Saving A Piece Of History

by Edward P. Wasserman,
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As a result of its restoration, the bridge can now carry all legal loads. All photos: TDOT

In 1926, the town of Elizabethton, in Carter County, Tennessee, proudly cut the ribbon to open a newly completed concrete bridge, the Elk Avenue Bridge over the Doe River, just downstream from its only other river crossing, a covered timber bridge, built in 1882. The beautifully ornate bridge has stood just off the town square for over 80 years, surrounded by buildings dating from the 1700s to the 1930s.

By the late 1990s, the bridge had begun to suffer the affects of its age and lack of maintenance. It was required to be weight restricted and subsequently became a candidate for replacement under the Federal Highway Rehabilitation and Replacement Program. However, during discussions with the local government and citizens, it became apparent that there was a strong desire to save this treasure. The Tennessee Department of Transportation (TDOT) agreed.

The Elk Avenue Bridge is a classic example of a reinforced concrete fixed arch design developed by Daniel B. Luten, a 1894 graduate in Civil Engineering from the University of Michigan. Later, moving to Purdue University as an instructor, Luten was one of the leading United States proponents of using steel bar reinforcement in concrete arch construction in order to maximize structural efficiency and minimize cost.

profile

ELK AVENUE-DOE RIVER BRIDGE / ELIZABETHTON, TENNESSEE

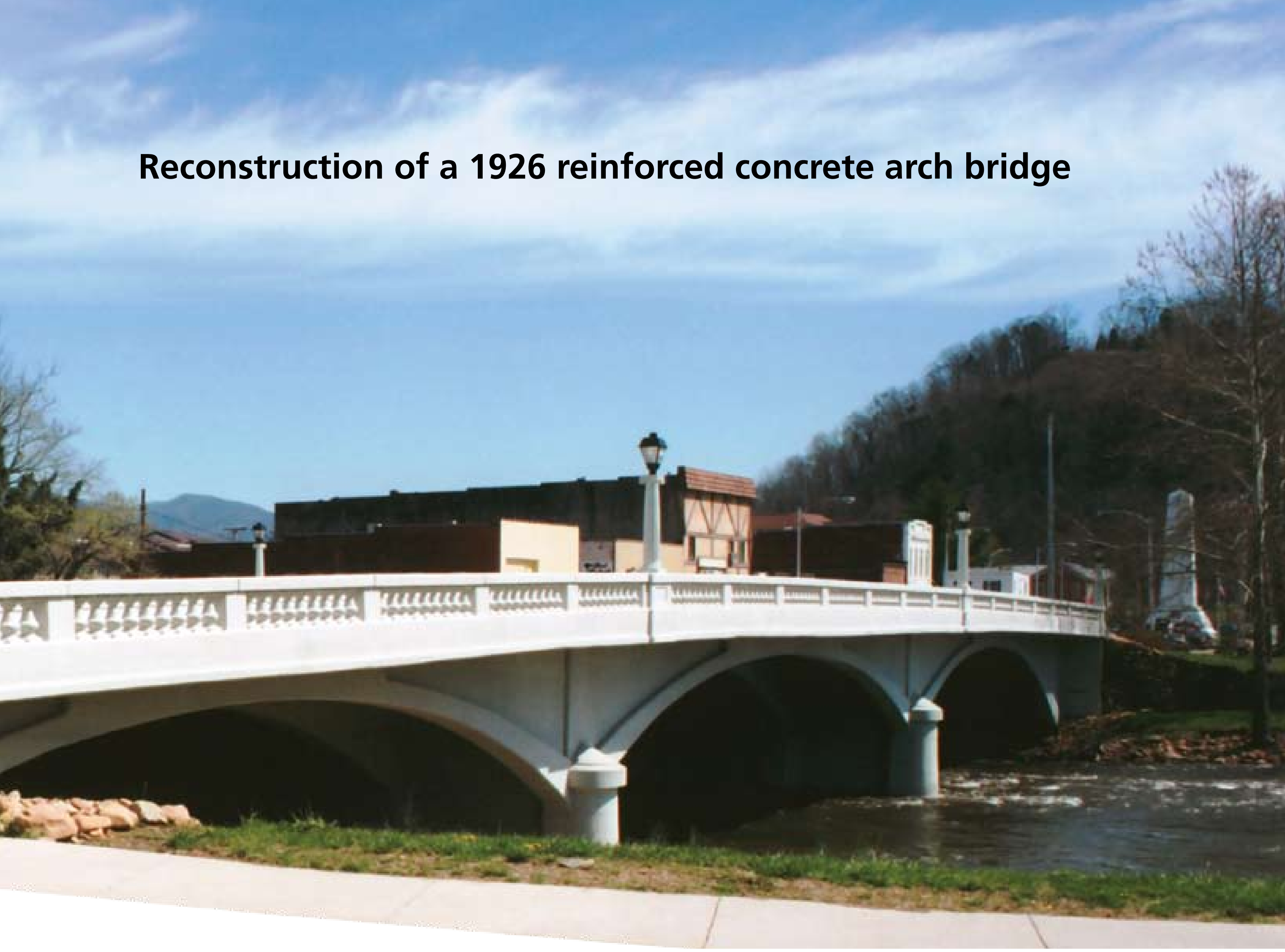
ENGINEER: Division of Structures, Tennessee Department of Transportation

PRIME CONTRACTOR: General Constructors, Elizabethton, Tenn.

CONCRETE SUPPLIER: Summer-Taylor Construction Company, Elizabethton, Tenn.

AWARDS: *Award of Excellence, PCA 2006 Tenth Biennial Bridge Awards Competition*

Reconstruction of a 1926 reinforced concrete arch bridge



Whereas many structural engineers of the day preferred to design arches using either steel bar mesh or structural shapes embedded in a cement and sand mortar mix to carry the stresses, Luten recognized the greater potential of structural concrete using sand, stone, and cement. He transformed arch construction by introducing the concept whereby steel bars provided a maximum of tension reinforcement and a minimum of compression reinforcement, allowing the concrete to serve as the main structural member resisting compressive stresses.

The Elk Avenue Bridge is one of only 1000 left, out of approximately 12,000 Luten bridges constructed. This particular one was designed and constructed by the Luten Bridge Company of Knoxville, Tennessee, one of several regional bridge companies established by Luten. The structure is a three-span arch with closed spandrel walls. Seven arch ribs support a 54-ft-wide roadway and two 12-ft-wide sidewalks on the 1-ft-thick concrete deck. Each span has a nominal length of 78 ft and a rise of 10 ft from the spring line.

A field inspection was undertaken to supplement the numerous biennial inspections that had previously been carried out under the National Bridge Inspection Standards. Limited cores were taken from the deck and indicated an average concrete compressive strength of about 3500 psi. Hands-on inspection in areas of evident deterioration as well as hammer soundings were used in order to quantify and characterize the type of repairs that would be required. Inspection was followed by a study of the details of construction, as well as limited analysis, to confirm to the

REINFORCED CONCRETE FIXED ARCH / CITY OF ELIZABETHTON, TENN., OWNER

BRIDGE DESCRIPTION: Three span arch with closed spandrel walls

STRUCTURAL COMPONENTS: Seven arch ribs with a span lengths of 78 ft supporting a 1-ft-thick concrete deck

BRIDGE REPAIR COST: Superstructure $506,000; Substructure $125,000

TDOT's satisfaction, that the bridge was indeed designed and constructed as a deck arch and not as a T-beam system. The existing reinforcement was square deformed bar and was assumed to be ASTM A 15-14 with allowable service load stress of 16,000 psi.

The general plan for rehabilitation called for complete closure of the bridge and then staged partial- and full-depth slab removal as well as removal and replacement of sections of the arch ribs in selected areas of each span. The work was organized such that only one line of arch ribs and contiguous concrete deck would be under repair on any given span, at one time. However, work in all spans could be carried out concurrently. In this manner, stable thrust block action could always be maintained in the bridge as a whole and it could be assured that the top of the arch ring and slab would remain in compression, as a system, after repairs. Upon completion of all repairs, the surfaces of the existing and repaired portions of the deck were milled 1-in. deep, swept, vacuumed, and washed and a 4½-in.-thick continuously reinforced concrete overlay placed.

The bridge is a three-span arch with closed spandrel walls that the residents wanted to save.

The 4½-in.-thick concrete overly was selected for three reasons:

- To bridge over existing temperature control joints with structural concrete;
- To provide an enhanced barrier against further ingress of chlorides; and
- To increase the compression area at the crown of the arch, thereby enhancing live load capacity.

The first two reasons are TDOT standards for most rehabilitation work. All reinforcement in the overlay was epoxy coated.

The quantity of estimated full-depth deck replacement increased about 25 percent during construction. More surprisingly to TDOT engineers, the amount of arch rib replacement tripled. The primary reason for this large overrun is rooted in the method of construction. For reasons unknown to TDOT, five of the seven 1-ft 4-in.-thick ribs were cast monolithically, while the first interior rib on each side of the bridge was 2 ft thick and cast with a longitudinal construction joint. During repair operations, it was determined that there were extensive internal pockets in these two ribs that contained uncombined sand, stone, and cement. Therefore, it was necessary to remove more rib material than planned.

Two classes of concrete were specified for the project. The repairs used a Class A concrete with a specified minimum compressive strength of 3500 psi and a maximum water-cementitious materials ratio of 0.45. The overlay concrete was a Class D bridge deck concrete with a specified minimum compressive strength of 4000 psi and a maximum water-cementitious materials ratio of 0.40. The contractor elected to use five different mixes for the Class A concrete depending on the application and the need to achieve the compressive strength at early ages. All concrete for the repairs was gravity fed and vibrated inside the forms. The overlay concrete was pumped.

The original spindles were made using a mortar and were replaced with precast concrete spindles.

The spindles of the original barrier were made using a cement-sand mortar and were badly deteriorated. The replacements, made of Class A concrete, were individually cast in a mold fashioned from one of the original spindles. The top rail was cast in place.

The restoration was completed within 12 months, and the bridge is ready for its second 80 years of service. The bridge can now carry all legal loads.

Because of the success of the Elk Avenue project, the TDOT proceeded to restore a sister, state-owned Luten arch located downstream, thus saving two outstanding examples of Daniel Luten's pioneering work.

Edward P. Wasserman is Civil Engineering Director, Structures with the Tennessee Department of Transportation.

For more information on this or other projects, visit www.aspirebridge.org.

'The bridge is ready for its second 80 years of service.'

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