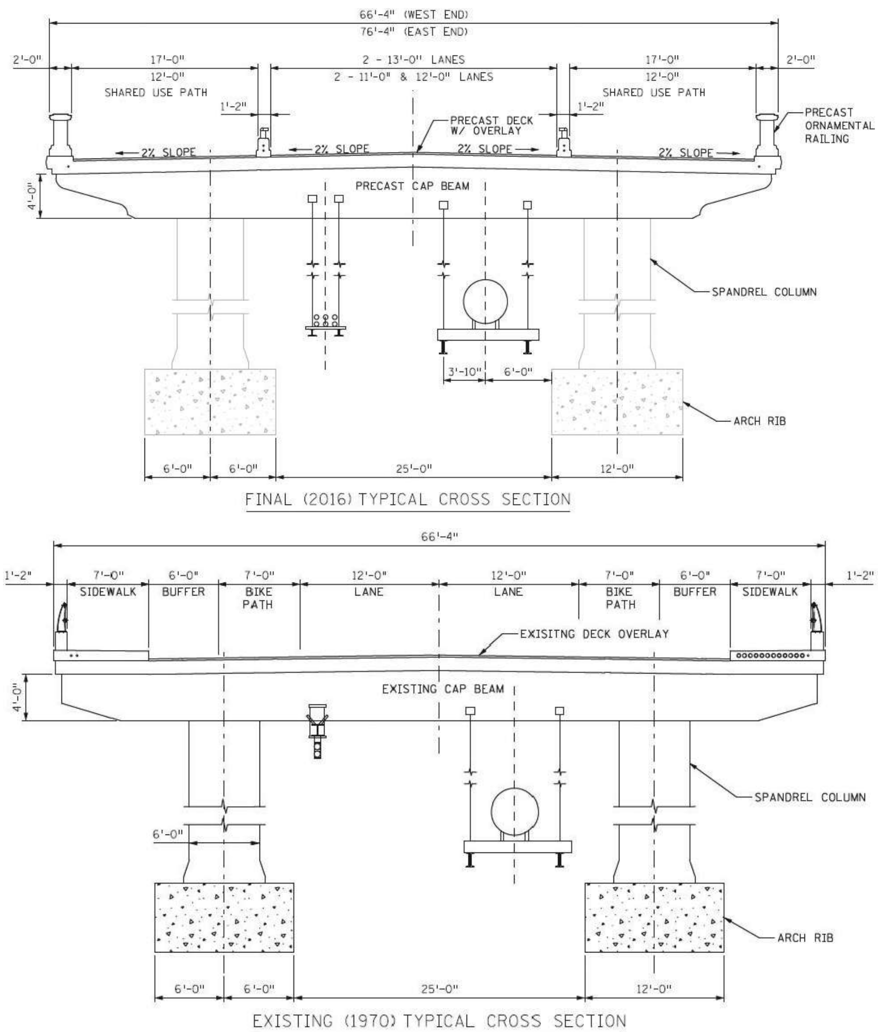
FRANKLIN AVENUE BRIDGE

ANALYSIS, DESIGN, AND ACCELERATED BRIDGE CONSTRUCTION

by Dan Enser, HNTB Corporation; Arne Johnson and Dr. John Lawler, Wiss, Janney, Elstner Associates Inc.; and Paul Backer, Hennepin County



New (2016) typical cross section (top) and existing (1970) typical cross section (bottom). All Figures and Photos: HNTB Corporation.

The historic Franklin Avenue Bridge in Minneapolis, Minn., was built in 1923 and rehabilitated in 1970. The 1050-ft-long, five-span, open-spandrel concrete deck arch structure has served as a vital link over the Mississippi River for nearly 100 years, connecting Minneapolis and St. Paul neighborhoods. Degradation and changing usage led to the full replacement of the deck and spandrel cap beams during the summer of 2016. By coupling accelerated bridge construction (ABC) techniques with prefabricated bridge elements and systems (PBES), the replacement of the superstructure was completed during a 116-day closure.

Inspection of the existing bridge revealed many elements were deteriorated and laden with chlorides. The original pier, arch rib, and abutment deterioration consisted of spalls, delaminations, and longitudinal reflective cracks along the top and bottom of the arch ribs in line with the Melan truss elements. The majority of the deterioration was caused by chloride intrusion and freeze-thaw damage. In addition, the as-inspected operating rating of the arch ribs of span 1 and span 5 was 0.63 (below 1.0); therefore, the bridge was load-posted to 18 tons

profile

FRANKLIN AVENUE BRIDGE / MINNEAPOLIS, MINNESOTA

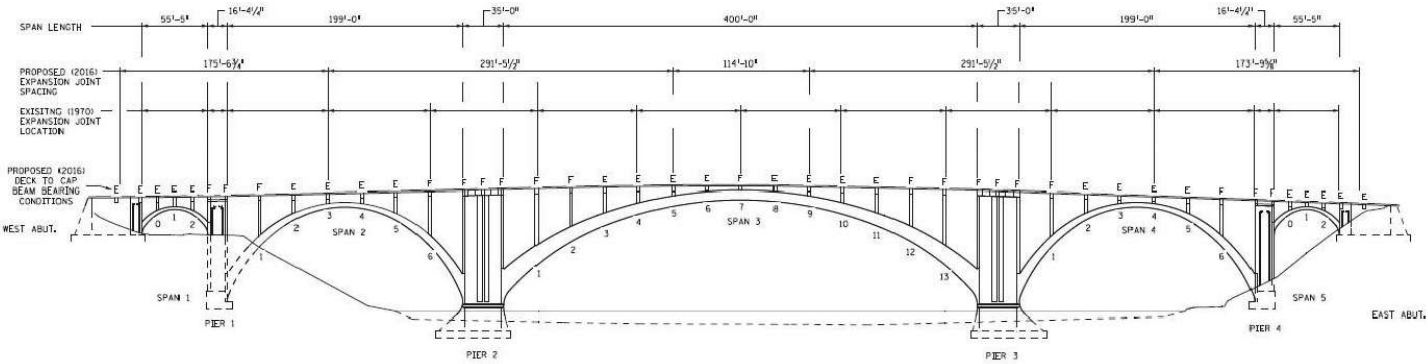
BRIDGE DESIGN ENGINEER FOR REHABILITATION: HNTB Corporation, Golden Valley, Minn.

SPECIALITY CONSULTANT: Wiss, Janney, Elstner Associates Inc., Northbrook, Ill.

PRIME CONTRACTOR: Kraemer North America, Burnsville, Minn.

PRECASTERS: Precast concrete deck panels: Kraemer North America, Burnsville, Minn.; precast concrete cap beams: Forterra Building Products, Elk River, Minn.—a PCI-certified producer; precast concrete ornamental railing panels: American Artstone, New Ulm, Minn.

OTHER MATERIAL SUPPLIERS: Stainless steel plates: Ryerson, Minneapolis, Minn.; PTFE sheets: D.S. Brown Company, North Baltimore, Ohio; expansion joints: Commercial Fabricators, Bridge View, Ill.; DUCTAL concrete (UHPC): Lafarge North America, Chicago, Ill.; premixed polyester polymer concrete (PPC): KWIK BOND, Benicia, Calif.



Bridge span layout with existing and proposed joint locations and deck-to-cap beam bearing conditions (E = expansion; F = fixed).

(two-axle, single-unit), 32 tons (three-axle, tractor-trailer), and 32 tons (four-axle, tandem). Extensive degradation of major bridge elements, together with low load postings, warranted full replacement of the deck and spandrel cap beams.

Closing the bridge for an extended period would have created major hardship to the traveling public. After consideration of the structural system and user impacts, the owner, Hennepin County, elected to use ABC methods and PBES to accomplish a short period of full closure in the summer, when activities at the nearby University of Minnesota and Augsburg College were reduced. The local community supported this full closure as opposed to the prolonged construction period associated with cast-in-place construction.

With the decision to close the bridge for four months to accelerate construction, PBES became the logical solution. Precast concrete spandrel cap beams, deck panels, and ornamental railing were chosen as the PBES.

Improvements to the Structure

Reduction in the number of expansion joints was critical to extend the life of the structure. The greatest levels of degradation were found at the 15 existing expansion joints, which had allowed chloride-laden water direct access to the underlying, non-air-entrained original concrete elements.

Reducing the number of expansion joints required a radical revision of the structural connectivity between the deck and cap beams. By allowing the deck to translate over the spandrel columns, the thermal forces within the spandrel columns and arch rib were greatly reduced. Releasing the connection between the deck and cap beams required a reliable, low-friction bearing assembly that would accommodate the translation associated with thermal movements.

A sliding-plate joint was developed, consisting of a polished stainless-steel plate embedded in the underside of the deck panels that slid on polytetrafluoroethylene (PTFE) bearing sheets recessed into stainless steel plates on top of the precast concrete cap beams. This innovative detail supported the deck loads and allowed the precast concrete deck panels to slide over the cap beams, offering minimal resistance to longitudinal translation.

Detailed structural models were developed to evaluate the outcome of the proposed approach and to predict the built-up forces within the system in both restrained and released configurations. Results from this parametric comparison strongly supported releasing the deck from the cap beams. While 15 of the existing expansion joints were removed, six were installed away from the substructure elements, reducing deterioration potential and extending bridge service life.

Restoring the original 1923 spandrel columns in spans 1 and 5, which had been removed during the 1970 rehabilitation, addressed the unbalanced flexural demand on the arch ribs by establishing a more uniform loading on the arch ribs. The effort resulted in increasing the operating load rating factor from 0.63 to 3.62.

In addition, the following improvements were made to the structure:

- The bridge cross section was revised to accommodate a multimodal facility.
- Spandrel cap beams with historic scroll ends were used.
- Full-depth precast concrete deck panels were joined with ultra-high-performance concrete (UHPC).
- A premixed polyester polymer concrete (PPC) overlay was installed to protect the deck panels and construction joints from water ingress.
- Ornamental railing panels replicated the original 1923 design.

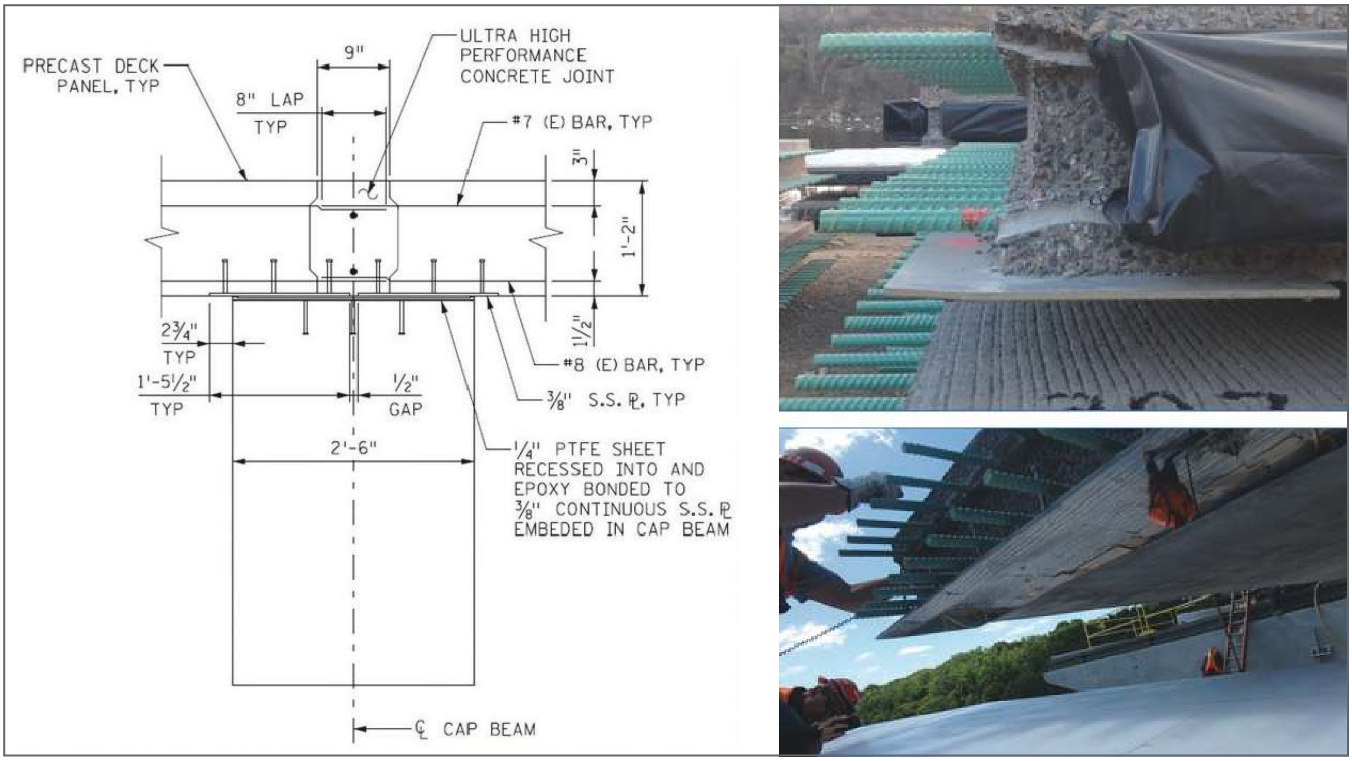
HENNEPIN COUNTY, OWNER

BRIDGE DESCRIPTION: Historic 1050-ft-long, five-span, open-spandrel concrete deck arch bridge built in 1923 over the Mississippi River; each arch rib contains a Melan lattice truss.

STRUCTURAL COMPONENTS: Three-hundred-fifty 14-in.-thick full-depth precast concrete deck panels; 33 precast concrete spandrel cap beams; 10 precast concrete pier cap beams; 163 precast concrete ornamental railing panels; 167 cast-in-place concrete pilasters; 350 yd^3 ultra-high-performance concrete; 2200 ft concrete parapet, 66,500 ft^2 polyester polymer concrete

BRIDGE CONSTRUCTION COST: Bid: $43,097,946.99 ($590/ft^2)

AWARDS: ACEC National Honor Award; ACEC Local Grand Award; APWA Local and National Project of the Year; 2016 MnDOT AGC MN Bridge Construction Award; 2017 MN Environmental Stewardship Award by MnDOT



Typical sliding-plate joint and precast concrete deck panel joint.

Precast Concrete Elements

Deck Panels

Three types of full-depth precast concrete deck panels were designed: expansion, sliding, and fixed. The panel length matched the spacing between spandrels, with the maximum length being 27 ft 11½ in. The panel width was 8 ft 9 in., to permit off-site casting and delivery to the bridge site.

The contractor fabricated the 350 reinforced concrete deck panels at a casting yard located approximately one mile upstream of the bridge. The proximity of the bridge allowed for barging the deck panels, thus mitigating logistical transportation problems and risks during the closure period. The yard was approximately 4.5 acres and consisted of five custom-made casting beds in conjunction with a custom-built steam-cure system that allowed the general contractor to fabricate up to 30 precast concrete deck panels per week. Rigorous quality control and assurance measures ensured that each unique deck panel would fit into its respective location.

Spandrel Cap Beams

The cap beams were designed as reinforced concrete elements. The spandrel cap beams were fabricated at a Fortera building products manufacturing facility in Elk River, Minn., and the cap beams over piers were fabricated by the contractor. To facilitate the ABC approach, embeds to support temporary works and cap beam connectivity to spandrel columns were incorporated into the design. Cap beams at sliding and expansion joints had stainless-steel plates embedded in the top of the cap beam, with a recess of 1/8 in. for the PTFE sheets.

Connecting the new cap beams expediently to the existing spandrel columns was critical. Developing a fully integral connection was not feasible, so a quasi-fixed connection was established by drilling and using epoxy adhesive to install reinforcing bars in the existing spandrel columns. A drill depth of 3 ft 6 in. was specified to provide adequate development of the new reinforcement in the existing concrete. For the other end of the connection, 2-in.-diameter corrugated plastic (HDPE) ducts, typically used for post-tensioning, were placed in the precast concrete cap beams during fabrication.

Ornamental Railing Panels

Precast concrete ornamental railing panels were designed and fabricated to replicate the original 1923 design. The panels were connected to steel posts that were then connected to the deck. Each post was located at an ornate pilaster. Once the railing panels were installed, concrete was placed in the hand-formed pilaster, encapsulating the post and the end of each precast concrete railing panel.

Use of Innovative Materials

Innovative materials made the Franklin Avenue Bridge project feasible. UHPC allowed the deck to be continuous over the supporting cap beams with narrow joints between deck panels. The new cap beams, at 2 ft 6 in. wide, would not have accommodated traditional reinforcement bar splices without significant additional falsework. The rapid strength gain of UHPC allowed the contractor to move swiftly to the next erection step. The physical properties of UHPC, together with its material characteristics, provided a perfect application for this material. It is the first project in Minnesota to use UHPC to join deck panels and the second largest application of UHPC in the United States.

The PPC overlay provided a durable roadway surface with minimal dead load, allowed construction equipment on the bridge four hours after placement, and provided a waterproofing system to protect the deck panel joints.

ABC

The bridge was closed on May 8, 2016, and on-site construction began. The use of ABC together with PBES allowed for an accelerated construction time frame and minimized disruption to the public. On September 1, 2016, after 116 days, the third rehabilitation of the iconic Franklin Avenue Bridge was complete and the bridge was opened to traffic, to the great appreciation of the public.

Lessons Learned

Pre-ABC planning is paramount to a project's success and includes bringing all contractual parties together to work out, in fine detail, how each operation will take place. It is necessary to eliminate as many potential issues as possible and have contingency plans in place in case an operation does not proceed as planned.

When using PBES on an existing structure, a recent survey of the existing bridge elements is critical to develop accurate shop drawings and ensure proper fit-up of the precast concrete elements.

Clearly communicated fabrication and erection tolerances for all precast concrete elements are also necessary. Planning efforts need to address quality assurance procedures for both the contractor and the inspectors. Topics that should be discussed include: what will be measured, when will it be measured, how will it be measured, and what needs to happen if a measurement is not within tolerance.

Accelerated bridge construction (ABC) operation.

For concrete arch bridges, erection plans need to take thermal movements into account, in addition to dead load deflections. Arch ribs deflect very little under changes in dead load, but deflect considerably from thermal changes; this must be considered when determining the setting elevations of precast concrete elements.

The long-term durability of the precast concrete deck panel system relies on the UHPC joint performance. Deck panel edges must have a roughened surface with aggregate exposed. Joints must have a saturated-surface-dry condition immediately prior to UHPC placement. UHPC requires proper forming, mixing, placement, and curing. Strength gain in UHPC is temperature-sensitive and the placement sequence must be well thought out to avoid loading joints prematurely.

Key ABC tasks and timeline:

ABC task	Task completion (days after closure)
Existing deck removal	Day 36
Existing cap beam removal	Day 39
Precast concrete cap beam erection	Day 43
Precast concrete deck panel erection	Day 51
UHPC placement at deck panel joints	Day 79
Ornamental steel railing post placement (north sidewalk)	Day 101
Precast concrete ornamental rail panel installation and pilaster casting (north sidewalk)	Day 113
PPC overlay placement	Day 114
Bridge opened to traffic	**Day 116**

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