Rehabilitation of Historic Hillhurst (Louise) Bridge

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Precast/prestressed concrete was used very effectively from an architectural, structural, constructability and cost viewpoint to rehabilitate the 75-year-old Hillhurst (Louise) Bridge in Calgary, Alberta, Canada. This historic five-span, spandrel wall arch structure is 172.21 m (565 ft) long with the length of each clear span equal to 32.0 m (105 ft). The total deck width is 19.6 m (64.3 ft). In the rehabilitation work, the following precast concrete components were used: (1) Precast, prestressed concrete deck panels; (2) Precast, concrete sidewalk support brackets; and (3) Precast concrete architectural balustrades. Erection of the precast concrete components took only 3½ months, finishing the project a week ahead of schedule. The total cost of rehabilitating the bridge was $5.1 million (Canadian).

Rehabilitation of the 75-year-old Hillhurst (Louise) Bridge (see Fig. 1) in downtown Calgary, Alberta, Canada, involved the development and implementation of several structural innovations that accommodated a relatively short construction schedule in a cost effective manner. Major consideration was given to restoring the bridge's original historic architecture. Also of significance was the sensitivity allotted to the imposed disruption on local residential and business communities.

The Hillhurst (Louise) Bridge was originally a five-span, earth-filled, spandrel wall arch structure. The bridge spans the Bow River and connects the central business district of the City of Calgary on the south shore to the vibrant Hillhurst/Sunnyside communities and the Kensington business community on the north shore. Historically, the Hillhurst (Louise) Bridge represents an important part of Calgary's heritage. Fig. 2 shows an artist's rendering of the rehabilitated bridge.

The original architecture of the bridge comes from similar arch structures constructed across the Thames River in London, England, around the turn of the century. The structure was built in 1921 to carry street car traffic and pedestrians. Today, the bridge carries 26,000 vehicles per day, in four lanes, to the current 63 tonnes GVW (gross vehicle weight) legal load limit, with two outside sidewalks.

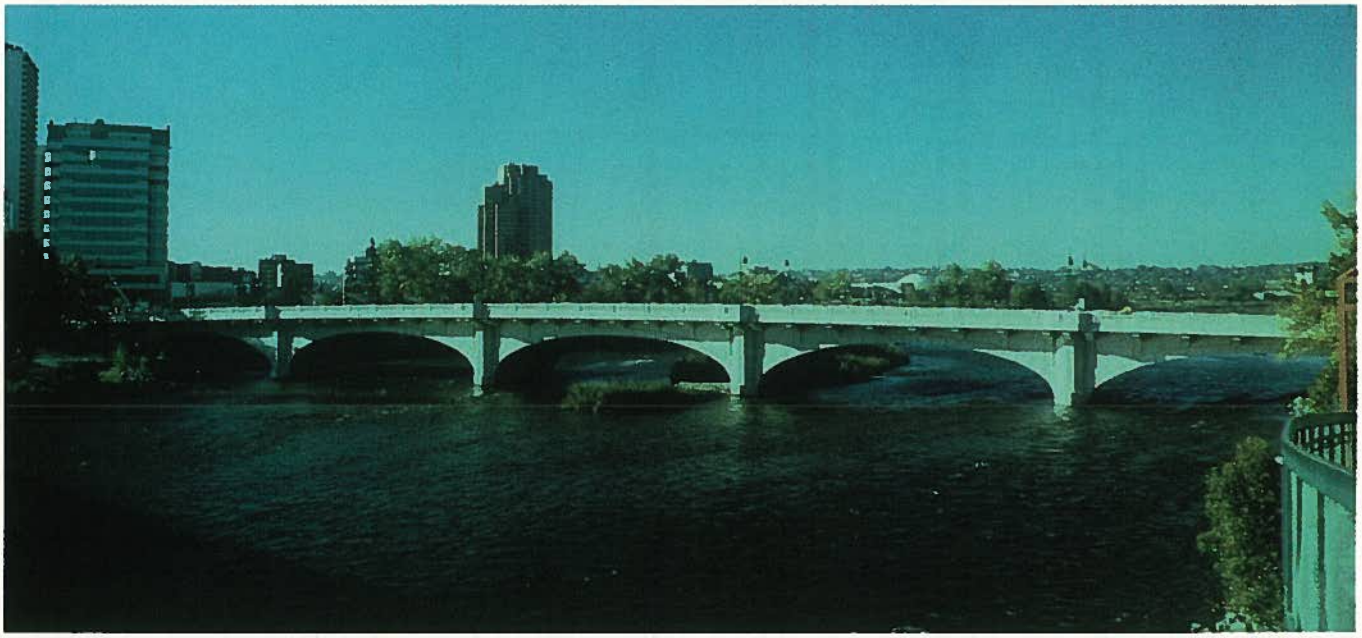

Fig. 1. Panoramic view of rehabilitated Hillhurst (Louise) Bridge.

The original structure consisted of five reinforced concrete arches varying in thickness from 760 mm (30 in.) at the crown to 1520 mm (60 in.) at the piers, with individual clear spans of 32.0 m (105 ft). Concrete spandrel walls along both sides of the arch contained granular fill and concrete buttresses and brackets supported the exterior sidewalks.

The plan, elevation, and typical cross section of the rehabilitated Hillhurst (Louise) Bridge are shown in Fig. 3. The overall length of the five-span bridge is 172.21 m (565 ft) with the length of each clear span equal to 32.0 m (105 ft), as in the original structure. The total deck width is 19.6 m (64.3 ft).

Over the past 75 years, the original concrete spandrel walls and arch

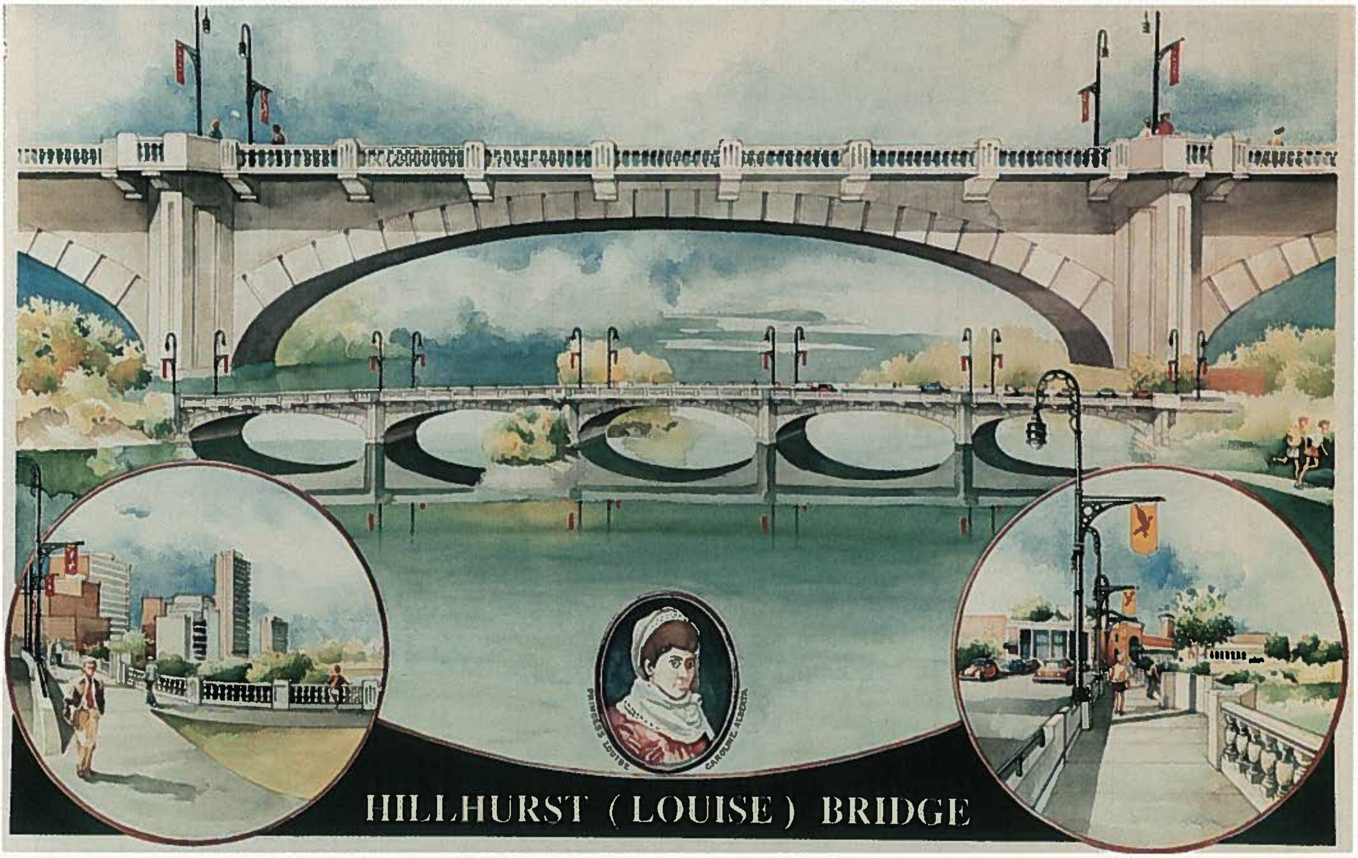

Fig. 2. Artist's rendering of new Hillhurst (Louise) Bridge.

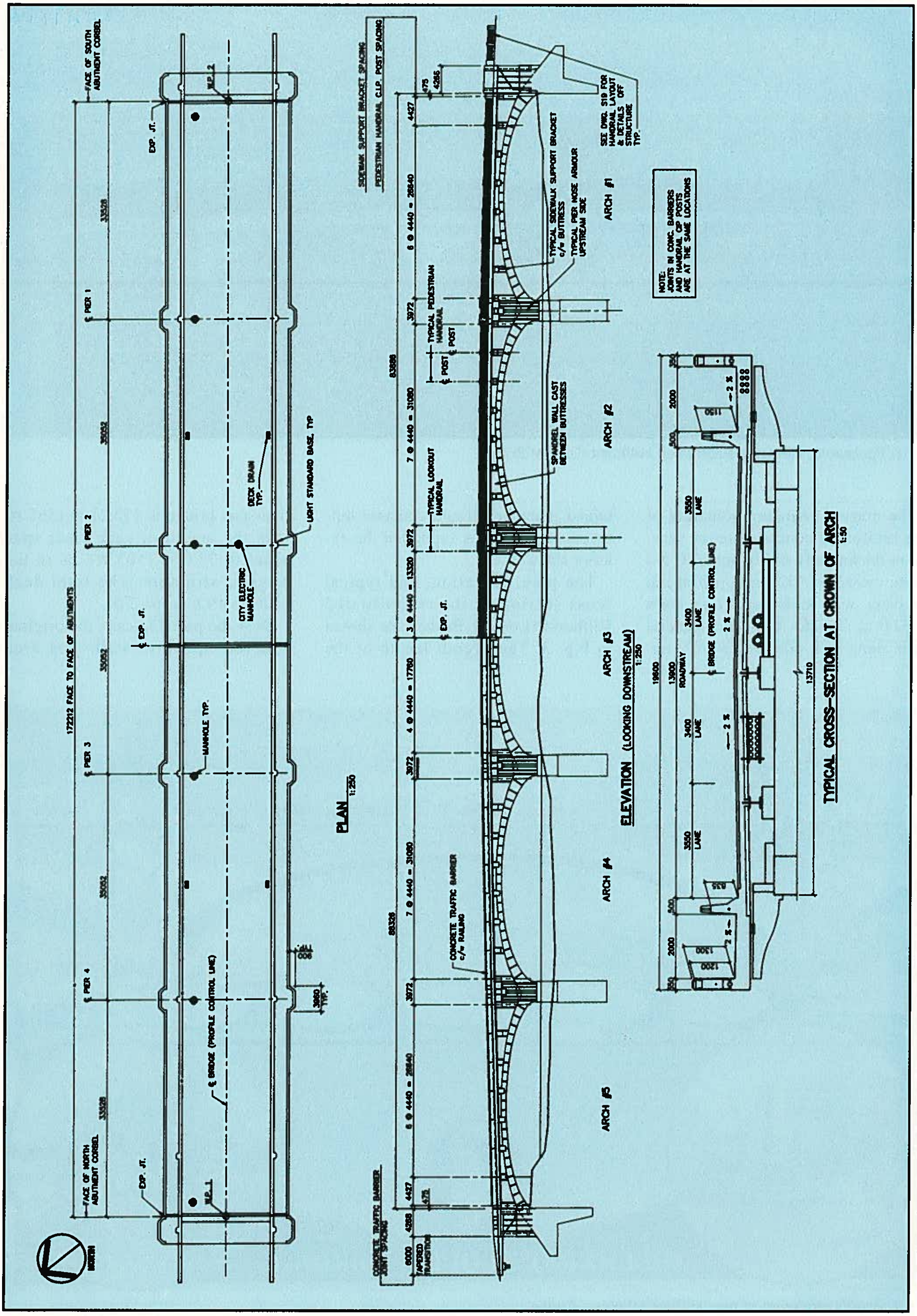

Fig. 3. Plan, elevation and typical cross section of bridge.

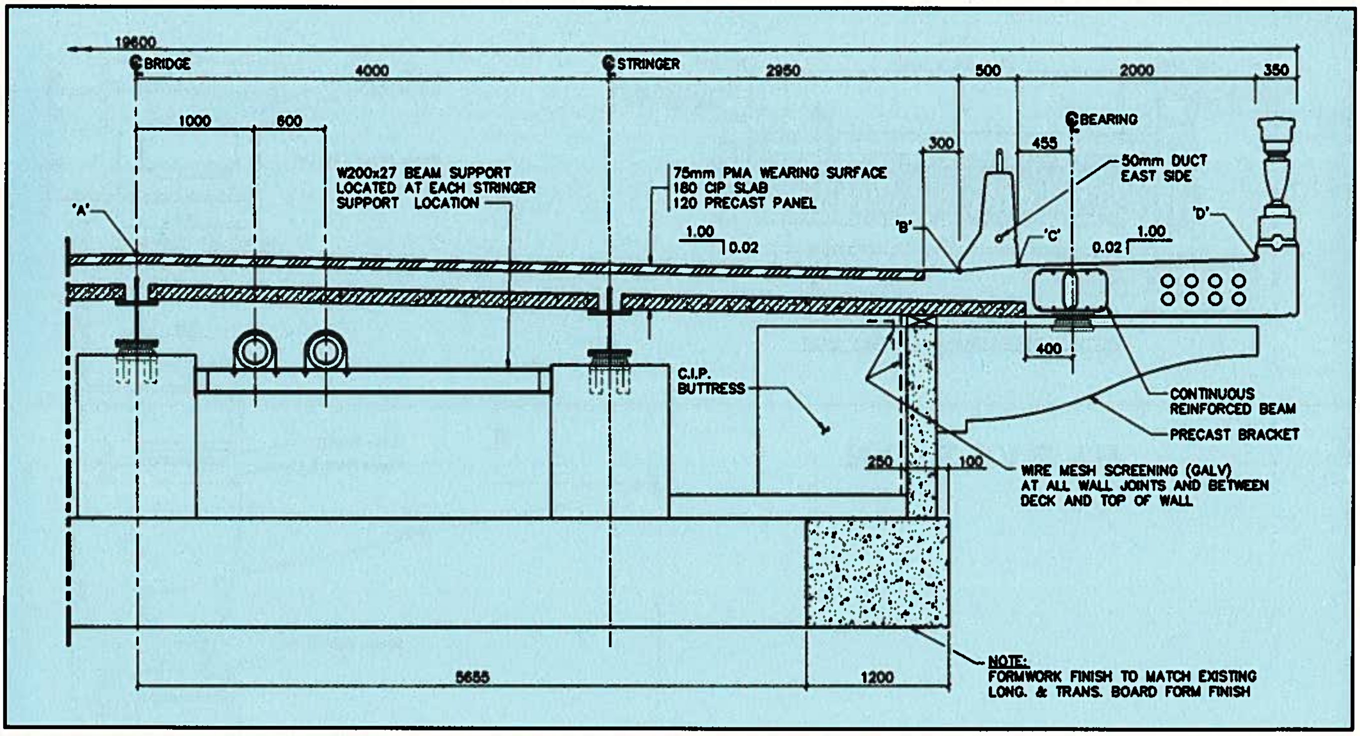

Fig. 4. Typical cross section of bridge showing new precast bracket, deck panel and balustrade.

edges had suffered severe deterioration due to poor drainage within the fill. Deterioration had been aggravated by the use of de-icing salts since the late 1960s. Concrete deterioration was concluded to be primarily due to a combination of freeze/thaw damage and, to a lesser extent, alkali-aggregate reactivity. Severe concrete deterioration was present over almost the entire area of the spandrel wall and pier nosings, the exterior 1 m (3.3 ft) of each side of each arch, and those portions of the abutments above grade. Relatively good quality concrete was found within the remaining portions of the main arches.

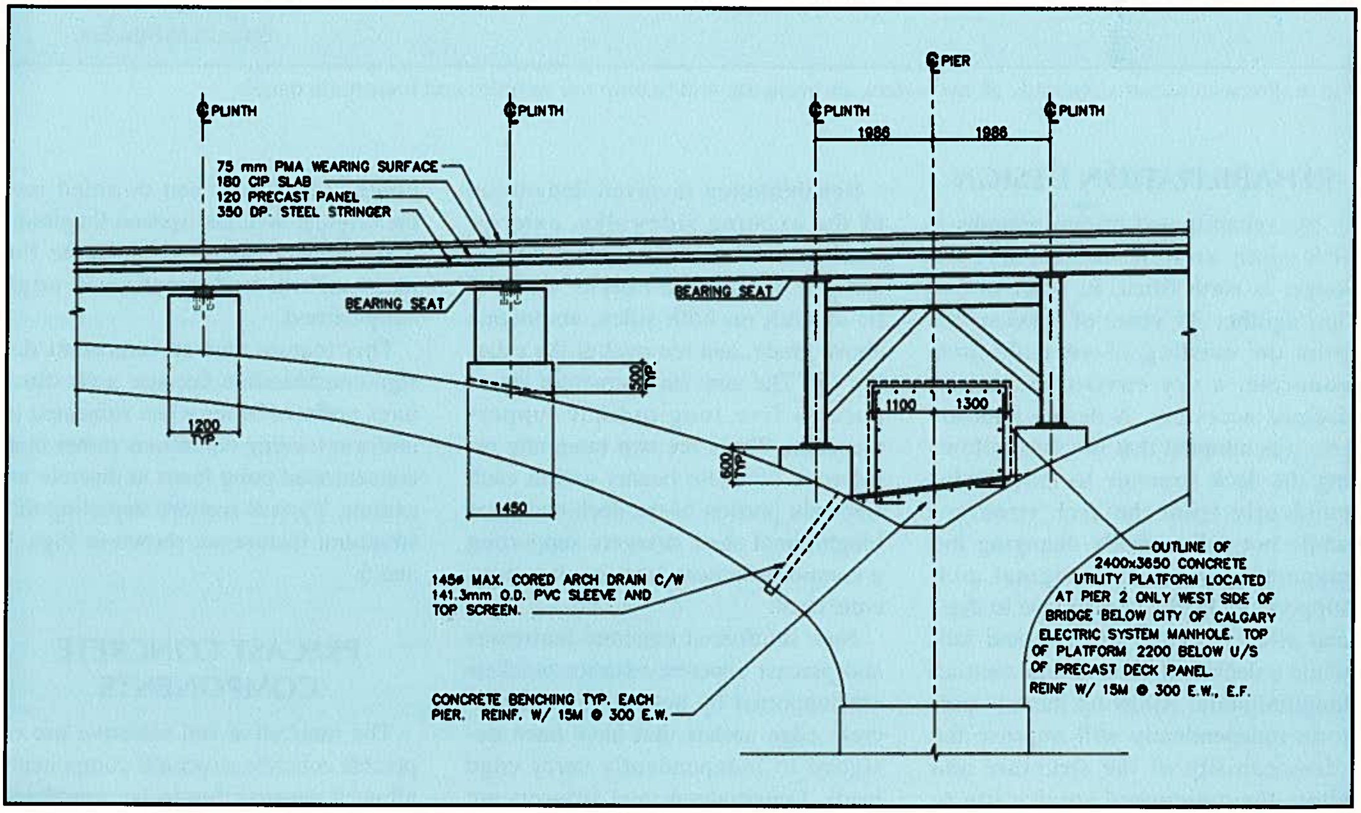

Fig. 5. Typical longitudinal section of bridge showing additional reinforcement under structure.

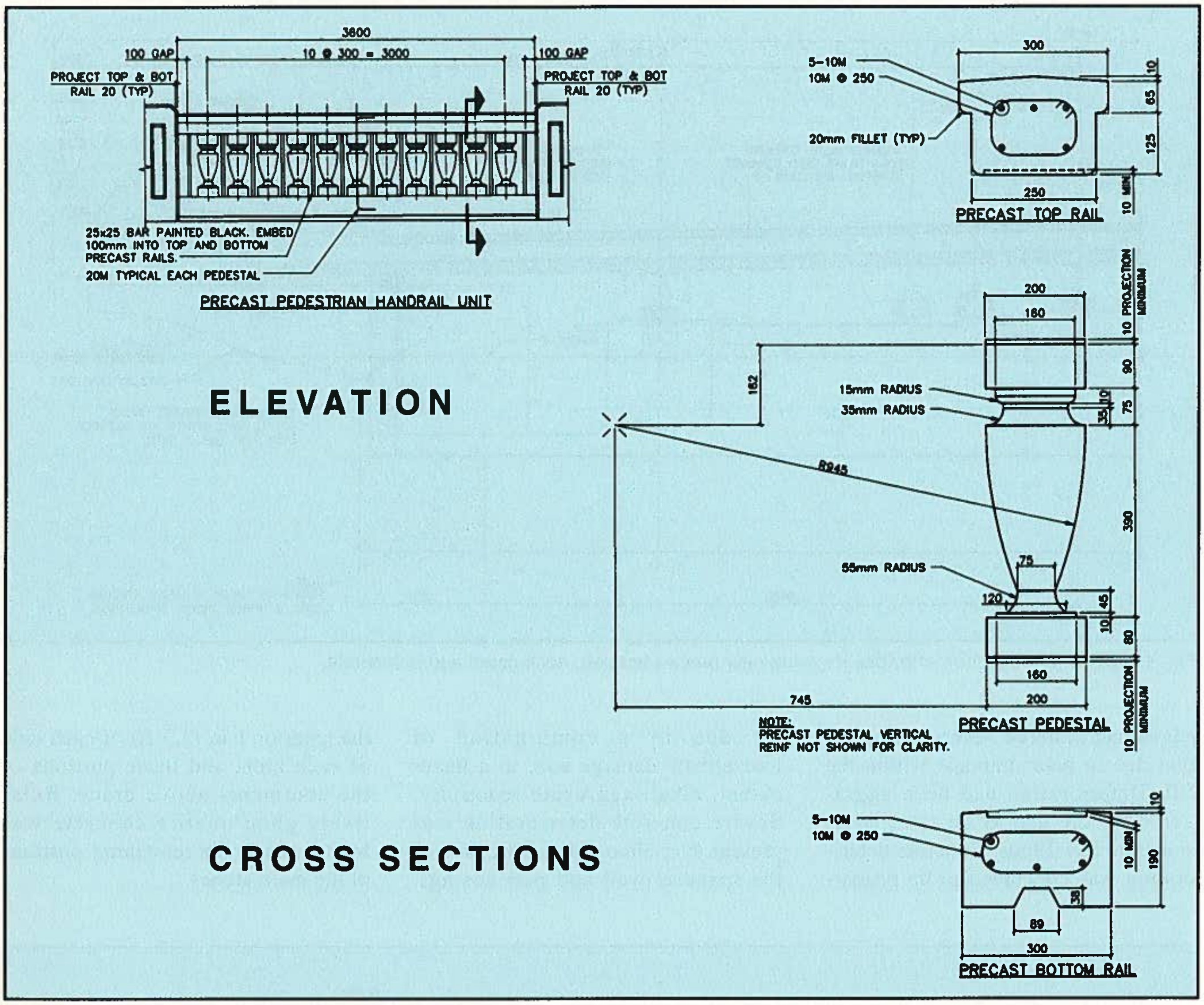

Fig. 6. Precast concrete assembly at top of deck showing top and bottom rail spindles and balustrade panels.

REHABILITATION DESIGN

The rehabilitated bridge remains a five-span arch structure, but no longer is earth filled. In order to obtain another 35 years of service life from the existing 75-year-old arch concrete, a dry environment was deemed necessary. A design philosophy was adopted that involved allowing the deck structure to move independently from the arch structure while not substantially changing the manner in which the original arch supports its loads. In response to thermal effects, arches will rise and fall, while a deck will expand and contract longitudinally. Allowing them to perform independently will improve the serviceability of the structure and allow the anticipated service life to be realized.

Rehabilitation involved demolition of the existing sidewalks, exterior brackets and buttresses, spandrel walls and pier nosings, the exterior 1 m (3.3 ft) of arch on both sides, abutments above grade, and removal of the existing fill. The new superstructure incorporates five longitudinal support members. There are two integrally reinforced concrete beams within each sidewalk portion of the deck and three longitudinal steel stringers supporting a composite precast/cast-in-place concrete deck.

New reinforced concrete buttresses and precast concrete exterior brackets are supported by new reinforced concrete edge arches that have been designed to independently carry edge loads. Longitudinal steel stringers are supported by new reinforced concrete plinths that have been doweled into the original arch and spaced longitudinally and laterally to replicate the more uniform load that the arch originally carried.

This feature was an important design consideration because arch structures perform better when subjected to uniform loading conditions rather than concentrated point loads at discrete locations. Typical sections depicting this structural feature are shown in Figs. 4 and 5.

PRECAST CONCRETE COMPONENTS

The innovative and selective use of precast concrete structural components allowed construction to be completed quickly and cost effectively. Prefabrication allowed the components of the bridge to be constructed off site while demolition and substructure construction proceeded. The precast concrete components included:

- Precast, prestressed concrete deck panels
- Precast concrete sidewalk support brackets
- Precast concrete balustrades

Each of these components are discussed below:

Prestressed/Precast Concrete Deck Panels

The new concrete deck is a composite precast/cast-in-place deck with precast, prestressed concrete deck panels designed to support wet cast-in-place deck concrete, in the temporary case, and full dead and live loads in the continuous composite condition. The deck was designed as a one-way slab spanning between longitudinal supports.

The use of precast, prestressed concrete deck panels eliminated the need for installation and removal of traditional temporary timber falsework over the majority of the width of the deck. This saved both time and money, combining the use of a temporary construction support element as part of the final design. Falsework was still required below the sidewalks.

The top surfaces of the precast concrete deck panels were intentionally roughened to provide the desired shear-friction interface between the precast and cast-in-place concrete. Prior to placing the cast-in-place concrete portion of the deck, a cement slurry was applied to the surface of the precast panels. No mechanical connections were used between the precast and cast-in-place concrete except at the exterior ends of the outside panels where prestressing strands were extended a development length into the sidewalk slab.

The concrete for the precast deck panels included silica fume to facilitate early strength gain. The minimum compressive strength specified at the time of strand release was 30 MPa (4351 psi). The strength requirement at 28 days was 35 MPa (5076 psi) as it was for the cast-in-place deck concrete. Panels were cast 2.4 m (7.87 ft) wide x 4.0 m (13.1 ft) long (spacing between steel stringers) x 125 mm (5 in.) deep. Prestressing steel specified was seven-wire, 12.7 mm (1/2 in.) diameter strand with an ultimate strength of 1860 MPa (270K). Strands were spaced at 135 mm (5.3 in.) on center.

Table 1. Number, dimensions and details of precast concrete components.

Precast concrete component	Number of components	Size of component
Deck panels (precast, prestressed)	300	3.96 m x 2.44 m x 127 mm
Sidewalk support brackets (precast)	88	2.74 m long x 762 mm wide x 254 to 914 mm deep
Architectural balustrades (precast)	100	3.66 m long x 1016 mm high x 300 mm wide

Note: 1 m = 3.281 ft; 1 mm = 0.0394 in.

Precast Concrete Sidewalk Brackets

The number of sidewalk brackets on the project provided economies for the cost effective consideration of precasting. The on-site time saving, as compared to cast-in-place concrete work, was also desirable. Architecturally, it was important to achieve a reasonable amount of uniformity, which precasting could ensure. A pocket was included in the cast-in-place buttress to form a mechanical connection between the bracket and buttress.

Temporary bracket supports were provided across the top of the pocket until it was cast with concrete and had developed sufficient strength to support the bracket load. Brackets were normally reinforced with Grade 400 steel and cast with 30 MPa (4351 psi) concrete, at 28 days. Precast concrete sidewalk brackets were prefinished, with a base coat of a penetrating silane sealer and two top coats of a pigmented sealer, in the plant prior to delivery as a means of reducing on site construction time.

Precast Concrete Balustrades

Precast concrete balustrades have been utilized along both sidewalks on the bridge and along both approaches to the bridge. Their geometric design is based on the original configuration, yet slightly modified in height to meet current code requirements. Vertical steel bars were also added between spindles to ensure that no gaps existed that were greater than 150 mm (5.9 in.) wide. These bars were galvanized and specially blast prepared for a urethane paint finish.

Top rail, bottom rail, spindles and steel bars were fabricated individually, then assembled together and attached by the use of a grouted threadrod through the center of each spindle. Spindles were spun cast in epoxy forms such that a cylindrical void was left for threadrod installation and grouting. Prefabricated balustrade panels were manufactured in lengths of 3.66 m (11.8 ft). An expanded view of the precast assembly is shown in Fig. 6.

On site, the panels were easily erected in place and connected to the structure with cast-in-place end posts. Erected panels were also shimmed on the underside upon erection and later grouted after end posts had been cast. Precast concrete balustrades were also prefinished, with a base coat of a penetrating silane sealer and two top coats of a pigmented sealer, in the plant prior to delivery as a means of reducing on-site construction time.

PRODUCTION HIGHLIGHTS

Nearly 500 precast concrete components were fabricated for this project. The components comprised precast, prestressed deck panels, precast sidewalk support brackets, and precast architectural balustrades. For individual numbers, dimensions, and details of the components, see Table 1.

The precast concrete products were manufactured by Lafarge Construction Materials, a long-time PCI Producer Member company with many years of high quality service. Lafarge also erected all of the precast components except for the balustrades. Most of the

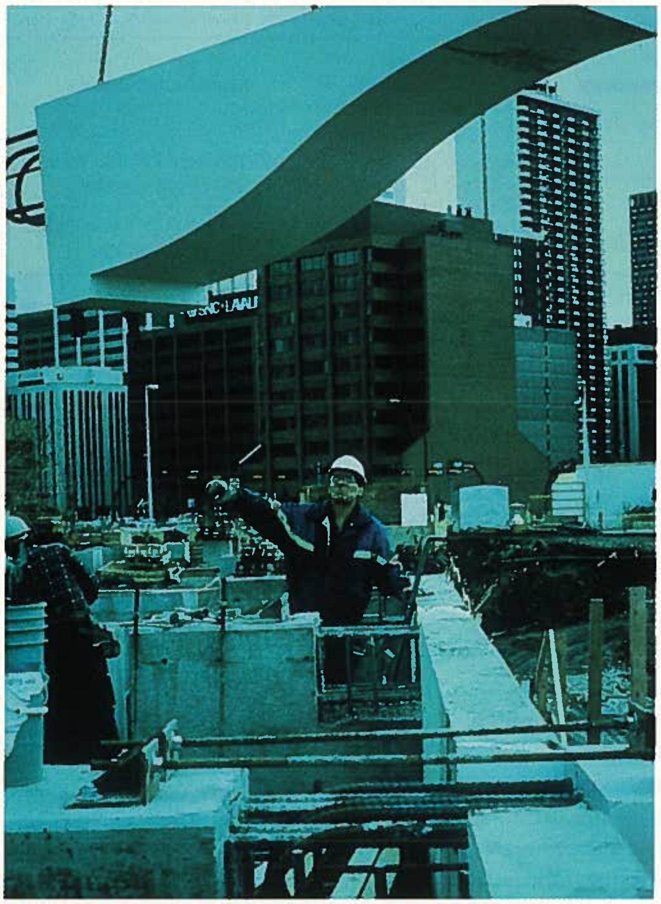
Fig. 7. Installing precast bracket.

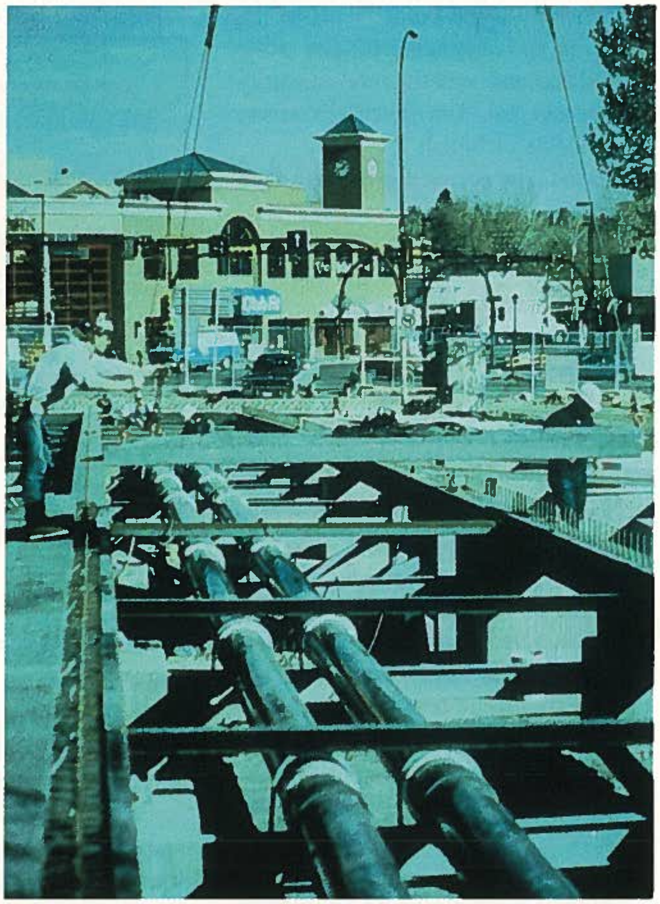
Fig. 8. Installing precast deck panels.


Fig. 9. Installing bearings at precast bracket locations.


Fig. 10. Installing precast balustrade.

Fig. 11. Precast deck panels in place.

components were fabricated at their plant in Calgary, about 20 km (12 miles) from the project site. Some of the decorative components, such as the balustrades, were fabricated at Lafarge's Edmonton, Alberta, plant, about 300 km (186 miles) from the project site. The precast components were transported by specially rigged truck-trailer. The precast concrete products were manufactured during a 6-month period in the fall and winter of 1994. The precast contract amounted to $850,000 (Canadian).

A major advantage of prefabrication is that the deck panels, sidewalk support brackets, and balustrades could be manufactured off site in a well-controlled plant environment while demolition and other substructure work could proceed uninterrupted. This process significantly reduced the fabrication and erection schedule of the precast decking.

The use of precast concrete helped complete this project one week ahead of schedule because the early setting of the decking served as falsework for the construction that was to follow. A major incentive to expedite construction was to stay ahead of rising spring and summer river water levels.

Partial demolition of the old structure and new construction of the rehabilitated bridge began in early 1995. Total construction took about 8$^1/_2$ months. Figs. 7 through 12 show various construction phases of the new bridge.

Erection of the precast components took only 3$^1/_2$ months to complete. The new rehabilitated bridge was essentially completed by September 21, 1995. It was opened to highway traffic shortly thereafter.

Figs. 13 through 15 show various shots of the completed bridge.

CONCLUDING REMARKS

The new construction was completed at a cost of approximately $5.1 million (Canadian) in the relatively short time frame of 8$^1/_2$ months. The bridge was actually opened to traffic one week ahead of schedule. Through innovation in engineering, the rehabilitation of the Hillhurst (Louise) Bridge illustrates how the partial reuse and recycling of existing infrastructure can cost effectively improve serviceability to an existing structure and provide an architecturally pleasing appearance.

The project also shows how this can be accomplished in a timely manner through the innovative use of precast concrete components. It became apparent during construction that many citizens of the city took a personal interest

Fig. 12. Bridge span construction almost complete.

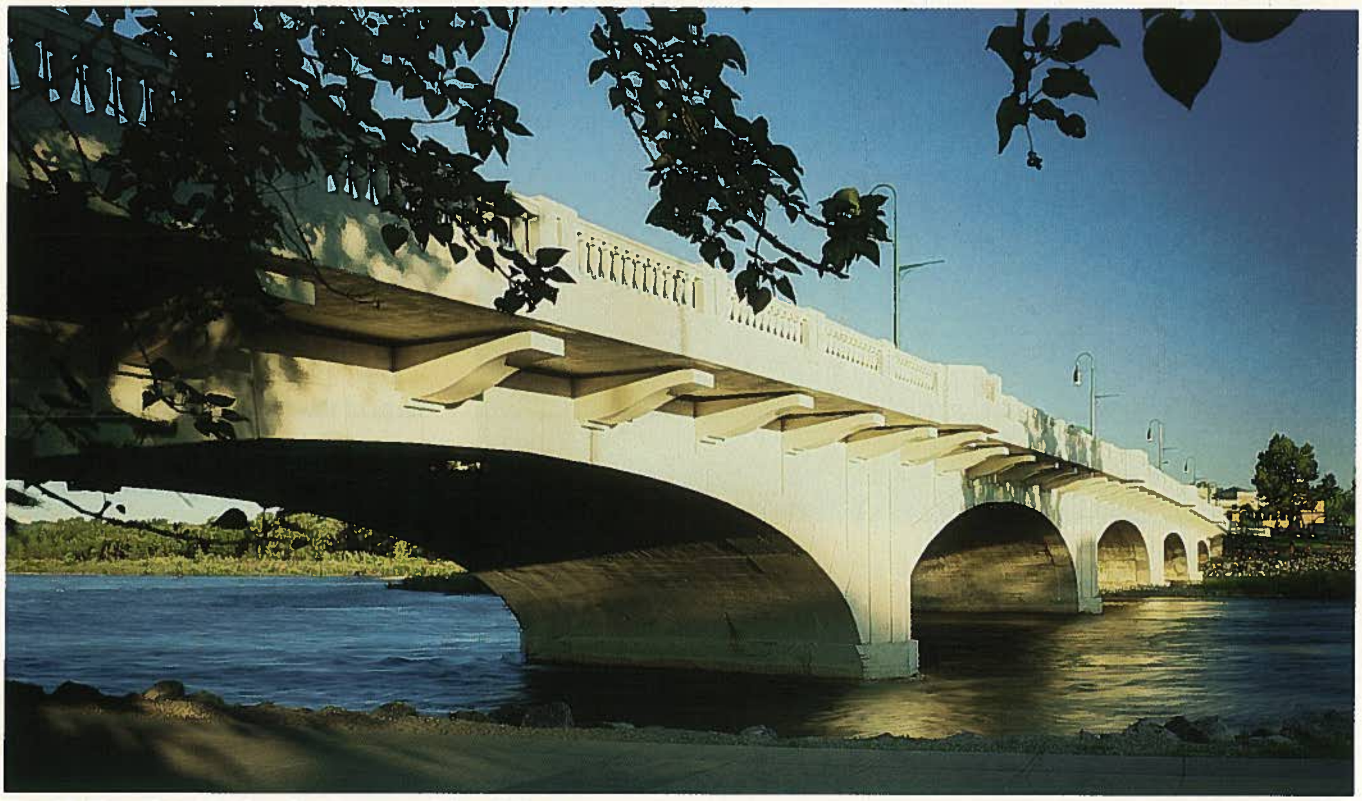

Fig. 13. Completed bridge showing graceful arch form.

in the development of the rehabilitation of "their" bridge. The success of this project can best be measured by the popular acceptance, by the citizens of the City of Calgary, of the final product.

In the 1996 PCI Design Awards Program, the Hillhurst (Louise) Bridge won an award for "Best Rehabilitated Bridge." The jury's citation read:

"The use of precast concrete allowed for the widening and rehabilitation of a piece of history, a valuable historical structure that has been preserved for the future while being used now. The use of precast brackets, floor panels for the deck, and railing was an effective way to augment the architectural and functional aspects of an attractive, historical, cast-in-place arch bridge."

The project has been recognized in a number of other award programs. In addition to receiving the Reid Crowther Presidents Award in 1996, the Consulting Engineers of Alberta honored the project with its Award of Excellence in the Infrastructure Category at its Showcase Awards in January 1997.

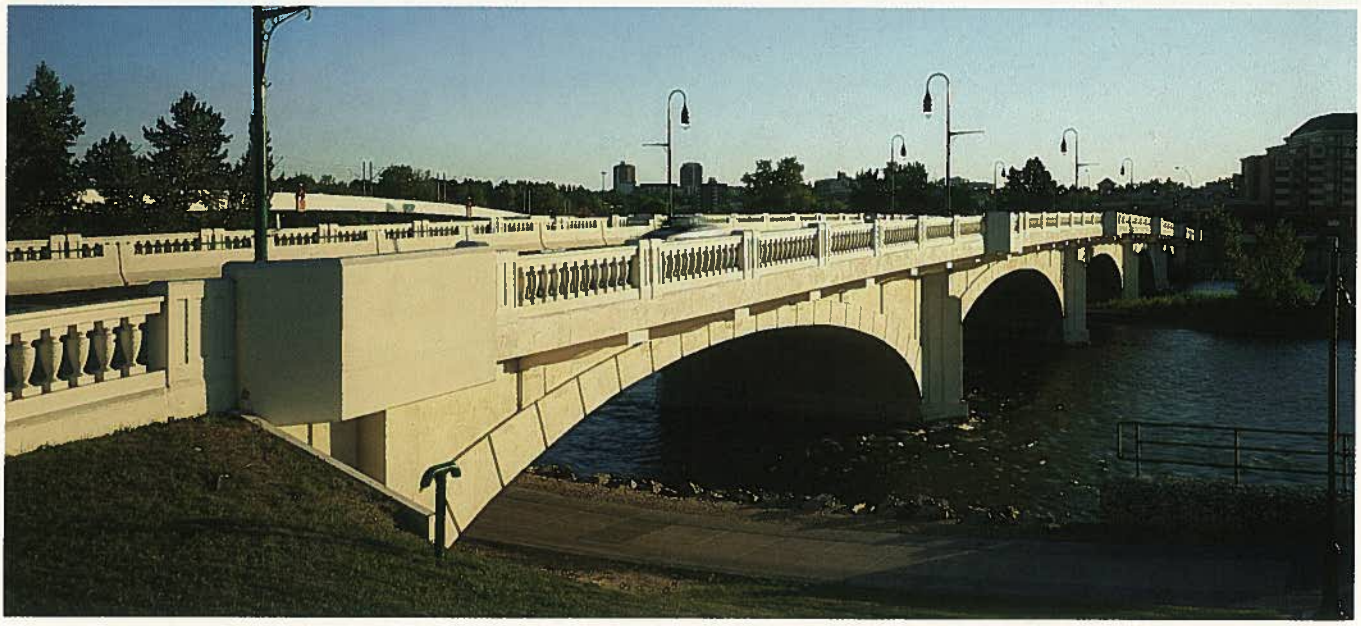

Fig. 14. Panoramic view of completed bridge.

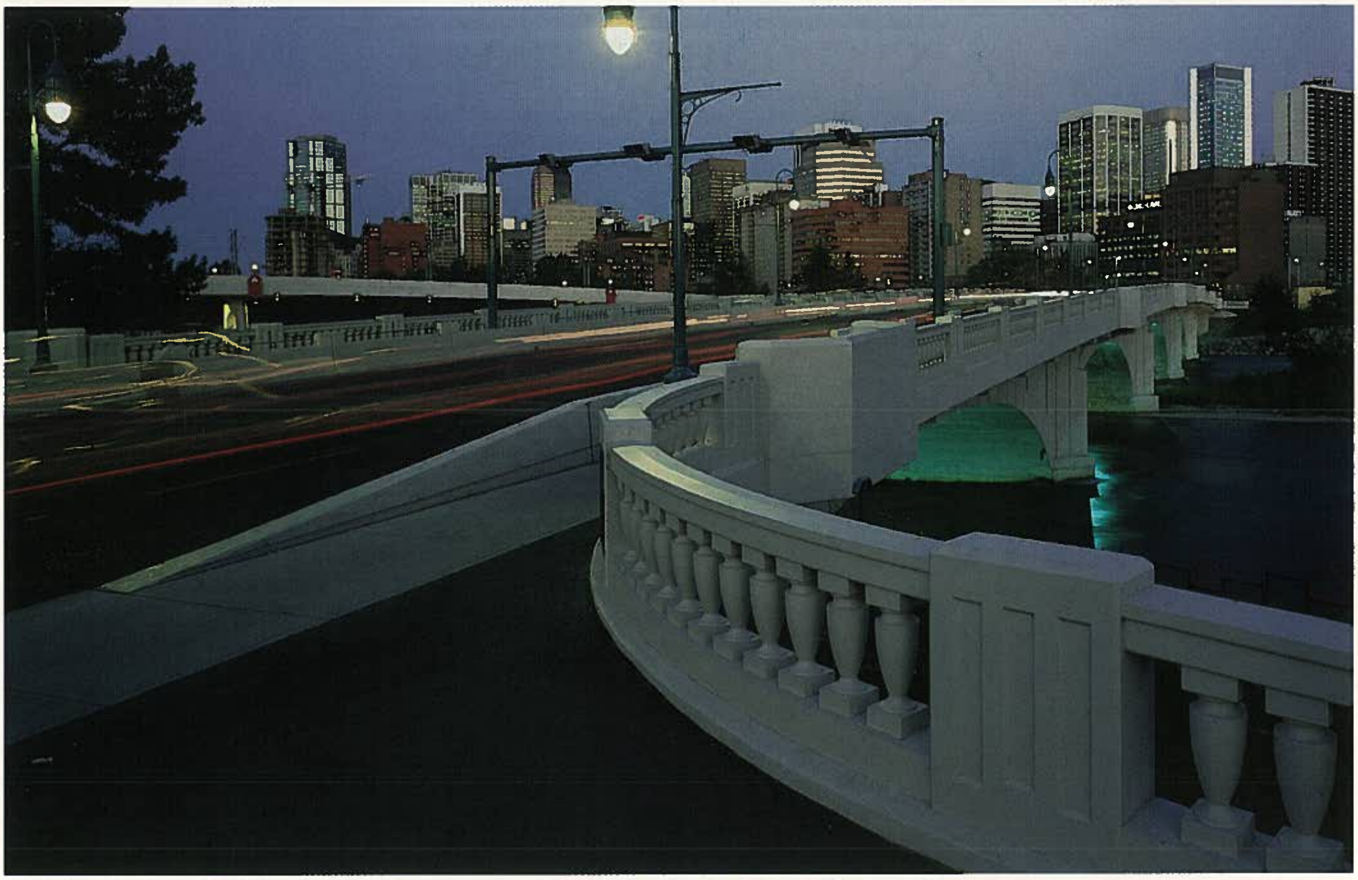

Fig. 15. Top view of bridge showing attractive precast balustrades with City of Calgary in background.

In April 1997, the Alberta Chapter of the American Concrete Institute honored the Hillhurst (Louise) Bridge with the Award of Excellence for Design and Construction in Concrete.

The rehabilitated bridge has now been in operation for about 1½ years. In retrospect, all parties concerned in the decision to rehabilitate the structure, including the people who use the bridge, are pleased with the new facility. In many respects, the measures employed have set a standard for the rehabilitation of other heritage bridge structures in the City of Calgary. Indeed, the bridge will serve as an important link to a rich historic heritage that will carry well into the next century.

CREDITS

Owner: City of Calgary, Calgary, Alberta, Canada

Architect: Simpson Roberts Wappel, Calgary, Alberta, Canada

Structural Engineer: Reid Crowther & Partners, Ltd., Calgary, Alberta, Canada

General Contractor: PCL-Maxam, a joint venture, Calgary, Alberta, Canada

Precast Concrete Manufacturer: Lafarge Construction Materials, Calgary, Alberta, Canada