2019 CANADIAN CONSULTING ENGINEERING AWARDS

JOHNSON STREET BRIDGE REPLACEMENT

Submission Category: Transportation

ASSOCIATION OF CONSULTING ENGINEERING COMPANIES | CANADA
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wsp

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PROJECT SUMMARY

New Johnson Street Bridge on opening day in comparison to original bridge

The original Johnson Street Bridge opened on January 11, 1924. It was designed by Joseph Baermann Strauss, the famed designer of the Golden Gate Bridge. The “Blue Bridge,” as it was known in Victoria, was painted blue in 1979 - 55 years after it opened.

The Blue Bridge was seismically vulnerable and at the end of its service life, and in 2010 the City held a referendum and voted to replace the bridge with an iconic structure that would serve the community for the next 100 years. WSP was selected by the City to make their vision a reality.

The new Johnson Street Bridge is an engineering marvel and new City landmark that provides vastly improved community connections coupled with seismic resiliency and improved marine access to Victoria’s Inner Harbour and industrial lands. Through its stunning LED lighting, the sleek new bridge is transformed from its daytime light grey to a brilliant nighttime blue that respects the heritage of the historic bridge it replaced.

Nighttime - showing the fully illuminated underside of the Orthotropic Steel Deck (OSD)

WSP has designed hundreds of bridges over the past 60 years and the new Johnson Street Bridge is in a class by itself when it comes to uniqueness. It is the largest single leaf bascule bridge in Canada and one of the largest in the world (53m). Further complicating the design and fabrication, the pedestrian and cycle paths are offset from the main truss and follow a different vertical profile.

One of the bridge’s most unique design features is the rolling bascule design with hidden counterweights that allow the main span of the bridge to rotate on the outer surface of its two rings about a “virtual” centre axle.

The team integrated modern load equalizing and support systems like those used on large retractable roofs and utilized load distribution techniques like those used on modern mechanized cranes. This feature is a key differentiator from the more traditional bascule bridge design that incorporates a centre trunnion (axle) and overhead counterweights and allows the new Johnson Street Bridge to have a modern low-profile design that vastly improves city view corridors. The upper lobes on the two rings of the main span are filled with a combination of lead and concrete and the main bridge counterweight sits below the east approach ramp making it invisible to the public, unlike the enormous overhead monolithic concrete counterweight of the old bridge that blocked out the skyline.

The massive 3,000 tonne moveable span is operated by 3 high torque, low speed 75 kW hydraulic pumps motors. From the operator's hut, the moveable span can be raised or lowered in 90 seconds. The hydraulic lift system is extremely efficient due to the near perfect balance between the bridge span and the counterweight system.

While the main span gets most of the attention, the overall project involved the creation of a myriad of new roadway, walkways, cycling paths and public gathering spaces that have created vibrancy and renewal in the area that will last for generations.

PROJECT ACHIEVEMENTS

Nighttime – fully illuminated ring and truss taken from east side of pedestrian walkway

The City of Victoria needed to replace the iconic 90-year old Johnson Street Bridge which was nearing the end of its service life and was likely to fail in the event of a major earthquake. This was a transformative project for the City since the bridge is a gateway to the Inner Harbour and a key connector for the community.

In 2010 the City set out to build an iconic structure that would serve the City for the next 100 years and their objectives were to:

- **Provide a new bridge with a 100-year service life** – all major components of the bridge have a 100-year service life;
- **Provide a new bridge that would be useable after a major earthquake** – the new bridge is designed to Canadian Highway Bridge Code (CHBC) as a lifeline bridge to allow it to be useable following a major earthquake;
- **Respect the historic place and guidelines** – blue LED lighting has been used to preserve the memory of "Old Blue";
- **Provide a dedicated multi-use path and pedestrian walkway separated from vehicular traffic** – a new pedestrian walkway (PED) and new multi-use deck (MUD) are cantilevered off the south and north sides of the bridge and completely isolated from vehicle traffic;

- **Provide 3 vehicle lanes and dedicated on-bridge bike lanes** – the new bridge has 3 full lanes and dedicated eastbound and westbound cycling lanes, a vast improvement over the old 2-lane span;
- **Consolidate green space and create new public gathering places** – new public plazas with stunning views of the City and Inner Harbour have been created on the east and west sides of the bridge;
- **Integrate existing and proposed pedestrian pathways and bike lanes** – new pathways have been created linking the bridge walkways and cycling lanes to the Galloping Goose Trail and the new David Foster Way;
- **Provide a wider navigation channel** – the navigation channel was increased by 4m to make transits easier for both commercial and pleasure boats; and
- **Improve road approaches on both sides of the bridge** – the roadways on both sides of the bridge are vast improvements over the congested corridors of the old bridge.

WSP INVOLVEMENT

WSP's involvement allowed the City to realize their objectives. In addition to our role as prime consultant for the overall project providing project management, design management and construction support services for the duration, we were also responsible for the design of the bridge approach spans, moveable span rest pier, roadways and pathways, road safety and public plazas. Hardisty & Hanover (H&H) were the designers of the moveable span including the bascule pier. PBX Engineering Ltd. was responsible for the electrical design as well as the roadway functional lighting and bridge lighting.

CHALLENGES, SOLUTIONS AND ACHIEVEMENTS

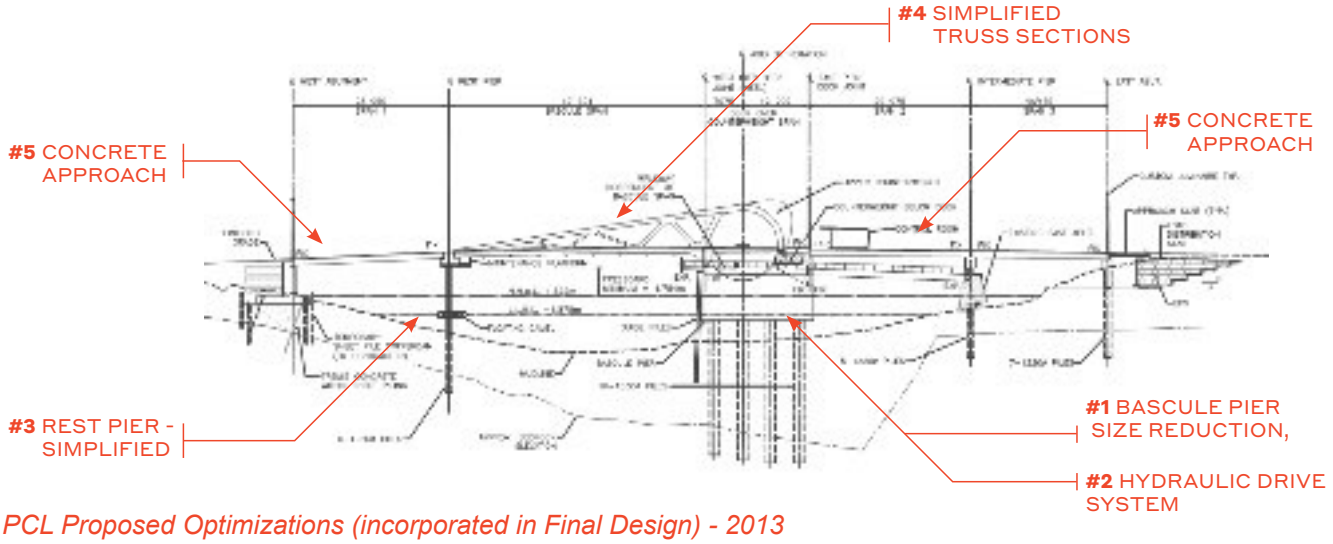
Complexity

- **Procurement** - The City selected Early Contractor Involvement as the delivery method that would allow them to "fast track" the project to meet the grant funding deadline. WSP prepared an indicative design that was issued for contractor proposals and contractors were encouraged to submit alternatives that would allow them to meet the City's project affordability ceiling. PCL's proposal included the following alternatives that formed part of their fixed price:
- **Bascule Pier Size Reduction** – stacking the electrical room overtop of the mechanical room reduced the overall footprint of the bascule pier (where moveable bridge operating components are housed);
- **Hydraulic Operating System** – the use of a hydraulic drive system was more compact and less expensive than a more traditional mechanical drive system;
- **Rest Pier** – a simplified geometry that was easier and faster to construct;
- **Simplified Truss Designs** – modified the bridge architect's original vision for 7-sided truss members to a rectangular cross-section to simplify fabrication; and,
- **Use of Concrete Instead of Steel** – for approach spans and the off-bridge multi-use deck and pedestrian walkways.

Times Columnist, March 31, 2018 – Say hello to the new Johnson Street Bridge

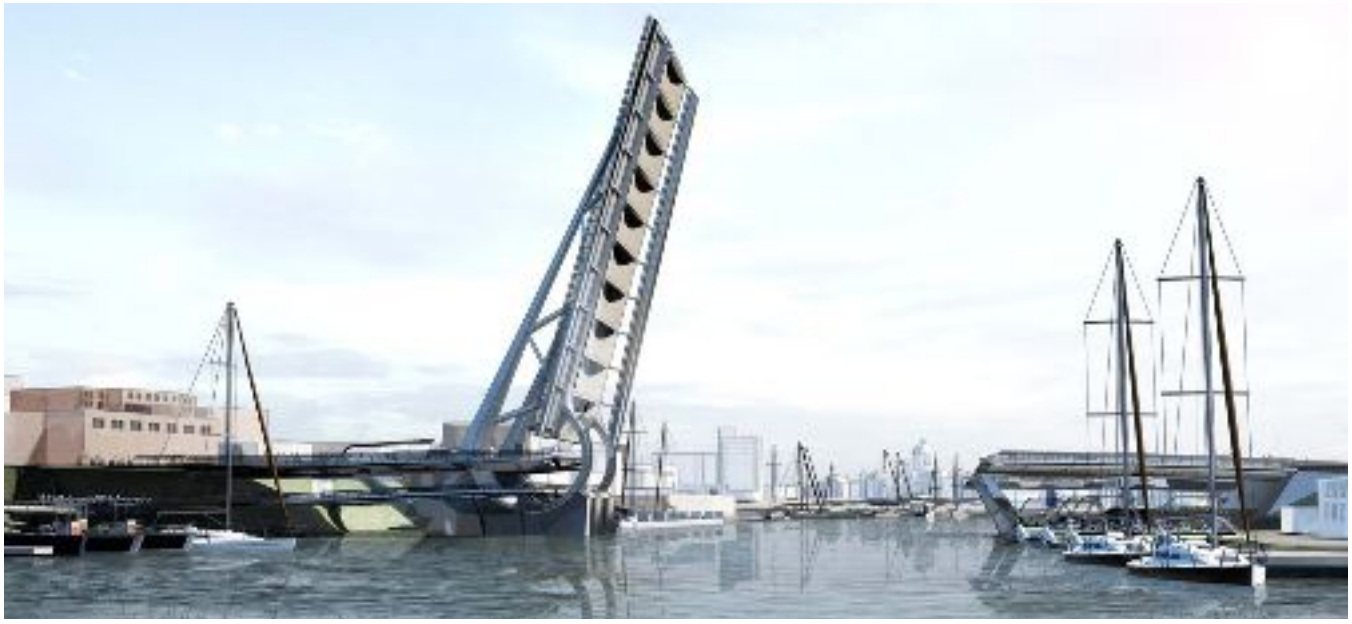
"It's a bridge for the next 100 years, a modern design that might one day carry self-driving, fuel free cars. This bridge will last for generations. I think today is really a day of celebration. It's a day of looking at what does the next 100 years in Victoria look like with this bridge as our anchor?"

Mayor Lisa Helps



PCL Proposed Optimizations (incorporated in Final Design) - 2013

Opening Day Ceremony (March 31, 2018)



Rendering of Original Concept (2010)

The City awarded the contract to PCL Constructors Westcoast Ltd. (PCL) at the very end of 2012. WSP was then tasked with completing the detailed design and incorporating PCL's optimizations (based on conceptual level engineering undertaken by PCL) without impacting PCL's price. This monumental challenge required a highly flexible approach with continual rebalancing of the final designs with construction costs with schedule. The path to the project finish line necessitated an elevated and sustained level of collaboration between the City, the WSP design team, and PCL from design through to construction completion. Given the challenges of moving forward with a fixed price contract and a partially completed design, the fact that the final construction cost and final project cost at completion are only 5% and 13% higher respectively than originally forecast in 2013 is a testament to the skill and ingenuity of the WSP project team, PCL Constructors Westcoast Ltd. and the City of Victoria.

Project Budget	2013	2018
Total Project Budget	$92.8 million	$105 million
Construction Budget	$66.0 million	$69.5 million

Moveable Span Fabrication

The new Johnson Street Bridge is designed as a Fracture Critical Bridge, which is commonly defined as a bridge with steel tension members, or steel tension components of members, whose failure would be expected to result in a partial or full collapse of the bridge. Fabrication of a fracture critical structure has very precise requirements for materials, welding and cutting.

The moveable span was fabricated in China by Jiangsu Zhongtai Bridge Steel Structure Co., Ltd. (ZTSS), and as the project team we had to overcome the challenges of remote project management, language and cultural barriers, a 13-hour time difference, and fabricator adaptation to meet rigorous North American standards of fracture critical fabrication.

ZTSS's first fabrication was fraught with an insurmountable number of what were determined by PCL's Quality Control team and WSP's Quality Assurance team to be unresolvable non-conformances, and early in 2014 the project team had to make the very difficult decision to completely restart fabrication knowing it would add two (2) years to the overall project completion schedule. A more rigorous Contractor's Quality Control program was implemented with PCL taking the lead and heightened Owner's Quality Assurance oversight through to final fabrication completion.

New Johnson Street Bridge in 'open' position

TECHNICAL EXCELLENCE AND INNOVATION

The new Johnson Street Bridge is an engineering marvel and new City landmark that provides vastly improved community connections coupled with seismic resiliency and improved marine access to Victoria's Inner Harbour and industrial lands. Through the use of stunning lighting, the sleek new bridge is transformed from its daytime light grey to a brilliant nighttime blue that respects the heritage of the historic 90-year old bridge it replaced.

WSP has designed hundreds of bridges over the past 60 years and the new Johnson Street Bridge is in a class by itself when it comes to uniqueness. Unique features that showcase innovation and excellence include:

- **Single Leaf** – the new bridge is the largest single leaf bascule bridge in Canada (53 m / 175 ft.) and one of the largest in the world.

- **Virtual Axle Design** – the rolling bascule design has no trunnion (fixed centre axle) and the new bridge rotates on the outer surface of its two rings about a "virtual" centre axle. This feature is a key differentiator from the more traditional bascule bridge design that incorporates a centre trunnion (axle) and large overhead counterweights, and it allows the new Johnson Street Bridge to have a modern low-profile design that vastly improves city view corridors.

- **Unique Span Support/Drive Mechanism** – the span support drive systems are a modern adaptation of the roller bearing support bascule design first patented by John Philo Cowing in the early 20th Century and unique in North America. The team improved upon this concept by integrating modern load equalizing and support systems like those used on large retractable roofs and utilization of load distribution techniques like those used on modern mechanized cranes. Jonathan Huggett, the City's Project Director was frequently quoted as saying ***"It's more like a building Swiss watch than a bridge".***

Close-up of the Span Support Roller Assembly and Rack Support System

South Ring of the Moveable Span being set in place by the Dynamic Beast - a 900 tonne floating crane

- **Seismic Design -** movable bridges are notoriously difficult to design for earthquakes. A massive overhead counterweight can significantly increase seismic demands, as was the case for the old Blue Bridge. Movable parts must be designed to accommodate seismic loads and be able to tolerate post-earthquake displacements, and the bridge (seismic) response must consider multiple open/closed configurations. To further challenge our team, Victoria is Canada's most seismically-active major city, defined by the long-anticipated and very large subduction earthquake from the nearby Cascadia Zone convergent plate boundary. The design team drew on state-of-the-art analytical tools and modern structural detailing to ensure reliable performance for this lifeline structure.

- **Hidden Counterweights** – the upper lobes on the two rings are filled with a combination of lead and concrete (counterweight) and the main bridge counterweight sits below the east approach ramp making it invisible to the public, unlike the enormous overhead monolithic concrete counterweight of the old bridge that blocked out the skyline.

- **Hydraulic Drive** – the massive 3,000 tonne (6,000,000 pounds) moveable span is operated by a closed loop hydrostatic transmission with 3 high torque, low speed 75 kW (100 hp) hydraulic pump motors. From the operator's hut located on the east approach ramp the moveable span can be raised or lowered in 90 seconds.

The Johnson Street Bridge has already been recognized for its engineering achievements by the American Council of Engineering Companies (ACEC) – New York (submitted by H&H) where it won a 2019 Engineering Excellence Diamond Award for Category C: Structural Systems.

SOCIAL AND/OR ECONOMIC BENEFITS

- **Old Blue Remembered** - LED lighting is used to transform the bridge from its daytime light grey to a brilliant nighttime blue that preserves the heritage of the historic 90-year old "Blue" bridge it replaced, satisfying the City's objective of respecting the "historic" place.

- **Up Close and Personal** – the new bridge includes a pedestrian walkway through the rings to allow the public to see the bascule pit, lower counterweight and bridge operating mechanism.

Nighttime view inside the bascule pit showing the span support roller assembly, rack support gear teeth and pedestrian walkway through the rings.

- **Seismic Resiliency** – the new bridge is a "lifeline bridge" and has been designed to be usable by emergency vehicles and for security/defense purposes after a 1:2,500-year return period earthquake, allowing the City to maintain emergency services in a time of chaos.

- **Active Transportation Enhancements** – in a city that is becoming renowned for its cycling infrastructure and walkability, more than 50% of the new bridge surface area is dedicated to pedestrians and cyclists including connections to the existing Galloping Goose Trail and the new David Foster Way.

New Bridge in raised position after removal of "Old Blue" showing the west side approach span, western plaza areas, connecting walkways and new pedestrian bridge (foreground).

Side by side comparison of sleek new design with 50% of deck surface dedicated to pedestrians and cyclists

- **Improved Public Safety** – the bridge includes a dedicated pedestrian footpath and a multi-use deck that are cantilevered off the main bridge deck, providing a physical separation from vehicular traffic, as well as dedicated on-road bike lanes. ***Since it opened, cycling traffic across the bridge has increased by more than 50%.***

- **New Public Space** – new pedestrian plazas have been created on the Victoria and Victoria West sides of the bridge, creating public space that will be used by both city residents and the multitude of annual visitors to the "Garden City"– something that was completely absent on "Old Blue"

ENVIRONMENTAL BENEFITS

Like many waterfront industrial areas in British Columbia, the lands on both sides of the existing bridge were contaminated from past industrial uses, including rail activity dating back to the late 1800s. The construction of the new bridge afforded the City the opportunity to clean up and reclaim foreshore areas at the new bascule pier, rest pier, and along connecting roadways, as well as the areas surrounding the old rail line/rail bridge and the existing bridge. All excavated soil was tested, and removed from site and disposed of at a special waste handling facility if the contamination level exceeded industrial land standards.

The size of the bascule pier was reduced during detailed design. This eliminated the need for a cofferdam and allowed all construction activities to be undertaken on land without any in-water works other than piling for the rest pier, vastly reducing the impact of construction on the marine environment. Environmental compensation in the form of riprap placement was undertaken.

Enhanced active transportation opportunities translate directly into fewer vehicles, less congestion and decreased greenhouse gas generation. Since it opened, cycling traffic across the bridge has increased by more than 50%.

Late in the project, it was decided to add the ability to dim the LED bridge lights during spawning season so that fish transiting under the bridge will not be illuminated to the seals that ply the waters under the bridge looking for an easy meal.

Opening Day, March 31, 2018 - Mayor Lisa Helps' first walk across the new bridge

Times Columnist, March 31, 2018 – Say hello to the new Johnson Street Bridge

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Mayor Lisa Helps

SUMMARY

WSP is proud to have provided project management, design and construction administration services on the challenging and exciting replacement of the Johnson Street Bridge. Collaborating with the City, PCL and our lead subconsultants was one of the more rewarding aspects of the project. This was memorialized in being able to take part in and share the opening experience with the people of the City of Victoria on March 28, 2018. This was one of, if not the most, challenging projects that our team had ever been part of and we take great satisfaction and pride in being able to help the City realize their vision and achieve their objectives of providing a bridge that will last for 100 years, remain in service following a major earthquake, facilitate marine passage, encourage the use of alternative modes of transportation, and bring the community together.

Orthotropic Steel Deck with Pedestrian Walkway and Multi-use Deck attached being lifted into position by the Dynamic Beast - a 900 tonne floating crane

Demolition of «Old Blue»