Two Bridges with a Shared Design

A proven precast concrete solution increases efficiency on an emergency Kansas City project

by Eric Schrader and
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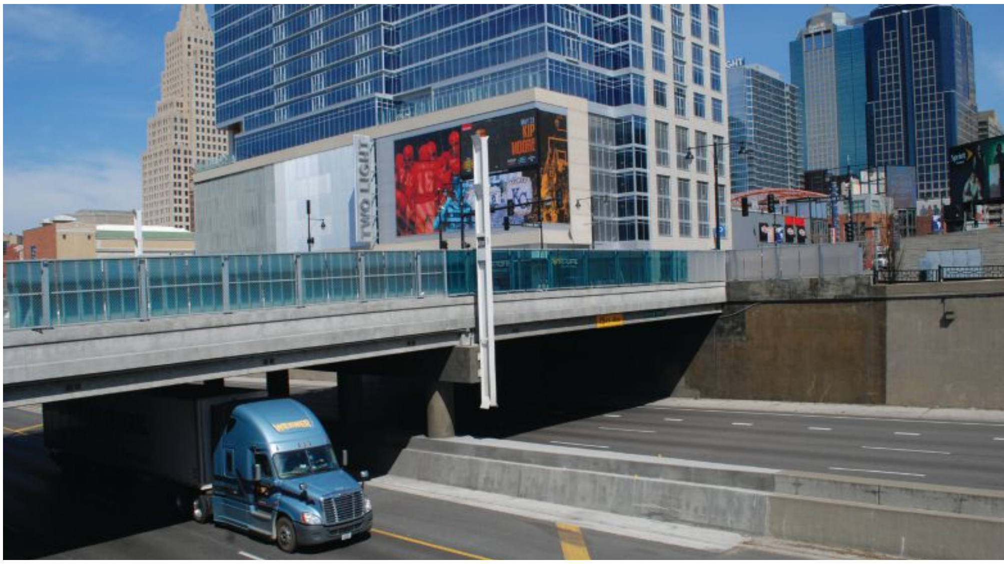
Interstate 670 (I-670) is a busy corridor cutting through the heart of downtown Kansas City, Mo., with many downtown streets bridging over the depressed highway. In the last decade, two bridges over I-670, the Main Street Bridge and the Grand Boulevard Bridge, were replaced. Each project had unique goals and challenges: Main Street was chosen as the corridor for the Kansas City Streetcar, and Grand Boulevard was envisioned as a new bike-friendly corridor through downtown. But similarities in the two projects—vicinity, environment, size constraints—allowed project teams to employ solutions already proven on the first bridge replacement to meet an aggressive emergency schedule on the other.

Elevation view of the Main Street Bridge. Note that a streetcar is crossing the bridge. All Photos and Figures: HDR.

The Main Street Bridge

The first project, begun in 2012, was the replacement of the Main Street Bridge. It was a fast-paced project requiring close coordination between the City, the Missouri Department of Transportation (MoDOT), numerous local stakeholders, and the team overseeing the Kansas City Streetcar project. The existing bridge was at the end of its useful life, and, with an impending need for a bridge to carry the streetcar, replacement was chosen as the appropriate course of action.



Elevation view of the Grand Boulevard Bridge.

As survey and geotechnical investigations began, the bridge and roadway design

profile

MAIN STREET AND GRAND BOULEVARD BRIDGES / KANSAS CITY, MISSOURI

BRIDGE DESIGN ENGINEER: HDR, Kansas City, Mo.

PRIME CONTRACTORS: Pyramid Contractors Inc., Olathe, Kans. (Main Street Bridge); Clarkson Construction Company, Kansas City, Mo. (Grand Boulevard Bridge)

PRECASTER: Coreslab Structures, Kansas City, Kans.—a PCI-certified producer

Streetcar rails were embedded in the Main Street Bridge deck. For improved durability, epoxy-coated reinforcement was used in the decks and piers of both bridges.

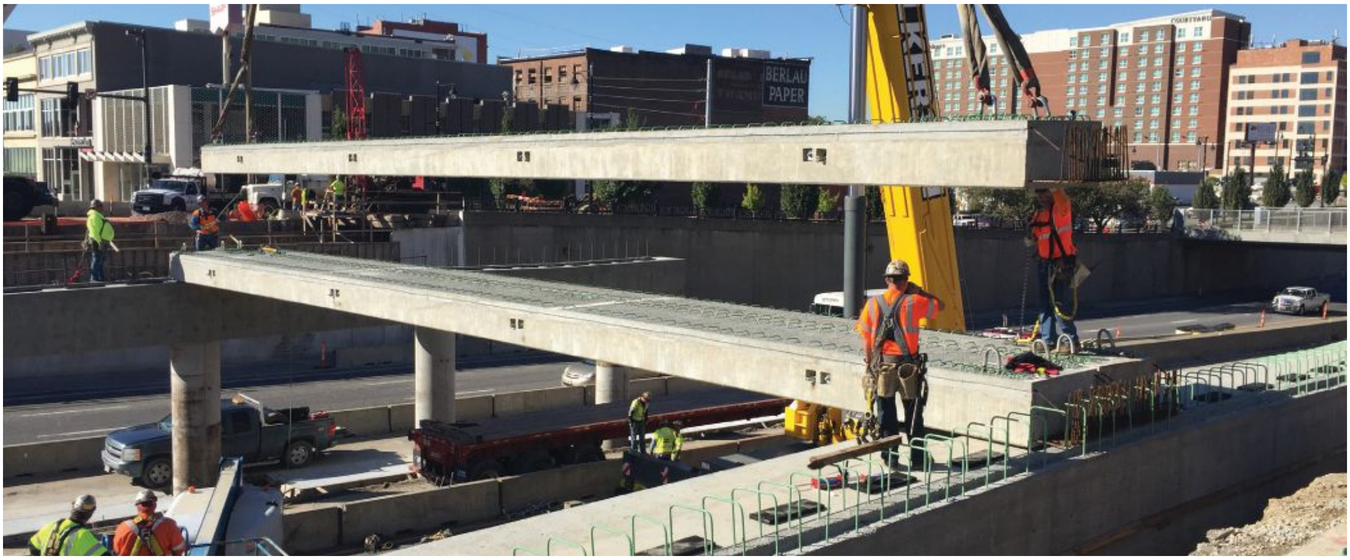
staff faced their first major challenge: increasing the vertical clearance under the bridge (over I-670) while minimizing profile grade adjustments to Main Street. Any significant raise in profile grade would adversely affect neighboring businesses and intersecting streets. The existing 141 ft, two-span concrete voided-slab bridge had a shallow superstructure depth of 2 ft 3 in. and a 66 ft out-to-out width. The new configuration of Main Street required increasing the out-to-out width by 2 ft, to 68 ft. Like the old bridge, the new bridge was designed as a two-span structure, but with a total length of about 148 ft because the design placed the new abutments behind the existing retaining walls and abutments.

Finding the most efficient superstructure type was paramount. After different superstructure types were studied during the preliminary design phase, an adjacent concrete box beam superstructure was determined to be the most efficient structure type that would satisfy the project objectives.

Because the adjacent concrete box beams are shallow with minimal deck thickness, they proved to be the right choice for a replacement superstructure that needed to increase vertical clearance below and widen the roadway on the bridge. The precast, prestressed concrete box beams were also preferable because they were manufactured off site and then quickly installed on site, which minimized traffic impacts to I-670.

The beams chosen were 72-ft-long, 24-in.-deep box beams, either 3 or 4 ft wide, with a 28-day design concrete compressive strength of 8 ksi. The 3-ft-wide box beams had twenty-four 0.6-in.-diameter prestressing strands initially tensioned to 1055 kip, and the 4-ft-wide box beams had 26 strands tensioned to 1143 kip. The beams were designed for both streetcar and highway vehicular live loads. Initially, a minimum deck thickness of 6 in. was chosen for this adjacent box-beam superstructure, but the thickness was later increased to 7.5 in. minimum to provide adequate depth to inlay the new streetcar rails in the deck.

Erection of a 72-ft-long, 2-ft-deep precast, prestressed concrete box beam for the Grand Boulevard Bridge. To facilitate the tight schedule of the emergency bridge replacement, the project team used the same beam design (length and strand layout) and shop drawings as the Main Street Bridge. Note the blockouts for transverse connections between beam units.



CITY OF KANSAS CITY, MO. (MAIN STREET BRIDGE), MISSOURI DEPARTMENT OF TRANSPORTATION (GRAND BOULEVARD BRIDGE), OWNERS

BRIDGE DESCRIPTIONS: Two-span, 148-ft-long bridges using precast, prestressed concrete box beams with cast-in-place concrete multicolumn bents on drilled-shaft foundations. The Main Street Bridge was designed for streetcar traffic as well as other vehicles.

STRUCTURAL COMPONENTS: 24-in.-deep precast, prestressed concrete box beams; cast-in-place concrete deck; with epoxy-coated reinforcement cast-in-place concrete bents caps, columns, and drilled shafts

Erection of one span of prestressed concrete box beams for the Grand Boulevard Bridge. The reverse crown in the cross section and pier cap is visible.

A fast-paced schedule was required to replace the bridge before construction of the Kansas City Streetcar project commenced. Final plans were completed and the bid package was prepared to meet the accelerated schedule. The project was under construction by September 2013, with a planned project duration of only 50 days. The new bridge was opened to traffic in December 2013.

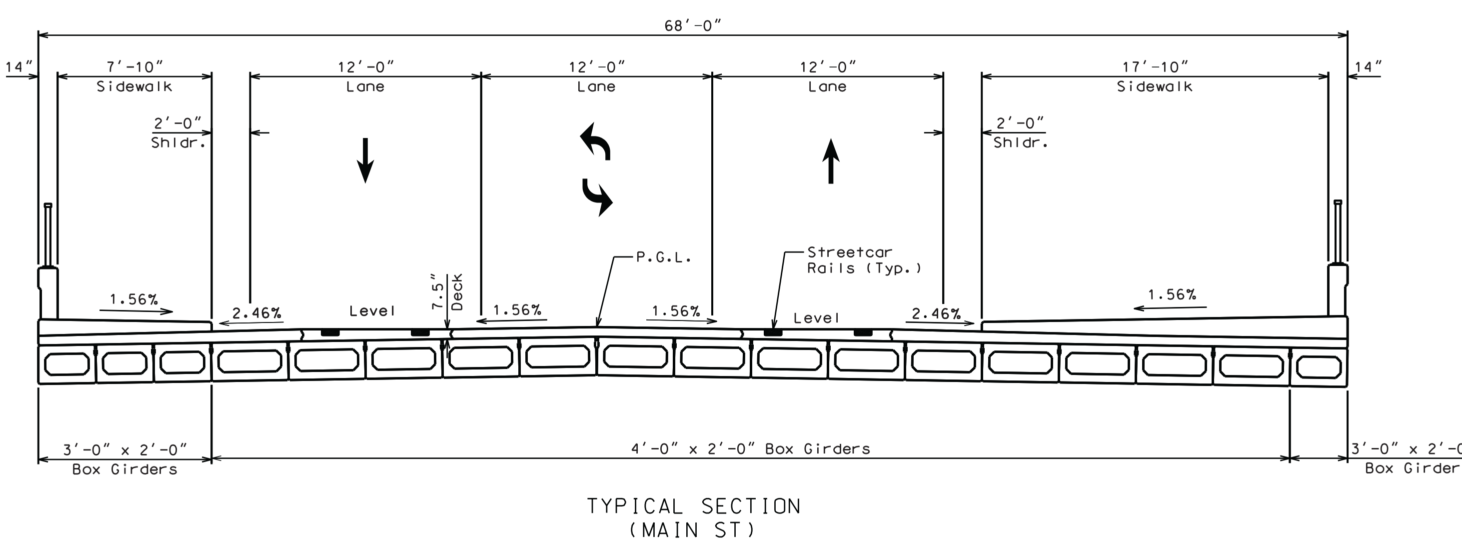
The Grand Boulevard Bridge

Less than three years later, emergency replacement of the existing concrete voided-slab Grand Boulevard Bridge, two blocks east of the Main Street Bridge, was deemed necessary after significant cracking was observed in the edge of the slab near the pier. An emergency closure shut down traffic on May 6, 2016, and shoring was installed near the pier under the damaged area. Given the recent success of the nearby Main Street Bridge replacement, the design team for that project was also selected for the replacement of the Grand Boulevard Bridge.

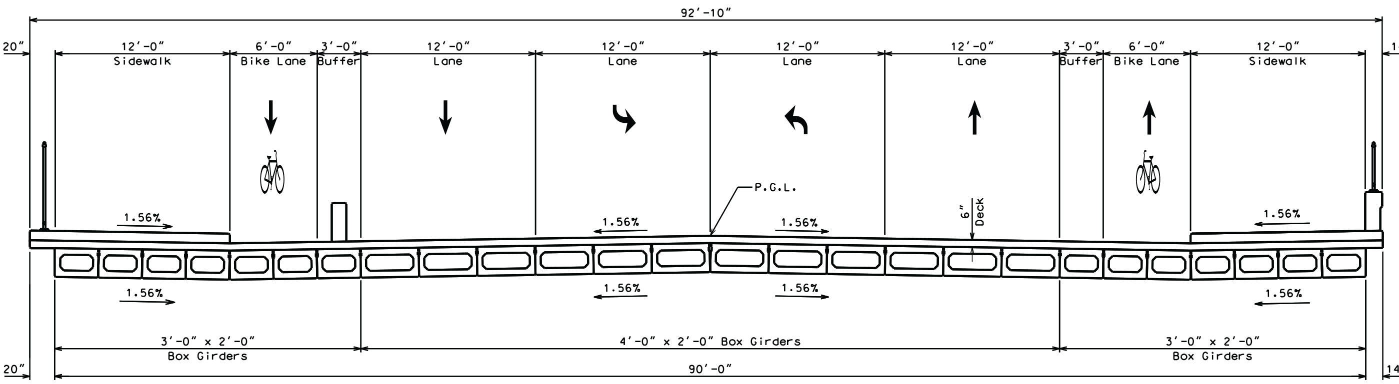
Many of the same challenges encountered on the Main Street Bridge project were faced again on Grand Boulevard, including the need for a wider bridge and greater vertical clearance below. The out-to-out width of the bridge was being widened from 84 ft to 92 ft 10 in. to accommodate wider sidewalks and a protected bike lane.

Minimizing the project's impact on intersecting streets and nearby businesses was once again a challenge, but this time the team could draw from what they had learned while meeting these challenges just two blocks away on the Main Street project.

For the Grand Boulevard Bridge, designers proposed using the same two-span design that had been used on Main



Typical section of the Main Street Bridge showing the different roadway cross-slopes, including level sections at the flush-mounted streetcar rails. The wide right sidewalk provides safe access for pedestrians and cyclists.



TYPICAL SECTION
(GRAND BLVD)

Typical section of the Grand Boulevard Bridge. The 12-ft-wide sidewalks and outer four box beams were sloped inward to obtain the minimum required vertical clearance for Interstate 670 below.

Street. By duplicating the earlier project's dimensions, the design team could reuse the concrete box-beam superstructure design. The Grand Boulevard Bridge used the same 72-ft-long, 24-in.-deep box beams, with an identical design concrete compressive strength and prestressing strand layout and force, as the Main Street Bridge.

Because the configuration was unchanged, MoDOT and the design team agreed to include the previously approved shop drawings from the Main Street Bridge in the contract's Job Special Provisions to allow the contractor to expedite the beam fabrication process. The project still followed the normal bidding process, but the previously approved shop drawings could be reused at the contractor's risk to speed up the delivery and construction process. Faced with the time crunch of an emergency replacement on an important city street, this successful strategy was a major time saver.

Because the bridge width was increasing by nearly 9 ft compared with the existing bridge width, the challenge of improving the vertical clearance over I-670 proved to be difficult to resolve. The innovative solution was to provide an opposite cross slope from the normal crown on the roadway under the sidewalks, creating a "gull-wing" design. The new bridge has two, 12-ft-wide raised sidewalks on each edge. The roadway has a normal crown at the centerline of the bridge, but the sidewalks are sloped to drain toward the gutter on the roadway, creating an inverted crown at the gutter of the roadway. By making the adjacent box beams under the sidewalk match the slope of the sidewalk and matching the inverted crown at the gutter, the bottom of the bridge superstructure was raised for the outer 12 ft of each side of the bridge. This allowed the low point of the superstructure to be pulled in significantly, achieving the desired increase in vertical clearance without raising the profile of Grand Boulevard.

After the design's completion, plans were submitted to MoDOT in mid-July 2016, two months after the bridge closure. Demolition of the existing bridge began in the last week of August, and the new bridge was opened to traffic in the first week of December 2016.

Ensuring Durability

The durability of both bridges was an important design consideration. Winters in Kansas City can be harsh, and deicing salts are used to prevent bridges from icing. Epoxy-coated reinforcement was used in the decks to protect the reinforcing bars from corrosion and deterioration due to the effects of moisture and deicing salts.

Because I-670 is depressed and bordered by retaining walls as it passes under Main Street and Grand Boulevard, the highway can create a severe splash zone, which can have a whirling effect from traffic. When deicing salts are applied on the highway below the bridges, the splashing and whirling of moisture can be detrimental to the long-term durability of the structures. Therefore, epoxy-coated reinforcement was used in the piers as well as the deck. An epoxy protective coating was also applied to the surface of the concrete to protect the piers and retaining walls in front of the abutments for both bridges.

In addition, several details were used to encourage uniform vertical deflection of the box beams to minimize reflective cracking in the cast-in-place concrete deck. The adjacent box beams were connected with a combination of post-tensioned rods and grout-filled keyways. Adjustments for alignment were achieved with a series of wedges placed between the box-beam flanges.

Conclusion

Precast, prestressed concrete box beams provided the ideal superstructure type for both of these fast-moving bridge replacement projects. The shallow structure depth, the ease of beam placement, and the efficiencies gained by using the same beam design on both projects helped the design and construction teams achieve the objectives of these projects despite the aggressive schedules. It would have been difficult to be as efficient in design and construction with any other superstructure type.

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