

Wichita Riverfront Pedestrian Bridges

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ABSTRACT

As part of the riverfront development program in Wichita, Kansas, two cable-stayed pedestrian bridges were constructed as part of a bike and pedestrian transportation system. HNTB was responsible for the preliminary and final design of these two unique pedestrian bridges, which spanned 320 feet and 240 feet to provide access across the confluence of the Arkansas and Little Arkansas Rivers. To allow for both an aesthetically pleasing superstructure depth and minimal construction in the rivers, the bridges were designed segmentally with four longitudinal post-tensioning tendons in each bridge. The typical segment was 32 feet long and included the embedded lower cable anchorage plates. The bridge design also included consideration for lateral and vertical pedestrian-induced excitation, and tuned mass dampers were provided to meet the pedestrian comfort criteria. The total construction cost for both bridges was approximately \$6,800,000, and was funded by the City of Wichita.

Keywords: Cable Stay, Precast, Post Tensioning, Pedestrian, Tuned mass damper

INTRODUCTION

To enhance the City of Wichita's bike and pedestrian transportation system, a cable-stayed bridge design concept with asymmetrical tower locations was recently completed in May 2007. The bridges link paths on each side of the river, and between the two bridges lies the "Keeper of the Plains," a 45-foot, raised statue that is one of the city's icons. The bridge's tapered tower pylons and unique stay-cable configuration are reminiscent of feather shapes and patterns found in some Native American headwear. HNTB provided the preliminary and final design of these two unique pedestrian bridges, which span 320 feet (Bridge #1) and 240 feet (Bridge #2) to provide access across the confluence of the Arkansas and Little Arkansas Rivers. The total construction cost for both of these signature bridges was \$6.8 million. Figure 1 shows the layout for Bridge #1.

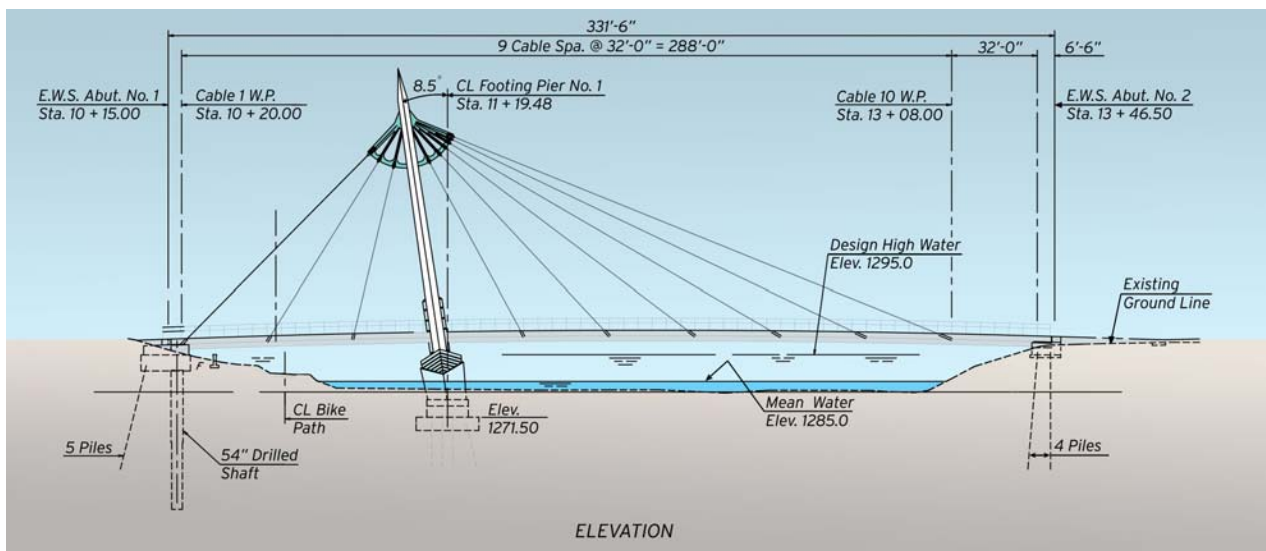


Fig. 1 Layout of 320 foot long Bridge #1

SUBSTRUCTURE DESIGN

The substructure for each bridge consists of a fixed abutment, an expansion abutment, and a river pier with accompanying steel tower. The river pier and expansion abutment (at end of the main span) are founded on steel H-piles. The fixed abutments for both bridges are founded on a combination of two 4.50 foot diameter drilled shafts and battered steel H-piles. Because the tension in the main anchor cable results in uplift at the fixed abutment, the superstructure box segment is post-tensioned to the anchor abutments. Correspondingly, the drilled shafts are designed for an uplift force of approximately 575 kips per shaft. To resist the horizontal component of the anchor cable tension, steel H-piles are battered in the longitudinal direction (away from the bridge) and are also designed in tension.

STEEL TOWER LEGS

In order to support the cable-stayed superstructure, a two-leg welded steel tower is embedded in the steel reinforced concrete river pier and extends upward to a height of 124 feet above the pier along an 8.5° slope. See Figure 2. Each tower leg is also curved along a 300 foot radius. The cross-section for each tower leg is an equilateral triangle that reduces in cross section as it is curves upward toward the other tower leg. The triangular cross-section tapers from a 5.0 foot width at the base to 3.67 feet at the top. The structural steel for the tower legs was Grade 50W.

For aesthetic purposes, rusticated copper cladding is attached to the lower portion of upstream tower leg and upper portion of river pier.



Fig. 2 Erection of steel tower legs

SUPERSTRUCTURE DESIGN

To allow for both an aesthetically pleasing superstructure depth of 4.0 feet and minimal construction in the rivers, the bridge superstructures feature a segmental box girder with four longitudinal post-tensioning tendons in each bridge. The typical segment is 32 feet long and includes the embedded lower cable anchorage plates. Because of the slenderness of the superstructure, the bridge design also included consideration for lateral and vertical pedestrian-induced excitation. The design live loading is the maximum of

either an 85 psf uniform load or an AASHTO H10 truck (20 kips), which accommodates emergency vehicle access.

The stay cables are typically 2.0 inch diameter galvanized structural strand with standard open strand sockets at upper anchorages and standard anchor strand sockets at the lower anchorages. Stay cables located nearest the anchor abutments are 3.375 inch diameter structural strand with similar socket types. All of the stay cables are designed to be replaced individually, if required.

PRECAST GIRDER SEGMENTS

The match-cast segmental concrete superstructure was cast with the lower stay cable anchorages embedded within the segments at time of casting and oriented both longitudinally and transversely to receive the stay cables. The two cell concrete segments are 12.33 feet out to out and provide a 10 foot walkway. The concrete for these superstructure segments is Class AAA(AE) and has a design strength of 6,500 psi. Since there are temporary access openings in the top slab of each box segment to allow for connection of the post-tensioning ducts, the deck has a 1.50 inch silica fume concrete overlay. See Figure 3 for a typical cross-section of the deck.

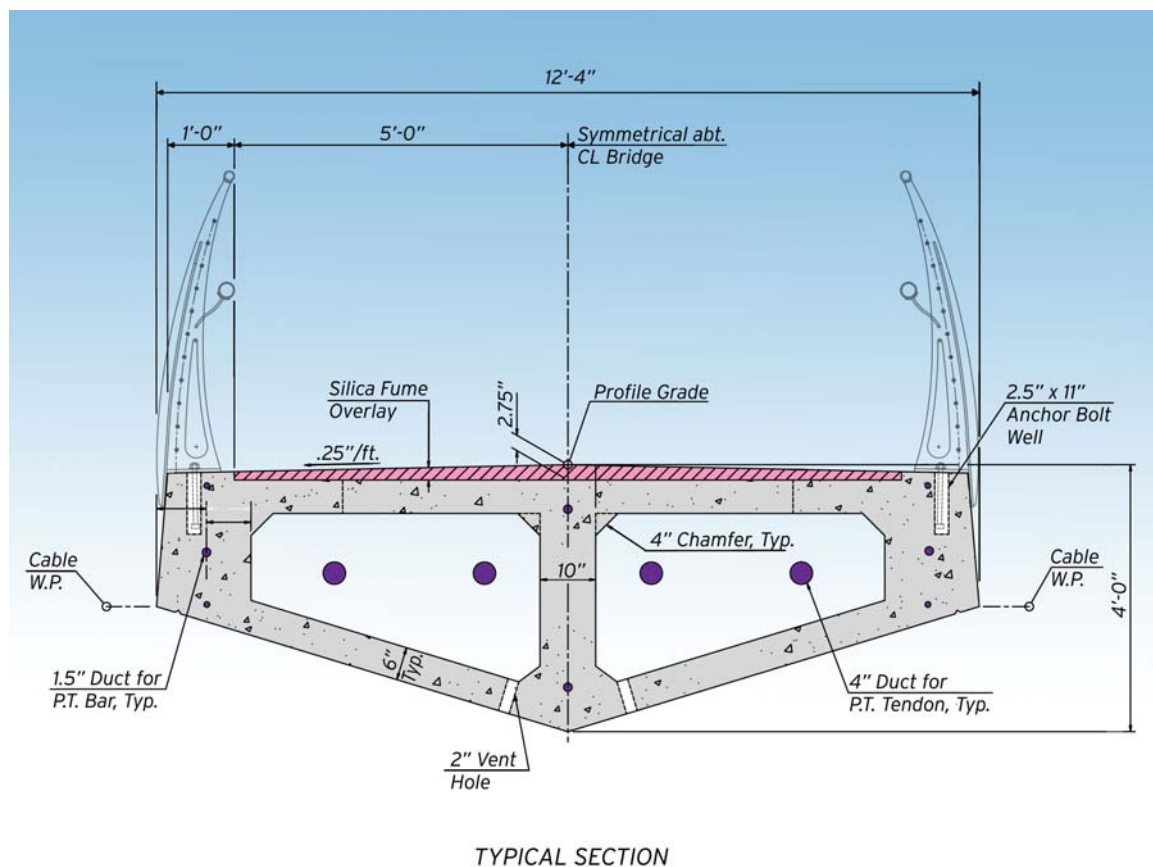


Fig. 3 Typical cross-section

For construction of the bridges, the concrete segments were transported to the site, erected on falsework over the river, post-tensioned and then lifted off falsework as tensioning of the stay cables progressed. After all stay tensioning was completed, tuned mass dampers were installed within the concrete segment cells of each bridge and adjusted to counter pedestrian live load movement that could excite the natural superstructure frequency. Further discussion on the tuned mass dampers can be found later in this paper.

The bridge railing is comprised of custom fabricated curved steel posts with a top pipe rail, a mid-height hand rail and eleven lines of 0.3125 inch diameter stainless steel wire rope spaced at about 4.0 inch centers, see Figure 4. In addition, walkway light fixtures are anchored to the deck and flood lights are fixed to the lower anchorage of each stay cable to provide aesthetic lighting of the cables.

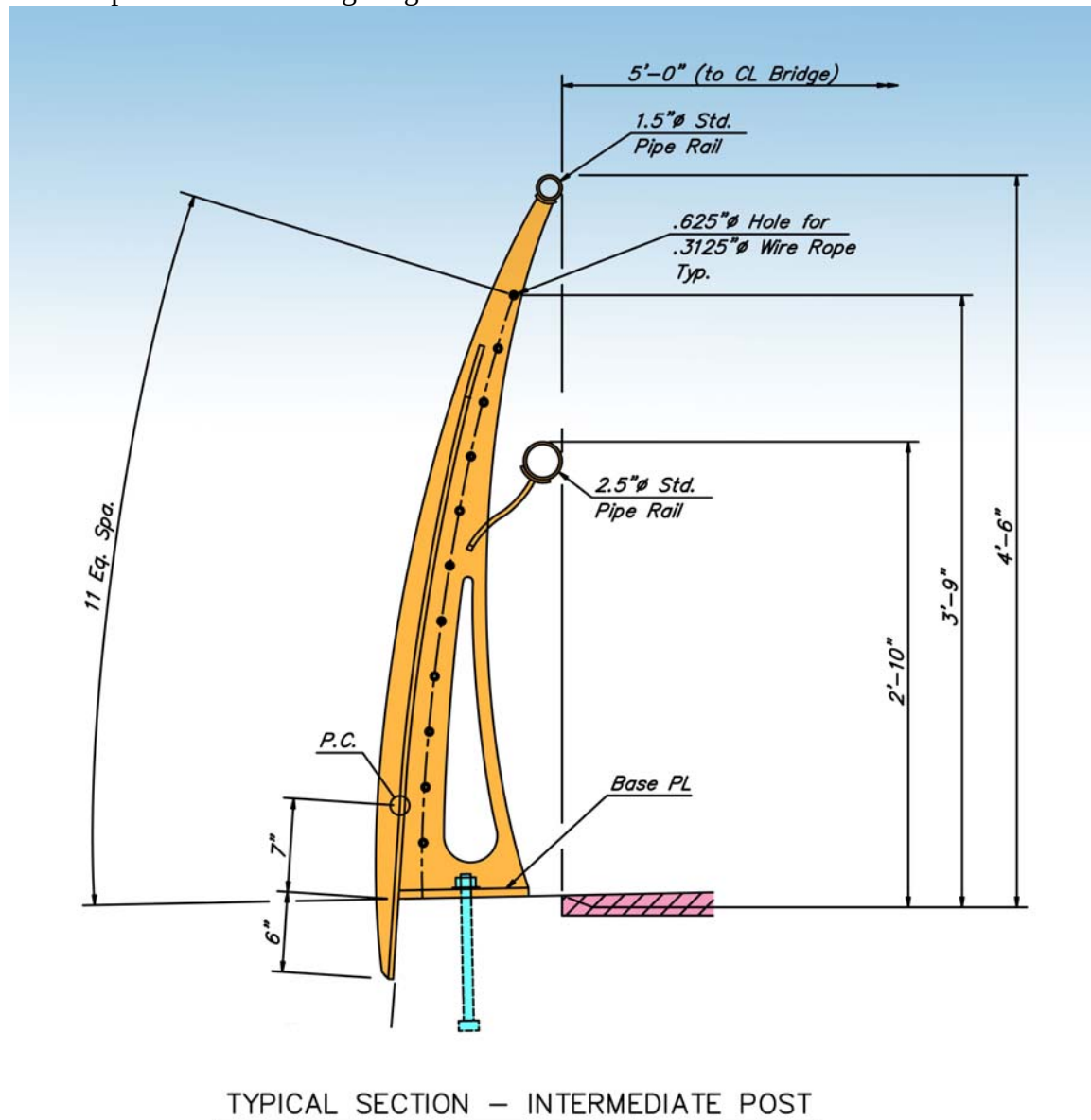


Fig. 4 Typical Railing Section

LOWER CABLE ANCHORAGES

At the deck level, the cable anchorages consist of built up steel plate sections that are embedded into the concrete superstructure segments. Welded to one end of the anchorage plate, a pipe receives the strand anchor socket. The remaining portion of the plate was embedded into each segment's eight foot thick solid concrete diaphragm. To transfer the load from the anchorage plate to the surrounding concrete diaphragm, 0.875 inch diameter shear connectors were welded on both sides of the plates. Figure 5 illustrates the anchorage plate in relation to the typical section. With the large cable loads concentrated in these steel sections, a finite element analysis was conducted to ensure there were no stress concentration details that could affect the integrity of the connection. Additionally, because of the small superstructure cross-section, great effort went into detailing and verifying any conflicts between the embedded steel anchorage plates, post-tensioning tendons and bars, and reinforcing bars. Figure 6 shows the lower cable anchorage plate after being set into the precast forms.

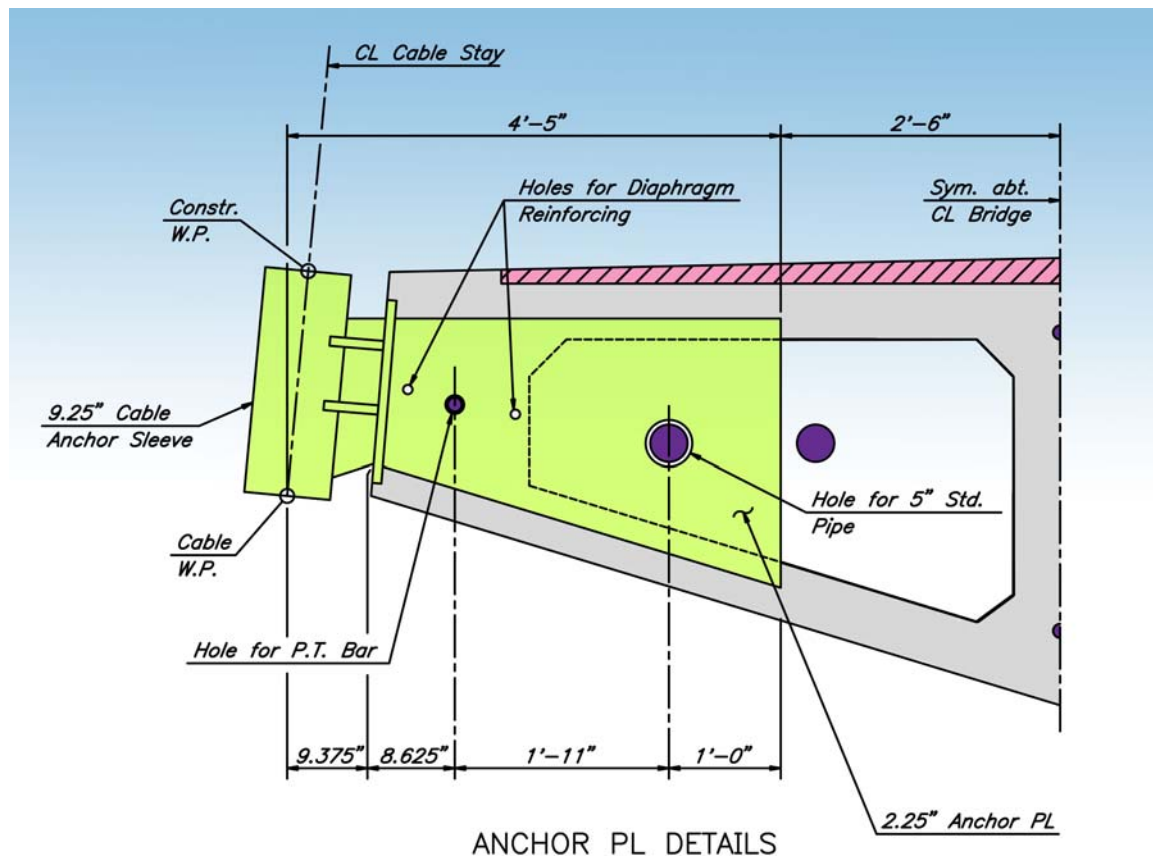


Fig. 5 Lower Cable Anchorage Plate



Fig. 6 Lower Cable Anchorage Plate placement

UPPER CABLE ANCHORAGE

The upper cable anchorage is a built-up welded steel section, radial in shape, and is located at the junction of the two steel legs approximately 85 feet above the deck. The anchorage assembly is attached to the tower legs via a bolted connection to a steel box section framed into the tower legs.

This steel plate anchorage assembly is shaped aesthetically as a “headdress”, and was designed with constructability in mind. The steel plate anchorage plate assembly was detailed with field-welded splice locations to allow for transportation of the approximately 30 foot wide, 22 kip anchorage assembly. Figure 7 shows the “headdress” being raised into position before the cable stays are connected.

The stay cables are comprised of structural strand with an open strand socket at top and an adjustable anchor socket at the lower cable anchorage plate.



Fig. 7 Upper Cable Anchorage Assembly & Tower Top

TUNED MASS DAMPERS

Due to the slenderness and flexibility of the superstructure, a vibration analysis was conducted on both bridges. During preliminary design, the potential for vortex shedding instability was identified, and thus a sectional model wind vibration study was conducted by RWDI, Inc. in Guelph, Ontario, Canada. The results indicated that the structure would be stable for the maximum sustained wind conditions at the site.

Also of special interest was the potential for pedestrian vibrations to excite the natural frequencies of the structure (similar to the Millennium bridge incident in London). After detailed analysis, HNTB elected to use tuned mass dampers so that the pedestrian comfort criteria would be met. Motioneering, Inc. was tasked with the conceptual and final design of the tuned mass dampers. For Bridge 1, lateral mode 3 and vertical modes 6 and 9 were damped by the use of dampers at two different locations. Bridge 2 was damped for vertical modes 1 and 7 and lateral mode 9 in a similar manner. Figure 8 shows the orientation of the tuned mass dampers inside the concrete segment, shortly before the slab opening is formed up.

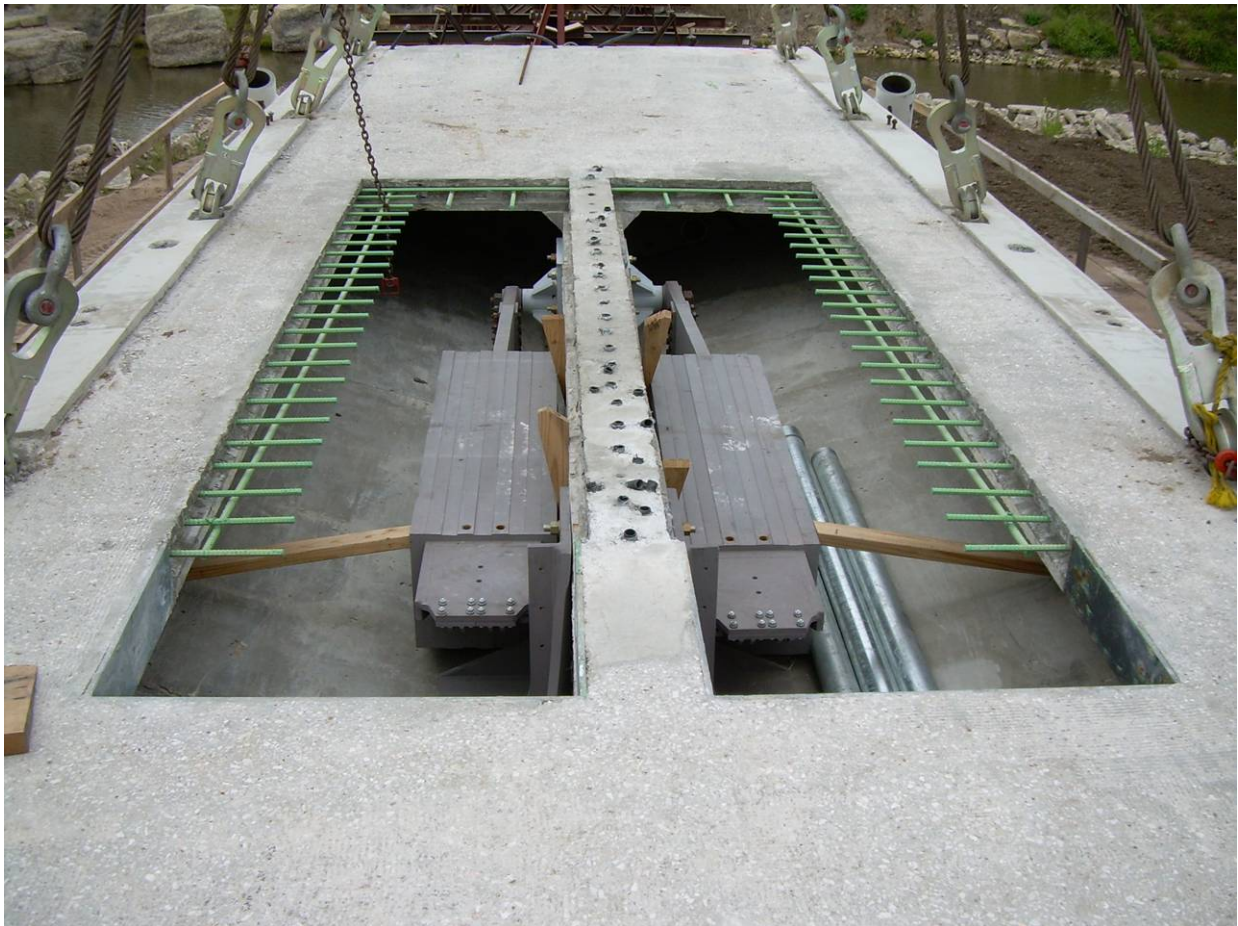


Fig. 8 Installed Tuned Mass Dampers

SUMMARY

The design of these bridges proved to be very challenging and unusual in many different aspects: drilled shafts anchored in tension, upper cable anchorage assembly, lower cable anchorage plates, and pedestrian vibrations. All of these challenges were overcome successfully and allowed the City of Wichita to have two “signature” structures as part of their enhanced riverfront park. The construction of these two pedestrian bridges was successfully completed in May 2007 (see Figure 9) and they have been well received by the community.

ACKNOWLEDGEMENTS

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Additional team members were Law Kingdon (architects), and Motioneering (tuned mass damper analysis and fabrication).



Fig. 9 Completed Pedestrian Bridges