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Heron Road Bridge Rehabilitation

Ottawa, Ontario

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PROJECT HIGHLIGHTS

The Heron Road Bridge located in the nation's capital, is a vital link within the City of Ottawa's transportation network being one of several bridges crossing the Rideau River that divides the east and west parts of the City and one of three major east-west cross town routes. Constructed in 1966/1967, it consists of long twin structures carrying Heron Road over the Rideau Canal (National Historic Site of Canada and UNESCO World Heritage site), the National Capital Commission (NCC) pedestrian pathway, Colonel By Drive, the Rideau River, and the Vincent Massey Park access road. Part of the bridge collapsed during original construction and this tragedy remains one of Ontario's worst construction accidents in history. Each structure consists of seven spans carrying three lanes of traffic. The north structure is about 267m long and the south structure is 276m long. The superstructure consists of cast-in-place post-tensioned voided concrete deck cantilevered to support three suspended spans. The suspended spans consist of nine simply supported prestressed girders, with reinforced concrete deck. The precast girders are supported by corbels at the ends of the cantilevered post-tensioned deck. The substructure consists of six intermediate piers and abutments at each ends. The piers in the vicinity of the Rideau River are supported on spread footing on bedrock whereas the remaining piers and abutments are supported by piles driven to bedrock.

Detailed bridge inspection and condition assessment, structural and seismic evaluation revealed that the structure was in need of significant rehabilitation and major seismic retrofit. The Bridge renewal took advantage of the extensive structural rehabilitation work required, (which included replacement of the sidewalk, barriers, railings, waterproofing and asphalt surface), to reconfigure the lanes on the structure to accommodate dedicated cyclist and bus lanes and a wider sidewalk. The seismic retrofit used the elegant, simple seismic isolation approach which required modifications to the bridge articulation; the introduction of seismic isolation bearings; and the use of bumper restrainers to connect the drop-in suspended spans to the adjacent post-tensioned deck and to prevent the unseating of the suspended span segments under seismic events. The structural rehabilitation included the replacement of existing external post-tensioning system at the suspended span corbels with an innovative Carbon Fibre Reinforced Plastic (CFRP) external post-tensioning system, the first application of its kind in Canada.

The rehabilitation work required approvals from federal authorities under the Fisheries Act, Heritage Canal Act, and the Navigable Waters Protection Act. Coordination with the NCC and Parks Canada was required to develop an Environmental Screening Report in accordance with the Canadian Environmental Assessment Act (CEAA).

Rehabilitation of this structure required two construction seasons. Construction commenced in February 2011 and the rehabilitation was completed in December 2012. Construction resulted in minimal interference to pedestrian / cyclist traffic on the bridge; minimal interference to the vehicular traffic; and with no interference to the boat traffic on the Rideau Canal and the pedestrian/cyclist traffic along the Rideau Canal pathway. Despite all its challenges the bridges opened to traffic ahead of schedule and all engineering works were completed under budget.

PROJECT DESCRIPTION

Services Provided

As Prime Consultant, Delcan's services included detailed bridge inspection and condition assessment, structural and seismic evaluation, retrofit detailed design, environmental approvals, contract administration and engineering services during construction. The scope of engineering disciplines included bridge and structural engineering, construction engineering, roadway engineering, utilities and services relocation, approvals and liaison with stakeholders.

Project Objectives, Solutions and Achievements

The objective of this project as set by the City of Ottawa was to upgrade the bridge "to the extent feasible, practical and economical in accordance with current standards, thus extending the service life of the bridge". Delcan's goal was to meet the City's objective while achieving technical excellence on this project through the successful completion of the following design and construction elements:

- Integration of design elements with agency requests and approval requirements;
- Management of traffic and pedestrian movements during construction;
- Incorporation of sustainable construction practices;
- Selection rehabilitation strategies that minimize environmental impacts to the waterway; and
- Employing design innovations where feasible in order to achieve cost and time savings.

To better comprehend the success of this major rehabilitation project, the following is a detailed list of some of the project objectives/challenges, as well as the associated solutions which were implemented by the design team to address each item.

- The requirements of the Federal EA Screening Report (NCC and Parks Canada) were satisfied by the selection of a railing system that met the stringent crash-testing requirements of the Canadian highway Bridge Design Code and provide an open railing system to improve aesthetics and views. Cut-off roadway lighting was used to mitigate spillover into the adjacent Canal and to respect the cultural and historic resources of the area. Additional environment requirements from the Rideau Valley conservation Authority (RVCA) and the Department of Fisheries and Oceans were met and permits were obtained ahead of construction without any delays.
- Minimizing disruption to vehicular, pedestrian and cyclist traffic. Vehicular traffic was accommodated with minimal disruption by staging the work in which one structure was closed and traffic was detoured on the adjacent structure while accommodating

two lanes of traffic in each direction. Pedestrian and cyclist traffic movement on the open structure as well as their access to the Colonel By Drive and the Vincent Massey Park was addressed using proper traffic signage to integrate the bicycle traffic with vehicular traffic and by raising the railing on the sidewalk to meet the height requirement of a pedestrian / cyclist barrier. The waterway and the pathways in the vicinity of the Rideau Canal remaining open with no disruptions to pedestrians, cyclists and boaters.

- Coordination of construction staging and utilities relocation was paramount in relocating major fiber optic cables for both Rogers and Bell. The scheduling for relocating utilities was planned to occur between the two construction seasons of the bridge rehabilitation and by providing a clear separation in time and location between the different contractors.
- Seismic evaluation revealed two major deficiencies with the structure including: inadequate piers, abutments, and associated bearings and foundations to transfer the seismic loads to the deep foundations and significant risk of unseating/collapse of the suspended spans under a seismic event. Two retrofitting schemes were considered for the piers and abutments including: brut force strengthening approach and the seismic isolation strategy. The strengthening approach involves strengthening the foundation, substructure elements and bearing replacement and would require significant in water works. The seismic isolation approach involves replacing the pier bearings with seismic isolation bearings and modifying the articulation at the abutment to accommodate the anticipated seismic movements. This retrofit scheme works by partly isolating the bridge deck from the ground motions induced by the seismic event, which would significantly reduce the loads experienced by the substructure members. The specialized isolation devices, used in such schemes, also help dampen the seismic energy, reduce seismic displacements and restore the bridge to its original location, following a seismic event. The seismic isolation approach was implemented for the Heron Road Bridge as it is the simplest and most cost effective solution.
- Securing the suspended spans and addressing all existing issues associated with their probable unseating and full failure in the event of a significant earthquake, was one of the critical aspects of the seismic retrofit. This was achieved by the development of a custom bumper restrainer system which accommodates the everyday thermal movement of the structure and can transfer the seismic forces after a predetermined movement is traversed to prevent unseating of the suspended spans.
- Failed external post-tensioning system supporting the bearing seat of the suspended span requires replacement. This system was implemented to remedy a defect in the original design of the bridge and has previously failed at other locations before and was becoming a maintenance issue to the City of Ottawa. A new external post-tensioning system consisting of post-tensioning CFRP strips was implemented. The CFRP strips were stressed and glued with epoxy to the concrete corbel.

At the end, an innovative comprehensive rehabilitation was designed, tendered under budget, executed without any significant impact to users and the environment, and regardless of the many complexities the bridge was opened ahead of schedule. The final result is a bridge that is safer, more durable and offers better accessibility to all users.

Technical Excellence and Innovation

The project involved numerous challenges that were listed in the previous section which were tackled with a high degree of technical excellence and innovation solutions. Herein are the further details on a few of the key challenges and the associated innovations:

Seismic Evaluation and Retrofit:

Various factors contributed to the complexity of the seismic analysis of the structure including: variation in soil profile along the length of the bridge from rock to soft soils; different foundations at the various piers and abutments (piled foundations and spread footings on bedrock); the presence of the suspended spans which are attached to one end of the post-tensioned deck and free to move at the other end and the bridge classification as an "emergency route" by the City of Ottawa. These factors resulted in the structure being considered "irregular" and a multi-modal analysis was required per the requirements of the Canadian Highway Bridge Design Code. Several structural analysis models were considered to capture the behavior of the structure taking all these variables into account. However, this analysis method do not accurately model the highly non-linear seismic isolation devices and bumper restrainers especially for the wide range of site conditions ranging from rock to soft soil. As such the seismic retrofit was validated using non-linear time history analysis using site specific spectra developed for the bridge location by the Geotechnical Engineer. This complex analysis resulted in the refinement of the design and the use of a bumper restrainer in lieu of a more complicated lock-up device initially envisaged, which resulted in a significant cost saving.

External Post-Tensioning system:

An external post-tensioning system was previously utilized at the end of the post-tensioned deck supporting the suspended spans. This system was installed to assist with crack control due to insufficient transverse reinforcement in the original design. However, this system failed at several locations and had already been fully replaced before. During the recent rehabilitation several replacement options were considered. Delcan made use of advancement in the CFRP technologies which included the development of an anchorage system that works with CFRP strips. The system has been used in numerous bridge rehabilitation projects in Europe but this was the first application of its kind in Canada. The design of this system was carried out in collaboration with Sika and VSL. The final product required much smaller anchorages than the existing system and the strips blend nicely with concrete surface and are hardly noticeably from a distance. The solution is therefore not only more durable, but it also significantly enhances the aesthetics of the bridge.

Level of Complexity

The project involved several technical complexities during the design and construction stages. The following attributes of the existing bridge complicated the structural and seismic analysis and retrofit design: the articulation of the structure consisting of four cast-in-place concrete post-tensioned decks cantilevered to support three suspended spans; different foundations types at the various piers and abutments (piled foundations and spread footings); variation in the soil profile along the length of the bridge from rock to soft soils; and the hinge detail at the abutment which allowed rotations.

The retrofitted structure included the following technical complexities:

- Modifications to the abutment articulation to accommodate the longitudinal and transverse seismic movements which are in the range of 80mm as well as uplift forces which could be experienced under certain live load patterns.
- Installation of the seismic isolation bearings required the jacking of the entire structure by about 250mm. This involved jacking the 8200 tonnes bridge at the piers and abutments by increments of 25mm from one end of the bridge to the other.
- The design of bumper restrainers which can accommodate the thermal movements of the structure and prevent the unseating of the suspended span during a seismic event.

Additional complexity during construction was the discovery of asbestos ducts in the sidewalks being replaced and the implementation of an abatement program without affecting the overall project schedule.

Contribution to Economic, Social and Environmental Quality of Life

This project has made a significant improvement to the economic, social and environmental quality of life by bringing this vital arterial in the City of Ottawa to current codes and standards. It also enhanced the functionality of the bridge to accommodate transit priority, enhanced pedestrians and cyclists experience along the bridge and adjacent pathways as well. Some examples on how the Bridge has contributed to the enhancement of the economic, social and environmental quality of life are as follows:

- Changed roadway configuration from three general purpose lanes to two general purpose lanes, one reserved bus-only lane and added a cyclist lane.
- The pathway link to the adjacent Vincent Massey park was modified and relocated to meet the accessibility standards and provide a better connection to the park.
- Bicycle channels were introduced at the stairs connecting the bridge to the pathway along the Rideau Canal and Colonel By Drive to help cyclists with transporting the bicycles along the stairs.
- Cut-off lighting was used to prevent spillage into the Rideau River and Rideau Canal and thus protecting the natural environment off the structure.
- An open railing system that met the stringent crash testing requirements of the Canadian Highway Bridge Design Code while keeping the views open to the roadway users.

As part of the environmental assessment screening process carried out by Delcan, all components of the social, economic and environmental conditions were considered in assessing the effects of the bridge retrofit design and construction. The majority of the adverse effects were short-term and occurred during construction, such as: disruption to traffic during equipment and material deliveries; and increase in noise, dust and visual disruption. As such, mitigation measures were identified to minimize or eliminate potential adverse effects, and to enhance the environmental quality, where possible. These measures were implemented during construction with no significant adverse environmental effects.

Acknowledgements

Delcan was the prime consultant to the City of Ottawa. The geotechnical sub-consultant was Golder Associates, and the lighting and electrical sub-consultants are Gabriel Mackinnon and McKee Engineering, respectively. The general contractor for this project was Pomerleau.

Project Completion

Rehabilitation of Heron Road Bridge twin structures required two construction seasons. Construction commenced in February 2011 and the rehabilitation was completed in December 2012 at a construction cost of $12.2 million.

Overall view of the Heron Road Bridge

Twin structures each carrying two general purpose lanes, one bus-only lane, a bicycle lane and a sidewalk

Overview of retrofitted bridge with new seismic isolation bearings and new external post-tensioning system

Existing bridge bearings

New seismic isolation bearings

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