Strengthening of the I-39 Bridges over the Kishwaukee River

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Summary

The Kishwaukee River Bridges, built in 1980, carry interstate I-39 over the Kishwaukee River Gorge south of Rockford, Illinois. These twin bridges consist of five spans of precast, post-tensioned segmental concrete box superstructure with a typical span length of 76.3 m. During the balanced cantilever erection of the southbound structure, the epoxy applied to the segment joints did not properly harden creating excessive stresses in the single-key shear keys. A retrofit was carried out before the structures were opened to traffic involving placing stainless steel dowels set in epoxy across the overstressed joints.

The box girder webs have been displaying continuous cracking and crack growth. A structural investigation determined that the passive method used to remedy the shear capacity deficiencies has left large forces in the shear keys responsible for the stress cracking observed in the bridge causing continued deterioration. Parsons proposed rehabilitation and strengthening of these structures using external post-tensioning tendons placed inside the box girders which actively reduce the shear forces and principal stresses in the box girder webs.

This paper focuses on the strengthening concept employed and special details developed to allow installation of the external tendons with minimal disturbance to the box girder's concrete and the embedded post-tensioning. Other highlights include a discussion of the supporting measures implemented to assure long-term safety and durability of these structures like the fixed anti-icing system that eliminates the need to use salt on the bridge deck.

Keywords: external post-tensioning; segmental; strengthening; bridge; fixed anti-icing spray technology.

1. Structure Study

A structure study was performed to determine the causes for the crack development in the webs of the northbound bridge and the continued crack growth in both structures and to developing strengthening concepts. Deficiencies were evaluated using a time dependent model and a load rating approach. The effectiveness of the strengthening concepts was evaluated by comparing load ratings of the structure following implementation of the strengthening concept with load ratings of the as-built structure.

Substandard ratings were calculated for combined web ultimate loadings at locations near the piers.

Principal stresses in the webs were examined and found to be above code limits prior to application of live loads. The high levels of principal tensile stresses have contributed to the continued crack development and growth in both bridges.

2. Strengthening Design

Four, 12-strand, 15 mm, draped post-tensioning tendons are being installed near each box girder web. The tendons are external to the concrete, located inside the box girder. The peaks of each

https://doi.org/10.2749/222137908796292254

tendon path coincide with either pier or abutment centrelines. Low points of the tendon paths coincide with either the fourth or seventh segment from the path peaks. The tendon layout used allows for stressing operations to be conducted at deviator blocks located at the piers, see Figure 1.

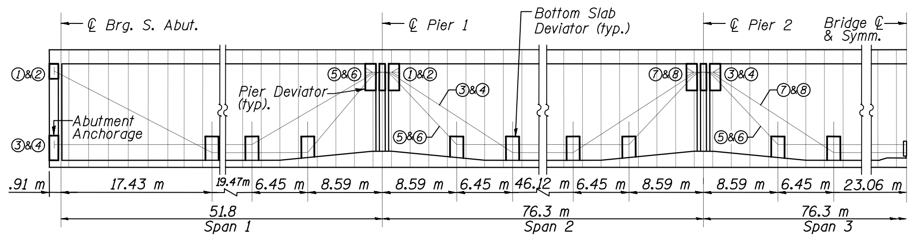

Fig. 1: Tendon Layout

The selected tendon layout required the addition of three elements to the structures: bottom slab deviators, pier deviators and abutment anchorages.

The bottom slab deviators consist of concrete block extending the entire width of the box girder, post-tensioned directly to the box girder webs. Tendon deviation paths are formed by diabolos. Diabolos can accommodate various tendon paths and provide the system with tolerances for tendon alignment in all directions.

Longitudinal post-tensioning bars are used to anchor deviator blocks at the piers to the existing 0.41 m thick pier diaphragms. Bent steel pipes inside oversized corings form the tendon paths at the diaphragms.

The abutment anchor blocks are cast on the abutment side of the abutment diaphragm and connected to the box girder using mild reinforcing steel.

Measures are being put in place to minimize the structures exposure to corrosive de-icing salts. A Fixed Anti-icing Spray Technology system is being installed consisting of spray nozzles embedded in the bridge overlay between the two traffic lanes every 12 m. The box girder top slab is protected with a waterproofing membrane and hot-mix asphalt overlay.

3. Strengthening Implementation (Construction)

The contractor is required to located existing post-tensioning adjacent to each core hole using ground penetrating radar (GPR). This requirement proved to be prudent as the as-build locations of several of the pier diaphragm tendons differed from their locations shown on the shop drawings, making it necessary to revise the locations for some corings. The resulting modification to the pier deviators did not affect the bottom slab deviators as the diabolos are able to accommodate the different tendon paths.

4. Conclusions

The application of external draped post-tensioning tendons is an effective way to strengthen concrete box girder structures. Key to a successful implementation is locating existing tendons, limiting hardware dimensions and weights, and minimizing impacts on the existing box girder. Traffic closure durations can be limited to the concrete deviator and anchor block pours and grouting of the installed tendons.