The Franklin Avenue Bridge:
Investigation and Rehabilitation Design

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The Franklin Avenue Bridge, constructed from 1919 to 1923 in Minneapolis, Minn., and listed in the National Register of Historic Places, crosses the Mississippi River with five open-spandrel, concrete arches. During the bridge's nearly 100-year history, harsh winters and aggressive deicing operations have resulted in advanced deterioration. Beginning with a condition investigation in 2007 and culminating in construction slated for completion in 2017, a rehabilitation project has been executed to restore this historically important structure. This Concrete Bridge Preservation article focuses on the investigation and rehabilitation design; an article[1] in the Summer 2017 issue of *ASPIRE*® focused on the structural analysis and the accelerated bridge construction methods used to replace the deck, cap beams, and railing. Additional details about this project can also be found in two articles published in *Concrete International*.[2,3]

The bridge spans consist of two parallel arch ribs ranging from 55 to 400 ft in length. The bridge has a total of five spans, an overall length of 1014 ft, and a 66-ft 4-in.-wide deck. The concrete arch ribs are reinforced using the Melan system—steel trusses composed of double-angle chords connected with riveted steel gusset plates and diagonal crossbraces. The steel trusses were erected between the piers, and then concrete was cast around the trusses forming the arch rib. No conventional reinforcement was included in the arch ribs. They were reinforced by the embedded trusses only. The historical concrete mixture incorporated gap-graded local aggregates. To accommodate the large (2½ in.), angular coarse aggregate, a high water-cement ratio (*w*/*c*) of about 0.50 was required in the non-air-entrained concrete mixture.

Investigation

The rehabilitation process began with comprehensive investigation of the condition, performance, and historic importance of the structure. A follow-up assessment was conducted during the repair design phase to refine the repair approach and update estimates of repair quantities. The scope of both condition assessments consisted of an overall visual examination of the bridge and subsequent detailed surveys, and nondestructive testing and sampling of materials at representative areas.

Franklin Avenue Bridge during condition investigation by snooper truck. Photo: WJE.

Concrete deterioration and reinforcement corrosion below deck expansion joints. Photo: WJE.

Close-up view of same pier showing loss of concrete cover at pier corner. Photo: WJE.

Applying board-form finish to dry-method shotcrete repair on the underside of an arch rib. Photo: HNTB.

The assessments identified widespread concrete deterioration in the original concrete piers, abutments, and arch ribs to a depths as great as 22 in. below the surface, as well as longitudinal cracking along the top and bottom surfaces of the arch ribs (generally aligned with the upturned legs of the embedded steel angles). Testing showed that the causes of the deterioration were primarily chloride-related corrosion of the embedded trusses and conventional reinforcement, long-term exposure to moisture, and freezing-and-thawing cycles.

The deterioration in the various bridge elements was largely determined by their exposure to chloride-laden water from deicing salts leaking through expansion joints or by drainage of water onto the concrete surfaces. For example, the deck soffit, cap beams, and some of the spandrel columns located below expansion joints exhibited widespread and sometimes advanced delamination, spalling, and corrosion of embedded reinforcement due to chloride contamination of the concrete; in contrast, elements away from deck joints were in much better condition. High levels of chloride in the deck had also begun to produce corrosion-related damage.

Rehabilitation Design and Details

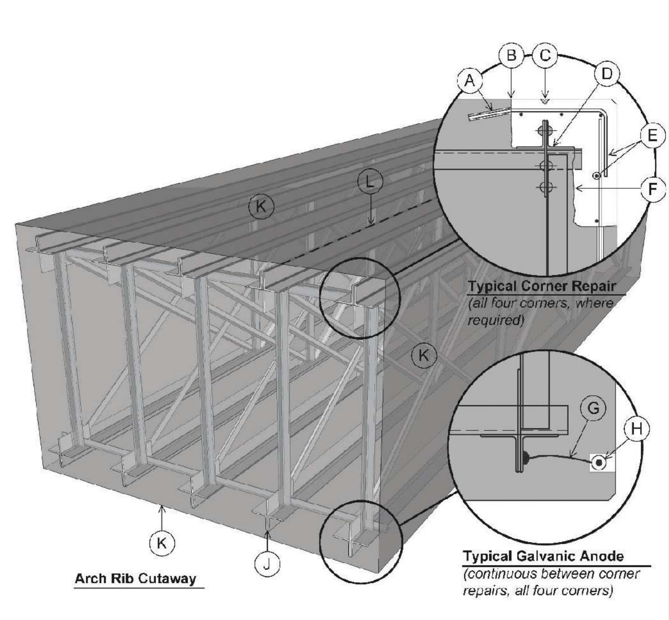
The investigation showed that the bridge was generally competent to support vehicle loading. However, deterioration in many of the bridge elements, particularly those located near expansion joints, along with a refined structural analysis and load rating, traffic study, historic property evaluation, and life-cycle cost analysis, prompted the following selective rehabilitation:

- complete removal and reconstruction of the deck and cap beams, with a traffic configuration of two central vehicle lanes flanked by barrier-separated pedestrian and bicycle lanes along the bridge length, and a wider four-lane roadway on the east end to transition into a challenging five-legged intersection just off the bridge;
- rehabilitation of the original historic concrete (piers, abutments, and arches) using historically sensitive, durable concrete repair methods supplemented with a water-resistant concrete coating and targeted corrosion mitigation along the arch rib corners; and
- restoration of historic features, including historic cap beams with scrolled ends, exterior ornamental barriers, light fixtures, deck fascia entablature, and re-created observation bays over the river piers.

The guiding principle behind the repair design was to detail the repairs in ways that would address the root deterioration mechanisms identified while recognizing the historic sensitivity of the structure. Based on a structural analysis of thermal effects, the new deck design reduced the number of deck expansion joints from 15 to 6, with none of the 6 joints located above a pier. This design reduces future leakage potential, which is expected to extend the life of the vulnerable historic concrete.

Concrete surface repairs were specified and detailed for all locations where delaminations and spalls were present. The specifications demanded high-quality concrete repair techniques, including perimeter saw cutting, removal to sound concrete using light chipping hammers, substrate preparation via sandblasting, sandblast cleaning and coating of exposed reinforcement, and anchorage using epoxy-grouted bars. The specifications were designed to allow the contractor to choose form-and-pour, form-and-pump, or shotcrete methods with either prepackaged or ready-mixed concrete for each type of repair. The contractor chose prepackaged dry-mix shotcrete for most repairs.

In portions of the bridge most visible to the public, the new concrete repairs were specified with a board-form finish to match the original surface texture. The new surface-coating and concrete-repair materials were colored to a light-buff color that was selected on site by the historian to be within the range of the original concrete color. Mock-ups and field trials were implemented to evaluate the contractor's materials and methods and conformance with the project specifications. The long-term durability of these concrete repairs was augmented with a film-forming coating throughout the bridge, as well as passive cathodic protection at targeted locations in the corners of the arch ribs.



Cutaway view of arch rib showing Melan truss reinforcement and typical concrete repairs. Figure: WJE.

A – epoxy-grouted dowels for anchorage;
B – saw cuts at repair perimeter;
C – tooled joint with sealant;
D – clean and coat existing steel;
E – crack-control reinforcement;
F – properly prepared, sound concrete substrate;
G – intermittent slots and wire connections to existing steel;
H – continuous zinc anode in sawcut slot;
J – Melan truss reinforcement;
K – typical surface repairs;
L – grout and seal crack

Several key factors contributed to the success of the project:

- a thorough, early investigation accurately identified the deterioration mechanisms and allowed for selection of appropriately targeted rehabilitation alternatives;
- due consideration of historic preservation principles led to the decision to protect vulnerable historic fabric by using a high-performance, water-resistant, opaque concrete coating;
- cathodic protection systems were targeted to slow corrosion at the most vulnerable locations and detailed to be less visible from the ground;
- step-by-step mock-ups validated the color, texture, and quality of the repair methods before full-scale implementation; and
- historic concrete assessment and rehabilitation experts collaborated with bridge analysis and design experts; historic preservation agencies; county engineers, technicians and inspectors; community stakeholders; and a contractor experienced in historic concrete repair.

References

1. Enser, Dan, Arne P. Johnson, John S. Lawler, and Paul Backer. 2017. "Franklin Avenue Bridge." *ASPIRE* Winter 2017: 24-27.

2. Johnson, Arne P., John S. Lawler, Dan Enser, Travis Konda, and Paul Backer. 2017. "The Franklin Avenue Bridge Part 1: History, Investigation, and Rehabilitation." *Concrete International* 39(6): 33–42.

3. Enser, Dan, Mario Grenville Ratnaraj, Arne P. Johnson, John S. Lawler, and Paul Backer. 2017. "The Franklin Avenue Bridge Part 2: Analysis, Design, and Accelerated Bridge Construction." *Concrete International* 39(8): 29–36.

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