## 1.0 INTRODUCTION

Harbourside Engineering Consultants wishes to thank Canadian Consulting Engineer Magazine and the Association of Consulting Engineering Companies of Canada for accepting the nomination of the Strandherd Armstrong Bridge Erection project for the prestigious Canadian Consulting Engineering Awards 2014.

Bridge Construction Engineering is an exciting field that requires a great deal of innovative thinking and detailed knowledge of construction methods and structural engineering theory. This field of engineering is high risk due to the fact that accidents and structural failures frequently occur during the construction phase of the project. With that said, when properly engineered and constructed, the method of construction of a bridge can significantly reduce costs and schedule, mitigate impacts on the public and surrounding environment, as well as the probability of serious accidents from occurring.

For the typical bridge site, where relatively easy access beneath the bridge is available to construction equipment, the use of land or barge mounted equipment such as cranes to erect bridge superstructure elements is usually the most cost effective method of construction. Where access below the bridge is problematic, as was the case with the Strandherd Armstrong Bridge, innovative construction and erection designs are required. The contract requirements for this project stipulated that the navigation channel must remain open from May to October throughout construction with no overhead work taking place every Friday through Monday during this time frame. In addition, the Strandherd Armstrong Bridge crosses the Rideau River, a designated UNESCO world heritage site, which further heightened the concerns to limit environmental impact to the site. In 2010, the contractor that had been awarded this $50 million dollar project felt that their current erection scheme choices were not viable and asked HEC if they could develop a cost-effective and constructible plan that satisfied the project requirements and still be practical and affordable. HEC embraced this challenge and developed a unique construction and bridge erection plan. After a single concept discussion with the contractor, HEC pitched this concept to the City of Ottawa (the Bridge Owner) and was given approval to proceed during the meeting. HEC's role on this project included conceptual, preliminary and detailed construction and erection engineering, PSS cable specialist services, and bridge specialist engineer quality assurance during construction.

The Strandherd Armstrong Bridge is a vital link across the Rideau River. It joins the community of Barrhaven to the rapidly growing community of Riverside South. The bridge provides the missing link between the southwest and southeast transit corridors in the city of Ottawa and is a necessary piece of infrastructure to reduce the increasing pressure on existing bridges.

The bridge is a multiple, independent, space-truss arch bridge with a cast-in-place concrete deck supported by steel framing that is, in turn, suspended from the arches by parallel strand system (PSS) cables. The deck steel framing consists of longitudinal trapezoidal box stringers that frame into transverse, box shaped floor beams. The cable hung deck provides lateral stability to the arches that each consist of three 508 mm diameter hollow structural section (HSS) chords with wall thicknesses ranging from 27 mm to 76 mm, and 219 mm diameter HSS web members. The arches rise above the deck level approximately 21 m at their peak at mid span of the bridge. The total span of the completed bridge is 143 m and will accommodate eight full traffic lanes, two bike paths, and two pedestrian sidewalks, resulting in a total bridge width of 58.7 m. The cast-in-place concrete abutments and thrust blocks at each end of the arch are founded on 1800 mm diameter reinforced concrete caissons and provide external thrust support to the three arches and support for the short approach spans at each end of the bridge. A typical cross section of the bridge superstructure is shown in Figure 1 with a typical elevation is shown in Figure 2.

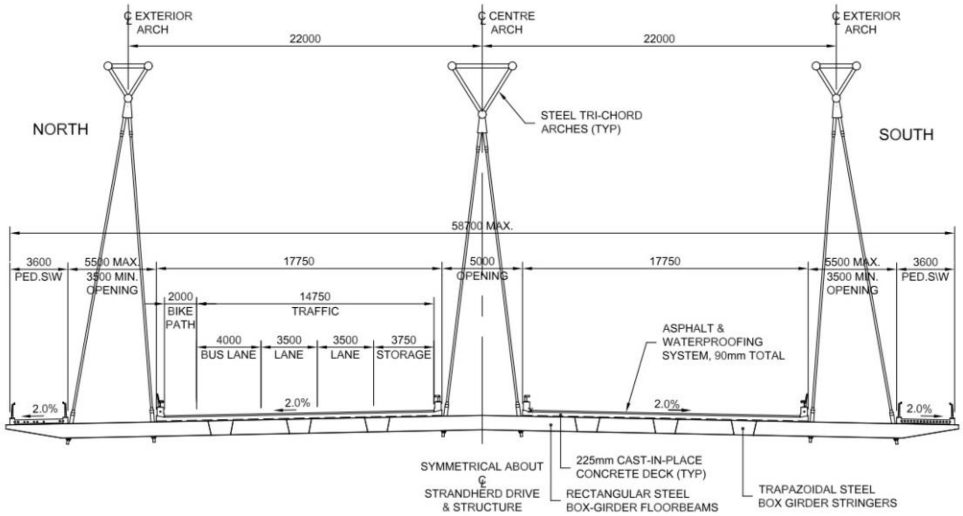


Figure 1. Typical bridge cross section.

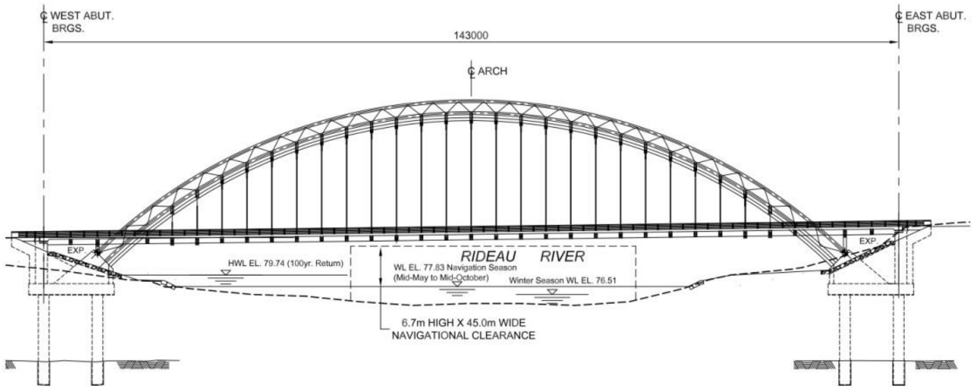


Figure 2. Typical bridge elevation.

## 2.0 CONCEPTUAL BRIDGE ERECTION CHALLENGES

The construction contract for the Strandherd Armstrong Bridge contained strict requirements and constraints which made the erection of the structure challenging. Perhaps one of the biggest challenges during construction of the bridge centered on the strict navigation channel requirements along the Rideau River. The channel had to remain open from May to October each year with no overhead work taking place between Friday through Monday of each week during this time frame. As is the case with most of Canada, construction during the winter months in Ottawa is difficult, time consuming and expensive; hence, an innovative erection methodology was considered necessary to allow construction to essentially be uninterrupted by the navigation channel restrictions set forth in the contract.

Additional challenges associated with the bridge construction included difficult field splicing of both the arch segments and deck grillage, strict tolerances and geometry control for all components of the bridge, including the arches, the PSS cable angles and alignment, the deck profile, and fit-up of the arches on the thrust block anchorages, and the requirement for the arch and deck system to remain stable during all phases of construction. Minimizing the environmental footprint of the project was another key objective of the project due to the fact that the Rideau Canal has been identified as a world heritage site by UNESCO, and a National Historic Site of Canada.

Several possible methods of construction were considered early on during the construction of the bridge. Two traditional arch erection techniques, a highline system and towers with cable stays, were examined. These methods erect the arches segmentally across the river with the steel deck framing installed after the arches are completed. A third option consisting of a purpose made gantry system to build the arches segment by segment over the water was also considered. All three of these options required the arches to be constructed in place over the water where maintaining stability of the three independent arches would be difficult under even moderate wind loadings. The navigation channel limitations greatly hindered the schedule and cost for these three methods. In response to the significant issues associated with the use of more traditional arch erection methods at this site, a technique that allowed the arches to be constructed on land with the deck system in place was conceptualized. After construction, the arches and deck would be launched into position over the river, over a two to three day period, and then strategically lowered into position onto the permanent thrust blocks. To allow for this method to be viable, it had to first be determined if there was enough real estate on one of the approaches to allow for the construction of the bridge superstructure without interrupting traffic on existing roadways. An investigation of the boundaries of the bridge construction site determined the land area on the east approach was just large enough to accommodate the required staging area for the bridge superstructure.

## 3.0 CONCEPT DESCRIPTION

An innovative construction method was developed by Harbourside Engineering Consultants (HEC) for the bridge that allowed 90 percent of the steel superstructure to be erected on temporary supports on the east approach before being launched into place across the Rideau River. After the arch segments were welded and the deck suspended, the ends of the arches were tied together with a “bow string” horizontal post-tensioned cable system and supported on railcars, which allowed the steel superstructure to be rolled across the temporary launch structure. The launch structure consisted of three parallel steel box trusses that are aligned transversely with each of the bridge arches and are founded on temporary piled bents consisting of drilled, then driven steel pipe piles and a reinforced concrete pile cap. The pile bents were strategically located outside of the navigation channel and the trusses were strategically designed to be positioned above the navigation channel during all phases of construction. To allow the bridge to be constructed on the east approach while the temporary works were installed, the temporary launch trusses were designed to be launched onto the temporary pile bents from the shorter western approach. After launching the arches and deck into position, lifting towers were installed from the approaches onto the end pile caps, the structure was lifted off of the launch trusses, and the trusses were de-launched back onto the western approach. With the trusses removed, the structure was strategically lowered onto the thrust blocks and the temporary ‘bow string’ removed prior to completing the installation of the short approach spans. With the conceptual construction method developed, the option was presented first to the general contractor, followed by the City of Ottawa and the bridge designers to obtain approval to proceed with the erection design.

Figure 3, below, illustrates the key elements used for the construction of the Strandherd Armstrong Bridge. A detailed description of each of the key elements is provided below Figure 3 and a detailed description of the construction methodology is provided in Section 4.

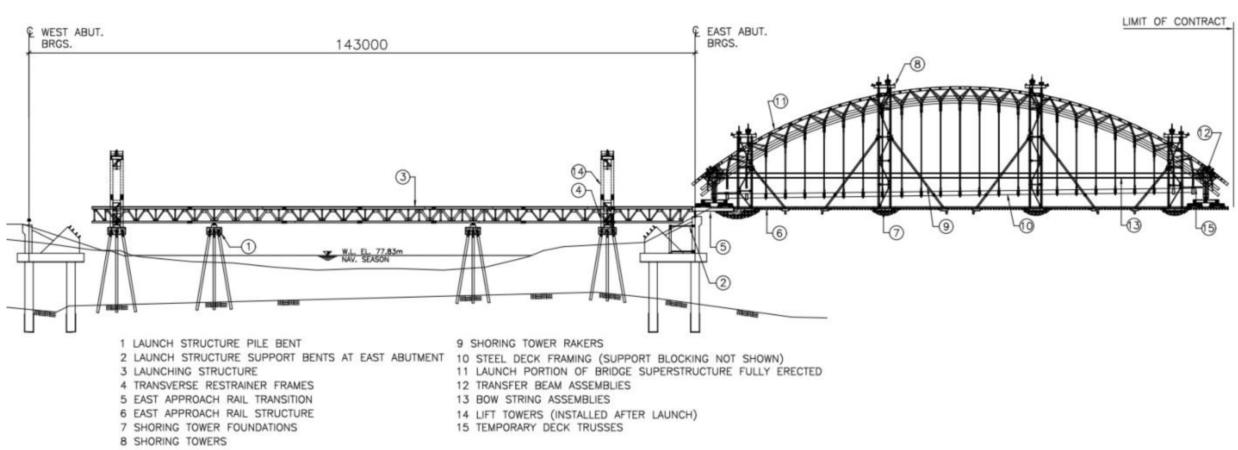

Figure 3. Key elements for the Strandherd Armstrong Bridge construction.

As briefly outlined above, the launch structure consisted of steel box trusses centred transversely under each arch and supported on temporary pile bents. The box trusses were designed to be assembled on the west approach and launched into position over the temporary pile caps utilizing an innovative saddle beam, roller and restrainer system that allowed for rapid launching of the trusses into position. With the trusses in place, purpose designed bearings and restrainers supported the trusses at each pile bent while the arch and deck structure was launched from the east approach over the trusses and into the final longitudinal and transverse position of the bridge. Purpose designed steel lift towers were installed from each approach onto the exterior pile bents after the superstructure launch to lift the structure off the trusses and allow for the rapid de-launch of the trusses back to the west approach. After truss removal is completed, the lift towers strategically lower the arches onto the permanent thrust blocks.

The east approach shoring towers supported the arch segments during their erection. The locations of the arch shoring towers (four per arch) were strategically detailed to match the arch field splice locations, thus providing easy access for welding crews to complete the full penetration field welds. The capacity of the arches to act as bending members between shoring towers under arch and deck dead load and 1 in 10 year wind load conditions was also verified. The tower geometry was limited in plan by the deck steel framing. In order to provide the necessary lateral support to the towers and the arches, rakers extending from mid tower height to discrete foundations were used. Transverse struts spanning between the top of the tall north and south towers and mid-height of the centre tall towers were installed to provide lateral support to the north and south towers as the available land area around the perimeter of the bridge erection site did not permit rakers. To accommodate the arch geometry, the towers reached a height of 25 m and were designed with bolted connections to allow for easy stripping of the towers after bow string post-tensioning/immediately prior to the superstructure launch. The shoring towers provided vertical and lateral support to the arches throughout their construction, thus ensuring stability of the arch prior to hanging of the deck from the PSS cables and tensioning the temporary bow string assemblies.

Figure 4. Shoring towers supporting centre arch during construction.

The transfer beam assemblies at each end of the constructed arches consisted of large diameter pipe sections threaded through the space trusses and connected to the arch with wing plates and temporary flare bevel welds. The transfer beams framed into a pair of columns which were connected with pin assemblies to railcars supported on a series 75 ton Hilman® roller assemblies. The transfer beam assemblies transferred gravity and wind loads down to the supporting railcar/roller assemblies, became the supporting structure for the temporary bow string assemblies that allowed the arches to achieve arching action during the launch, and enabled adjustment of the structure at various stages of the erection. The railcar assemblies were detailed to travel along the east approach rails, consisting of HP310 rails and hardwood timber ties, and along the top chords of the box trusses during the launching process across the waterway. Sophisticated finite element models were developed to verify the transfer beam design, determine stability of the arch and deck system during all phases of construction and to develop the stresses in the arch chords during erection.

The bow string assemblies that were supported by the transfer beam pipe beams were designed and detailed to resist the horizontal arch thrust during the launching process. These consisted of two sets of 19 – 15 mm diameter low relaxation prestressing strands for the north and south arches and two sets of 27 – 15 mm diameter strands for the centre arch. The strands spanned from one end of the arch to the other, connecting to the transfer beam at each end with sag supports located at quarter points along the span. By modifying the level of post-tensioning in the temporary bow strings within safe limits, the horizontal bow string ties also permitted minor adjustments to the position of the arch ends for the final installation onto the thrust blocks.

Figure 5. South arch transfer beam assembly with bow string.

Temporary in-plan deck trusses were designed at each end of the launch portion of the deck to serve several functions, including: to provide a longitudinal and transverse tie of the deck to the transfer beam columns under wind load effects, to provide a secondary stiff tie of the arch under transitory live load and vertical wind loads that post-tensioning in the bow strings were not calibrated for, and to provide a tie of the roller assemblies at each end of the bridge to mitigate rebound friction effects during the pulling of the structure during launching. The trusses were mounted to the top of the floorbeam and stringers using the floorbeams and stringers as part of the in-plan truss and threaded studs welded at the panel points to fasten the gusset assemblies and braces to the deck system.

## 4.0 CONSTRUCTION METHODOLOGY

The developed construction sequence enabled all contractual requirements to be met, maintained the stability of the arches and deck throughout construction, and allowed for safe access to the structure during all phases of erection. The erection of the Strandherd Armstrong Bridge was completed using the methodology described below.

### 4.1 Phase 1: Site Preparation and Installation of Temporary Works

- The bridge abutments and arch thrust blocks were constructed at both the east and west approaches. Adjustable steel frames were constructed around the thrust blocks in order to support the arch anchorage steel and to ensure the geometry of the connection was maintained throughout casting of the concrete. These frames were removed after casting was completed.
- 12 temporary support bents, consisting of a cast-in-place concrete pile cap founded on drilled, then driven steel pipe piles were installed in the waterway respecting a well-defined navigation channel for boaters. Steel rail transition beams were installed along each rail line at the east abutment to seamlessly transition from the approach rails to the launching trusses.
- The three launch trusses were assembled on the west approach and launched into position over the waterway utilizing the saddle beam and restrainer assemblies mounted to the top of the pile bents. At the end of the launch, the trusses were lowered on the saddle beam assemblies until the load was transferred to the rocker bearings at each pile bent.

- Shallow concrete foundations were constructed for the temporary arch shoring towers on the east approach.
- The east approach rail system, consisting of continuous HP310 rails and hardwood timber ties between shoring tower foundations were installed.
- Careful and continuous surveying was undertaken during the installation of all temporary works to ensure proper alignment with the structure during launching, lifting and lowering operations. The as-built positions of the anchorages on the thrust blocks were also considered in the layout of the temporary and permanent works.

**4.2 Phase 2: Erection of Superstructure on East Approach**

- The north half of the deck steel grillage was erected on adjustable blocking on the east approach. Erection of the deck steel on the south side was deferred to allow for the erection of the centre shoring towers and center arch segments. The deck steel was blocked to an elevated position in relation to the arches which allowed the proper length deck PSS cable hangers to be installed in a stress-free condition. The proper length hangers were determined based on both a comprehensive calibration/cable tuning analysis and the as-built condition of both the arches and the deck steel.
- The four north arch temporary shoring towers and the two tall interior centre arch temporary towers were installed along with the transverse and longitudinal rakers around the deck steel. The transverse struts were connected between the tall north and centre towers.
- Each segment of the north arch (excluding the short end segments at the thrust blocks) was erected and supported from the head works assemblies at each shoring tower. The arch head works assemblies at each tower permitted adjustments to be made to the arch chord alignment in order to place the adjacent segments in the proper alignment and to allow for the completion of the full penetration welding at each arch field splice location. A comprehensive three dimensional model of the entire constructed works was developed to allow for the determination of arch segment positioning coordinates. A methodology was also established to develop thermal corrections for the target coordinates, accurately taking into account the presence of the arch shoring towers, transfer beams, and approach rails in the boundary conditions for these models.
- Transfer beam assemblies were installed at each end of the arch. The north arch was fully supported by the four temporary shoring towers at this stage.
- The north arch bow string assemblies were installed (complete with bow string sag supports) through the anchorages at each transfer beam, but were not tensioned at this stage.
- The north arch hangers were installed in an unstressed state, with the deck supported in an elevated condition on the blocking frames.
- The remaining two centre arch shoring towers were installed in preparation for the erection of the centre arch.
- The centre arch segments were erected in a similar manner as previously described for the north arch. The transfer beam assemblies, bow strings and bow string sag supports were also installed, but the bow string assemblies were once again not tensioned at this stage of construction. The center arch was also supported by the temporary approach shoring towers at this stage.
- The south deck steel framing was erected and the welded field splices between the north and south deck steel were completed. The centre arch hangers were installed but not stressed as the deck was supported fully by the elevated blocking frames.
- The south arch temporary shoring towers were installed with all rakers and transverse struts.
- The south arch segments were erected and supported by the south temporary shoring towers. Transfer beams, bow strings, bow string sag supports, and arch hangers were installed. At the completion of this stage, all three arches were constructed and supported by the shoring towers, the arch bow strings were not tensioned, and the deck was supported in an elevation condition on the adjustable deck blocking frames.
- The deck was strategically de-propped and suspended from the arches which were supported by the shoring towers. A comprehensive analysis was completed to provide the sequence of blocking adjustments required to lower the deck sequentially without overstressing any component of the structure (deck, hangers and arches). Theoretical hanger lengths were determined such that under full dead loads, and considering both the elongation of the cables and the deflection of the arches, the deck fell to the desired final profile and the individual PSS cable loads were within tolerance without requiring adjustment of the cable hangers in the final condition when access to the anchorage blocks was difficult over the river.

Figure 6 shows an elevation view of the center arch with the deck de-propped and the assembly supported on the east approach shoring towers.

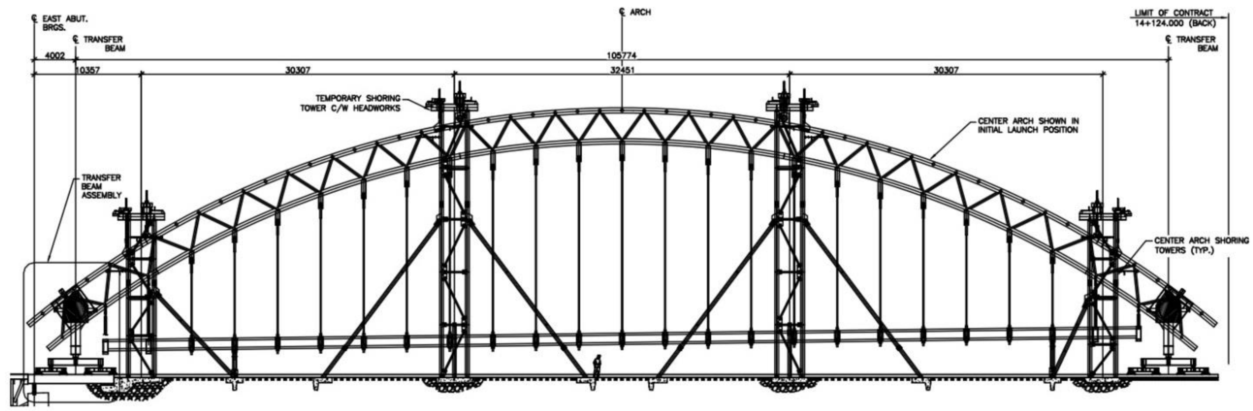


Figure 6. Elevation view of centre arch supported on shoring towers with suspended deck (north and south arches similar).

- The in-plan lateral truss system at each end of the deck was installed at this stage; only the east end of the deck was connected to the transfer beams at this stage to ensure that only the arch was affected by bow string stressing operations.
- With the deck suspended from the shoring tower supported arches, the bow string tensioning sequence was initiated and the superstructure self-weight was transferred from the shoring towers to the transfer beam systems at each end of each arch. A bow string stressing/shoring tower load relief phased procedure was developed to ensure that the structure remained stable and no components, temporary or permanent, were overstressed during the load transfer operations. Once the bow string tensioning was complete and the loads were completely relieved from the east approach shoring towers, the west end of the deck was connected to the columns of the transfer beam assemblies, creating a stable deck system, a secondary arch tie for transitory loads, and a tie between rail car assemblies at each end of each arch. At this stage, the superstructure was acting as a fully tied arch spanning from end to end and fully supported by the transfer beam assemblies and east approach rail system.
- The fully unloaded shoring towers were dismantled and removed from site. Pull assemblies housing hydraulic strand jacks were installed in a horizontal position at the west end of the steel box trusses in preparation for the launch. The concrete deck formwork was installed on the launch portion of the steel deck grillage prior to commencement of the launch to take advantage of the access provided on the east approach.

**4.3 Phase 3: Launch of Superstructure across the Waterway**

- The permanent and temporary works were designed for a 1 in 10 year wind event during all phases of construction, except during the short duration launch operation across the Rideau River when forecasted gusting wind speeds were not to exceed 50 km/hr. Limiting the wind speed during launching was only required to make the design of the box trusses, particularly in the long navigation spans, as economical as possible. Contingencies were made for the possibility of winds exceeding the stipulated 50 km/hr wind speed by detailing survival wind stopping locations along the box trusses near each support bent. At these locations and anywhere along the east approach the system was capable of withstanding a design 1 in 10 year wind event.
- The superstructure was launched, moving east to west, to its final longitudinal position which centered the transfer beams at each end of each arch over the exterior pile bents adjacent to the east and west thrust blocks. This was accomplished by pulling the transfer beam/railcar assemblies, which rolled first along the eastern approach rails, over the rail transition beams near the east abutment and then along the top chords of the previously launched box trusses, across the Rideau River above the contract stipulated navigation channel. The 140 meter launch of the 2250 Tonne launch portion of the Strandherd Armstrong Bridge was successfully completed over a two day period, starting early on July 11, 2013 and ending before dark on July 12, 2013. A one day exemption of having no work taking place over the navigation channel between Friday and Monday was granted on the second day of the launch on the condition that contractor supplied spotter vessels were provided

upstream and downstream of the bridge and launching operations were ceased anytime a vessel was required to pass under the site. Figure 7 shows an aerial view of the bridge at mid-launch.

- With the launch completed and the structure positioned in its final longitudinal and transverse position, the top portion of the lift towers were bolted to the lower portion of the towers that also comprised the saddle beam and restrainer assemblies on the exterior pile bent assemblies. The pull assemblies were removed and the lift tower construction was completed in a little over a week after completion of the launch. These towers were used to initially lift the full superstructure off the launch trusses to facilitate the de-launching of the box trusses back onto the west approach, and then to lower the structure onto the thrust block anchorages after the short end segments of the arch were installed and field welded to the ends of the launch portion of the arches.

Figure 7. Aerial view of bridge during launching across the Rideau River.

- Using vertical hydraulic strand jacks mounted on top of the lift towers and connected to hanger plates welded to each end of each transfer beam, the superstructure was lifted in a synchronized manner (approximately 15 mm) to unload the railcars and launch trusses. The railcars were disconnected from the transfer beam columns and removed. The initial lifting of the superstructure was completed in less than one hour.
- With the bridge raised and the railcars removed, the box trusses were de-launched onto the western approaches. Figure 8 shows an image of the bridge in its lifted state after the box trusses were de-launched onto the western approach.

Figure 8. Launched bridge structure supported on lift towers prior to lowering onto thrust blocks.

### 4.4 Phase 4: Lowering of the Launch Structure, Installation of the Arch End Segments, Load Transfer onto the Thrust Blocks and Completion of the Structure

- The end arch segments were installed onto the thrust blocks and supported by temporary shoring at their free ends. The arch end segment anchorages were detailed to allow for moderate adjustment of the end segment relative to the thrust block anchorages to ensure proper arch alignment and fit up of the as-built arches on the thrust blocks. The anchor bolts were not fully tightened and grouted until after the end segments were fully welded to the arch and the alignment and elevation of each arch chord was assured.
- The launched portion of the superstructure was lowered approximately 5 meters in a level manner to align the arch chords with the arch end segments. While supported on the lifting frames, fine tuning adjustments were made to the arch alignment prior to completing the final full penetration field splice welds of the arches.
- During the welding of the end segment field splices, the formwork was set to the screed elevations prior to placing the road deck reinforcing steel. The reinforcing was placed at this time to allow for parallel activities to take place and to facilitate the casting of the roadway decks during the fall of 2013, prior to the point where significant heating of the deck would be required during curing operations.
- The following operations were completed during an overnight and morning shift when thermal changes in the structure were kept to a minimum:
    - With the arch field splices completed, minor adjustments were made to the superstructure location on the thrust blocks. Once made, the anchorage was grouted with rapid curing high-strength grout and the anchor bolts were fully tightened.
    - The load of the superstructure was transferred from the lifting towers to the permanent thrust blocks by incrementally releasing the lift tower strand jack loads and de-stressing the bow strings with one end of the deck detached from the transfer beam assemblies. After completion of this stage, the bow string assemblies were removed along with the lifting towers. The transfer beam and column assemblies remained in place in order to provide lateral and longitudinal support to the deck steel (via the lateral truss assemblies) prior to the placement of the approach spans.
- With the arch supported from the permanent thrust blocks for the first time, the remaining approach span deck steel was erected and the bearing assemblies were installed. After the approaches were fully constructed, the transfer beam and column assemblies along with the lateral trusses were removed.
- The roadway decks were cast during a single 18 hour continuous casting operation.
- The roadway barriers were cast after the roadway decks had cured.
- At the time of writing this paper, the remaining construction activities are contemplated to be completed during the first half of 2014:
    - Casting of the sidewalk decks and barriers;
    - Mounting of the roadway barriers and sidewalk railings;
    - Casting of approach slabs and completion of top portions of abutment wingwalls;
    - Waterproofing and asphalting of roadway and sidewalk decks and approach slabs;
    - Completion of approaches, including final grading, paving and tie-ins to the existing road network; and
    - Removal of the remainder of the temporary pile bents (to be completed over winter months).

## 5.0 CONCLUSION

After weighing the advantages and disadvantages of the various construction concepts discussed in Section 2, it was evident that the limitations imposed on overhead work during the summer months made construction of the arches in place over the water impractical. It was inconceivable for a construction site to sit idle for four days of every week during the summer months and the costs and loss of schedule that would be incurred by this were unacceptable. Therefore, a method that significantly limited the amount of work completed over the waterway was the key to the project's success.

Stability of this type of structure through all phases of its construction becomes challenging since the final structure relies on the entire deck weight, the PSS cable hangers that tie the arches laterally to the deck, and the fixed anchorages at the thrust blocks to maintain stability of the structure. Having three independent arches constructed across the river without the deck providing stability through the hangers or stay cables would leave the arches susceptible to high winds. The use of shoring towers on land made construction of the arches much easier and much more accessible. The arch segments essentially became bending members, spanning between the vertical supports of the towers located at each segment field splice. The towers also provided the transverse and longitudinal support which ensured stability of the arch throughout its construction, even during high wind events when the deck was hung from the arches. The use of towers permitted safe access to the field splice locations during fit up as well as providing stiff support to the arch during the field welding process. Field welding of the 508 mm diameter chords with wall thicknesses as large as 76 mm proved to be very challenging. The issues associated with this welding would have been exacerbated by the flexible conditions created by over water segmental construction.

Construction of 90 percent of the superstructure on land allowed for the entire deck to be constructed independently of the arches. This meant that when the time came to complete the connection of the deck to the arches, it could be done in a controlled, symmetric manner, and any eccentric, unbalanced loading on the arches would be avoided. Had construction been completed over water, the arches could have been subjected to large eccentric loading which may have resulted in an in-plane buckling mode under gravity loads being initiated.

The alignment of the arches and the overall geometry becomes very difficult to achieve since there are so many variables in play. The method of constructing the arches and deck on land and then launching across the river meant that most of the arch could be erected before it was connected to the thrust blocks, allowing for easier alignment and tighter controls during construction of the structure. The use of the bow string provided the means to not only create a tied arch during launching and lowering onto the thrust blocks, but also to adjust the shape of the arch to ensure proper fit up at the thrust blocks. Minor adjustments could also be made to the position of the arches on the thrust blocks through the use of oversized base plate holes and custom bearing disc assemblies at each anchor position at each end of each arch chord.

The steel arches were fabricated by cold bending the hollow structural section chords to the desired profile. In addition to the erection and construction engineering design, a full analysis of the arches was completed in order to examine the effects of this process. Physical strain gauging of the segments during the bending process was completed in order to collect strain data to verify the theoretical method developed to determine the residual cold bending stresses. From the residual stresses, an equivalent bending moment representing the cold bending effects was determined. The demand to capacity ratio of this effect was reported to the bridge designer who used it to verify that the total interaction of the arch members, including cold bending effects was within the acceptable limits.

The method of construction was a success and met all of the contractual requirements. This was the first known time a structure of this type was constructed using this method in North America and it is hoped that the methodology developed will enable safe, cost effective, accurate and timely construction of future bridges of this type.

## 6.0 ACKNOWLEDGMENTS

Harbourside Engineering Consultants were the conceptual, preliminary and detailed construction and erection engineers, PSS cable specialists, and the bridge specialist quality assurance engineer. We would also like to thank the following organizations for their contribution to the success of this project:

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| General Contractor: | Horseshoe Hill Construction |
| Bridge Owner: | City of Ottawa |
| Steel Erector: | Montacier International |
| Steel Fabricator: | Cherubini Metal Works |
| PSS Cable Supplier: | Freyssinet International |
| Bridge Designer: | Delcan |