

**ESWP** Liberty Bridge ESWP Project of the Year Award Nomination

January 2019







### Liberty Bridge: from Life Support to Supporting Life

#### **Project History**

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

This complex, urban project was made more challenging by an accidental construction fire that heated and buckled a primary truss member, crippling the bridge and requiring immediate closure. Working around the clock, a first-of-its-kind jacking frame was designed, fabricated and installed to straighten the warped member and re-open the bridge in just 24 days.

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.

#### **Program Summary**

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. When a fire nearly destroyed the bridge during construction, the project team worked around the clock for or 24 days to invent and install a jacking frame and fix the structure. The rehabilitated bridge will support life in Pittsburgh for generations, permitting all people to enjoy crossing this historic structure.



## **Project Description**

#### HDR'S ROLE IN THE PROJECT

HDR served as the lead firm for rehabilitation design, and lead owner's agent for emergency fire response. Design: responsible for truss repairs, deck replacement design and designbuild specifications for maintenance of traffic. For the fire emergency: jacking frame concept development, design reviews, emergency safety assessment (3D modeling), and instrumentation/measurement coordination.

#### ROLE OF OTHER CONSULTANTS

Johnson, Mirmiran & Thompson, Inc.	Structural engineering
The Markosky Engineering Group, Inc.	Structural engineering
Monaloh Basin Engineers	Survey
Santangelo & Lindsay, Inc.	Lighting & Electrical Design
Lehigh University	Fatigue/Fracture consultation, testing & instrumentation for jacking repair.

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 was in poor condition.

To minimize impacting 55,000 vehicles a day, innovative techniques were used to maintain traffic while the deck - the size of three football fields - was replaced with Pennsylvania's first Exodermic deck. When a fire nearly destroyed the bridge during construction, the project team worked around the clock for 24 days to invent and install a jacking frame in order to fix the structure

#### **Technical Innovations**

By utilizing the first Exodermic deck in Pennsylvania, impacts to 55,000 vehicles a day were reduced while a deck the size of three football fields was replaced. Sections of this deck were

prefabricated in panels that could be installed over weekend closures and connected together with high early strength concrete. A custom rapid-set



custom rapid-set This was the first Exodermic deck in Pennsylvania concrete mix was created for this project, which

allowed traffic to use new deck sections just a few hours after the concrete was placed. The new deck combines the strength of steel Tbeams with reinforced concrete on top; making it strong, light and easy to overlay in the future.

Before deciding to completely replace the deck, an innovative yearlong test program was used to evaluate possible replacement overlay materials on the 170,000 SF of existing grid deck on the bridge. This grid was in poor condition. The asphalt surface worked like a sponge, holding rainwater that could be seen dripping through the deck days after the rain stopped. For the test, sections of asphalt were removed with highpressure water (hydro-demolition) and replaced with three different concrete materials to evaluate their performances. The wisdom of testing was shown when all overlays failed to perform adequately on this grid deck, leading to full deck replacement.

Innovations for the deck were planned, but the greatest innovations are often unplanned. When an accidental fire warped and buckled a main truss compression chord, forcing an immediate bridge closure, the team raced to develop a solution to fix the bridge and reopen this critical urban link. The bridge was in a perilous state; it was not known how badly the structure may be overstressed or if collapse was imminent. To assess and fix the bridge, teams of engineers worked many days and nights until the bridge reopened. A 3D analysis model was built to assess the crippled structure, including both trusses, every bracing member, and the partially removed deck. Using hand-drafted documents from the 1920s, hundreds of unique truss and bracing members were modeled. The day following the closure, the new model showed that most of the 2 million pounds carried by the damaged chord shed into the undamaged sister truss through wind bracing. No member was overstressed from the bridge dead load. This finding gave authorities confidence in opening the river below the structure to commercial traffic, preventing further economic impact to river commerce.

Without a historical precedent to go by, engineers also developed a jacking frame concept that same day to fix the buckled member. This frame would attach to the member to straighten the buckled steel. The final jacking frame included 11 jacks. Four 565ton jacks were aligned with the frame, capable of applying more than 4 million pounds to stretch the damaged member. Six 100-ton jacks were located on the sides of the frame, and would be used to straighten out severe buckles of the main structural plates, and the last 100-ton jack was located on a new bracing system added at the upper joint, and would fix the rotation evident at that joint. The whole system was designed to work together to twist, straighten, and stretch the damaged member back to its intended geometry.



North end of bridge (prior to overlay) showing checkerboard of rapid set concrete and new deck panels, installed over weekends.



Jacking frame and repaired truss member



To maintain safe operation of this complex machine, a 77-step jacking plan was developed. This plan included hold points when key steps were reached, so displacement and force data being collected through strain gages and instrumentation surrounding the frame could be processed. This data was used in real time to monitor the stiffness of the structure under load, and verify that structural response aligned with expectations from extensive 3D modeling. Through use of this sophisticated frame, the contractor safely rotated the upper joint and straightened the twisted member twenty-four days after the fire. On a momentous day for Pittsburgh commuters, traffic was restored on the bridge.

The project advanced the profession with several **new technical contributions**:

- Many large bridges in Pennsylvania have aging grid decks similar to Liberty Bridge. The overlay testing regime used for this project will provide valuable data to the Pennsylvania Department of Transportation (PennDOT) for future grid deck rehabilitation projects.
- With the first Exodermic grid deck in Pennsylvania, this project demonstrates that weight savings and rapid replacement are possible with lightweight, precast Exodermic deck panels. Engineers in Pennsylvania now have another option to meet the growing public demand for rapid bridge construction. Specifications for the deck panels, precast

concrete, and rapid-setting concrete have been developed for future use.

 Following the fire, researchers from Purdue, Lehigh, and Carnegie Mellon Universities, as well as experts from the Federal Highway Administration (FHWA) assisted engineers fixing the bridge. This unprecedented event provides an important example of structural redundancy and load-redistribution after member failure. Extensive material testing performed by Lehigh verified that the loadcarrying capacity of the steel was not compromised. This work resulted in a subsequent study on steel surface temperature based on paint discoloration.

#### **Benefit to Society**

The Liberty Bridge has been a landmark structure and local icon since it opened in 1928. This project has preserved this bridge for generations to come, while bringing it 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 and improve public safety. 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. Now everyone can enjoy the views afforded by the crossing.

Minimizing traffic disruption resulted in **positive public perception** for the project. When the bridge deck was last replaced in 1982, half the deck was closed, which would have severely impacted weekday commuters. For this project, three lanes of peak weekday traffic were maintained at all times, using quarter-width phasing and the ABC techniques.

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-footwide sections could be replaced rapidly. These closures were permitted for weekends only, and were planned and executed like a military operation. By precasting deck panels and utilizing high early strength concrete to stitch panels together, engineers showed the public innovations needed to keep traffic flowing. Contract bidding incentives were also used to drive down the time of lane closures and incentivize speed for the contractor.

The public became keenly aware of the importance of Liberty Bridge during its closure after the fire emergency. The bridge closure was a top story on the nightly news - with the whole city closely following daily repair progress. The

*"I found out [the bridge was reopened] at work, and everyone started cheering around the office. It was great! I'm absolutely loving it: such a refreshing change of pace."* Driver interview on the night the bridge reopened. emergency reminded the public of the importance of bridges, and the critical work of engineers to keep them safely functioning. The team worked hard to solve this unprecedented problem and get the bridge back in service for the 55,000 daily commuters that cross the structure.

Improvements to driver safety and experience were also included in the project. A new stateof-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.

#### **Commercial Success**

The main goals for PennDOT in this rehabilitation were to remove the load posting on the bridge, ensure the bridge was accessible and safe per current codes, and secure 40 more years of use from this historic truss.

By performing hundreds of unique steel repairs on beams, truss members, and connection plates, and by replacing the bridge deck and supporting stringers, trucks can now use the structure. This makes the movement of goods simpler and contributes to commerce in the region.

Replacing the bridge deck was crucial in order to preserve the bridge and allow it to function safely for another 40 years. The new deck, with modern bridge joints and drainage, provides a robust and waterproof "roof" to keep the steel

# LIBERTY BRIDGE OPEN 9 TON WEIGHT LIMIT

*"With a methodical combination of mechanics and engineering, the team was able to shift over one million pounds of force back to where it belonged."* Kym Gable, KDKA News, when the bridge reopened.



below dry and corrosion-free. In addition, replacing the old stringers along with the deck eliminated many poor details that are prone to cracking over time. Holes, cuts, and welds in these beams did not meet current fatigue requirements. As years of exposure to traffic mounted, these details were a long-term liability requiring detailed documentation for each inspection. By replacing all stringers with new, properly fabricated beams, this liability was eliminated. These investments in the structure will lower future maintenance costs and are a wise investment of public funds.

For this major urban project, the owner sought to limit traffic impacts as much as practical and to keep the traveling public informed of the schedule for any closures. The complete closure of Liberty Bridge due to the fire emergency suddenly required 55,000 drivers to find a new route to their destination each day. Opening the bridge as soon as safely possible became a critical goal of the client. Engineering professionals collaborated nearly 24 hours per day for 24 days to coordinate, develop, and review critical design and procedural documents to help fix the structure. This effort led to the bridge's quick repair, helping those 55,000 drivers return to their usual commute and showing the public PennDOT's ability to rapidly respond to complex problems.

Because of the Liberty Bridge Rehabilitation project, traffic is freely flowing on the new deck, guided by modern lane control and ITS systems. The new bridge deck and completely new paint coat system will preserve the bridge for generations to come, and protect the public investment in this structure.

#### **Summary**

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. When a fire nearly destroyed the bridge during construction, the project team worked around the clock for 24 days to invent and install a jacking frame and fix the structure. The rehabilitated bridge will support life in Pittsburgh for generations, permitting all people to enjoy crossing this historic structure.



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