Demolition of the Broadway Bridge over the Arkansas River

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ABSTRACT: This paper details the demolition of the 93-year-old Broadway Bridge over the Arkansas River. The bridge comprised 37 concrete-girder spans, three concrete-arch spans, and a single steel-arch span. Demolition activities occurred simultaneously with new construction over a short duration, requiring multiple machines to operate on the bridge at once for deck and girder removal. Spread-footing pier-stability limitations dictated that explosive demolition be selected as the demolition method.

INTRODUCTION

The Broadway Bridge has been a primary route over the Arkansas River for nearly a century, carrying traffic between downtown Little Rock and North Little Rock, Arkansas. Constructed in 1923, the bridge originally comprised of 37 cast-in-place concrete girder spans and five 200-ft concrete arch spans. In 1974, two of the concrete arch spans were replaced with a single 412-ft steel arch span. The entire length of bridge was successfully demolished in 2016 and replaced with two 440-ft tied-arch spans which were constructed on barge-supported falsework near the shoreline and then floated into position.

Figure 1 – Concrete Arches

Figure 2 – Steel Arch

CONSTRUCTION & DEMOLITION SEQUENCING

Because the new and existing bridge share a common alignment, demolition activities were limited to a short duration during a 180-day roadway closure that allowed new construction to take place concurrently. The sequencing of demolition activities required continuous coordination with the construction operations of the new bridge. A primary objective of the demolition was to first remove spans which interfered with progressing construction of the new bridge piers. New piers were located within the north approach spans (Bent 7), the two outer concrete arch spans (Bents 5 and 6), and the steel arch span (Bent 4). The bridge spans were divided into four separate zones of demolition, with activities occurring in each zone simultaneously.

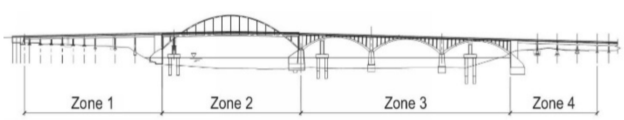

Figure 3 – Demolition Zones Overview

DEMOLITION ENGINEERING

A full evaluation of the structure was completed to determine what method and sequence of demolition would be feasible. The concrete arch and approach spans were nearly 100-years old by the time of demolition and were in a deteriorated condition. Much of the deck was in poor condition, with significant spalling observed from underneath at many locations.

The deck of the concrete arch spans and deck of the approach spans were originally designed to support both rail and vehicle traffic.

Figure 4 – Exposed Reinforcement in Beam

Based on information provided in the original construction documents, the concrete compressive strength and reinforcement yield strength of these spans were determined to be low. Four closely-spaced track girders acted as the primary longitudinal support of the arch spans, each spanning 10-ft between transverse capbeams. Four spandrel columns supported each capbeam and transferred load directly to two 12-ft-wide concrete arches.

The section of deck outside of the track girders was lightly reinforced and originally designed to support only a 15-ton design vehicle. This section of deck was 10-ft wide and spanned between the outer track girder and a curb girder near the deck edge. At 65,000 lbs, the excavators intended for use in deck removal were more than twice the weight of the road-roller design vehicle. Special restrictions were placed on the excavators to prohibit them from operating outside of the track girders. These restrictions required the machines to extend their arms between 20 and 25-ft to reach the outer barriers. To allow the excavators to work more closely to the edge of deck, timber crane mats positioned outside of the outer track girder were designed to support the outer excavator track by spanning between crossbeams, reducing load supported by the deck. Even with use of the crane mats, the low-strength deck was unable to support much of the remaining load without the outer excavator track remaining within 4-ft of the track girder. The capbeams and spandrel columns were determined to have adequate strength to support the demolition equipment.

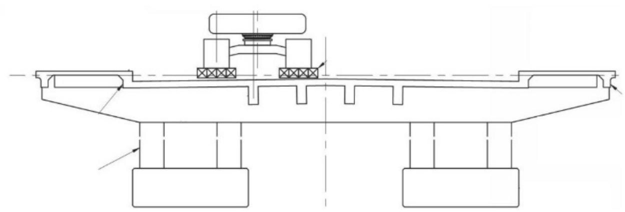

Figure 5 – Concrete Arch Span Deck

During a site visit, a number of discrepancies were observed between the original construction documents and the as-built condition of the bridge. At a few locations near expansion joints, two narrow spandrel columns were constructed instead of the single, wider column shown in the plans. These narrower columns were found to have a lower axial capacity due to their slenderness. At other locations, large holes were found cut through the center of capbeams for utility access. After these observations, a thorough investigation of the constructed-condition of the structure was conducted to confirm the accuracy of the demolition analysis.

The deck of the steel arch span was much newer than the concrete spans and had greater material strength. The stringers and floorbeams supporting the deck were determined to have adequate strength to support the demolition operations.

Figure 6 – As-Built Spandrel Columns

Figure 7 – Large Holes in Capbeams

The connections between the stringers and floorbeams were evaluated for uplift conditions which were experienced as the deck was removed from specific spans.

Demolition engineering for the three concrete arch spans proved to be the most complex aspect of the project, primarily due to the age of the structure and proximity of two of the new piers. Explosive demolition was initially disregarded as an option because of concern for damaging the new piers below and due to the proximity of downtown Little Rock.

An initial demolition plan studied the option of supporting the arches near midspan on falsework while breaking the arch section, allowing the unsupported portion of the arch to fall safely into the water away from the new pier. The supported section of arch would then be picked and carried away by a heavy-lift crane. Chipping away of the outer portion of the arches with a high-reach excavator was evaluated to reduce self-weight.

For this preliminary demolition plan to be feasible, the arches were required to support their own self-weight in flexure after being cut. While an arch is intact, it primarily experiences axial compression with little flexure. After a section is cut, however, the arch no longer experiences axial load and begins to act as a beam with significant flexure. During an evaluation of the flexural capacity of the arches, photos from the steel arch construction from the 1970s were investigated. In the photos, it was discovered that falsework was required to support the cut concrete arch only a short distance from the pier, suggesting the cut arch was unable to span a great distance while supporting self-weight.

The evaluation of the flexural capacity of the arches ultimately determined them to be inadequate to support their own self-weight, eliminating the option of cutting the arch during demolition. The conclusion was correspondent with the photos of previous demolition. At this time, explosive demolition was considered as the most viable option.

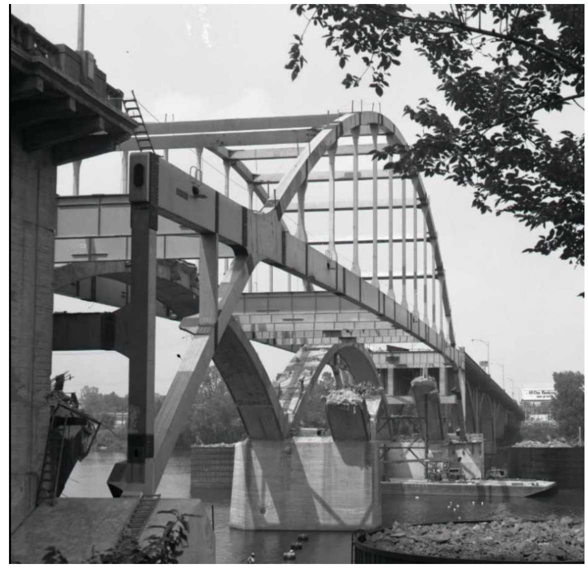

Figure 8 – Previous Demolition (1974)

After explosive demolition was selected as the method of arch removal, the sequence of demolition was evaluated. Removal of the two outer arch spans was the priority to provide access for completion of the new pier construction. Stability of the concrete arch piers controlled the sequence of removal. Since the five concrete arches were constructed simultaneously, the arch piers were not originally designed to support imbalanced loading. Removal of the arches from one side of a pier would induce unequal thrust and potential instability. In addition, the original construction documents indicated the base of the existing piers were physically set in rock, but not seated to resist uplift or develop rotational fixity.

The method of construction used for the steel arch replacement (1974) was important in fully understanding loading scenarios which the piers had previously experienced. During the replacement of two of the concrete arch spans, additional concrete was added to the outer arch pier (Pier 2) to act as a counterweight.

Figure 9 – Counterweight Added to Pier 2

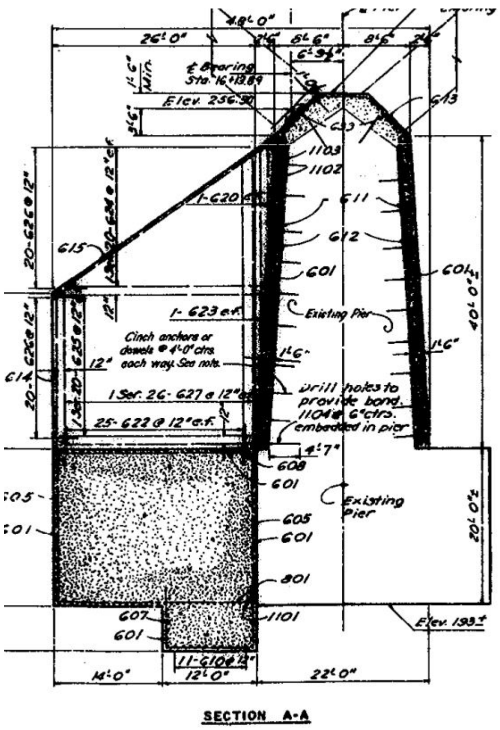

Figure 10 – Added Pier Counterweight

This counterweight provided stability to the pier against overturning as the concrete arches were removed from one side. The need for this counterweight suggested that the remaining unmodified piers could not support load from the concrete arches on only one side.

An evaluation of pier stability was completed to determine the requirements for order of demolition. The stability of Pier 2 (which supported both the steel arch and a concrete arch span) was evaluated considering both removal of either the steel span or concrete span first since the order of demolition was unknown at the time. The initial removal of the deck from each span benefited pier stability by reducing thrust from the arches on each side. Finite element models were developed for the steel and concrete arch spans to accurately represent loading to the piers. The models were built to allow for incremental removal of structural components of the spans, such as deck, stringers, crossbeams, spandrel columns, etc. The models also allowed for the width of the concrete arches to be reduced, representing the act of chipping away the sides of the arch to reduce load.

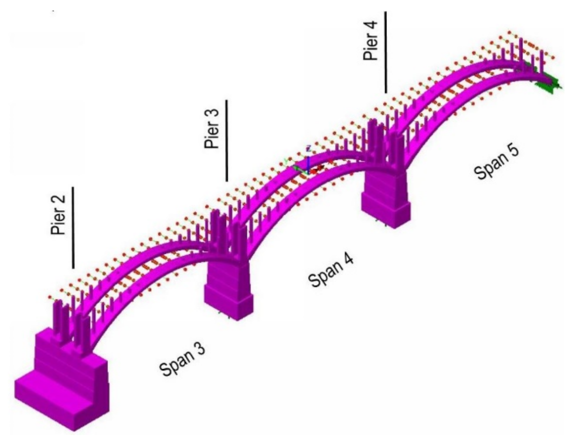

Figure 11 – Pier Stability Model

For the pier stability evaluation, a minimum factor-of-safety of 1.5 was deemed acceptable. The evaluation determined that Pier 2 could maintain stability while load from either the steel or concrete arches was completely removed. This was an important finding because it allowed the steel and concrete arches to be explosively demolished separately and in any order. Unfortunately, the other two piers (Piers 3 & 4) were determined to be unstable when the arch load was fully removed from one side. In addition, Piers 3 & 4 were determined to have minimal stability in a scenario in which the deck was removed from one side, but the deck remained on the other. From this evaluation, it was decided that the deck overhangs would be removed along all three concrete arch spans prior to full deck removal to improve stability conditions. In addition, the evaluation confirmed that all three concrete arch spans would need to be explosively demolished at once, unless a significant portion of the arches were to first be chipped away to reduce unequal loading on the piers

DEMOLITION OPERATIONS

Demolition activities began with removal of the deck in each zone. Multiple excavators utilized impact hammers to break up the concrete, which then fell below.

Figure 12 – Multiple Excavators on Deck

For the approach spans, the excavators operated directly over longitudinal girders and chipped away the concrete between. After the girders were all that remained, a high-reach excavator knocked them to the ground.

Figure 13 – Deck Removed Between Girders

Figure 14 – Deck Removed in Approach Spans

Beginning on the south concrete arch span, the excavators first removed the outer 7-ft of deck overhang and crossbeams. After the overhang removal had progressed 200-ft, an additional excavator followed behind and removed the remaining portion of the deck, crossbeams, and spandrel columns. To reach the lower portions of the spandrel columns, it was necessary for the excavator to be positioned very close to the demolished edge of the deck – approximately 1-ft from the edge at times. Restrictions were placed on excavator positioning near expansion joints in the spans to prevent the machine from being supported on isolated sections of deck.

Figure 15 – Deck Overhang Removed

Figure 16 – Excavator Deck Removal

Figure 17 – Excavator Deck Removal

Figure 18 – Edge of Deck Removal

Figure 19 – New Bridge Supported on Falsework with Demolished Bridge in Background

Steel arch deck removal began at mid-span, with two excavators simultaneously working in each direction. By having the deck removed simultaneously on each end, the steel arches did not experience unequal loading.

The concrete arches were explosively demolished simultaneously prior to demolition of the steel arch span.

The use of explosive demolition was originally planned for the steel arch span. To protect the new pier below the arches, a support system was designed to support the south end of the arches over the new footing while the remainder of the structure fell into the water. This system included temporary posts supported on the new pier, supporting the end of the arches. The end bearings of the arches were reinforced to provide the required support after the arches were cut. Locations of explosive charges were selected by others to break the structure into reasonably-sized sections that could later be picked from the river. The contractor was given a temporary waterway closure to bring down the span and remove the material from the river.

Figure 20 – Arch Support System

The steel arch structure was evaluated subject to the placement of sectional trimming as required for placement of the explosive charges. The trimmed sections were evaluated for structural adequacy supporting self-weight and wind load during a temporary condition prior to detonation.

Unfortunately, the span did not fall following the execution of the explosive detonation and the structure remained in-place in a compromised state and in an unknown state of stability. Since the stability of the structure was compromised from the detonation, it was dangerous for anyone to get near the bridge for an inspection.

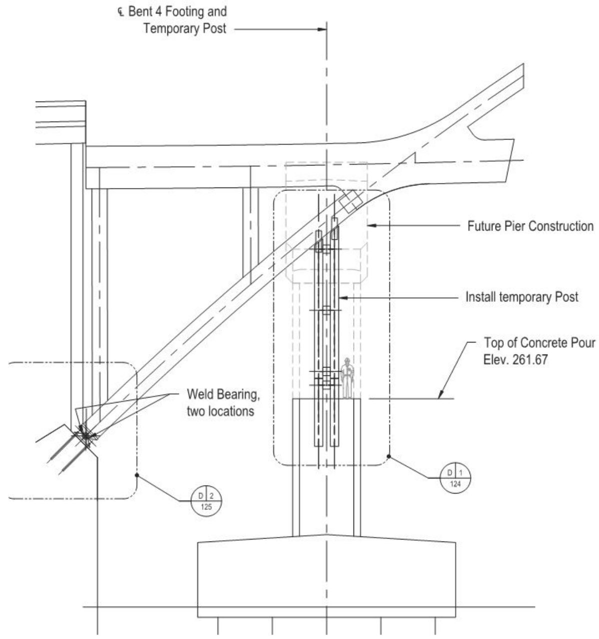

Figure 21 – South-End Arch Support System

Field staff were able to connect cables to the bottom chord member of the bridge and utilize barges to pull on the cables until the structure finally fell into the water. The bridge sections were lifted from the water as planned. The support system successfully held back the south end of the arch, even with the unconventional method of demolition.

Figure 22 –Steel Arch Span

ACKNOWLEDGMENTS

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