A steel network tied arch serves as the successor to a 1930s steel truss honoring the famous female flyer.

Replacing Amelia's Bridge

BY FRANK BLAKEMORE, P.E., AND NATALIE MCCOMBS, S.E., P.E.

MANY KNOW THE STORY of Amelia Earhart, best known for being the first female to fly solo across the Atlantic Ocean and later attempting a flight around the world at age 40. But likely few know the pioneering pilot was a native of Atchison, Kan., where a bridge named after her flew traffic over the Missouri River for 74 years.

The steel through truss, built as a Works Progress Administration (WPA) project in 1938, had been nursed through nearly 10 rehabilitations before the decision was made to replace it in 2002. Its shoulderless, narrow roadways fell short of 21st century needs. And the condition of its deck trusses worried the owners.

Because the bridge was a beloved, historic structure, both the Kansas and Missouri Departments of Transportation (KDOT and MoDOT) knew the community would have a significant voice in selecting the new design. In fact, citizens already had made one thing clear: The new bridge would be made of steel, like its predecessor.

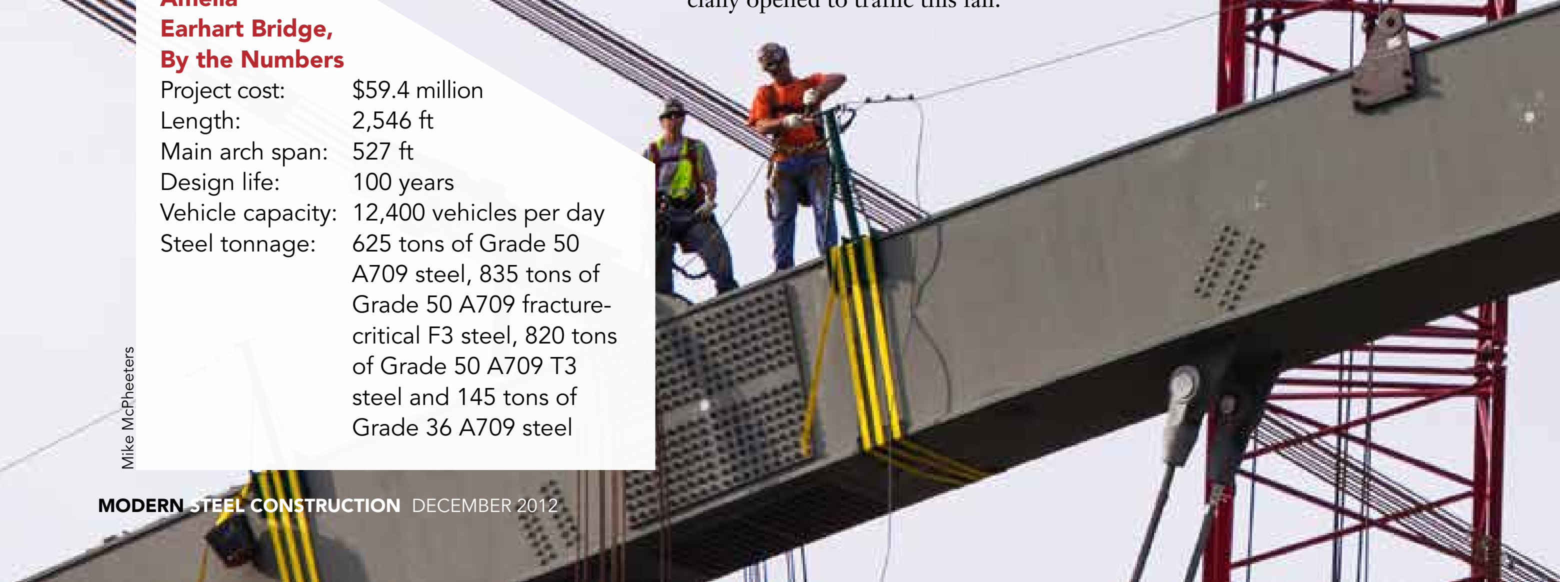
Steel Defines Different Designs

KDOT hired HNTB Corporation and AMEC in 2007 for final design of the project, with HNTB as lead bridge designer. HNTB performed preliminary design on several alternatives and presented KDOT and MoDOT with the two most cost-effective design alternatives: a steel through truss span and a steel tied-arch span with network hangers. In addition to an arch design being a community favorite, the design also came in under the truss span's cost estimate. The tied arch won and the design was set. To cover the project's $59.4 million cost, Kansas would contribute $30.6 million and Missouri would kick in $28.8 million.

Contractor Archer Western began construction in June 2009 with a targeted completion date of 2011, but historic flooding would suspend work not once but twice before the bridge officially opened to traffic this fall.

The Amelia Earhart Bridge, By the Numbers

Project cost:	$59.4 million
Length:	2,546 ft
Main arch span:	527 ft
Design life:	100 years
Vehicle capacity:	12,400 vehicles per day
Steel tonnage:	625 tons of Grade 50 A709 steel, 835 tons of Grade 50 A709 fracture-critical F3 steel, 820 tons of Grade 50 A709 T3 steel and 145 tons of Grade 36 A709 steel



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The new U.S. 59 Amelia Earhart Bridge, a four-lane, ample-shouldered network tied-arch bridge, rests just 78 ft south of the old bridge. Approximately 2,546 ft long, the structure consists of 2,019 ft of 78-in. NU (Nebraska University) prestressed concrete I-girder approach spans and a 527-ft steel tied-arch main span.

The new bridge has a 100-year design life and is capable of handling the 20-year traffic projections of 12,400 vehicles a day, twice the capacity of the previous bridge. The former bridge, kept open to traffic during construction, will be closed once traffic is shifted to the new bridge and will be demolished next year.

Steel suppliers, including Nucor-Yamato, SSAB and Arcelor-Mittal, shipped approximately 2,280 tons of Grade 50 A709 steel and 145 tons of Grade 36 A709 steel to fabricator Industrial Steel Construction. Fracture-critical F3 steel was used for tension members and T3 steel was designated for bending members.

When it came to constructability, the steel design facilitated construction in three ways:

- Falsework was kept to a minimum.
- The contractor, Archer Western, had the option of constructing the main arch span off-site, floating it in and lifting it into place or constructing the span over the river. (Because Archer Western had erection towers from a previous project, the span was built on-site as it was the more cost-effective option.)
- For the on-site option, crews could cantilever the steel erection over the navigation channel, which kept the river open to traffic during construction.

Steel also offered a greater span length. The main arch span length of 527 ft, an economical design not possible with concrete, was necessary due to the heightened potential for scour caused by


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▲ The bridge uses approximately 2,400 tons of steel.

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◄ A marker on the Missouri Riverfront in downtown Atchison commemorates the Lewis and Clark expedition's visit to the area.


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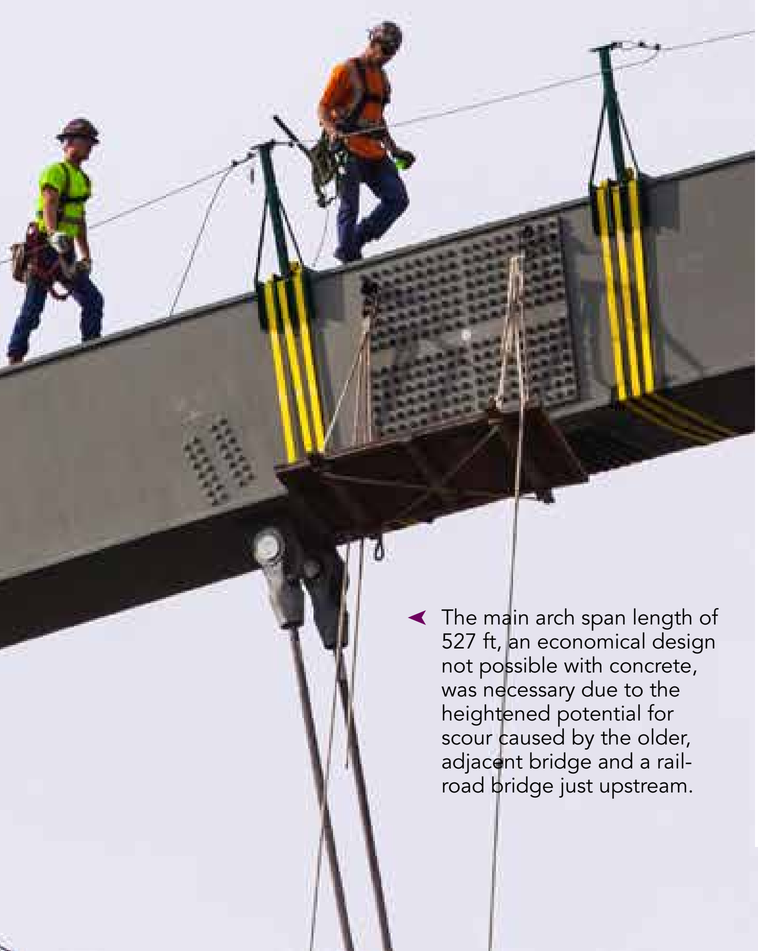

◄ The main arch span length of 527 ft, an economical design not possible with concrete, was necessary due to the heightened potential for scour caused by the older, adjacent bridge and a railroad bridge just upstream.


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the older, adjacent bridge and a railroad bridge just upstream. Steel also made it possible to achieve the required 52-ft vertical clearance over the river. (Concrete might have been applicable here but only if used in a more expensive cable-stay design.)

In terms of aesthetics, several aspects of the new bridge are references to either the original truss or to Amelia Earhart. The X-bracing between the ribs was chosen to provide a visual connection to characteristics of the earlier historic truss form. In addition, pier caps exhibit the rounded wing shapes of the planes Amelia flew in her day. At the community's request, designers added high-intensity beam luminaires to the arch portals, echoing the previous bridge's aesthetics. These twin beams of light cast an eternal gaze into the night sky and symbolize Earhart's passion for flying. Additionally, LEDs (light-emitting diodes) with changeable colors were provided along the top edge of the arch ribs to commemorate holidays, special events, and draw attention to the structure. Light poles and light fixtures were also selected by the community to tie in with the historic downtown.

A Springboard for Innovation

The designers were able to introduce several safety and cost-saving innovations to the steel tied-arch design:

Creating internal redundancy. Two main force-carrying components exist in the tied-arch system:

1. The arch ribs follow a parabolic curve, rising 90 ft above the driving surface for a span-to-height ratio of 5.83. The arch rib is a 4-ft wide by 4-ft, 6-in.-high welded box section, which allows for internal inspection of the arch rib and upper hanger connections.
2. The tie girder is a 4-ft-wide by 6-ft-high bolted box section between the ends of the arch ribs and contains the lower hanger connections. The bolted box section increases safety by internal redundancy.

Because tie girders carry tension and a loss of these members would result in catastrophic structural failure, tie girders are classified as fracture-critical. This weakness prompted a Federal Highway Administration (FHWA) advisory in 1978, recommending tie girders have redundant tie members. Since that advisory, few tied-arch spans have been designed until recently.

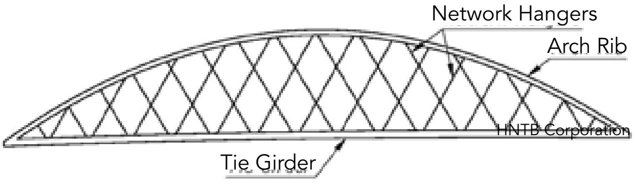
Engineers on the project addressed the FHWA advisory's concern by separating each tie girder plate. To create the necessary internal redundancy, the flanges were bolted to the webs, using 8-in. by 8-in. angles. If a crack were to occur in either flange or web, it would not continue through the adjacent plates and result in loss of the entire section.

Network hanger system increases redundancy. During the preliminary design phase, designers compared a network hanger system to a vertical hanger system and discovered the network hanger system provided increased redundancy, improved public safety and offered a 3% cost savings.

A network hanger system increases redundancy by connecting two hangers to the tie girder at the same point and angling them away from each other (Figure 1), so they attach to different locations on the arch rib. Using this technique, forces from a hanger loss are distributed to the adjacent hanger, and the tie girder still is supported at the hanger location.

The hangers used on the network arch of the new bridge are ASTM A586 pre-stretched bridge strand.

Figure 1: Network Hanger System



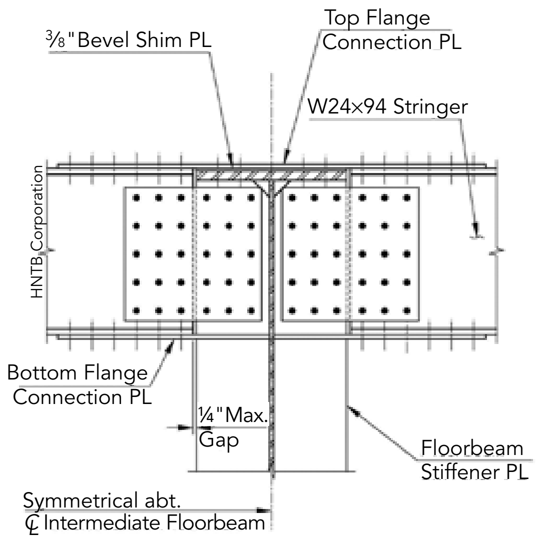


Figure 2: Stringer-to-Floorbeam Connection

The final arch rib, complete with topping out tree, being lifted into place.

Knuckles are critical to thrust transfer. The knuckle is where the tie girder and arch rib join, a critical component of a tied-arch design. Because the flanges in this region are discontinuous, the web plates are the critical link and must be able to transfer the arch thrust force to the tie girder. For the Amelia Earhart Bridge, the knuckle consists of 2¼-in. web plates on each side of the arch rib.

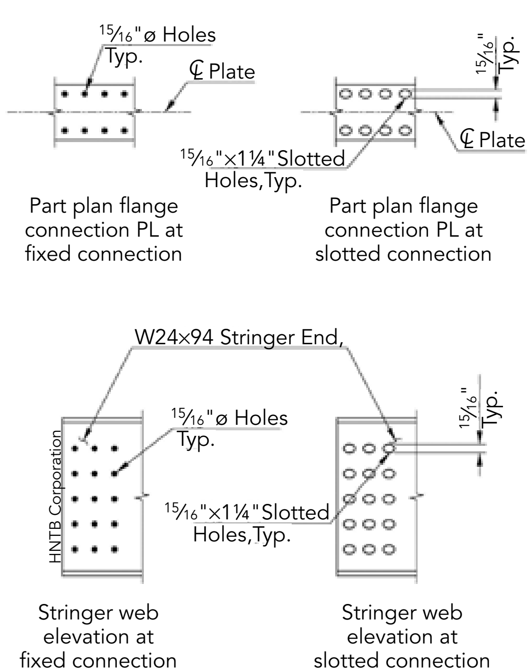
With the knuckle connections' complex geometry, using angles to connect the tie girder flanges to the knuckle web plate was not an option. Instead, crews welded a vertical tab plate to the top and bottom flange plates to allow bolting to the knuckle web plate. Because the knuckle is capable of carrying the entire tensile force in the web, shear lag effects had to be considered in the transition to the tie girder box shape.

Stringers framed into floorbeams address clearance restrictions. One of the biggest initial design challenges was securing the vertical clearance of approximately 52 ft over the river. The grade on the Atchison side of the new bridge was fixed because of an existing intersection, so designers had to reduce the superstructure depth as much as possible. To achieve this, they framed the stringers into the floorbeams so that the top of the floorbeam and the top of the stringer align (Figure 2). By comparison, a typical arch floor system uses stringers running atop the floorbeam.

In coordination with the framed-in stringer concept, designers detailed the stringer-to-floorbeam connections with slotted holes in one ply of the flange connection plate and the web (Figure 3). The slotted holes occur at every other floorbeam and allow the structure to elongate (bolts are only finger-tight) during erection and slab placement without inducing axial forces into the stringers under dead load. This allows the arch to deflect into shape with the placement of the deck. After the majority of the slab placement occurs, bolts in the slotted connections are fully tightened.

The resulting floor system of the new Amelia Earhart Bridge consists of floorbeams spaced at 15-ft intervals, corresponding to the location of the hangers with stringers spaced 8 ft, 3 in. apart. The intermediate floorbeams are 6-ft I-beam sections at

Figure 3: Stringer and Connection Plate End Connection Details



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▲ The final arch rib, in place.

the tie girder, with the top flange following the deck's slope. They are connected with 24-in. rolled beam stringers. The end floorbeam is a welded box section.

The new Amelia Earhart Memorial Bridge is the gem of the Atchison skyline—a signature structure that pays homage to its precursor and serves as a tribute to one of America's greatest pilots. MSC

Owners
Kansas Department of Transportation and Missouri Department of Transportation

Structural Engineer
HNTB Corporation, Kansas City

General Contractor
Archer Western, Chicago

Steel Team

Fabricator
Industrial Steel Construction, Inc., Gary, Ind. (AISC Member/AISC Certified Fabricator/NSBA Member)

Steel Detailer
Tensor Engineering, Indian Harbour Beach, Fla. (AISC Member/NSBA Member)