

Both waterways and vehicular traffic were kept free of interruption during a major steel bridge replacement over the Missouri River.

Open Channels

BY BRUCE A. BURT, PE | PHOTOS COURTESY OF MoDOT



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SINCE OPENING IN 1936, the two-lane Route 47 Bridge in Washington, Mo., has provided a prominent vehicular crossing over the Missouri River roughly 50 miles west of downtown St. Louis. Unfortunately, the historic two-lane steel truss bridge had become functionally obsolete in recent years and required replacement.

Just 15 ft upstream from where it once stood is its brand-new structural steel replacement (the distance between the new and old bridge centerlines is 60 ft), which provides a 52-ft vertical clearance for river traffic. The new 1,770-ft-long main span bridge, which opened to traffic in December 2018, features 12-ft lanes, 10-ft shoulders, and a protected 10-ft bicycle/pedestrian path. Structurally, the new bridge consists of five concrete 160-ft approach spans and four steel main spans. The main spans are each comprised of five steel plate girders whose depths range from 18 ft at the support piers to 10 ft, 6 in. at their midspans. The two outer spans are 385 ft long, and the two central spans are 500 ft long. In total, 5,800 tons of structural steel, including 75 girder sections, 346 cross-frames, 336 lateral braces, and 24 diaphragms, were used in its construction.

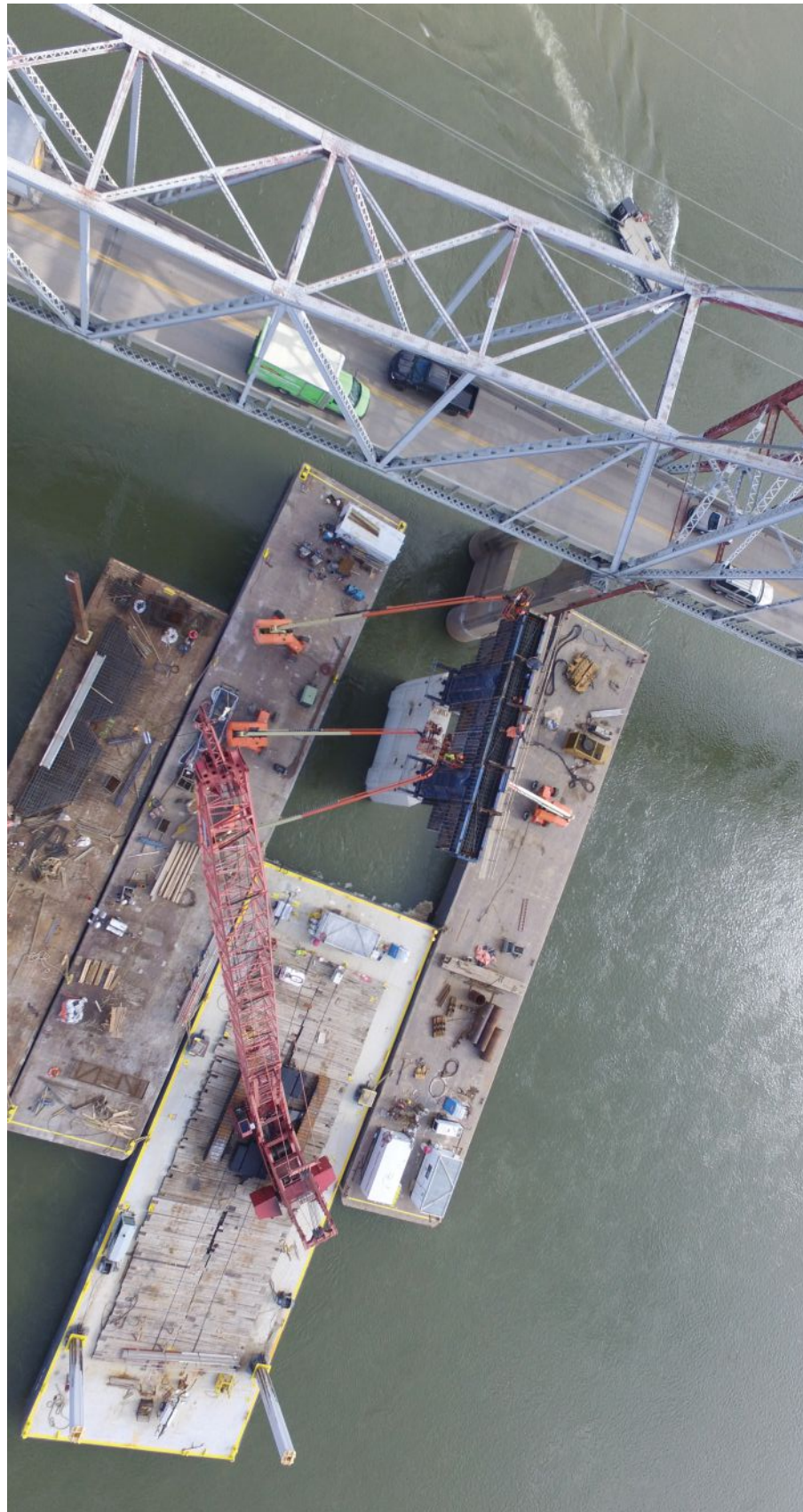
Minimizing Falsework

Close collaboration between general contractor Alberici Constructors and erection engineer Ruby+Associates resulted in an efficient erection plan that minimized falsework and



left: The superstructure for the new bridge, which uses 5,800 tons of structural steel in all, nearing completion.

below: A bird's-eye view of the temporary shoring towers, which were founded on compacted gravel and timber crane mats. The original bridge remained open to traffic during construction of the new bridge.



temporary shoring for the bridge. A flexible support bracket system was developed to reduce the length of girder cantilevers during erection. The bracket system was designed to move from pier to pier, resulting in a significant weight savings in steel falsework and river-based shoring.

Thanks to a comprehensive stability analysis and careful planning, the team was able to reduce the number of shoring locations to just three, with one shore placed on a temporary causeway and two within the waterway. A hybrid shoring system was developed for the two shoring bents located in the river. Salvaged 42-in.-diameter steel pipe was driven in the riverbed in four-pile groups, then cut to elevation above river high water datum. Temporary shoring towers were attached to the pile groups using conical transition pieces, allowing positional adjustability to account for piledriving tolerances. A temporary support girder



above: Girders were raised using a pair of crawler cranes.

left: The out-to-out distance between the new and old bridges is 15 ft.

below: Lifting one of the massive plate girders from the ground.



spanned between adjacent tower sections, and each hybrid tower—consisting of pipe piles, transition elements, and rented tower sections—was designed as a cantilevered column to eliminate the need for custom-fabricated, field-installed bracing between the towers.

To eliminate the need for piledriving at the third shoring location, a temporary causeway was extended and the temporary shoring towers were founded on compacted gravel and timber crane mats. To provide lateral stability of the shoring system without the need for expensive field bracing between tower sections, one shoring tower was designed as a cantilevered column and the adjacent tower was designed to lean on the cantilevered tower. Base fixity for the cantilevered tower was achieved by mounting it on outrigger beams and casting concrete blocks on the outriggers to provide overturning and sliding resistance.

To further reduce shoring requirements as well as the number of “air splices,” the ironworker crews needed to assemble two girder sections—one 100 ft long and the other 114 ft long—for the outer two bridge spans end-to-end on the ground. These pre-assembled girders, which combined to form 214-ft-long girder sections weighing more than 100 tons apiece, were raised using a pair of crawler cranes working in tandem. A midspan support was required to provide lateral stability for the first preassembled girder section, and a lightweight shoring tower was repurposed

from a previous Alberici project to provide the necessary support. Subsequent girder assemblies were erected using the same two-crane lift method, then laced back to the previously erected girder before being released from the crane. Due to the increased lateral strength of the now interlaced girders, intermediate shoring was not required beneath the remaining girders.

The temporary pier brackets mounted to the piers provided stability to the double-cantilever girder sections and were designed to deflect in order to accommodate deformations induced during erection as additional girder sections were added. This support bracket system was mounted to one concrete pier, then dismantled and reused at subsequent piers, and spacers of varying depths were placed at the tips of girder brackets to account for different girder profiles at each bridge pier.

Erection Sequence Proves Critical

One of the project’s main challenges required maintaining the 400-ft-wide shipping lane in the Missouri River, necessitating the erection of the 500-ft-long central bridge span above the shipping lane without the use of shoring or other waterway obstructions. A sequenced erection plan was developed to ensure the stability of the long cantilevers that resulted from the un-shored method, and a



The original bridge was demolished via synchronized demolition charges. The new bridge is fully visible in the third photo.

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procedure was developed for installing the final “key-stone” girder sections (called this because they are at the center of the middle 500-ft span).

In order to safely install the long cantilevers required to partially close the 500-ft span, the adjacent bridge spans had to be completed first. This entailed erecting the double-cantilever girder section on the concrete pier, using the temporary support bracket for stability, erecting girder sections at the opposite end of the span using the shoring towers for temporary support, and then completing the span with infill girder sections. Once the adjacent spans were installed, girders were erected from the double-cantilever girder sections to form 180-ft-long cantilevers projecting from the piers.

The shoring towers in the adjacent spans were equipped with hydraulic jacks that could raise or lower the adjacent bridge spans, which in turn affected the elevations of the ends of the cantilevers. This jacking system allowed precise elevation adjustment of the ends of the cantilevers to ensure the girder ends were properly aligned for the installation of the 140-ft-long keystone girder sections. The girders were installed slightly offset longitudinally from their final position to leave a gap for installing each keystone piece. The girders were placed on temporary low-friction polytetrafluoroethylene (PTFE) slide pads to facilitate the required longitudinal movement. With the necessary preparations

Overcoming Fabrication Complexity

General contractor Alberici Constructors partnered with fabricator Industrial Steel Construction (ISC) on the project for three key strategic and economic reasons: 1) ISC is AISC certified, 2) it can perform large girder line assemblies under roof (thanks to its 900-ft-long shop bay and 100-ton-capacity crane) to ensure proper fit-up, and 3) its location in Gary, Ind., gives it access to Lake Michigan, which facilitates barge shipping.

With 112-ft-long haunch girders over the piers varying in depth from 10 ft, 6 in. to 18 ft, ISC not only employed vertical butt splices but also horizontal butt splices in the web for 45 out of the 75 girders on this complex project. Butt splicing is typically used to join two steel plates together, but for this project four separate 1-in.-thick steel plates had to be joined together to make a web plate for one girder. The longest girder line assembly involved five girder segments with a total length of 612 ft, which ISC accomplished under roof. This moved the schedule forward by at least three months, since these assemblies could be achieved inside during the winter months.

In addition to the plate girders, the project also involved several secondary steel members, such as 346 cross frames, 336 lateral bracings, and 24 diaphragms that had to be fabricated in tandem with the plate girders in order to deliver the steel to the site on time. Luckily, ISC was able to dedicate another entire shop bay to process these members.

ISC shipped 50 girders by barge, from Lake Michigan to the Illinois river to the Mississippi river to the Missouri river, and finally to the job site, which helped reduce land transportation costs. A total of 10 barges was sent to the job site with approximately five girders loaded on each barge, and the girders were erected directly from the barges. The other 25 girders and the secondary steel members were transported by truck and erected from rock causeways on either side of the river. The transportation costs incurred by the materials transported via land were offset by the lower cost of erecting from land-based cranes in lieu of barge-mounted cranes, which typically takes twice as long.

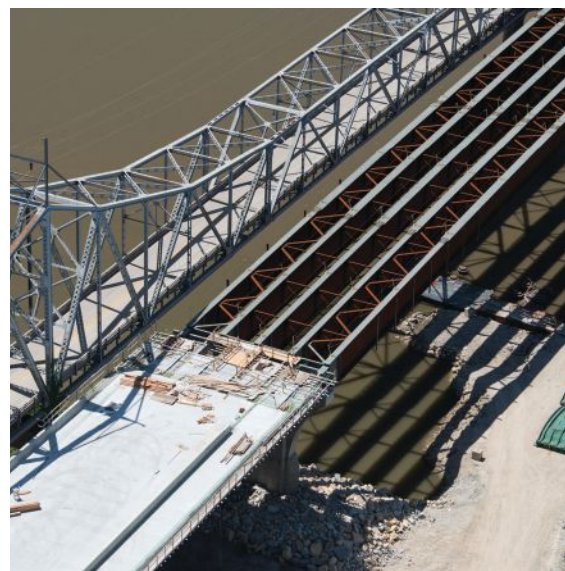
—Ankit Shah, Senior Project Manager, Industrial Steel Construction



above: The secondary structural steel contained 346 cross frames, 336 lateral bracings, and 24 diaphragms.

right: The contrasting framing schemes of the old and new bridges.

below: Children span the bridge's width on its opening day.



above and left: The bridge's superstructure is made up of 75 individual plate girders whose lengths vary from 100 ft to 140 ft and whose depths range from 18 ft at the support piers to 10 ft, 6 in. at the midspans.

complete, each keystone girder was lifted in place early in the morning. As the temperature of the steel increased throughout the morning, thermal expansion closed the gap left between girders, allowing ironworkers to bolt the girders together.

The entire project was performed without interrupting river or vehicular traffic, as the original bridge remained open during construction, and the new crossing accommodates a daily traffic volume of 13,000 vehicles. In April, the original bridge was demolished via synchronized demolition charges and its steel salvaged for reuse, perhaps as a future iconic steel structure. ■

Owner

Missouri Department of Transportation

General Contractor

Alberici Constructors, Inc., St. Louis

Bridge Designer

HDR Engineering, Inc., St. Louis

Erection Engineer

Ruby+Associates, Inc.,
Bingham Farms, Mich.

Steel Fabricator

Industrial Steel Construction, Inc.,
Gary, Ind. 

Rigorous Analysis

Fine-tuning the erection sequence and minimizing falsework required significant pre-planning by Alberici and sophisticated analysis from Ruby's engineering team, which performed a staged erection analysis using LARSA 4D bridge design software. This analysis allowed deflections of the steel to be accurately determined at each stage of construction, essential for ensuring proper fit-up of the steel during erection, developing the means for dimensional control, and allowing for critical girder stability checks. Due to their excessive weight—over 100 tons each—the steel plate girders were installed one at a time instead of in a more stable paired configuration. And the long cantilevers that resulted from un-shored erection of the 500-ft span also necessitated a rigorous stability review. Once confirmed in the staged erection model, girder stability was verified via empirical methods. In addition, the team used RISA 3D to design the flexible pier brackets, the hybrid shoring system, and the midspan girder support shores, and also used UT Bridge—a 3D finite analysis program developed by the University of Texas—to perform a validation review of girder stability.



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