MAKING a Signature Connection

BY NATALIE McCOMBS, SE, PE, AND SARAH LARSON, PE

An attractive steel arch and sophisticated engineering define Little Rock's new Broadway Bridge.

IN 2010, LITTLE ROCK'S BROADWAY BRIDGE was showing its age.

Completed in 1923, the bridge had served the region well as a landmark structure dedicated to veterans of World War I and was a vital connector over the Arkansas River between downtown Little Rock and North Little Rock, Ark. The existing structure consisted of one steel arch span, three concrete deck arch spans and multiple concrete beam spans. However, by 2010 the bridge was carrying 21,000 vehicles per day, becoming costlier to maintain, and was considered structurally deficient.

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Steel would play a vital role in the replacement bridge, which is designed to accommodate 34,000 vehicles daily. The new bridge features four 11-ft lanes with 4-ft shoulders and a 16-ft-wide shared-use path to increase access for pedestrian and bicycle users. These needs were addressed with two new bridge-to-ground access ramps—a mix of pedestrian bridges and paved paths supported by mechanically stabilized earth retaining walls that connected to the Arkansas River Trail System. While the $98.4 million project was administered by the Arkansas State Highway and Transportation Department (AHTD), it was made possible by a $20 million contribution from Pulaski County, as county officials wanted to establish the new bridge as an icon for the community.

Critical Constraints

When determining the structure type and erection method for the main spans, the plan needed to accommodate the limited construction and storage space on the site, as the bridge spans a navigable waterway designated as a connector for the Marine Highway M-40. Due to U.S. Coast Guard requirements, the waterway had to remain open during the construction phase, and closure windows were therefore limited.

Once the location limitations were established, the team determined the span configuration. The bridge would be made up of 440-ft tied arches for the two main arch spans (designed by HNTB) and welded steel plate girder approaches (designed by Garver, LLC, the prime design consultant for the project).

The initial design criteria included provisions to accommodate a future trolley on the bridge, using minimally invasive work

The new bridge is designed to accommodate 34,000 vehicles a day via four 11-ft-wide lanes with 4-ft-wide shoulders.

with light-duty construction equipment. While this was a relatively simple concept on the plate girder approaches, applying the same concept to the arch spans was more complicated due to the transverse floor beam and longitudinal stringer framing layout. The localized slab depth required to accommodate the trolley was nearly 16 in. thick, which would require an undesirable large haunch or make the floor beams noncomposite with the deck. The team initially decided that the longitudinal stringers would sit on top of the transverse floor beams, making them noncomposite. In addition, the look of the inclined basket-handled arches that were touching at the peak appealed to stakeholders. To meet vertical clearance on the roadway and have the arch ribs touch at the peak, the initial geometry of the arch ribs was set to tilt inward at a 25° angle from vertical.

Greg Davis

▲ The arch span uses 4,100 tons of steel in all.

▼ The tie girder cross section consists of a closed parallelogram box girder, made up of two inclined webs and two horizontal flanges.

HNTB

However, in order to keep the project within budget, HNTB reevaluated the design criteria for the arch spans to determine the most effective design. Major revisions involved accommodating the future trolley system and increasing the arch rib spacing at the peak from touching to approximately 21 ft. These two modifications changed the angle of the arch ribs from 25° to 18°. These changes allowed for shorter composite floor beams (reduced from 99 ft to 88 ft) and a framed-in stringer floor beam system, efforts that saved approximately 2,500 tons of structural steel as compared to the original plan; total tonnage for the arch spans is 4,100.

Building a Better Bridge

Throughout design and construction, great care was taken to observe the U.S. Federal Highway Administration's strict guidelines for fracture-critical members. The bridge was made with ASTM A709 Grade 50 steel, which includes the Charpy V-notch Zone 3 requirements for increased toughness. This was important for the tie girder, floor beams and hanger plates, as they are all considered fracture-critical

The project was let in September 2014 and substantially completed this past June.

members. For the tie girder, the cross section consists of a closed parallelogram box girder made up of two inclined webs and two horizontal flanges. The web plates are welded to tab plates with a double-fillet weld and are then bolted to the flanges. This bolted connection isolates a potential fracture of one plate without allowing the fracture to propagate throughout the cross section. The resulting three-sided tie girder section was designed to carry the structural demands at an extreme event limit state, and this internal redundancy eliminates the potential of a catastrophic structural failure.

The hangers are 2⅜-in.-diameter ASTM A586 bridge strand and are made with Grade 2 wire as opposed to Grade 1, and a Class C coating was applied to all wires in the strand to enhance durability. The strength of a hanger using Grade 1 wire with Class A coating is 344 tons, while Grade 2 wire with Class C coating throughout provides a capacity of 357 tons and was tested to failure at 395 tons.

A key element to consider in the tied arch design is the elongation of the tie girder that occurs when load is placed on the arch structure. When the slab load is applied, elongation occurs in the tie girder and forces the stringers to move along with it. Since the stringers are smaller in area, the stress that would be put on them would be high compared to that of the tie girder. HNTB alleviated this dead load axial stress by using slots in alternating stringer-to-floor beam connections. This allowed for movement to occur, with most of the weight of the slab in place. Closure pours at every other floor beam allowed bolts to be tightened once most the deck concrete was in place. To complete the riding surface, the closure pours were placed after bolts in the stringer-to-floor beam connections were tightened.

Rapid Reconstruction

The construction contract allowed the bridge to be closed to traffic for up to six months during the construction period, and AHTD officials employed an incentive bidding approach incorporating a rate of $80,000 for each day the bridge would be closed. New piers were built under the existing bridge (while traffic was maintained on it) while tied arch spans were simultaneously assembled on barges just downstream of the existing bridge. The existing bridge was then closed to traffic and demolished, the new arch spans were floated into place and the deck was poured. Most of the approach girders were delivered the day they were to be set so they could be picked directly from the truck.

With the new bridge built on the existing alignment, Massman constructed the foundations under the existing bridge prior to the closure period in order to minimize closure time. Using a tied arch superstructure also minimized impact to the traveling public and allowed for rapid reconstruction, as this structure type is stable and can be assembled off-line and transported to the job site via barges.

The float-in of the arches posed a significant risk to the contractor. Because the arches were designed to have a certain amount of freeboard, they couldn't be floated in if the water surface was too high or too low. There had to be at a "sweet

The arch ribs are welded plates resembling an H-shape that is 4 ft wide by 3 ft, 10 in. deep. The tie girders are 4 ft wide, 5 ft deep and about 73 ft long. The floor beams are I-shaped welded plate girders that are 5 ft deep at the tie girder and increase in depth to match the profile grade. The final floor beam lengths are approximately 88 ft and the beams are spaced at 36 ft, 8 in.

spot" of sorts. If the surface is too high, water velocity and lowering becomes a concern, and with increased water velocity it becomes too difficult to position the spans; the tug boats must fight the water current to get the arch spans set within a +/-1-in. tolerance. And if the water is too low, there isn't enough freeboard to float over the new piers.

The construction team assessed the river conditions for the right windows, and the first span was floated in in mid-November, followed by the second span in early December 2016. In the end, the crossing only had to be closed for five months instead of the allotted six, and a new steel icon now graces Arkansas' capital city. ■

Owner
Arkansas State Highway and Transportation Department

General Contractor
Massman Construction Company, Kansas City

Structural Engineers
Garver, LLC, North Little Rock, Ark.
HNTB, Kansas City

Steel Team

Fabricators
Veritas Steel, Palatka, Fla. (Arch Spans)
DeLong's, Inc., Jefferson City, Mo. (South Approach)
W&W|AFCO Steel, Little Rock (North Approach)

Detailers
Tensor Engineering, Indian Harbour Beach, Fla. (Arch Spans)
DeLong's, Inc. (South Approach)
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