGE CONDITION (PRE-PROJECT)

While the project was in design, the Liberty Bridge had become the "poster child" for the ongoing US Infrastructure Funding Crisis. Pennsylvania's Governor, Ed Rendell, had delivered several press conferences under the bridge, and it also was featured on the national news program, "60 Minutes".

While the asphalt overlay on the existing grid deck was in "good condition", underlying deterioration was abundant, yet not apparent to the travelling public. Severe steel deterioration was occurring at most of the joint locations. The asphalt and grid deck was saturated along the gutter lines, with water leaking down onto the superstructure below during the driest of weather. (Fig. 2).

Figure 2: typical superstructure condition at leaking joint.

There were also many locations of broken downspouting, and long horizontal downspouting runs, clogged, and leaking.

Therefore, the general scope was a complete bridge painting, steel and concrete repairs, and new deck overlay. The biggest question during design was, what was the proper overlay treatment. During initial project scoping, and for most of the design process, the deck was going to be left in place, except for the gutterline areas, as most of the deck was in very good condition.

DECK ASSESSMENT

At the time of the 1980's rehabilitation, the grid deck was flush filled, and overlaid with a latex modified concrete wearing surface. This LMC overlay lasted approximately 10 years. The overlay was removed, and overlayed with asphalt in subsequent years, leading up to the current rehabilitation. A new waterproofing membrane, and asphalt overlay was not desired due to the challenge of removing the water, without draining onto the superstructure below. Through careful deliberating, 3 overlay options were being carefully considered.

It was further decided to perform some actual test patches of the 3 overlay options, (AAA concrete, LMC, and Polyester Polymer Concrete). Other than testing the performance of each overlay on the bridge, other benefits were at hand. We could verify the condition of the deck under the asphalt, as well as test the feasibility of surface preparation for the new overlays.

Figure 3: existing grid deck condition following hydro-demolition

In the end, all three overlays failed to perform adequately, while the surface preparation would be extremely slow, expensive, and difficult. It was decided to replace the deck, late in the design process due to these valuable findings.

4. FINAL DESIGN

Full replacement of approximately 250,000 SF of grid deck on the bridge presented several challenges. First, since the deck profile needed to match existing elevations at each end of the bridge, the profile could not be raised much, meaning the new deck had to fit within a tight vertical envelope. Second, the new deck self-weight needed to closely match that of the existing grid, to prevent extensive truss strengthening. And finally, with 55,000 vehicles cross the bridge each day, the new deck would need to be installed quickly. For some areas on the north end of the bridge, 4 lanes of traffic were carried on a section of bridge just 44 feet wide. ABC overnight or weekend replacement of this deck was envisioned to prevent major impacts to interstate I-579 traffic.

After investigation of several deck replacement options including lightweight cast-in-place and precast decks, traditional steel grid decks, and Exodermic grid decks, the Exodermic grid deck was selected. This type of deck is fabricated using WT sections which are made composting with approximately 4 inches of concrete (see Figure 4). The concrete includes one mat of reinforcement bars in each direction, acts in compression for positive bending, and provides a traditional wearing surface. The concrete can be cast in place after the panels are set like SIP forms, or it can be precast to accelerate construction.

Figure 4: Exodermic grid deck panel with reinforcement bars and precast panel zones

When the deck concrete is precast, as shown in Figures 4 and 5, blockouts are left around the steel panel edges, as well as over the locations of supporting beams. The prefabricated panels are placed on the bridge deck, and high early strength concrete can be used to fill these blockouts. This concrete makes the deck system composite with the supporting steel beams, and connects adjacent steel panels to form one composite deck structure. This permits installation of grid deck in short closure periods.

Figure 5: Exodermic grid deck panel with precast zones assembled on the bridge

The use of WT sections allows this type of grid deck to span longer distances with a high weight to strength ratio. The Exodermic panels for Liberty Bridge were designed to span almost 10 feet, which reduced the number of new stringers that were needed. The existing stringers were removed with the deck, since the grid deck was welded to the stringer top flanges prior to being filled with concrete. By removing these stringers, many repairs for section loss and poor fatigue details were eliminated, and the new stringer spacing could be optimized for the Exodermic grid deck.

Primary goals for the Rehabilitation Project were bringing the structure up to current standards for engineering, safety, and ADA accessibility.

When the bridge was built in 1928, there were no seismic requirements. Supports at the bridge joints were extended for this project to meet current seismic requirements. The new deck, joints, and drainage system will protect the steel from road salts and reduce maintenance costs. While the existing bridge did have a pedestrian sidewalk, it terminated in a long staircase on the city side of the bridge, making it inaccessible for those in wheelchairs. By repurposing a portion of the existing roadway along the Boulevard of the Allies and Second Avenue, this project added more than 800 feet of new sidewalk to enhance the pedestrian connection to the city and make the structure ADA compliant.

Improvements to driver safety and experience were also included in the project. A new state-of-the-art electronic lane control system with variable message boards to improve safety and provide better directions for travelers. Solid concrete barriers at the edges of the deck were replaced with open, modern steel rail barriers, which permit much better views of the Monongahela River valley, South Side, and Pittsburgh skyline, improving driver experience of this stunning urban view-shed.

5. CONSTRUCTION

The contract for Liberty Bridge Rehabilitation was awarded to JB Fay for $80M. While the contract documents were developed assuming precast deck concrete would be used, use of cast-in-place (CIP) concrete was given as an acceptable alternative. The winning contractor elected to use CIP concrete for most of the deck, using precast panels only on the northern end of the bridge where the deck had to be replaced in sections during brief full-bridge closures.

For most of the bridge, the deck could be replaced in quarter width passes, shifting three lanes of daytime traffic away from the work zone. Figure 6 shows a section of deck being removed. Following milling off all overlay material to save weight, panels of deck connected to individual stringers were sawcut. Lifting chains attached to an excavator supported the panels while the supporting stringer was cut at each end.

Figure 6: Preparation of the existing deck for removal: torch cutting stringer ends

At night, the contractor was permitted to close an additional lane to aid in material removal, so much of the demolition work took place then.

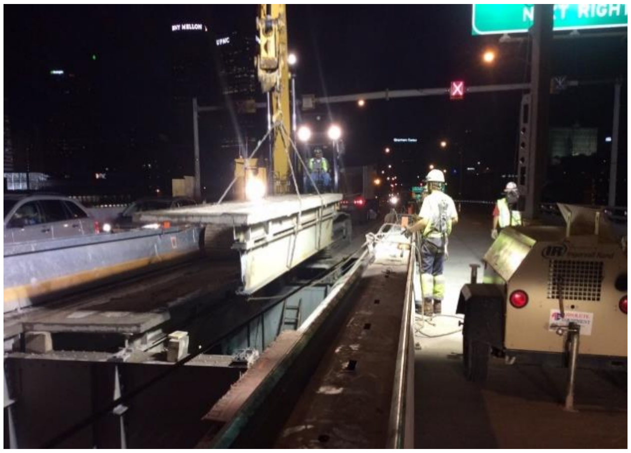

Figure 7: Removal of existing stringer with section of deck during nighttime lane closure

Following removal of the grid deck in each construction phase, the new stringers were installed with new clip angles or bearing seats. The Exodermic deck panels were placed on the stringers, and shear studs were then welded to the top flanges. For most of the bridge deck, lightweight concrete was placed on the deck panels, and finished using a traditional rail-mounted screed.

Three lanes of traffic for peak weekday commuters was maintained on most of the bridge by replacing the deck in four phases. However, at the north end of the bridge, four lanes of mainline traffic squeezed under adjacent structures with only 11-foot-wide lanes and no shoulders. To maintain traffic, there was no partial-width phasing option available for deck replacement. Instead, the bridge required complete closure in off-peak periods so 44-foot-wide sections could be replaced rapidly. These closures were permitted for weekends only, and were planned and executed like a military operation. Each closure required the following operations sequence, executed with around-the-clock work:

(1) Cut grid deck into panels

(2) Cut ends of stringers supporting the deck and remove with deck panels

(3) Install new stringers

(4) Install new Exodermic deck panels on the new stringers

(5) Survey and adjust panels for precise alignment,

(6) Place forms between panels

(7) Place rapid setting concrete between panels and in blockouts over each stringer to stitch the deck together

(8) Install temporary ride plates between new and old sections of deck

(9) Open bridge to Monday morning traffic

Figure 8 shows the northern section of bridge after the precast panels have been fully connected to each other and to the stringers using this high early strength concrete mix. This temporary surface will be prepared and overlaid with a Latex Modified Concrete (LMC) permanent wearing surface after all deck construction is complete. This overlay helps to protect the deck construction joints from moisture and provides a uniform appearance and ride quality.

Figure 8: Completed precast Exodermic grid deck section showing CIP concrete joints (lighter)

6. CONCLUSIONS

Since opening day in 1928, Liberty Bridge has been noteworthy and its recent rehabilitation is no exception. Impacts to 55,000 vehicles per day were reduced using innovative techniques to maintain traffic while a deck the size of three football fields was replaced with the first Exodermic deck ever used in Pennsylvania. The rehabilitated bridge will support life in Pittsburgh for generations, permitting all people to enjoy crossing this historic structure.

For a structure as large as Liberty Bridge, thorough evaluation of the existing deck system was vital to making the most of the funds invested in this structure. Through a detailed test patch installation and evaluation program, it was evident that trying to patch and persevere the existing deck system was not a wise long-term solution. The project team was able to identify a modular deck system that permitted Accelerated Bridge Construction (ABC), while meeting the weight and geometric constraints of a bridge rehabilitation.

Figure 9: Completed rehabilitated structure with downtown Pittsburgh in the background