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CANADIAN NIAGARA POWER FOREBAY BRIDGE RECONSTRUCTION

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ELLIS Engineering Inc.
214 Martindale Road, Suite 201
St. Catharines, Ontario
L2S 0B2
www.ellis.on.ca

ELLIS Engineering Inc.

PROJECT SUMMARY

The Niagara Parks Commission required rehabilitation of an existing historic five span stone arch structure at the forebay of one of the first power stations ever built, near the brink of the Horseshoe Falls, in Niagara Falls, Ontario. In the fall of 2012 ELLIS Engineering Inc. developed an innovative approach to build a new bridge superstructure, saving the beautiful 1905 stonework, and retaining the look of the original arched bridge.

Figure 1. Canadian Niagara Power (CNP) Forebay Bridge Site Location

ELLIS Engineering Inc. was awarded the prestigious 2015 Willis Chipman Award by Consulting Engineers of Ontario (CEO) for their work on the Canadian Niagara Power Forebay Bridge Reconstruction project. This premier award of CEO recognizes the project that best demonstrates consulting engineers' contributions to the social, economic, and environmental well-being of Ontario.

1. INNOVATION

The project was developed around a design-build contract for the Niagara Parks Commission. At the outset, the intention was to rehabilitate the existing Canadian Niagara Power (CNP) Vehicular Forebay Bridge.

A deck condition survey report, completed at contract award, identified that the exposed steel trusses in the deck soffit were severely corroded and the concrete at the stonework-arch interfaces was generally in poor condition. Due to the extent of the deterioration, rehabilitation of the existing deck was not a feasible option and deck replacement options were considered.

Figure 2. Vehicular Forebay Bridge prior to construction (view of soffit)

The final design concept included a thin cantilevered reinforced concrete arch structure that could be constructed and poured using the existing deck structure as formwork.

The original stone arch fascia and parapet walls were preserved and integrated into the new structure through the innovative design of reinforced concrete 'edge beams'. The edge beams connect the existing stone masonry walls to the new reinforced concrete arches.

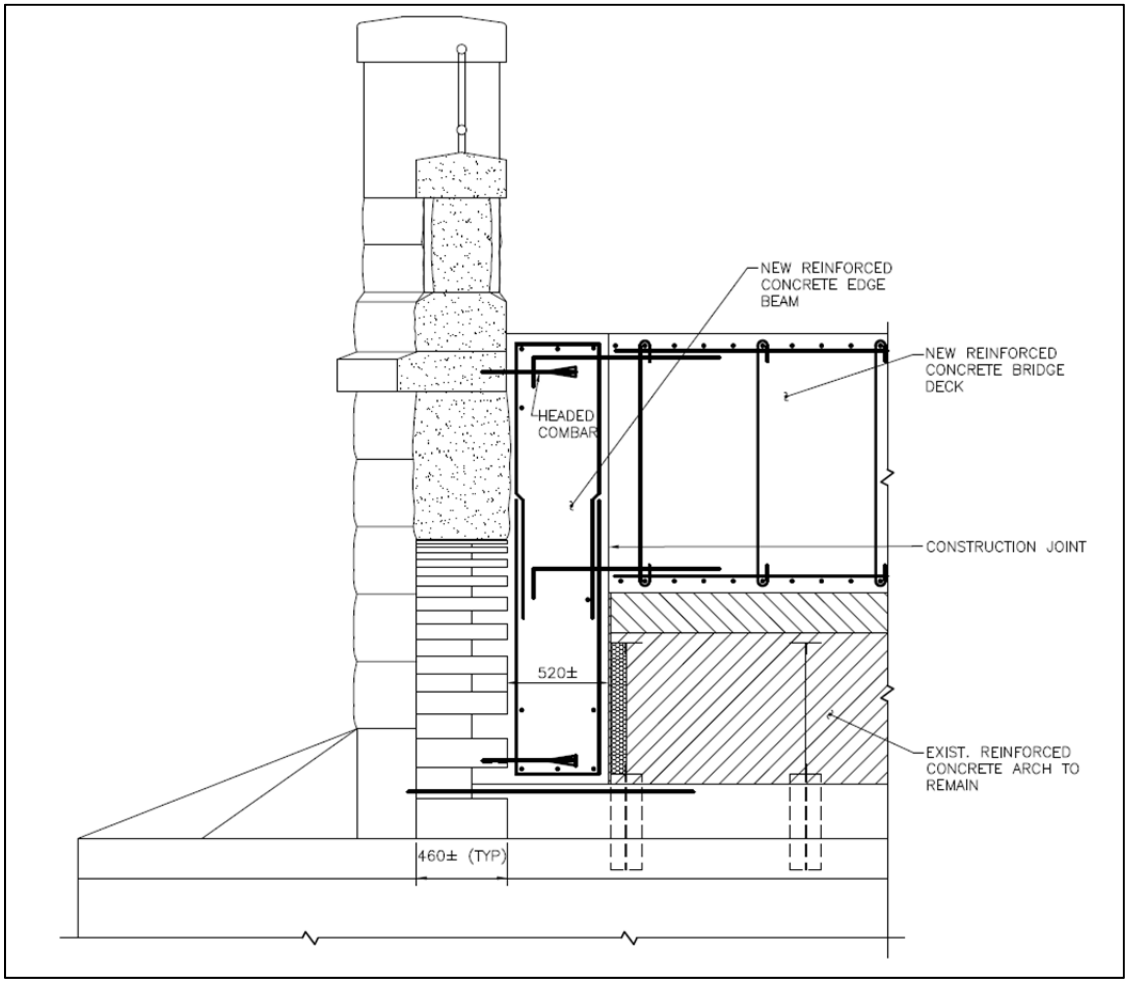


Figure 3. Detail of stonework anchored to 'edge beam'

The parapet walls of the Vehicular Forebay Bridge were located on the stone masonry arches which were self-supporting. However, there were concerns that the arches or walls may become laterally unstable as existing material was removed between the stonework and the existing concrete deck to make room for the edge beams. The contractor, Rankin Construction Inc., developed a falsework system to brace the stonework in both directions during construction.

Figure 4. Lateral bracing of the existing stone fascia

Utilizing the existing structure created roadway geometry conflicts that would not allow enough space for a pedestrian sidewalk on the Vehicular Forebay Bridge. The design team developed an inventive solution by repurposing the adjacent 'Ice Bridge' as a new pedestrian walkway.

Whereas similar stone arch structures would require complete replacement of the entire superstructure, including removal of the stonework and erection of formwork, this design approach is distinguishable in that the majority of the existing structure was preserved and minimal formwork was required. The design concept resulted in significant cost savings and shorter construction time over replacing the entire superstructure. As well, the use of a thin cantilever reinforced concrete arch structure allowed for the roadway elevation to remain the same. This minimized the amount of approach roadwork and modifications to the stone parapet walls.

2. COMPLEXITY

The original scheme included relocating the Niagara Parkway, thereby reducing traffic on the existing Vehicular Forebay Bridge (from 4 lanes to 2 lanes) and creating plenty of space for pedestrians and cyclists. However, complications arose when the Niagara Parkway could not be relocated as previously planned and would still cross at the CNP Vehicular Forebay Bridge, requiring 4 lanes of vehicular traffic. With modern lane widths, there would be no room for a sidewalk on the bridge.

A solution was found in the adjacent 'Ice Bridge'. The Ice Bridge was constructed circa 1912 to act as a barrier for ice entering into the forebay for the adjacent power generation station.

Figure 5. Ice Bridge prior to construction

The decommissioned bridge had a railway track that conveyed a small vehicle with a special attachment that hung over the side of the bridge to break up any ice present. This vehicle was known as the 'Ice Drag'. During the rehabilitation work the Ice Drag was removed from the bridge. In the interest of preserving this piece of history, a special concrete pad was poured adjacent to the bridge to accommodate the Ice Drag. Existing railings and gates were removed from the Ice Bridge, rehabilitated, and then placed around the relocated Ice Drag.

The Pedestrian Ice Bridge was rehabilitated with new parapet walls and railings and a new heated walkway surface. The rehabilitated pedestrian bridge provides a safe and convenient path for pedestrians and also affords an excellent view of the Niagara River rapids immediately upstream of the Horseshoe Falls.

Figure 6. Ice Bridge rehabilitated for a pedestrian walkway

3. SOCIAL AND ECONOMIC BENEFITS

The reconstruction of the Vehicular Forebay Bridge included preservation of historical aspects of the original structure as well as incorporating modern design and architectural elements to blend with the surrounding environment.

Accompanying the preserved original stonework are new reinforced concrete pedestals that were poured at the ends of the bridge and at each pier. Formliners were inset into the centre of each pedestal to simulate the cut stones in the parapet wall. Between the pedestals, an architectural steel railing was placed. The black painted steel railings match those that are found along the Niagara Parkway. The railings serve both an aesthetic purpose and provide a safety barrier for cyclists crossing over the bridge.

An architectural light standard was installed at each pedestal. The design of the pedestals and light standards was derived from a similar setup on the roof of the adjacent William B. Rankine generating station.

Figure 7. Architectural railings, pedestals, and light standards

Through innovative design and attention to architectural details, Rankin Construction Inc. and ELLIS Engineering Inc. were able to continue the tradition of marrying form with function that was set in motion by the original bridge designers.

The design-build model was effective in mitigating costly revisions during construction as changes in site conditions could be quickly reviewed and incorporated into the design. The reconstruction work on the Vehicular Forebay Bridge was completed in December, 2013, within the budget of $3,000,000 and ahead of the scheduled completion date of May, 2014. The rehabilitation of the adjacent Pedestrian Ice Bridge was also completed in December, 2013.

4. ENVIRONMENTAL BENEFITS

The design team's goal was to construct a sustainable structure that would meet current needs without compromising the needs of future generations. The vision of this goal was to construct a bridge that would last, while preserving the surrounding environment which includes several historic structures and landmarks.

The new thin cantilevered arch structure was constructed using the existing deck structure as formwork. This construction process allowed for minimal impact on the surrounding environment and drastically reduced the quantity of materials required. This process also reduced the production of waste material since the majority of the existing structure was reused.

Another environmental benefit of using the existing structure as formwork was the protection of the Niagara River waterway below the structure. Construction debris was contained within the shell created by the existing deck and stone walls. In addition, no in-water work was required as the existing abutments and piers were reused.

The original stone arch fascia and parapet walls were preserved and integrated into the new structure with reinforced concrete edge beams. At the top and the bottom of the edge beams, the stonework was anchored into the beams via Glass Fibre Reinforced Polymer (GFRP) dowels. The GFRP rebar was chosen for its anti-corrosive properties as salt chlorides from road de-icing operations are expected to infiltrate between the stonework and the edge beams. The use of this material ensures minimal maintenance over the life of the rehabilitated structure.

Figure 8. Glass Fibre Reinforced Polymer reinforcing in the edge beam

5. MEETING THE CLIENT'S NEEDS

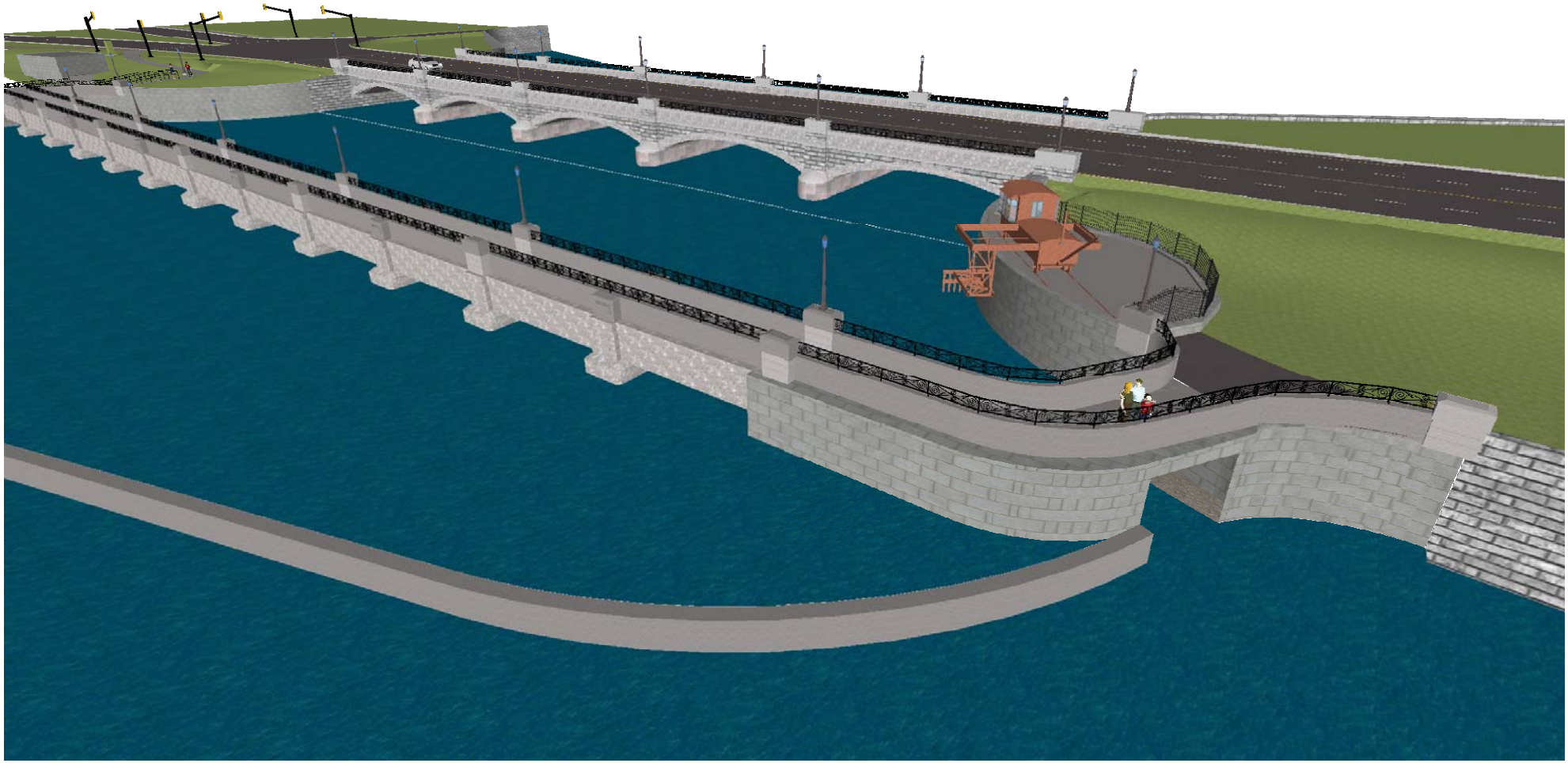
The main objectives and constraints guiding the design were: to provide a structure capable of carrying Canadian Highway Bridge Design Code loads; to maintain pedestrian and vehicular traffic during construction; and to preserve the aesthetics of the bridge and surrounding area.

In order to meet the objectives and constraints for the Vehicular Forebay Bridge, several design elements were developed and incorporated into the completed structure. The design of the thin cantilevered reinforced concrete arches for the bridge was completed in accordance with the Canadian Bridge Code. A finite element structural analysis program (S-FRAME) was utilized to analyse the structure under various loading conditions.

The construction was completed in stages to maintain vehicular and pedestrian traffic over the Vehicular Forebay Bridge at all times. Upon completion of the Pedestrian Ice Bridge, the pedestrian pathway was relocated from the Vehicular Forebay Bridge to the rehabilitated Pedestrian Ice Bridge overlooking the Horseshoe Falls.

The original stone arch fascia and parapet walls were preserved and integrated into the new structure. Reinforced concrete pedestals and architectural light standards were constructed to match the aesthetics of those found on the nearby generating station. As well, black painted steel architectural railings were installed to match the railings on the pedestrian walkway along the Niagara Parkway.

Figure 9. Reconstructed CNP Vehicular Forebay Bridge



Niagara Parks
An agency of the Government of Ontario since 1885

ELLIS Engineering Inc.

Rankin Construction Inc.

NIAGARA PARKS COMMISSION -
CANADIAN NIAGARA POWER ICE BRIDGE
(DESIGN BUILD)

LOOKING SOUTH WEST

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