PARSONS

LaSalle Causeway Bascule Bridge

Steel Deck Grating Replacement Study – Phase 1 Feasibility Assessment (Rev.1)

PSPC Project Numbers: R.09736.004 and R.089507.003

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Executive Summary

Steel Deck Grating Replacement Study – Phase 1 Feasibility Study

Parsons Inc. was retained by Public Services and Procurement Canada (PSPC) in August 2019 to perform a Feasibility Study for the Steel Deck Grating Replacement of the LaSalle Causeway Bascule Bridge (Bascule Bridge), in Kingston, Ontario. This assignment included the collection and review of all relevant available data and the identification and assessment of different options for the Bascule Bridge deck and sidewalk. The impact of replacement options on the bridge's balancing and mechanical and electrical system was considered as part of the options assessment.

Options were screened for feasibility based on two controlling criteria: wind and dead load. Viable options were then evaluated based on a weighted score analysis and a class D cost estimate of the viable options was prepared. Based on the results of the decision tree process and of the weighted score analysis, it is recommended to replace the existing open steel grating by a new open steel grating and to maintain the existing sidewalk until it deteriorates sufficiently to justify replacing it with a new FRP sidewalk.

A detailed Class D Cost Estimate was prepared for a new open steel grating deck. It includes the replacement of the existing grating, sills and stringers by new elements. Two options were considered for the new deck: the first is a replacement "in kind" of the existing elements, with a new 65 mm thick grating with new sills and new stringers; the second involves replacing the existing grating and sills by a 125 mm thick grating and replacing the existing stringers by a new stringer system (optimized spacing and sections). The latter option would accelerate the construction schedule, reduce the number of elements and potentially the wind surface of the deck in the open position. It will result in a slight change in the vertical position of the center of gravity of the deck, but this change is considered marginal and manageable by limited balancing adjustments to the counterweight. The estimate for the replacement in kind option of the new steel deck grating is $2,163,100, and for the optimized deck system with 125 mm thick grating it is $2,331,200.

Cost estimates for the replacement of the existing timber sidewalk with a new timber sidewalk as well as its replacement with a new FRP sidewalk were also prepared. All options consider maintaining the existing combined pedestrian and cyclist railings. The Class D cost estimate for the replacement of the sidewalk with a similar timber sidewalk is $231,300 and for replacement with an FRP sidewalk is $669,500.

One of the main disadvantages of the existing deck is the poor riding quality of the serrated grating. Vibrations caused by passing cars and trucks create an uncomfortable driving condition and high noise levels. Noise mitigation measures have been successfully implemented in the past on several open deck bridges, including moveable bridges, which typically consists of filling the grating in the wheel paths with concrete. Preliminary analysis of this mitigation measure for the Bascule Bridge shows that using concrete would increase the weight past the acceptable threshold and hence this option is not considered viable. Using FRP strips topped with a lightweight wearing surface at the wheel paths would respect the weight increase limit, but it would increase the wind surface near or slightly above the acceptable limit. If using FRP strips in the wheel paths as a noise mitigation measure is considered for further analysis, the opinion of specialists in Wind Engineering should be sought during the detailed design phase to ascertain the impact on the wind drag of the deck in the open position. The Bascule Bridge deck structure is comprised of four layers of elements (grating, sills, stringers and floorbeams) which creates wind drag in the open position. By comparing the wind drag of the existing deck system with the streamlined new deck system (125 mm thick grating without sills), it might be possible to show that the addition of closed FRP strips in the wheel paths does not significantly increase the wind drag of the deck in the open position. Finally, if the wheel-path FRP strips are contemplated, special attention should be given to the longitudinal joints between the grating and the FRP strips to avoid safety and serviceability issues (potential slip hazards to motorcyclist and damage caused by snowplows, etc.)

Considering the potential safety issues related to the substandard skid resistance of the grating and to the possible fracturing of cracked stringers, a maximum two-year timeframe is proposed for the replacement of the grating, sills and all the stringers. Extending the replacement timeframe may increase the likelihood of accident caused by substandard skid resistance and increase the risk of stringer fracture, which could necessitate immediate partial or complete closure of the bridge to vehicular traffic, depending on the location of the fractured stringer. To mitigate these risks, regular inspections, crack monitoring and repair, speed limit reduction and signalization could be implemented. Such measures will become more important as the structure continues to age and deteriorate.

1.0 Introduction

The LaSalle Causeway (the Causeway), owned and operated by Public Services and Procurement Canada (PSPC), carries Highway 2 across the Cataraqui River within the City of Kingston, providing an important transportation link between the downtown area on the west side of the river with the Barriefield/CFB Kingston area on the east side of the river. Approximately 25,000 vehicles cross the Causeway daily, with approximately 2% commercial vehicles. The Causeway consists of five (5) interconnecting structures: the west bridge (including its west approach), the west wharf, the bascule bridge, the east wharf, and the east bridge (including its east approach). The bascule bridge also provides marine access to the inner harbour of Kingston, lifting an average of 900 times per year, and access to the southern entrance of the Rideau Canal. The number of average openings per year has varied over the life of the structure. It is estimated that the bridge has opened approximately 193,000 times since its construction was completed on April 15, 1917. The location of the Causeway is shown on the key plan (Figure 1). Currently the nearest alternate crossing is via Ontario Highway 401 over the Cataraqui River, a detour of 17 km.

Parsons Inc. was retained by PSPC in August 2019 to perform a feasibility study (Phase 1), for the replacement of the bascule bridge steel deck. Phase 2, an investment analysis report, will be carried out separately. The current deck systems dates from the 1973 and comprises an open steel deck grating supported by transverse sills and longitudinal stringers. It exhibits numerous signs of reaching the end of its lifespan including: fatigue cracking of many stringers and main bearing bars of the open steel grating; complete wear of grating serrations in the wheel tracks; coating failure; and corrosion. The feasibility study aims at performing a review of existing relevant background information; identifying and assessing the different viable options for sidewalk and deck systems, including the rehabilitation or replacement of the supporting steel sills and the stringers; evaluating the impact of a new deck and sidewalk system on the bridge's mechanical and electrical operating and balancing system; and carrying out a financial analysis of the viable options.

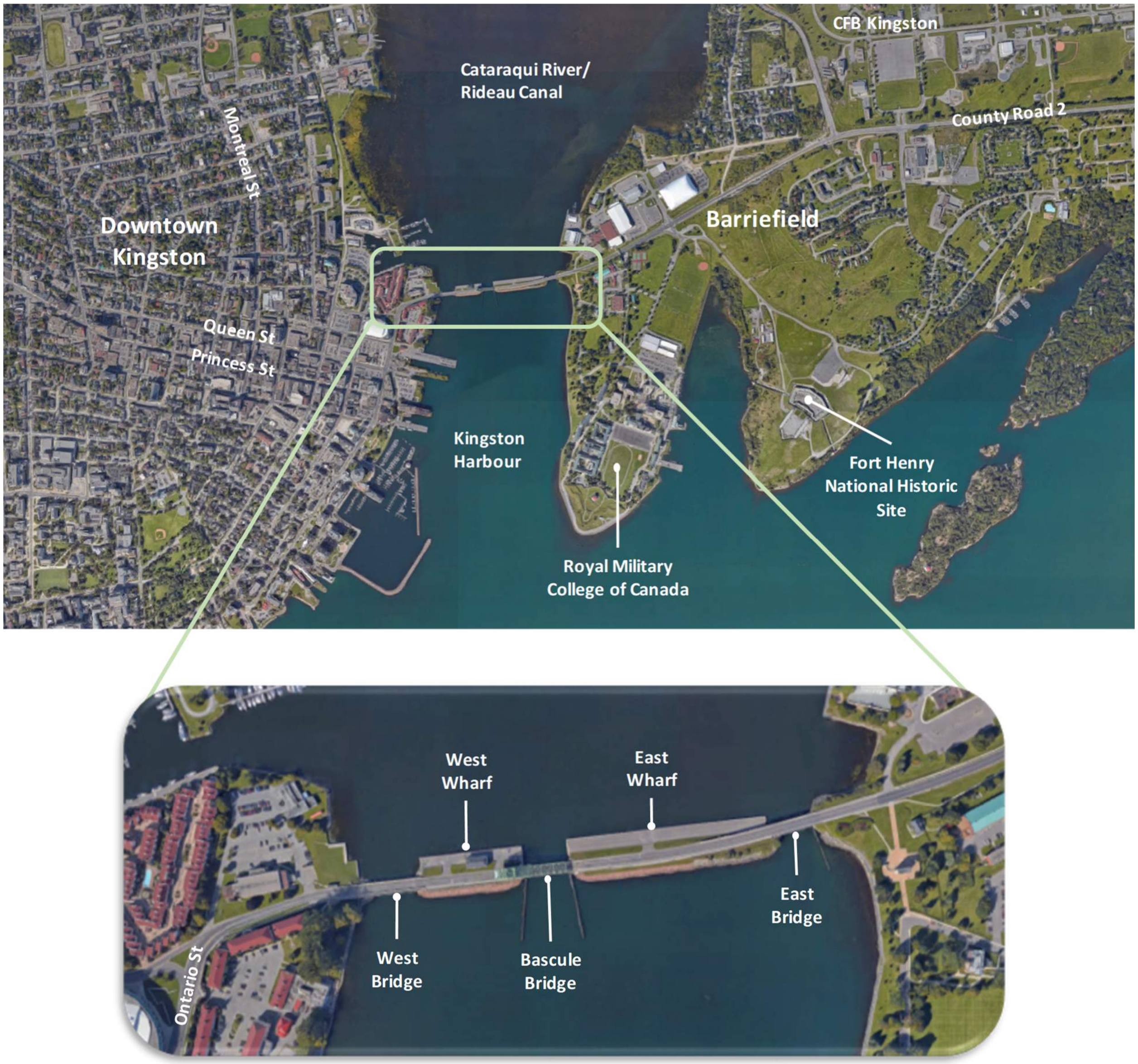

Figure 1: Key Plan

2.0 Structure Description

The bascule bridge is a single leaf Strauss heel trunnion, designed by The Strauss Bascule Bridge Co. of Chicago, and constructed in 1917. The main span of the bridge consists of a modified Warren through-truss with a span length of 48.77 m (160’). The center-to-center truss width is 8.23 m (27’) and the center of the bottom chord to center of top chord height varies from the east end to the west end from 6.10m (20’) to 7.92 m (26’). The concrete counterweight weighs approximately 550 tonnes (1,200,000 lbs.).

The deck system is comprised of an open steel grating, supported by sills, stringers and floorbeams and dates from 1973. This existing deck was installed in 1972-1973. The original stringers were spaced to accommodate railroad or streetcar tracks, as shown on Sheet 09 of the original bridge drawings[1]. No drawings showing the

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[1] See Appendix E of the 2018 Fatigue Inspection and Evaluation Report, by Parsons, PWGSC Project No. R.090045.001,

installation of tracks were found, and there is no historical documentation of trains or street cars on the Causeway based on research by PSPC. The original spacing of stringers was maintained when the original stringers were replaced in 1972-1973.

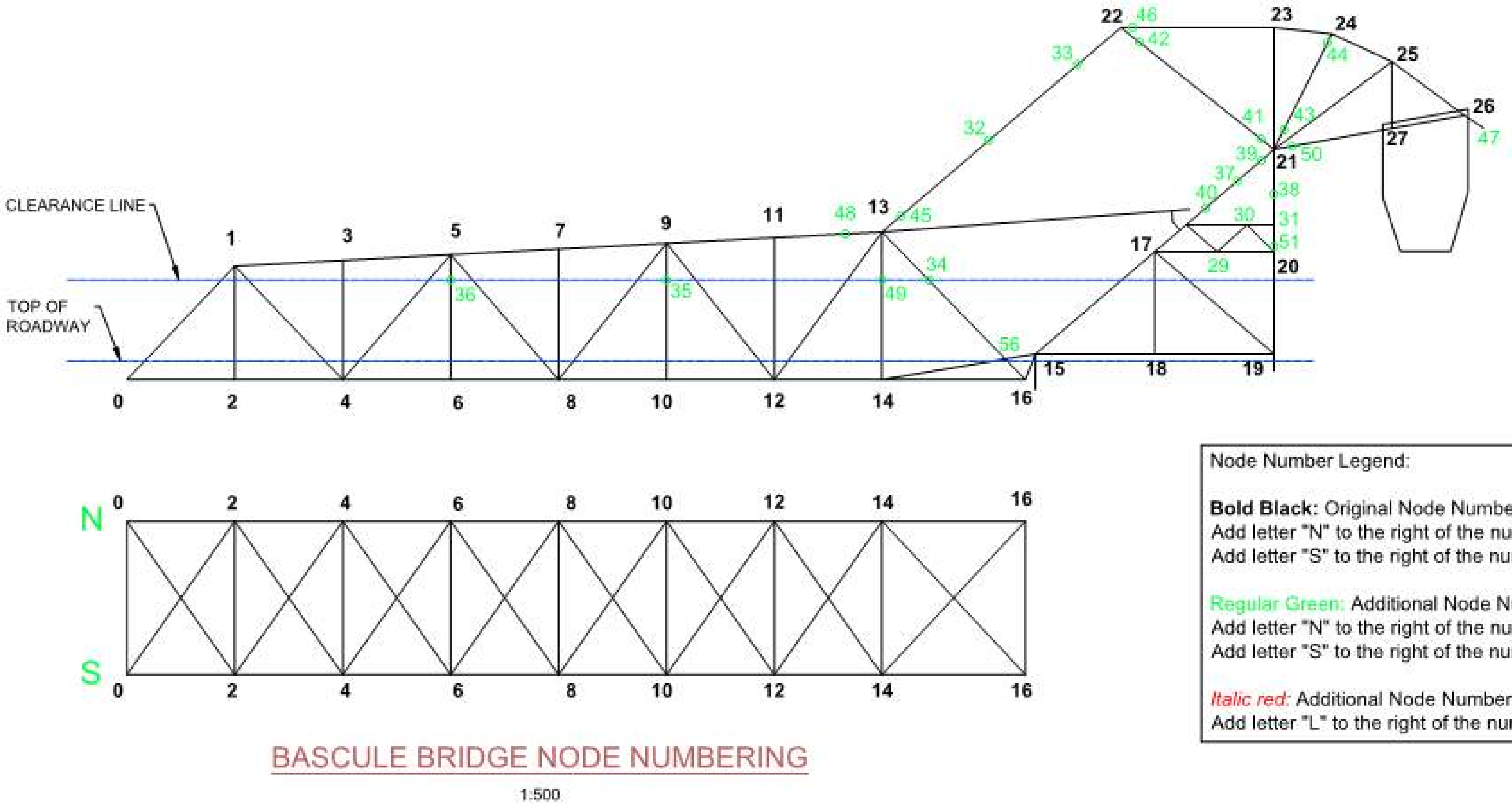
2.1 Deck Condition

The existing Bascule Bridge deck is an open steel grating supported by transvers sills, longitudinal stringers and floorbeams. According to available as-built drawings the current steel deck grating system which was installed in the mid-seventies has been in service for more than 47 years. The 2018 Comprehensive Detailed Inspection Report by Parsons noted bent and broken bearing and crossbars throughout the steel deck grating, several cracked bar-to-bar and bar-to-sill welds, and broken bars at the west and east ends. The serrated top edge of the grating has been completely worn away within the wheel tracks in each vehicular lane meaning the grating no longer provides the adequate skid resistance which could increase vehicle braking distances especially in poor weather conditions. In February 2017, a large piece of grating failed and broke off. The coating system (assumed to be galvanized) on the grating has typically deteriorated and there is light corrosion on the vertical faces of the cross bars and bearing bars and medium corrosion along the north and south edges.

2.2 Nomenclature

For reference within this report, primary members of the Bascule Bridge, truss nodes and member numbers were adopted from the 1915 original drawings. For some secondary members, no node numbers are provided on the original drawings. To address these nodes in this evaluation report, additional node numbers were defined. Node numbering is graphically presented in Figure 2 and in more detail on SK-01 in Appendix A of the 2017 Structural Evaluation.

Figure 2: LaSalle Causeway Bridge Node Numbering



Node Number Legend:

Bold Black: Original Node Numbers
Add letter "N" to the right of the number for nodes in the north truss
Add letter "S" to the right of the number for nodes in the south truss

Regular Green: Additional Node Numbers
Add letter "N" to the right of the number for nodes in the north truss
Add letter "S" to the right of the number for nodes in the south truss

Italic red: Additional Node Numbers of Lateral Members
Add letter "L" to the right of the number for each node

3.0 Historical Information

3.1 Maintenance and Inspection History

The Bascule Bridge is a complex historical structure that has evolved over the century it has been in operation, with many modifications and repairs being made over its lifespan. Each separate system composing the bridge is interconnected to the others in one way or another, and integration of all knowledge of the separate bridge components is paramount to understanding the impacts of any proposed modifications to the structure. All previous, current, and future projects, maintenance activities, and other important events must be well understood prior to considering an undertaking like a complete deck replacement. A detailed maintenance and inspection history of the Bascule Bridge was incorporated into the LaSalle Causeway 2018 Annual Comprehensive Detailed Inspection Report. It is summarized herein as it outlines members which have been replaced or strengthened and forms part of the basis upon which the 2017 Structural Evaluation and the 2018 Fatigue Evaluation were conducted.

3.1.1 Maintenance History

The Bascule Bridge has undergone numerous repairs and rehabilitation works since its construction in 1916-1917. The following is a list of some of the major works undertaken:

- In 1966, the Bascule Bridge operating mechanism was renewed, including a new operator's cabin and control electronics.
- In 1972-1973, the Bascule Bridge floor beams were replaced with welded wide flange beams, the floor system stringers were replaced, along with the timber sidewalk stringers and deck planks.
- In 2001, two buffers were added to the Bascule Bridge to reduce impact when the bridge lands.
- In 2004, a maintenance contract on the Bascule Bridge was completed to replace rivets in fatigue prone members of the counterweight.
- In 2009-2013, the Bascule Bridge underwent a major rehabilitation, which included: removal of lead paint and application of low VOC protective coating system to all structural steel members of the bridge; structural repairs to deteriorating steel members (i.e. operating arm, bottom gusset plates, exterior splice plates in the bottom chord, etc.); reinforcing certain diagonal truss members; replacing timber sidewalk stringers and deck planks; installation of new pedestrian railing meeting CHBDC requirements for a combination pedestrian/bicycle barrier; replacing traffic barrier; and replacing wood stairway treads with steel treads; installation of a new steel counterweight for balancing the bridge.
- In 2016, new W-beam guide rails were installed on the northeast and northwest approaches of the west bridge, along the south side of the sidewalk on the west wharf, along the south side of the sidewalk on the east wharf and along the northeast and southeast approaches of the east bridge. New pedestrian railings were installed on the southeast and southwest wing walls of the Bascule Bridge, and repairs were carried to the southeast and southwest training walls. New chain link fences were installed on the southeast and southwest embankments of the Bascule Bridge and at the westbound traffic barrier.
- In 2017, the following rehabilitation and inspection contracts for the Bascule Bridge were initiated: replacement of the buffers; detailed inspection and repair options report for the steel deck grating; repairs to the span locks and bottom chords of the leaf truss; upgrades to the motor drive and motor control upgrade, rehabilitation of the guide assemblies, reinforcement of members 13N-14N and 13S-14S following the discovery of cracks in interior angles of 13N-14N.
- In 2020, a structural steel repair contract is currently underway with the intent of repairing the most urgent defects found during recent inspections. The repairs will address BIM Priority A recommendations from the 2018 Fatigue Inspection and Evaluation Report, as well as new Priority A findings from the 2019 CDI evaluation and will include crack grinding, member plating and grating repairs.

The list of repairs and rehabilitation works above is not comprehensive. However, it highlights the major rehabilitation work undertaken.

3.1.2 Inspection History

Parsons performed the following recent inspections on the Bascule Bridge:

- 2019 – LaSalle Causeway 2019 Annual Comprehensive Detailed Inspection; PSPC Project Number R.090045.001 (in progress)
- 2018 – LaSalle Causeway 2018 Annual Comprehensive Detailed Inspection and Fatigue Inspection; PWGSC Project Number: R. 0090045.001;
- 2017 – LaSalle Causeway Deck Grating Inspection and Repair Report; PWGSC Project Number. R.082857.001;
- 2016 – LaSalle Causeway 2016 Annual Comprehensive Detailed Inspection Report; Project Number: R. 055058.002;
- 2015 – LaSalle Causeway Bascule Bridge 2015 Detailed Measurements; Project Number: R. 055058.002; and
- 2015 – LaSalle Causeway 2015 Annual Comprehensive Detailed Inspection Report Project Number: R. 055058.002.

3.2 Bridge Specific Reference Material

The following relevant reference material has been reviewed for this evaluation:

- 2020 – Parsons Inc – “LaSalle Causeway Bascule Bridge Main Trunnion Rehabilitation Study – Structural Evaluation Report (Draft)”, PWGSC Project No R. 099350.002,
- 2018 – Parsons Inc – “2018 Fatigue Inspection and Evaluation Report”, PWGSC Project No. R.090045.001,
- 2018 – Parsons Inc – “LaSalle Causeway 2018 Annual Comprehensive Detailed (Bascule) & General Inspection Report”, PWGSC Project No. R.090045.001;
- 2017 - SBE Engineering – “Machinery and Prime Mover Evaluation Memorandum”.
- 2017 – Parsons Inc – “LaSalle Causeway Bascule Bridge Structural Evaluation Report,” PSPC Project No. R055058.002;
- 2017 - Parsons Inc – “LaSalle Causeway Deck Grating Inspection and Repair Report,” PWGSC Project No. R.082857.001;
- 2016 – Parsons Inc. - “LaSalle Causeway – Bascule Bridge, Replacement of Span Locks”; Issued for Tender Drawings; Project No. R.082857.001;
- 2016 – Parsons Inc – “LaSalle Causeway 2016 Annual Comprehensive Detailed (Bascule) & General Inspection Report,” PWGSC Project No. R.055058.002;
- 2015 – MMM Group – “LASALLE CAUSEWAY Trunnion Joint Inspection and Analysis Report”;
- 2013 – Delcan Corporation – “LaSalle Causeway Bascule Bridge Deck and Sidewalk Concepts Report”;
- 2010 - McCormick Rankin Corporation - “LaSalle Causeway – Bascule Bridge, Repairs and New Coating”; As-Built Drawings S01 to S25; Project No. R.012359.001;
- 2005 - McCormick Rankin Corporation – “Kingston Bascule Bridge Fatigue Review and Rehabilitation of Counterweight Members”;
- 2005 - McCormick Rankin Corporation - “Kingston Bascule Bridge – Fatigue Review and Rehabilitation of Counterweight Members (Updated After Construction)”; January 2005;
- 2001 - McCormick Rankin Corporation – “Seismic Structural Analysis of the LaSalle Bascule Bridge”;
- 1998- Technology Directorate, Architectural and Engineering services, Public Work & Government Services Canada – “Fatigue Probabilistic Assessment of the LaSalle Causeway Bascule Bridge”;

- 1997 – David C. Stringer Engineering Inc- “LaSalle Causeway Bascule Bridge Fatigue Investigation Report”;
- 1973 - C.C. Parker and Associates Limited – “LaSalle Causeway – Repairs to Bridges As-Built Drawings, PWGSC Project Number 81254”;
- 1971 - Public Works of Canada, Ontario Region -“Bascule Bridge – Repairs to Floor System”: Design Drawings: Sheet 1 of 1;
- 1915 - The Strauss Bascule Bridge Co., Chicago -“Strauss Trunnion Bascule Bridge (Patented) over Cataraqui River, Kingston Harbor Improvements for Dept. of Public Works”; As-Built Drawings (1 to 22).

4.0 Structure Condition and Performance

The 103-years-old Bascule Bridge shows several signs of its age; the various inspections carried out recently revealed many issues such as section losses to some of its major structural components (main truss members, heel trunnion), deterioration of the counterweight concrete, fatigue cracking of main truss members and stringers, cracking and wear of the steel grating. Furthermore, structural and mechanical evaluations (2017 Structural Evaluation, 2018 Fatigue Evaluation, 2020 Trunnion Rehabilitation) have shown that many systems (structural members, prime mover and gearing) of the bridge do not comply with the current CHBDC requirements and that some members of the structure have reached their theoretical fatigue design life or will do so in the near future. The global condition of the structural and mechanical components of the Bascule Bridge is detailed in depth in the most recent Comprehensive Detailed Inspection (CDI), Structural, Fatigue and Mechanical evaluation reports listed in the Bridge Specific Reference Material section. This report will focus on the condition of the existing deck system and the existing sidewalk and will evaluate the implications of various deck and sidewalk replacement options on systems such as the main structural members, the counterweight and the mechanical/electrical systems.

4.1 Structural Components

The deck is an integral part of the complex system that is the Bascule Bridge; all the components of the system interact with each other and thus the condition of the other components must be well known and taken into account in the deck replacement option analysis.

4.1.1 Condition

Details of the condition of each bridge element can be found in the latest CDI report (2018). The main truss members of the leaf, tower and counterweight truss are in generally good condition, with localized section losses due to corrosion. Most of the corrosion has occurred at or below deck level, especially at nodes, where debris and road salt tend to accumulate. Many of the main members have been reinforced especially at or below deck, and hundreds of rivets have been replaced by hexagonal headed structural bolts. The coating system is generally in good condition, having been replaced completely during the 2009-2013 rehabilitation, thus removing the lead paint. However, the adherence of the topcoats of the new system seems to be questionable at some locations. Cracking in structural steel members has been observed throughout the bridge, in both primary and secondary members. Verticals, top chord, bottom chord, stringers, tower truss main members and counterweight truss main members have shown various degrees of cracking. The origin of most of the cracks are sharp indentations created by corrosion and poorly designed and executed details (90° stringer copes, uncontrolled welding, torch cut-outs, etc.) and a few cracks originate from lamination defects and probable undetected internal flaws. The counterweight concrete is in poor condition, with delamination and spalling over large surfaces areas. The grating serrations are completely worn down in the wheel paths, thus reducing the skid resistance and increasing braking distances. Many main bearing bars have broken in the last few years and it is generally understood that the grating has reached the end of its useful lifespan. The open grating allows debris and road salt to accelerate deterioration of the structure underneath and to fall in the waterway. The current sidewalk consists of wooden planking and stringer over a steel supporting frame and is generally in good condition, along with the new combined steel pedestrian and cyclist railing.

4.1.2 Structural Considerations

The existing leaf, tower and counterweight trusses were designed for early 1900's loading, with vehicular loads significantly lower than the current CHBDC requirements and moveable load cases far from the requirements of the CHBDC. The bridge has structural limitations tied directly to its initial design, as mentioned in Parsons' 2017 Structural Evaluation Report:

> *"Our results show that with reinforcing of members 9N-12N and 9S-12S (*Figure 2*), the structural capacity of the bridge will be sufficient to meet the full live load of vehicular traffic without load posting (standard loading). [...]* ***The bridge does not satisfy CHBDC special load case code requirements for moveable bridges****. The results of our analysis for these special load combinations are generally in agreement with the June 2015 report by MMM Group Limited, Trunnion Joint Inspection and Analysis Report. Per our analysis, during a bridge lift, the structure seems unable to satisfy the code requirements regarding the load combinations including operating impact forces, wind load, and horizontal force. The severity of member overstressing is the highest when the wind loads and impact forces are combined. It should be noted that the bridge would have been deficient on these demands from its time of construction, meaning the current design code has more stringent requirements than the bridge was originally designed for. [...] It is unclear what, if any, formal design requirements would have been required at the time of design, however, the bridge has performed well since constructed. An upgrade to current code requirements may be cost prohibitive and require lengthy highway lane and marine traffic closures. It is likely the costs of such an upgrade could be impractical compared with replacement, and a life-cycle cost analysis should be completed. "*

Following the completion of the 2017 Evaluation Report, members 9N-12N and 9S-12S were reinforced to avoid bridge posting. However, several members are within 10% to 15% of reaching a Demand to Capacity Ratio (D/C) of 1, meaning that any substantial load increase would require comprehensive strengthening of the main truss members to comply with the current CHBDC vehicular loading cases.

Regarding the moveable load cases, the bridge has performed relatively well so far, despite not complying to the current design codes for moveable bridges. This is probably due to the low probability of occurrence of the modern design loading cases combined with the experience of the bridge operators of the past 100 years that have refrained from opening the bridge during high wind events. As stated in the 2017 Structural Evaluation Report, a rationalization of the current loading case can be determined and, combined with well-defined operating procedure, sustainable safe bridge operation can most probably be maintained. However, any substantial increase in wind loading of the bridge in its open position should be avoided, unless a comprehensive rehabilitation of all the Bascule Bridge systems (structural, mechanical, electrical, balancing, trunnions) is considered. Furthermore, fatigue cracking observed in the main truss members (leaf, tower and counterweight trusses) and theoretical calculations[2] indicate that some of the bridge main structural components have reached their fatigue design life. Stress cycles responsible for fatigue associated with the opening and closing of the bridge originate from the variation of the position of the center of gravity of the bridge components (leaf truss, counterweight truss, deck, counterweight, etc.) as the structure moves. Hence, the key factor in bridge closing-opening fatigue is the dead load magnitude and position, not the live load as it is the case for the typical vehicular-induced bridge fatigue. Consequently, any increase in dead load of the main leaf truss would amplify the stress cycles and thus exacerbate some of the fatigue problems of the structure. On the other hand, the fatigue cracking observed in stringers is a typical bridge fatigue case, most probably caused by the stress cycles originating from vehicular traffic. The nature of the cracking in those members - systematic and substantial -

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[2] See 2018 Parsons Inc – "2018 Fatigue Inspection and Evaluation Report" PWGSC Project No. R.090045.001,

makes their replacement or comprehensive rehabilitation in the short term a necessity. Substantial increase of the deck weight would necessitate the stringers' replacement or reinforcement, for their actual structural reserve capacity, even without the fatigue cracking issue, is limited.

4.2 Mechanical and Electrical Components

The Strauss Bascule Bridge design relies on a balanced structure to limit the required mechanical force to lift and close the bridge. But even with a well-balanced structure, a force has to be applied by the mechanical system, through the operating arm, to overcome slight imbalance, friction, inertia, wind and ice loads. Mechanical and associated electrical systems are a vital part of the bridge system and they must be taken into consideration when analyzing any modifications to the structure.

4.2.1 Limitation of the Existing Systems

The bridge mechanical system has been rehabilitated several times since its construction. However, many original elements remain. As discussed in the previous section, the original bridge design load cases are far from the current codes. Hence, the bridge's mechanical and electrical systems have operational limitations below the requirements of the current code[3]. According to the latest (2017) evaluation, the mechanical system is overloaded by a factor of 1.50 when analyzed as per Chapter 13 of the CHBDC (S6-14). The capacity of the new prime mover was chosen to be consistent with the existing gear capacity as increasing the prime mover capacity would not be possible unless virtually all the gears are replaced, which constitutes a significant and high-risk undertaking. With the existing mechanical and electrical system, the maximum wind speed during bridge operation is limited to 69 km/h. Any increase in deck surface area subject to wind loads would increase the risk of damage to the Bascule Bridge and would require reducing the wind speed operational constraint even more. This could lead to more instances where the bridge cannot be raised to allow ships to pass, due to wind stronger than allowable.

4.2.2 Rehabilitation

In order to sustain any substantial increase in wind loading, for example through the use of a solid deck, the gearing, prime mover and electrical systems would have to be thoroughly replaced. An approximate cost for the replacement costs of these elements was provided by Stafford Bandlow Engineering, a Division of WJE in 2020, and is in the 10M$ range.[4]

5.0 Project Considerations

5.1 Impacts on Users

The LaSalle Causeway is a vital transportation link for the Kingston region and the Bascule Bridge even more so since it allows unimpeded marine navigation from Lake Ontario to the Rideau Canal which is a UNESCO World Heritage Site. Major work such as a deck replacement will inevitably have impacts on all users, and therefore utmost care is warranted for the selection of replacement deck options that allows an efficient construction sequence. A deck replacement project must consider staging, accelerated bridge construction (ABC), night work, work outside the navigational season, mitigation strategies and a comprehensive traffic control plan for vehicles, pedestrians, cyclist and other users.

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[3] See 2017 Structural Evaluation, 2017, SBE Engineering – Machinery and Prime Mover Evaluation Memorandum and 2020 Main Trunnion Rehabilitation Structural Evaluation Report (DRAFT).

[4] See SBE correspondence in Appendix B

5.2 Authorities and Stakeholders

The analyses of the deck and sidewalk options will consider the requirements and needs, during and after construction, of the relevant authorities and stakeholders such as:

- Public Services and Procurement Canada;
- The City of Kingston;
- Emergency services (Police, Fire Department, Ambulances);
- Parks Canada (Rideau Canal Waterway);
- Ministry of National Defense (CFB Kingston and Royal Military College);
- Ontario Ministry of the Environment
- Fisheries and Oceans Canada;
- Input from other stakeholders not listed above could be integrated in the analyses if deemed necessary by PSPC.

5.3 Design Codes and Standards

The deck and sidewalk system analyses will be undertaken in accordance with the current edition of the following (including all amendments, supplements and revisions thereto):

- CAN/CSA S6-19 Canadian Highway Bridge Design Code (CHBDC);
- MTO Structural Manual, Revision #58, September 2016;
- MTO Structure Rehabilitation Manual, April 2007;
- Federal and Provincial Environmental Regulations (including latest revisions of all regulations);
- AASHTO LRFD Bridge Design Specifications 6th Ed. Part I Sections 1 – 6;
- AASHTO LRFD Moveable Highway Bridge Design Specifications (2nd Edition) with 2008, 2010, 2011, 2012, 2014, and 2015 Interim Revisions;
- AASHTO Manual for Bridge Evaluation (3rd Edition);
- AASHTO Guide Specification for Analysis and Identification Fracture Critical Members;
- AASHTO Moveable Bridge Inspection, Evaluation, and Maintenance Manual - 1st Edition (1998);
- Canada Labour Code Part II and Canada Occupational Health and Safety Regulations;
- Federal, Provincial and Municipal Traffic Acts and Regulations;
- Applicable Electrical and Mechanical Codes and Regulations;
- Ontario Traffic Control Manual (2014), including latest revisions;
- NSBA “A Fatigue Primer for Structural Engineers,” John W. Fisher, Geoffrey L. Kulak, Ian F. C. Smith.

5.4 Key Criteria for Options Analysis

Replacement bridge deck and sidewalk systems need to fulfill many different and sometimes competing interests. Criteria to assess the performance of replacement proposed deck systems have been identified and are presented herein. Each criterion will be weighted and used in the comparative analysis of the various options.

5.4.1 Dead Loads

The bridge deck dead load is of critical importance for any moveable bridge and even more so for this historical structure. As discussed previously, the dead load has an impact on the mechanical, electrical and structural (demand to capacity ratio and fatigue) elements of the bridge. Substantial increases in the bridge deck dead load are impractical since they would require major rehabilitation to most of the major components of the bridge, such as counterweight, trunnions, prime mover and main structural members. More information on the limitations of the various components can be found in reports such as the 2013 LaSalle Causeway Bascule

Bridge Deck and Sidewalk Concepts Report, 2017 Structural Evaluation Report, the 2017 - SBE Engineering – Machinery and Prime Mover Evaluation Memorandum, 2018 Fatigue Inspection and Evaluation Report and the 2020 Main Trunnion Rehabilitation Structural Evaluation Report.

Changes in the weight or weight distribution of any of the leaf trusses or counterweight trusses elements will result in a change of balance in the bridge system. A large addition of weight would necessitate major modifications to the counterweight itself. A large subtraction of weight to the leaf trusses is easier to accommodate, since it can be compensated by removal of some of the ballast in the counterweight voids or by the addition of removable ballasts positioned below deck to avoid modification to the counterweight itself. No major rehabilitation of main structural or mechanical component is anticipated in the case of a deck lighter than the existing, because the balancing status quo could be almost maintained with proper use of ballasts. Depending on the deck system chosen, variation in the position of the center of gravity (vertically and horizontally) would require limited balancing adjustments to the counterweight, addition of in span ballast weight and adjustments to the mechanical systems. Such changes are anticipated to be relatively manageable[5].

As discussed in the Structural Considerations section, a dead load increase has a negative impact of the finite remaining fatigue lifespan of the main structural components. Substantial increases in weight should be avoided to preserve the structure that already shows signs of fatigue cracking. On the other hand, choosing a lighter deck system will contribute to increasing the bridge fatigue life, by decreasing the amplitude of the stress cycles at each opening. However, this beneficial effect has a practical limit since reduction of deck weight has to be modest if modifications to the counterweight are to be avoided.

The negative impact of a substantial weight increase on the main components and residual fatigue life was already recognized in section 2.2. of the 2013 LaSalle Causeway Bascule Bridge Deck and Sidewalk concepts report section:

> *"[…] the new deck system should not represent more than a 5% dead load increase to practically achieve a balanced structure. With some in-depth investigation and potential retrofitting for rebalancing a 10% dead load increase represents the maximum upper limit possible for this structure."*

Since the publication of this report in-depth evaluations of the mechanical and structural components, including the main trunnions, have shown the lack of reserve capacity of many of the main elements. This situation and the age of the structure justify a cautious approach where Engineering judgment plays a key role in the decision-making process in order to preserve the performance and safety of the bridge. Considering all of the aforementioned issues, any deck system creating a global load increase of more than 5% is deemed impractical and will be not be carried forward. This criterion will be evaluated on a pass or fail basis in the Deck Replacement Options Decision Tree section of this report and will be weighted as of critical importance in the weighted score analysis.

5.4.2 Wind Loads

Moveable bridges experience wind loading both when closed and during their opening cycles. Loads on the open structure, especially for bascule bridges, create high demands in the structural and mechanical components of the structure. Previous reports[6] have shown that during its opening cycle several main members of the bridge have insufficient capacity under the special load cases of Section 13.6.10 of CHBDC S6-14. Wind loading on the structural elements during the bridge opening have since then augmented (CHBDC S6-19 section 13.6.4.1) thus increasing the already high Demand to Capacity (D/C) ratios of some elements. The calculations of wind loads take into account a surface reduction factor of 0.85 for the openings in the deck grating (CHBDC S6-14 section 13.6.4.5 and CHBDC S6-19 section 13.6.4.6). Replacing the existing grating by a closed deck system will

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[5] See section 2.2.2 of the 2013 LSC Bascule Bridge Deck and Sidewalk concepts report

[6] 2017 Structural Evaluation Report, 2017 SBE Machinery and Prime Mover Evaluation Memorandum and the 2020 Main Trunnion Rehabilitation Structural Evaluation Report (DRAFT)

increase the loading by 18% compared to the loading used in the 2017 reports. If the new CHBDC S6-19 loading is considered in addition to a surface increase, the total increase of the wind loads for the structural elements would be of 70%, yielding unacceptably high D/C for some of the main structural members.

Mechanical design has specific wind loading requirements that differ from the structural wind loading. These requirements spelled out in section 13.7.14.7.2 of the CHBDC S6-14, did not change with the new version of the code (S6-19). However, the bridge mechanical systems and specifically its gears are unable to withstand the loading specified by the code. The 2017 SBE Machinery and Prime Mover Evaluation Memorandum explained that in order not to replace all the gearing, the maximum permissible wind pressure has to be limited to 240 Pa, which corresponds to a maximum permissible wind speed of 69 km/h. The memorandum recommended the installation of dedicated wind measuring equipment at the bridge location to implement this wind restriction. The new prime mover installed in 2018 was designed accordingly with the gearing capacity, following an accepted code deviation to avoid major rehabilitation of the gearing. Hence, the mechanical system of the bridge has limitations that would create more severe operational constraints and risk if the effective wind surface on the bridge deck was increased.

This makes the wind a vital criterion in the analysis; any option substantially increasing the bridge wind loads would require major structural, mechanical and electrical retrofitting. This criterion will be evaluated on a pass or fail basis in the Deck Replacement Options Decision Tree section and will be weighted as a criterion of critical importance in the weighted score analysis.

5.4.3 Design Life

The design life of any deck replacement option is an important criterion for system selection, especially considering the critical importance of the LaSalle Causeway in Kingston's transportation network. Even a well planned and executed deck replacement will create major constraints on the traffic circulation flow on the Causeway. PSPC has indicated considering a target design life of 25 years for the new system. Longer deck lifespan reduces the amount of deck replacements required over the remaining life of the structure, thus reducing impact on users. Furthermore, sustainability and costs are interlinked with the design life. Limiting the number of deck replacements over the life of the structure is beneficial for the environment by reducing the amount of materials used and potentially discarded. Costs are also linked to design life. Some short lifespan deck systems are low cost and thus seem attractive. However, the indirect costs of bridge deck replacement such as traffic control, engineering, project management and costs to users (lost time, detours, etc.) must be taken into account. Hence for the sake of the deck replacement option analysis, a longer design life will be deemed as a benefit and will be weighted as a criterion of high importance.

5.4.4 Future Maintenance Requirements

Low maintenance costs are a benefit, not only for the obvious financial aspect, but also because it implies less time performing maintenance on the deck and less impact to users. Like the design life, maintenance is also linked to sustainability as material and energy are required to maintain a system. Thus, a high maintenance system has a heavier environmental footprint than a low maintenance one. Maintenance requirement evaluation will also consider maintenance to the underlying steel elements; closed deck systems will reduce the need for repairs to the coating system and structural steel members (stringers, floor beams and bottom chords) by capturing the salt-laden water from the roadway and discharging it in a controlled way. Open deck systems expose the underlying elements to accelerated deterioration that increases the maintenance needs. For the sake of the deck replacement option analysis, low maintenance requirements will be deemed as a benefit and will be weighted as a criterion of high importance.

5.4.5 Corrosion Resistance

A high corrosion resistance reduces maintenance and increases design life. Systems susceptible to galvanic corrosion, organic decay, or with poor corrosion resistance will get a low performance score for this criterion. Corrosion resistance will be weighted as a criterion of high importance.

5.4.6 Fire Resistance

Resistance to fire is a primordial requirement for bridges for the safety to users, for emergency response and to protect the owner’s investment in the infrastructure. High fire resistance will be deemed as a benefit and will be weighted as a criterion of high importance.

5.4.7 Skid Resistance

Skid resistance of the wearing surface is crucial for users' safety by the role it plays in limiting braking distances and improving vehicle handling. The durability of the wearing surface plays a key role in the maintenance needs for a specific deck system. Wearing surfaces can be either integral to a deck system (e.g. steel grating) or external (e.g. asphalt on concrete slabs). Most lightweight deck systems use proprietary wearing surfaces, such as epoxy aggregate. The performance of those proprietary systems is highly dependent of the quality of installation, on the flexibility of the deck and on the intrinsic characteristics of the system. Projects have successfully used proprietary wearing surfaces in challenging environments for decades while other have sustained failure in the very first months after installation. The ease of replacement of the wearing surface is another important aspect affecting the performance of the wearing surface. Systems with integral wearing surfaces such as steel grating are extremely hard to retrofit. For instance, once the serrations of a steel grating have worn out, reinstating them in practically impossible, for cost, structural and safety aspects. For the sake of the deck option analysis, proven, easily replaceable, high friction wearing surfaces will be ranked high while new systems, integral or low friction systems will be ranked low. The performance of the wearing surface will be weighted as a criterion of high importance.

5.4.8 Capital Cost

Systems with low capital cost will be given a high score. System costs are a critical aspect to consider, but capital cost is only an element of the global life cycle system costs that includes maintenance, carbon footprint, user impact and replacement costs. The global life cycle cost is evaluated through the weighted score analysis. Capital cost will be weighted as a criterion of high importance.

5.4.9 Riding Quality

The riding quality is a part of the wearing surface performance, but such an important one to users that it deserves its own criteria. Wearing surfaces providing a poor user experience by their roughness or the noise they produce will be rated as having a low performance. The riding quality will be weighted as a criterion of medium importance.

5.4.10 Long-term Proven Bridge Technology

Some deck systems have a well-documented almost century-long service history in a variety of environments. Problems that can arise during their service life are known, solutions to address those problems have been developed and prognostics on their behavior is generally reliable. On the other hand, some newer deck systems do not have such a comprehensive history to rely on when evaluating their potential long-term performance. Use of those systems in new environments or under new conditions can lead to unforeseen problems for which no solution readily exists, potentially leading to long and costly repair design development phases that can necessitate in the worst of cases scientific research to identify the root causes and find adequate, durable solutions. For the sake of this analysis, long-term proven bridge deck technology will get a high score for the criteria, while new proprietary systems will get a low score. The criterion will be weighted as a criterion of medium importance.

5.4.11 Curbs and Barrier Performance

The existing Bascule Bridge curbs are made of wooden beams, while the barriers constitute W-beam rails attached directly to the main truss members. The barriers do not meet the crash-tested requirements of the current CHBDC. New system curbs will be evaluated against the existing for their maintenance needs, design life and carbon footprint. At this point, all systems would use the existing barrier/W-beam rails hence this element will not be part of the option analysis. Curbs having little maintenance needs, a long design life and a low carbon footprint will be given a high score. The criterion will be weighted as of medium importance.

5.4.12 Constructability

This criterion includes the ease of installation of the system (duration, complexity), possibility of phased construction, modification required on the approaches, closures required, etc. The most constructible deck system is one that has no impact on the approaches that can be installed in a short time using phased construction at night, with no full closure or day lane closure. The less constructible deck system is one that requires highly specialized construction methods and workers (proprietary systems); necessitate major changes to the approaches because of an increase height (e.g.: deck significantly thicker than the existing) and or crowning (e.g.: any closed deck) and requires full-day closure (e.g. to control vibrations during cast in place concrete setting period). The criteria will be weighted as of medium importance.

5.4.13 Drainage and Snow Removal

The Bascule Bridge current deck has a straight profile, without a slope or longitudinal crowning to help with the evacuation of surface water. All closed deck systems will require a crown and cross-slope for drainage and systems with a continuous, closed curb will necessitate provision for water capture and conveyance, such as gutters and downspouts. Snow removal is performed by plowing the roadway and shoveling the sidewalk. Systems impeding snow removal, trapping snow and ice, or requiring drainage gutters posing maintenance issues will be given a low score for this criterion. The criteria will be weighted as of medium importance.

5.4.14 Environmental Performance

Deck systems with a high carbon footprint (concrete) or allowing road salt, sand and debris to leach in the river will be considered to have a poor environmental performance and given a low score, while systems with a small carbon footprint (timber decks) or capturing the runoff water and discharging it in a controlled way will be given a high score. The criteria will be weighted as of medium importance.

6.0 Identification and Analysis of Deck Options

The following section will explore different scenarios for the future bridge deck options, including the status quo and different replacement options. General characteristics of each scenario will be presented, along with the main advantages and disadvantages. Some characteristics are common to a given option category, for instance all closed decks increase the wind surface compared to the existing open deck grating.

6.1 Existing Sills, Stringers and Floor Beams

All deck replacement options (except for the Status Quo) will include replacement of the existing grating, sills and stringers. Dozens of the existing stringers have active fatigue cracks. The cracks are located at the top and bottom copes at the ends of the stringers, with bottom cope cracking being more prevalent. The cracking originates for a poorly designed and poorly executed detail that created a notch at the corner of the 90^{o} cope, facilitating the development and propagation of fatigue cracking. A steel repair contract is under way to stabilize the situation, however given the number of cracks, their extent, the unknown notch toughness of the steel and the variable efficiency of repairs to this type of cracking, the stringers are deemed unsalvageable and should be replaced at the nearest opportunity. Hence, all options but status quo will consider a full replacement of the existing stringers by new stringers, with properly designed connections. The spacing of the stringers can be altered to improve the efficiency of the system, reduce weight and facilitate phasing during construction. Those aspects are to be investigated during the detailed design of the preferred option.

Based on the results of the 2017 structural evaluation and the recent inspections, the existing floor beams are in good condition and of sufficient strength to comply with CHBDC S6-14 vehicular loading. Thus, all options consider maintaining the existing floor beams.

6.2 Status Quo

This option consists of keeping all of the existing deck elements: the steel grating, sills and stringers would be maintained in their current state and only necessary repairs such as strengthening of broken bearing bars and cracked stringer repairs would be performed. The existing deck is an open system, providing a 0.85 reduction in the surface for calculation of the wind loads for the bridge in the open position. However, the openings allow salt-laden water to leach from the roadway onto the structural elements below, accelerating the deterioration of the coating and steel elements (section losses and corrosion-induced fatigue cracking). The skid resistance of the existing grating has been significantly reduced by the wear to the bar serrations, thus increasing the braking distance and creating a potential hazard to motorists and motorcyclists. The grating generates high noise levels and offer a poor riding quality to users, particularly cyclists. The existing steel deck grating, sills and stringers system has an average mass of approximately 200 kg/m^2 (grating, sills, stringers, corrosion protection, welds and bolts included; floor beams excluded). The existing deck thickness from the top flange of the floor beams to the top of the grating is approximately 214 mm.

6.3 Replacement Options Considered

6.3.1 Open Steel Grating

This option consists of replacing the current open steel deck grating system with a similar new deck system. For this option, the existing grating, sills and stringers are replaced by new elements. The existing floor beams are maintained.

Several variations of this option are possible, such as replacing the existing sills and grating in-kind or replacing them with a deck system without sills, using a deeper grating spanning from one stringer to the other. Introduction of noise mitigation measure could also be considered. A more detailed discussion on possible variations is presented in the Analysis of Viable Deck Options section.

A preliminary estimate for this option shows a mass equal to or slightly lower than the existing deck system mass is attainable. The vertical and horizontal position of the center of gravity of the deck would only be marginally modified by this option, thus limiting the balancing needs. Furthermore, wind loads with this option are identical to the existing deck. Noise mitigation options could increase the wind loading and necessitate in-depth analysis, which is discussed later on in this report.

6.3.2 Half Concrete Filled Steel Grating

This type of deck system is a variation of the steel grating where a horizontal steel plate is introduced at mid-height of the grating to allow the casting of normal, epoxy or low density concrete in the upper half of the grating, thus creating a composite, waterproof and relatively lightweight deck system. Typically, no supplemental wearing surface is installed, the exposed serrated steel grating bars and the concrete providing a low-noise skid resistant wearing surface. Some systems provide an overfill where the steel grating bars are completely covered by the concrete; in this case a traditional wearing surface can be installed to increase the riding quality, waterproofness and durability of the deck.

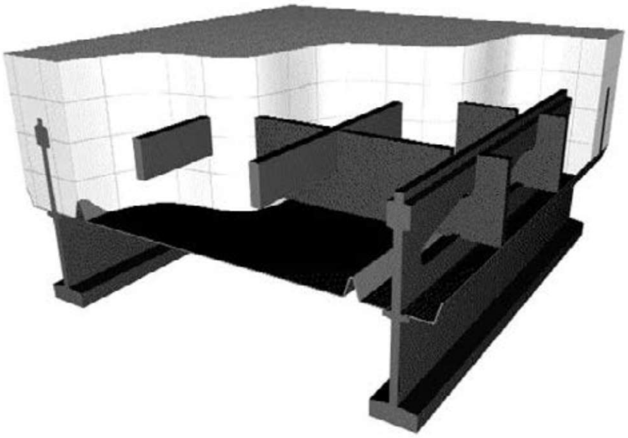

Figure 3: 125 mm / 5'' RB 1-.2 Concrete Half-Filled Grid with Overfill (credit: LBFoster fabricated bridge products catalog)

Deck thicknesses for this option are compatible with the existing deck thickness. For example, a 125 mm deep half concrete steel grating could replace the existing grating and sills. Deck crowning would be required for drainage and could be achieved through shims installed on the floor beams and stringers; those shims would at the same time allow to match the existing 214 mm deck thickness, thus limiting the impacts to the approaches and joints to the transition from the road profile to the deck crown. Existing stringers would be replaced by new, optimized sections.

This type of deck would increase the wind loading by 18% when compared with the existing deck (CHBDC S6-19 section 13.6.4.6). The deck mass for this system is in the range of 360 kg/m^2 to 400 kg/m^2 (125mm half-filled grating and stringers), almost double of the existing deck system mass.

6.3.3 Exodermic Deck

This deck type consists of a hybrid system constituted from a reinforced concrete slab on top of an open steel deck grating. It is in fact an optimized half concrete filled steel grating. The cast-in-place or pre-cast concrete slab on top is made composite with the steel bottom half to maximize concrete compressive strength and steel tensile properties. The system provides the advantages of a closed deck surface (riding quality, noise reduction, waterproofness), while being significantly lighter than traditional full-depth concrete decks. A standard wearing surface can be installed on the concrete slab to increase the riding quality, water tightness and durability of the deck. This type of deck has been used in North America for bridge deck replacements for more than 35 years. A deck mass of 280 kg/m^2 to 360 kg/m^2 has been achieved according to the 1998 “Exodermic Decks and Steel Bridges” article by Robert A. Bettigole[7]. Optimized design with modern codes could probably achieve an even lighter deck system. Deck thickness ranges from 165 mm to 240 mm without the wearing surface, which is compatible with the existing deck thickness, thus limiting impacts to the approaches and joints to the transition from the road profile to the exodermic deck crown.

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[7] https://www.aisc.org/globalassets/modern-steel/archives/1998/11/1998v11_exodermic.pdf

Figure 4: Exodermic deck cross section (photo credit http://www.faddis.com/product/bridge-decks/)

For the exodermic deck option, existing grating, sills and stringers would be replaced by new stringers and an exodermic deck. This type of deck would increase the wind loading by 18% when compared with the existing deck (CHBDC S6-19 section 13.6.4.6). Deck mass, even for a modern design, would be at least 25% heavier than the existing deck, ranging between 250 kg/m^2 and 400 kg/m^2.

6.3.4 Cast-in-Place Concrete Slabs

This is the most common bridge deck system, with rebar providing tensile resistance and concrete bearing the compressive forces. Deck cross-fall would be required for drainage and could be achieved through variable height gussets on the steel members. Height compatibility with the existing deck could be achieved, thus limiting modifications to the approaches and joints due to the transition from the road profile to the deck crown. A standard wearing surface could be installed on the concrete slab to increase the riding quality, waterproofness and durability of the deck. With this option, the construction time is significantly longer than options using prefabricated panels, since lengthy lane closures are required for formwork, rebar and concrete placement. Full closure would also be required to protect concrete from vibrations during the curing period.

With the cast-in-place concrete deck option, the existing grating, sills and stringers would be replaced by new stringers and a cast-in-place slab. A 225 mm reinforced concrete (normal density) deck has a mass of 550 kg/m^2 (wearing surface excluded); this represents 275% of the existing deck mass and would necessitate reinforcement or replacement of many structural and mechanical elements such as but not limited to floor beams, main truss members, counterweight, mechanical gears, prime mover, etc. Furthermore, as all per all closed deck options, a cast-in-place deck would create an increase of the wind loading of 18% when compared with the existing deck (CHBDC S6-19 section 13.6.4.6).

6.3.5 Prefabricated Prestressed Concrete Slabs

This is also a common bridge deck system, with prestressing strands and rebars providing tensile resistance and concrete bearing the compressive forces. The strands are tensioned in order to efficiently use concrete compressive strength and to avoid concrete cracking under service load, thus creating an efficient and durable deck. Crowning would be required for drainage and could be achieved through variable height gussets on the steel members. Height compatibility with the existing deck could be achieved, thus limiting impacts to the approaches and joints due to the transition from the road profile to the deck crown. Standard waterproofing and asphalt wearing surface could be installed on the concrete slab to increase the riding quality, waterproofness and durability of the deck. While this option can be implemented more rapidly than the cast-in-place options, steel tensioning, casting of closure strips, installation of waterproofing membrane and wearing surface still necessitate lengthy lane closures and even full closure to protect the concrete in the closure strips from vibrations during the curing period.

With the prestressed concrete deck option, the existing grating, sills and stringers would be replaced by new stringers and prefabricated prestressed slabs. The new deck mass (wearing surface excluded) would be between 490 kg/m^2 to 610 kg/m^2 depending on the thickness; this represents 275% of the existing deck mass and would most probably necessitate the reinforcement or replacement of many structural and mechanical elements such as but not limited to floor beams, main truss members, counterweight, mechanical gears, prime mover, etc. Furthermore, as per all closed deck options, a prefabricated prestressed concrete deck would create an increase of the wind loading of 18% when compared with the existing deck (CHBDC S6-19 section 13.6.4.6).

6.3.6 Orthotropic Steel Deck

Orthotropic steel systems are widely used in bridges where limiting weight is important such as for long span cable supported bridges or moveable bridges. Traditional orthotropic decks are made of a solid top plate, welded to open or closed ribs, orthogonally welded to beams. Those beams are supported by the main structural components like truss members or edge girders. The 2013 Delcan Corporation "LaSalle Causeway Bascule Bridge Deck and Sidewalk Concepts Report" has studied this option extensively for the LaSalle Causeway Bascule Bridge, going to the extent of having a preliminary custom design performed by one of the leading Canadian suppliers (Canam) of steel orthotropic decks in order to obtain the lightest steel orthotropic deck possible. The custom deck has a top plate, closed longitudinal ribs and transverse beams supported by four (4) new stringers attached to the existing floor beams.

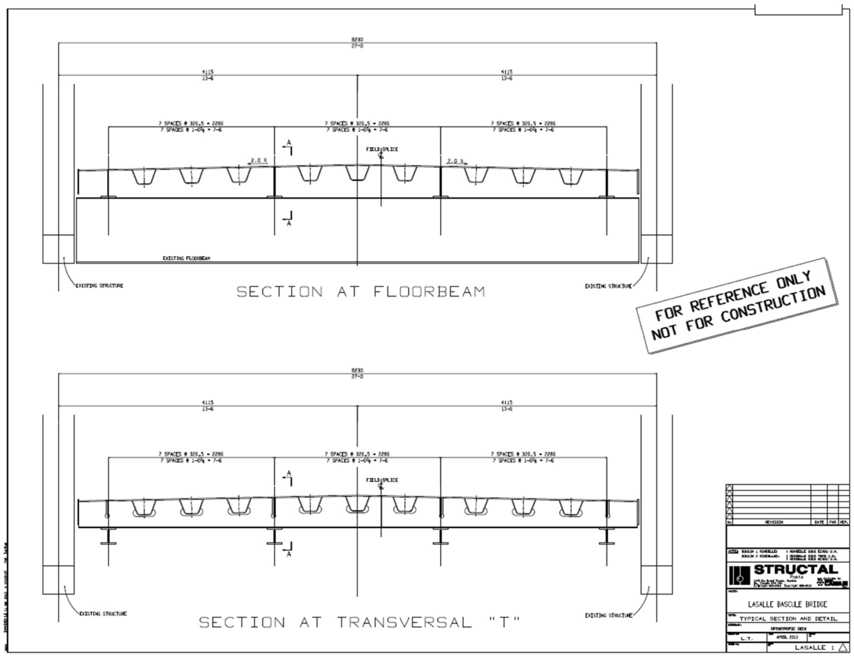

Figure 5: Optimized steel orthotropic deck for LaSalle Causeway Bascule Bridge

Similar to all closed deck systems crowning would be required for drainage. Furthermore, the installation of a wearing surface (epoxy aggregate or other similar lightweight product) is required to provide sufficient skid resistance and protect the top steel plate. The thickness of the custom orthotropic steel deck is estimated to be between 400 mm to 500 mm, requiring modification to the roadways, abutments, curbs, railings and joints. This option would replace the existing grating, sills and stringers by a new orthotropic deck and stringers; the existing floor beams would be maintained. The estimated mass for the optimized orthotropic steel deck system is 230 kg/m^2 with the wearing surface. Note that this weight is for an optimized, 12 mm top plate orthotropic deck that would need a design deviation from the CHBDC for the top plate thickness. If the CHBDC minimum 16 mm thick top plate[8] is used, the mass increases to 260 kg/m². As with all other closed deck options, the orthotropic steel deck would create an increase of the wind loading of 18% when compared with the existing deck (CHBDC S6-19 section 13.6.4.6).

6.3.7 Orthotropic Aluminum Deck

Orthotropic aluminum decks consist of extruded hollow aluminum profiles of various shapes, friction-stir welded together to create panels. Once assembled on-site by bolting, those panels create a lightweight closed deck stiffer than open steel grating. However, their use is currently mostly limited to proprietary products. Some Department of Transportation (DoT) in the US such as the Florida DoT have investigated this type of deck in depth, because of the significant weight reduction they yield compared to typical closed deck such as cast-in-place concrete, or because they provide a weight neutral closed deck solution to replace existing open deck grating. Challenges of using aluminum in bridge construction such as galvanic corrosion and differential thermic movements have been successfully addressed in some prototype projects[9].

Figure 6: Florida DOT Aluminum Orthotropic Deck Test Panel, with wearing surface, bolted on steel stringer[10]

Similar to all closed deck systems, crowning would be required for drainage. Furthermore, the installation of a wearing surface (epoxy aggregate or other similar lightweight product) is required to provide sufficient skid resistance and protect the top aluminum plate. A deck thickness similar to the existing is achievable with the use 125 mm (5'') deep extrusion panels with shims on floor beams and stringers, as demonstrated in Delcan's 2013, "LaSalle Causeway Bascule Bridge Deck and Sidewalk Concepts Report." The use of 125 mm deep panels requires the use of a minimum of three to four stringers, the latter configuration being better for constructability (phasing). With the use of 125 mm deep orthotropic aluminum panels with shims on the stringers and floor beams, modifications to the roadways, abutments, curbs, railings and joints are limited to adjustments to match the approaches to match the deck crowning.

This option would replace the existing grating, sills and stringers by a new orthotropic deck and reduced number of optimized stringers; the existing floor beams would be maintained. The estimated mass for the 125 mm orthotropic aluminum deck on steel stringers is 200 kg/m² with the wearing surface, thus offering a weight-neutral solution. As with all other closed deck options, the orthotropic aluminum deck would create an increase of the wind loading of 18% when compared with the existing deck (CHBDC S6-19 section 13.6.4.6).

6.3.8 Timber Deck

Timber has been used for bridge construction for centuries and is still commonly used today for pedestrian bridges, low traffic volume moveable bridges and for vehicular bridges on resources roads and low traffic volume

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[8] AASHTO LRFD 8th Edition sections 9.8.3.6.1 and 6.7.3 requirements as per CHBDC S6-19 section 10.16.1

[9] Aluminum Orthotropic Deck Research UPDATE Florida Department of Transportation AASHTO Bridge Subcommittee Meetings T-8 Movable Bridges June 13, 2017, Presented by George Patton, PE, Principal Associate, Hardesty & Hanover, LLC

[10] Figure credit: Aluminum Orthotropic Deck Research UPDATE Florida Department of Transportation AASHTO Bridge Subcommittee Meetings T-8 Movable Bridges June 13, 2017, Presented by George Patton, PE, Principal Associate, Hardesty & Hanover, LLC

unpaved roads. A timber deck replacement option could take several different configurations: 200 mm thick solid laminated deck (nailed, bolted or glued laminated timber); 191 mm x 191 sawn timber at 382 mm center to center with 100 mm thick planking on top as wearing surfaces (traditional steel-wood bridge deck); laminated 200 mm thick solid deck (nailed, bolted or glulam) with waterproofing membrane and epoxy aggregate wearing surface[11], etc. All the timber options share common characteristics such as being lightweight, low cost, having a low carbon footprint and a good constructability (easy prefabrication, fast to assemble if not already prefabricated, short lead time for procurement, easy on-site modifications if required, etc.), having a poor fire resistance, require on-going maintenance and having a short life,. The poor fire resistance constitutes a security risk since a deck fire could severely damage or even destroy the main structural components of the leaf truss. Traditional timber options where the wood acts as the wearing surface have short lifespans, require high maintenance, offer low skid resistance and are only partially waterproof. Options with a waterproofing membrane and a wearing surface have been used for a few decades in various jurisdictions, mostly as pilot projects, with generally good results. Some bonding problems of the wearing surface have been encountered, as is the case for all non-traditional wearing surfaces installed on flexible decks (steel or aluminum orthotropic, FRP, FRP-glulam, SPS have all experienced similar problems). Crowning of wood decks is not typically required, due to the gaps between the planks that allow run off water to drain. However, a deck with a waterproofing membrane and a wearing surface would require crowning and downspouts. A traditional timber deck would require adjustments to the roadways, abutments, curbs, railings and joints. However, a timber deck with new stringers could be optimized to match the new deck height to the existing, thus requiring no significant modifications to the approaches.

With this option, the existing grating, sills and stringers would be replaced by new optimized stringers (to suit the wood deck design), wood deck (nailed laminated, glulam, sawn timber beams, etc.) and wearing surface (wood planking or epoxy-aggregate on waterproofing membrane). The mass of a sawn timber deck made of 191 mm x 191 mm beams spaced at 382 mm center to center with 100 mm thick planking on top (acting as wearing surface) is only 180 kg/m^2 (stringers included), thus providing a weight reduction compared to the existing deck. With a waterproofing membrane and epoxy-aggregate wearing course, a weight neutral solution could be achieved. As with all other closed deck options, the timber deck would create an increase of the wind loading of 18% when compared with the existing deck (CHBDC S6-19 section 13.6.4.6).

6.3.9 Fiber-Reinforced Polymer (FRP) Deck

FRP decks are proprietary products made from fiber reinforced polymer on the exterior top and bottom surfaces, linked by vertical fiberglass shear webs. The space between the webs is filled by lightweight material, which differs depending on the supplier (closed cell foam, glulam timber, etc.). A lightweight wearing surface is installed on the top, typically epoxy-aggregate or other resin mixed with aggregates. As in all closed deck options, crowning has to be implemented, either integrally in the FRP panels or by the use of shims on the underlying steel structure. Curbs can also be integral to the panels or independent (semi-open wood curbs, steel curbs, etc.). If solid curbs are used, gutters and downspouts will be required. The FRP decks are intrinsically durable by either using inert materials (fiberglass, closed cell foam) or by completely encapsulating degradable material (FRP-timber); an FRP deck service life would equal or even surpass the residual service life of many if not all of the main components of the existing Bascule Bridge.

FRP decks have been used in the rehabilitation of many projects in the last few decades, with varied outcomes. The replacement of the Minto Bridges decks in Ottawa has been a success so far; however, some challenges with the wearing surface have been encountered during construction. The type and volume of traffic on the Minto Bridges are different from the conditions prevailing on the Bascule Bridge, hence caution is warranted when using this project as a benchmark. Furthermore, some major issues have occurred with FRP decks in other

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[11] Recent example : Albanel wood bridge, https://aqtr.com/association/actualites/pont-bois-dalbanel

projects[12], where debonding and cracking of the wearing surface as well as failure of the fiberglass panels have occurred within the first 10 years of service. FRP decks are less vulnerable to fire than timber deck, but more so than cast-in-place or prefabricated prestressed concrete. An improved fire resistance can be achieved by the use of fire retardants.

This option would replace existing grating, sills and stringers by a new FRP deck and a reduced number of optimized stringers; existing floor beams would be maintained. A mass below 200 kg/m^2 is achievable for an FRP or FRP-timber deck with an epoxy-aggregate wearing surface and new steel stringers, as demonstrated in the 2013 "LaSalle Causeway Bascule Bridge Deck and Sidewalk Concepts Report," thus offering a weight-neutral solution. As with all other closed deck options, an FRP deck would create an increase of the wind loading of 18% when compared with the existing deck (CHBDC S6-19 section 13.6.4.6).

6.3.10 Other Closed Deck Systems

A variety of atypical proprietary bridge deck system exist, most of which were developed to achieve durable lightweight options for deck replacement. However, due to the unproven nature of those systems and, in some case because of their poor performance when implemented on roadway bridges, no further analysis of these will be performed. It is worth noting that any closed deck option will create an increase of the wind loading of 18% when compared with the existing deck (CHBDC S6-19 section 13.6.4.6).

7.0 Identification and Analysis of Sidewalk Options

The existing sidewalk system comprises timber planking, supported by timber beams on steel cantilevered steel floor beams attached to the south truss of the Bascule Bridge. The structure is generally in good condition as discussed above and options are presented for either eventual replacement once the existing elements reach the end of the service life or for an anticipated replacement to take advantage of the mobilization of a contractor for the replacement of the vehicular deck. A limited number of options will be considered based on a pre-screening based on the weight and skid resistance criteria: only weight-neutral or lighter options offering a skid resistance equal or better to the existing will be considered. Delcan's 2013 "LaSalle Causeway Bascule Bridge Deck and Sidewalk Concepts Report," evaluated the possibility of widening the sidewalk to meet current design standards for combined pedestrian and cyclist use; however as discussed previously, recent analyses have demonstrated that any wind surface and significant dead load increase should be avoided, thus a sidewalk widening is not considered as desirable.

7.1 Status Quo

As mentioned above, the sidewalk is in good condition and there is no need for immediate replacement based on the current condition. The Status Quo is a viable option until the wood planking and beams deteriorate substantially. The residual service life of the existing sidewalk depends on maintenance, use, incidents, etc. and is thus hard to estimate accurately. However, given the current age and condition, replacement within the next 5 to 15 years should be anticipated based on the typical lifespan of wooden sidewalks. The current functional issues with the sidewalk originate from its limited width; however, increasing it is unpracticable as it would increase the wind and dead loads on the structure. The main disadvantages of keeping the existing timber planking and beams are: high maintenance, low fire resistance (vulnerability to vandalism) and low skid resistance.

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[12] See p16 of Delcan Corporation 2013 – "LaSalle Causeway Bascule Bridge Deck and Sidewalk Concepts Report"

7.2 Replacement Options Considered

7.2.1 Timber

A timber sidewalk is a viable option for replacement as it would constitute the “replace in kind” scenario, offering a fast, low-cost option with a good service life and a skid resistance identical to the actual. However, a timber sidewalk is very slippery when wet, is not completely waterproof and will allow the continued leaching of salt-laden water on the steel elements of the south truss such as the sidewalk cantilevered floor beams, bottom chord and lower section of diagonal and vertical truss members. The fire resistance of this option is low, and vandalism is a threat. A sidewalk fire could damage severely or even destroy the main structural components of the leaf truss. Maintenance requirements are relatively high, with potentially lag screws and planks requiring regular interventions.

7.2.2 Fiber-Reinforced Polymer (FRP)

As described in the deck option section, FRP is an extremely durable and lightweight option with good fire resistance if retardant is used. Given the balancing requirement of the bridge, removing too much weight would create issues, but those are easily overcome with the addition of ballast attached to the steel framing under the sidewalk. Furthermore, those ballasts could be removed eventually to compensate for the weight of any future structural reinforcements of the main trusses. The FRP panels would completely seal the sidewalk, with appropriate cut-outs around the vertical and diagonal, hence increasing the durability of the underlying steel elements. Crowning and downspouts would be required to capture and dispose of run-off water. An epoxy aggregate wearing surface would be installed on the top surface, thus providing a superior riding quality than the existing wood planking. Note that since cyclists are required to dismount to cross the Bascule Bridge, the skid resistance improvement would benefit only to a limited number of users (pedestrians, wheelchairs, strollers, etc.)

8.0 Analysis of Non-Financial Factors

This section presents the analysis of options considered for the deck and for the sidewalk. First, a discussion on the existing structure limitations will be presented. Then a logical screening process will be performed for the deck options to ascertain their viability. Finally, an analysis of the retained options will be performed to provide a weighted score for each of them.

8.1 Impact of Bascule Bridge Condition and Initial Design on Option Assessment

The Bascule Bridge was designed a century ago, based on codes and regulations far from the current standards, and the original structural, mechanical and electrical (upgraded) designs make the bridge non-compliant to current codes. Any significant increase in loading (dead, wind) will create additional issues with one or all the major components of the structural, or mechanical systems. In order to consider any option creating such an increase as viable, the cost of the required alterations to the mechanical and electrical systems system has to be added to the option cost. Furthermore, structural reinforcement costs also have to be accounted for.

Any substantial weight increase would also amplify the stress range in the main truss members each time the bridge opens. As shown by the 2018 Fatigue Inspection and Evaluation Report, many of the main truss members have reached or will soon reach their theoretical Fatigue Design Life and some of the members are already experiencing fatigue cracking problems. Hence, it is highly recommended not to consider options increasing substantially the weight of the deck. This falls in line with the recommendations of Section 2.2 of Delcan’s 2013 “LaSalle Causeway Bascule Bridge Deck and Sidewalk Concepts Report,” as mentioned in the Dead Loads section of this report. Therefore, any option increasing the deck dead load by more than 5% will not be carried forward for further analysis.

For wind loading, the current failure of the bridge systems to comply with modern codes (structurally and mechanically) is due to the combination of deterioration and from the original design criteria, the latter being predominant. Since the Bascule Bridge in its current configuration (with an open steel grating deck that provides a 15% wind surface reduction) doesn't comply with the current codes, any wind surface increase should be avoided, unless a major mechanical, electrical and structural retrofit are planned at the same time. The cost of such retrofitting, estimated to be close to 10M$[13], is considered prohibitive compared to the advantages gained. Therefore, any option increasing the deck wind surface by more than 5% will be discarded without further analysis.

8.2 Deck Replacement Options Decision Tree

The dead load and the wind load have proven to be governing the technical analysis since options creating substantial load increases are not viable unless a comprehensive rehabilitation of most of the main bridge components is performed, yielding prohibitive costs to the owner. Given the issues identified in the previous sections, all options will be screened through a decision tree process based on the two governing technical criteria: weight and wind surface. This process is presented below in Figure 7: Deck Replacement Option Decision Tree. Options that will fail to pass through the tree will be disregarded and no further analysis will be provided, as they will be deemed impracticable. The options succeeding in proceeding through the tree will be advanced to the Analysis of Viable Deck Options section. The results of the process are presented in Table 1: Decision Tree Screening Analysis.

Figure 7: Deck Replacement Option Decision Tree

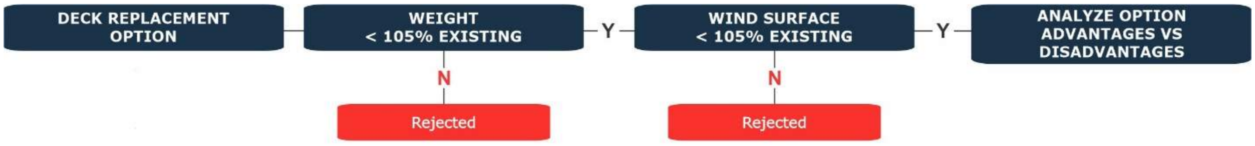

Table 1: Decision Tree Screening Analysis of Deck Replacement Options

Option Name	Decision Tree Result	Failed Criteria
Status Quo	Pass	n/a
Open steel grating	Pass	n/a
Half concrete filled steel grating	Fail	Weight, wind surface
Exodermic deck	Fail	Weight, wind surface
Cast in place concrete slabs	Fail	Weight, wind surface
Prefabricated prestressed concrete slabs	Fail	Weight, wind surface
Orthotropic Steel Deck	Fail	Weight, wind surface
Orthotropic Aluminum Deck	Fail	Wind surface
Timber Deck	Fail	Wind surface
Fiber-Reinforced Polymer (FRP) Deck	Fail	Wind surface
Other closed deck systems	Fail	Wind surface

The result of the decision tree analysis is that only two options are viable, with all other options failing to meet the limitations of the existing structure to support additional dead or wind loads. The successful Status Quo and Steel Grating options proceed to the weighted analysis of advantages and disadvantages.

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[13] See SBE correspondence on the matter in Appendix B.

8.3 Analysis of Viable Deck Options

The Status Quo and the Open Steel Grating options were analyzed for each criterion defined in the section Key Criteria for Options Analysis. The criteria were weighted to reflect their relative importance and options were scored for their performance for each of the defined criteria. A multiplication of the criteria weight by the option performance score gives a weighted score, then all the criterion weighted scores are added to give the option's overall weighted score.

Table 2: Weighted Score Deck Option Analysis

Deck Options Performance Analysis

Criteria		Options Performance[14]		Weighted Score	
Name	**Criteria Weight[15]**	**Status Quo**	**Open Steel Grating**	**Status Quo**	**Open Steel Grating**
Dead Load	5	8	8	40	40
Wind Load	5	10	10	50	50
Design Life	4	0	8	0	32
Future Maintenance Requirements	4	0	6	0	24
Corrosion Resistance	4	0	6	0	24
Fire Resistance	4	6	6	24	24
Skid Resistance	4	0[16]	6	0[16]	24
Capital Cost	4	10	6	40	24
Riding Quality	3	2	2	6	6
Long-term Proven Bridge Technology	3	10	10	30	30
Curbs and Barrier Performance	3	6	6	18	18
Constructability	3	10	10	30	30
Drainage and Snow Removal	3	8	8	24	24
Environmental Performance	3	2	2	6	6
			Global Score (max 520)	268[16]	356

The analysis shows that the Open Steel Grating option outperforms the Status Quo, principally since the existing grating has reached the end of its service life and no longer offers appropriate characteristic to users. As discussed previously, the existing steel grating serrations are completely worn out in the wheel paths, and the skidding resistance of the existing deck has been dramatically reduced, thus increasing the braking distance and increasing the likelihood of control losses, especially for motorcycles on rainy days. This situation could lead to slips and falls of motorcyclists with potentially catastrophic consequences because of the proximity of the eastbound and westbound traffic lanes. Given the reduced skid resistance of the existing steel deck grating, the current grating is considered substandard for user safety. Attempts to restore the skid resistance such as notching bearing bars or welding attachment will reduce the resistance of the grating or cause crack initiation points and are considered impractical. Moreover, the existing grating shows many signs of having probably reached its fatigue design life, with numerous bearing bars fracturing. In this option, the existing stringers would

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[14] Option Performance score ranking scale: Excellent: 10; Good: 8; Average: 6; Fair: 4; Poor: 2; Substandard: 0. The option with the higher score is more favorable.

[15] Criterion weight importance scale: Critical: 5; High: 4; Medium: 3; Limited: 2; Low: 1

[16] Options with score of 0 for a criterion involving safety such as skid resistance should be discarded.

also be maintained, posing an additional risk given the presence of systematic active fatigue cracking at the end copes. Given the issues stated above, this option is discarded and will not be subject to further analysis, leaving only the Open Steel Grating option as a viable replacement option for the deck.

8.4 Analysis of Viable Sidewalk Options

The Status Quo, new Timber and FRP options were all successful through the Decision Tree process and were analyzed for each criterion defined in the section Key Criteria for Options Analysis, except for the Curbs and Barrier Performance criterion that is not applicable to the sidewalk[17]. The criteria were weighted to reflect their relative importance and options were scored for their performance for each of the defined criteria. A multiplication of the option weight by the option performance gives a weighted score, then all the criterion weighted scores are added to give the option overall weighted score.

Table 3: Weighted Score Sidewalk Option Analysis

Sidewalk Option Performance Analysis

Criteria		Options Performance[18]			Weighted score		
Name	Criteria Weight[19]	Status Quo	Timber	FRP	Status Quo	Timber	FRP
Dead Load	5	8	8	10	40	40	50
Wind Load	5	6	6	6	30	30	30
Design Life	4	4	6	10	16	24	40
Future Maintenance Requirements	4	2	4	10	8	16	40
Rotting/Corrosion Resistance	4	2	4	10	8	16	40
Fire Resistance	4	2	2	6	8	8	24
Skid Resistance	4	4	4	10	16	16	40
Capital Cost	4	10	6	4	40	24	16
Riding Quality	3	4	4	10	12	12	30
Long-term Proven Bridge Technology	3	10	10	6	30	30	18
Constructability	3	10	10	8	30	30	24
Drainage and Snow Removal	3	8	8	6	24	24	18
Environmental performance	3	6	6	8	18	18	24
			Global Score (max 490)		280	288	394

The analysis shows that the Status Quo and the replacement of the sidewalk with a Timber structure ("replace in kind option") offer essentially the same performance, which is normal given the existing sidewalk is still in good condition and that those two options are essentially the same system. However, replacing the existing sidewalk with an FRP structure would offer a significant improvement in performance when compared to a new Timber sidewalk and even more so when compared against the existing Timber Sidewalk; as the existing structure ages and its performance deteriorates, the advantages of the FRP option will only increase when compared to the existing Timber sidewalk.

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[17] The current pedestrian and cyclist railing is recent and in good condition, hence replacement options were not considered.

[18] Option Performance score ranking scale: Excellent: 10; Good: 8; Average: 6; Fair: 4; Poor: 2; Substandard: 0.

[19] Criterion weight importance scale: Critical: 5; High: 4; Medium: 3; Limited: 2; Low: 1

8.5 Recommended Options for Further Analysis

Based on the results of the Decision Tree process and of the Weighted Score analysis, it is recommended to replace the existing open steel grating by a new open steel grating and to maintain the existing sidewalk until it deteriorates sufficiently to justify replacing it with a new FRP sidewalk.

A detailed Class D Cost Estimate was prepared for a new open steel grating deck and is presented in Appendix A. It includes the replacement of the existing grating, sills and stringers by new elements. Two separate options were considered for the new deck: the first one is a replacement “in kind” option of the existing elements, with a new 65 mm thick grating with new sills and new stringers. The cost estimate for this option is $2,163,100. The second option would replace the existing grating and sills by a 125 mm thick grating and replace the existing stringers by a new stringer system (optimized spacing and sections). The cost estimate for this option is $2,331,200. This second option would accelerate the construction, reduce the number of elements and potentially the wind surface of the deck in the open position. It would cause a slight change in the vertical position of the center of gravity of the deck, but this change is considered marginal and manageable by limited balancing adjustments to the counterweight.

Appendix A also presents the cost estimates for the replacement of the existing Timber sidewalk in-kind ($231,300) as well as its replacement with a new FRP sidewalk ($669,500). As discussed above, all options maintain the existing combined pedestrian and cyclist railings.

One of the main disadvantages of the existing deck is the poor riding quality of the serrated grating, particularly for cyclists. Vibrations caused by passing cars and trucks create an uncomfortable driving condition and high noise levels. Noise mitigation measures have been successfully implemented in the past on several open deck bridges, including moveable bridges, which typically consists of filling the grating in the wheel paths with concrete. Preliminary analysis of this mitigation measure for the LaSalle Bascule Bridge shows that using concrete would increase the weight past the acceptable threshold and hence this option is not considered viable. Using FRP strips topped with a lightweight wearing surface at the wheel paths would respect the weight increase limit, but it would increase the wind surface near or slightly above the acceptable limit. If using FRP strips in the wheel paths as a noise mitigation measure is considered for further analysis, the opinion of specialists in Wind Engineering should be sought during the detailed design phase to ascertain the impact on the wind drag of the deck in the open position. The Bascule Bridge deck structure is comprised of four layers of elements (grating, sills, stringers and floorbeams) which creates wind drag in the open position. By comparing the wind drag of the existing deck system with the streamlined new deck system (125 mm thick grating without sills), it might be possible to show that the addition of closed FRP strips in the wheel paths does not significantly increase the wind drag of the deck in the open position. Finally, if the wheel-path FRP strips are contemplated, special attention should be given to the longitudinal joints between the grating and the FRP strips to avoid safety and serviceability issues (potential slip hazards to motorcyclist and damage caused by snowplows, etc.)

8.6 Existing Deck and Stringers Replacement Scheduling

The timeframe to replace the existing deck and stringers must be evaluated based on various factors, with the safety of users being the most important. As discussed in previous sections, the substandard skid resistance of the grating due to the wearing of its serrations creates safety issues to users. Furthermore, the cracking of bearing bars will lead to increased maintenance requirements and the likelihood of accidents on the bridge since a broken bearing bar could potentially puncture tires or cause a motorcyclist to slip and fall.

The replacement of the grating should include the removal of the existing sills: since they are welded to the grating, removing the grating only would require lengthy and tedious work to cut or grind all the welds without damaging the sills, thus significantly increasing the cost of the removal work due to the additional manpower required.

Replacing the grating and sills by new elements can be done without replacing the stringers or floorbeams. The floorbeams are in good condition and require no major intervention at this point. The stringers, however, are in a very different situation, with fatigue cracking affecting dozens of coped ends. To this day, systematic non-destructive testing of all stringer coped ends has not been performed, so it is likely that existing cracks are still undetected. The 2018 Fatigue Inspection[20] and the 2019 CDI Inspection projects determined that the cracking affects almost all bays of the deck floor system and that some crack lengths increased between the 2018 and 2019 inspections. Given the progression of the cracks, their location and lengths[21], the rapid propagation of a crack leading to the fracture of a stringer cannot be ruled out. A design contract to repair many of the defects found during the 2018 Fatigue Inspection project is currently underway, but efficiently repairing cracks of this nature has proven difficult and is often only a temporary solution, with the crack progression resuming past the repair (such as a drilled hole at the end of the crack). Predictions on the behavior of the repaired cracked stringers are hard to make, especially in the absence of data on the steel notch toughness[20]. Given the severity and quantity of the known cracks and the poorly designed and executed copes that affects all stringers, the complete replacement of all stringers is the option to consider for ensuring reliable service and maintaining a high level of user safety. Replacing the stringers without removing the sills and grating would require extensive temporary work to support the deck, and this (combined with space constraints) would yield high construction costs; it is therefore recommended that all the stringers are replaced at the same time as the deck replacement.

Considering the safety issues related to the substandard skid resistance of the grating and the potential fracturing of cracked stringers, a maximum two-year timeframe is proposed for the replacement of the grating, sills and all the stringers. Extending the replacement timeframe may increase the likelihood of accidents caused by substandard skid resistance and increase the risk of stringer fracture, which could necessitate the immediate partial or complete closure of the bridge to vehicular traffic, depending on the location of the fractured stringer. To mitigate these risks, inspection of sensitive elements at regular intervals, crack monitoring and repair, speed limit reduction and signalization could be implemented. Such measures should be considered without regard to the expected timeframe for deck replacement, but they will become more important as time goes by since risks will continue to increase as structure deterioration increases.

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[20] See 2018 Parsons Inc – “2018 Fatigue Inspection and Evaluation Report” PWGSC Project No. R.090045.001,

[21] See 2018 Parsons Inc – “2018 Fatigue Inspection and Evaluation Report” PWGSC Project No. R.090045.001,

9.0 Closure

The Feasibility Study for the replacement of the Steel Deck Grating of the LaSalle Bascule Bridge has demonstrated that the original, century-old design of the bridge limits the deck options that can be considered due to the limitations of the structural and mechanical systems due to wind and dead loads. The wind surface and the dead weight constraints dictate the choice of an open steel grating as the only viable replacement option to consider, while the wear, condition and age of the existing grating discards the Status Quo as a viable option, mainly for safety reasons. Two options for a new open steel deck have been discussed and should be developed during the detailed design stage, with the 125 mm deep grating option as replacement of the existing grating and sills being the most promising. Noise mitigation measures were also evaluated; however, their implementation is conditional to specialized wind study of the deck wind drag to ascertain there is no increase in the wind surface. The sidewalk replacement was also analyzed, but its current condition makes the status quo a viable option for the short to mid-term; replacement with an FRP sidewalk is the preferred option once the existing timber sidewalk reaches the end of its service life. Cost estimates were prepared for the recommended options for the deck and the sidewalk and are presented in Appendix A. Considering the safety and serviceability issues related with the condition of the grating and stringers, a maximum two-year timeframe is proposed for their replacement. Extending this timeframe will increase the likelihood of accidents caused by the reduced skid resistance of the existing grating and the probability of emergency lane or bridge closures caused by a stringer fracture. To mitigate these risks, regular inspections, crack monitoring and repair, speed limit reduction and signalization could be implemented. Such measures will become more important as the structure continues to age and deteriorate.

We trust this report is adequate for your present requirements. If you have any comments or questions, please contact the authors.

Yours truly,

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Appendix A:
Class D Cost Estimates

Deck Replacement Options Analysis

La Salle Causeway Bascule Bridge, Kingston, Ontario

COST REPORT
CLASS D - FEASIBILITY ESTIMATE
MARCH 2, 2020

11 Randolph Street, Halifax, Nova Scotia, Canada, B2P 2A9
www.qsolv.ca

Preamble

INTRODUCTION

The Class D - Feasibility Indicative Estimates enclosed represents the construction value for the deck replacement options to the LaSalle Causeway Bascule Bridge located in Kingston, Ontario as designed by Parsons Inc. for Public Services and Procurement Canada.

The project generally includes: selective removals; three options for deck replacement; removal and replacement of steel stringers; sidewalk replacement; guardrail modifications; and traffic control.

APPROACH

The construction costs for this report include all materials, labour, equipment, overheads, general conditions, plus markups, contractor's profit, and contingencies for the bridge deck replacement options as presented in the project documents. Construction costs are shown as costs excluding HST and escalation.

A summary of construction costs for deck options is as follows:

Option 1 - 65mm Steel Grating	$	2,163,100
Option 2 - 125mm Steel Grating	$	2,331,200
Option 3 - FRP Panels	$	3,566,600
Option 4 - Sidewalks - Timber	$	231,300
Option 5 - Sidewalks - FRP Panels	$	669,500

Quantities were measured based on the Canadian Institute of Quantity Surveyors (CIQS) standards for Method of Measurement and presented in elemental format.

Pricing reflects competitive bids for every element of the work for a project of this type, procured under an open market stipulated lump sum bid contract in Kingston, Ontario. Unit costs are developed and expressed as typical sub-contractor pricing and are inclusive of subcontractor's overheads and profits.

This estimate is an indication of the probable construction costs and is intended to represent fair market value of the construction costs. This estimate should not be considered a prediction of the lowest bid.

SPACE MEASUREMENT

The Gross Bridge Deck Area (GDA) was measured at 401 square metres (m2).

COST BASE

All costs are expressed in first quarter 2020 Canadian dollars (1Q2020).

Preamble

COST BASE

All costs are shown exclusive of the 13% Harmonized Sales Tax (HST). Please refer to the Summary Sheets where the HST is identified.

ESCALATION

An Escalation Allowance is excluded from this cost plan. Once a project schedule is developed, an opinion on construction escalation may be provided.

CONTINGENCIES

A Design and Pricing Contingency Allowance of 10% for Options 1, 2 and 4 and 15% for Option 3 and 5 is included in this report to allow for scope and pricing adjustments during the design phase.

A Construction Contingency Allowance of 10% is included in this report to allow for costs associated with site unknowns and change orders issued during the construction stage.

ALLOWANCES

No cash allowance have been identified in the contract documents.

EXCLUSIONS

The following have been excluded from this cost report:

Premium for single source materials or equipment
Third party commissioning
Interim financing
Land acquisition fees and disbursements
Legal fees and surveys
Risk allowance
Design fees and disbursements
Owner's fees and disbursements
Project management fees and disbursements
Material testing
Salvage costs from demolished or removed items
Hazardous materials abatement
Service relocations (mechanical or electrical)

DOCUMENTATION

This Class D estimate is based on the following documentation:

Drawings	**Rev:**	**Dated:**
SK-01		
SK-02		
SK-08		

Preamble

DOCUMENTATION

Drawings	**Rev:**	**Dated:**
SK-07		
S12	1	July 8, 2009

Specifications/Reports	**Dated:**
Deck and Sidewalks Concept Report	June 2013

ELEMENTAL COST SUMMARY

Option 1 - 65mm Steel Grating

PROJECT:	DECK REPLACEMENT - OPTIONS ANALYSIS	DATE:	MARCH 2, 2020
LOCATION:	LASALLE BRIDGE, KINGSTON, ONTARIO	CLASS:	D - FEASIBILITY
CLIENT:	PUBLIC SERVICES & PROCUREMENT CANADA	FILE	13003
DESIGNER:	PARSONS INC	GDA: m2	401

GROSS BRIDGE DECK AREA 401 m2

ELEMENT	RATIO TO GDA	ELEMENTAL QUANTITY		ELEMENTAL UNIT RATE	ELEMENTAL AMOUNT	RATE PER GDA	TOTAL AMOUNT	%
A BRIDGE						$ 3,524	$ 1,413,200	65.33
A1 BRIDGE SUBSTRUCTURE						$ -	$ -	0.00
A11 Foundations	1.000	401	m2	$ -	$ -	$ -		0.00
A12 Bridge Abutments	1.000	401	m2	$ -	$ -	$ -		0.00
A13 Approaches	1.000	401	m2	$ -	$ -	$ -		0.00
A2 BRIDGE STRUCTURE						$ 3,524	$ 1,413,200	65.33
A21 Shop Fabrication	1.000	401	m2	$ 1,322.44	$ 530,300	$ 1,322		24.52
A22 Shop Assembly	1.000	401	m2	$ -	$ -	$ -		0.00
A23 Site Installation	1.000	401	m2	$ 2,201.75	$ 882,900	$ 2,202		40.82
A3 BRIDGE MECHANICAL						$ -	$ -	0.00
A31 New & Refurbished Components	1.000	401	no	$ -	$ -	$ -		0.00
A32 Mechanical Site Installation	1.000	401	no	$ -	$ -	$ -		0.00
A4 BRIDGE ELECTRICAL						$ -	$ -	0.00
A41 Supply New Components	1.000	401	m2	$ -	$ -	$ -		0.00
A42 Electrical Site Installation	1.000	401	sum	$ -	$ -	$ -		0.00
A5 BRIDGE TESTING & COMMISSIONING						$ -	$ -	0.00
A51 Testing & Commissioning - Shop Assembly	1.000	401	m2	$ -	$ -	$ -		0.00
A52 Testing & Commissioning - Site Assembly	1.000	401	sum	$ -	$ -	$ -		0.00
NET BRIDGE SUBTOTAL - LESS SITE AND ANCILLARY WORK						$ 3,524	$ 1,413,200	65.33
B SITE AND ANCILLARY WORK						$ -	$ -	0.00
B1 EARTHWORK						$ -	$ -	0.00
B11 Excavation and Backfill	1.000	401	m2	$ -	$ -	$ -		0.00
B12 Environmental	1.000	401	m2	$ -	$ -	$ -		0.00
B2 ROAD REALIGNMENTS						$ -	$ -	0.00
B21 Road Realignments	1.000	401	m	$ -	$ -	$ -		0.00
B3 SITEWORK FINISHES						$ -	$ -	0.00
B31 Soft Landscaping	1.000	401	m2	$ -	$ -	$ -		0.00
B32 Landscaping Fittings and Fixtures	1.000	401	m2	$ -	$ -	$ -		0.00
B4 ANCILLARY WORK						$ -	$ -	0.00
B41 Bridge Demolition	1.000	401	m2	$ -	$ -	$ -		0.00
B42 Site Reinstatement	1.000	401	m2	$ -	$ -	$ -		0.00
NET BRIDGE SUBTOTAL - INCLUDING SITE AND ANCILLARY WORK						$ 3,524	$ 1,413,200	65.33
Z GENERAL REQUIREMENTS AND ALLOWANCES						$ 1,870	$ 749,915	34.67
Z1 GENERAL REQUIREMENTS AND FEES						$ 934	$ 374,498	17.31
Z11 General Requirements and Overheads		15%			$ 211,980	$ 529		9.80
Z12 Contractors Profit		10%			$ 162,518	$ 405		7.51
Z2 ALLOWANCES						$ 936	$ 375,417	17.36
Z21 Design and Pricing Allowance		10%			$ 178,770	$ 446		8.26
Z22 Escalation Allowance		0%			$ -	$ -		0.00
Z23 Construction Allowance		10%			$ 196,647	$ 490		9.09
TOTAL CONSTRUCTION COST (HST EXTRA)				$5,394 per m2			$ 2,163,100	100.00

Element	Quantities		Unit Rates	Sub-totals

BRIDGE STRUCTURE

A21 Shop Fabrication

Element	Quantities		Unit Rates	Sub-totals
PHASE 1				
1 Supply Stringers				
- Fabricate new steel stringers	11900	kgs	$ 6.00	$ 71,400
- Fabricate sills (W150x24)	10600	kgs	$ 6.00	$ 63,600
2 Deck Grating				
- Supply galvanized steel grating (65mm deep)	190	m2	$ 585.00	$ 111,150
- Miscellaneous connections	1	sum	$ 10,000.00	$ 10,000
PHASE 2				
3 Supply Stringers				
- Fabricate new steel stringers	14900	kgs	$ 6.00	$ 89,400
- Fabricate sills (W150x24)	10600	kgs	$ 6.00	$ 63,600
4 Deck Grating				
- Supply galvanized steel grating (65mm deep)	190	m2	$ 585.00	$ 111,150
- Miscellaneous connections	1	sum	$ 10,000.00	$ 10,000
A21 Shop Fabrication Subtotal	401	m2	$ 1,322.44	$ 530,300

A23 Site Installation

Element	Quantities		Unit Rates	Sub-totals
PHASE 1				
1 Secure Bridge				
- Traffic control	1	day	$ 1,500.00	$ 1,500
- Chain bridge down	1	day	$ 2,900.00	$ 2,900
2 Establish Traffic Lane				
- Traffic control	5	days	$ 1,500.00	$ 7,500
- Supply precast jersey barriers	75	no	$ 300.00	$ 22,500
- Temporary traffic lights	1	sum	$ 15,000.00	$ 15,000
- Miscellaneous signage	1	sum	$ 10,000.00	$ 10,000
- Install jersey barriers	75	no	$ 185.00	$ 13,875
- Traffic lane maintenance	1	sum	$ 20,000.00	$ 20,000
3 Deck Replacement				
- Remove decking, sills, stringers	190	m2	$ 550.00	$ 104,500
- Remove and reinstall span locking mechanism	1	sum	$ 50,000.00	$ 50,000
- Refurbish existing steel structure	1	sum	$ 25,000.00	$ 25,000
- Install stringers, sills, galvanized steel grating deck	190	m2	$ 850.00	$ 161,500
- Supply timbers curbs	1	mfbm	$ 3,000.00	$ 3,000
- Miscellaneous connections and hardware	1	sum	$ 1,000.00	$ 1,000
- Install timber curbs	1	sum	$ 5,000.00	$ 5,000
- New X-bracing	1	loc	$ 10,000.00	$ 10,000
PHASE 2				

Element	Quantities		Unit Rates	Sub-totals
4 Establish Traffic Lane				
- Relocate jersey barriers	75	no	$ 275.00	$ 20,625
- Traffic lane maintenance	1	sum	$ 25,000.00	$ 25,000
5 Deck Replacement				
- Remove decking, sills, stringers	190	m2	$ 650.00	$ 123,500
- Refurbish existing steel structure	1	sum	$ 30,000.00	$ 30,000
- Install stringers, sills, galvanized steel grating deck	190	m2	$ 850.00	$ 161,500
- Supply timbers curbs	1	mfbm	$ 3,000.00	$ 3,000
- Miscellaneous connections and hardware	1	sum	$ 1,000.00	$ 1,000
- Install timber curbs	1	sum	$ 5,000.00	$ 5,000
- New X-bracing	1	loc	$ 10,000.00	$ 10,000
6 Balance/Commission Bridge				
- Re-balance counterweight, commissioning	1	sum	$ 50,000.00	$ 50,000
A23 Site Installation Subtotal	**401**	**m2**	**$ 2,201.75**	**$ 882,900**
General Requirements and Fees				
Z11 General Requirements and Overheads				
- Contractor's Overheads			15%	$ 211,980
Z11 General Requirements and Overheads Subtotal	**15**	**%**		**$ 211,980**
Z12 Contractor's Profit				
- Contractor's Profit			10%	$ 162,518
Z12 Contractor's Profit Subtotal	**10**	**%**		**$ 162,518**
Allowances				
Z21 Design and Pricing Allowance				
- Design and Pricing Contingency			10%	$ 178,770
Z21 Design and Pricing Allowance Subtotal	**5**	**%**		**$ 178,770**
Z23 Construction Contingency				
- Construction Contingency			10%	$ 196,647
Z23 Construction Contingency Subtotal	**15**	**%**		**$ 196,647**

ELEMENTAL COST SUMMARY

Option 2 - 125mm Steel Grating

PROJECT: DECK REPLACEMENT - OPTIONS ANALYSIS
LOCATION: LASALLE BRIDGE, KINGSTON, ONTARIO
CLIENT: PUBLIC SERVICES & PROCUREMENT CANADA
DESIGNER: PARSONS INC

DATE: MARCH 2, 2020
CLASS: D - FEASIBILITY
FILE 13003
GDA: m2 401

GROSS BRIDGE DECK AREA 401 m2

ELEMENT	RATIO TO GDA	ELEMENTAL QUANTITY		ELEMENTAL UNIT RATE	ELEMENTAL AMOUNT	RATE PER GDA	TOTAL AMOUNT	%
A BRIDGE						$ 3,798	$ 1,523,000	65.33
A1 BRIDGE SUBSTRUCTURE						$ -	$ -	0.00
A11 Foundations	1.000	401	m2	$ -	$ -	$ -		0.00
A12 Bridge Abutments	1.000	401	m2	$ -	$ -	$ -		0.00
A13 Approaches	1.000	401	m2	$ -	$ -	$ -		0.00
A2 BRIDGE STRUCTURE						$ 3,798	$ 1,523,000	65.33
A21 Shop Fabrication	1.000	401	m2	$ 1,415.46	$ 567,600	$ 1,415		24.35
A22 Shop Assembly	1.000	401	m2	$ -	$ -	$ -		0.00
A23 Site Installation	1.000	401	m2	$ 2,382.54	$ 955,400	$ 2,383		40.98
A3 BRIDGE MECHANICAL						$ -	$ -	0.00
A31 New & Refurbished Components	1.000	401	no	$ -	$ -	$ -		0.00
A32 Mechanical Site Installation	1.000	401	no	$ -	$ -	$ -		0.00
A4 BRIDGE ELECTRICAL						$ -	$ -	0.00
A41 Supply New Components	1.000	401	m2	$ -	$ -	$ -		0.00
A42 Electrical Site Installation	1.000	401	sum	$ -	$ -	$ -		0.00
A5 BRIDGE TESTING & COMMISSIONING						$ -	$ -	0.00
A51 Testing & Commissioning - Shop Assembly	1.000	401	m2	$ -	$ -	$ -		0.00
A52 Testing & Commissioning - Site Assembly	1.000	401	sum	$ -	$ -	$ -		0.00
NET BRIDGE SUBTOTAL - LESS SITE AND ANCILLARY WORK						$ 3,798	$ 1,523,000	65.33
B SITE AND ANCILLARY WORK						$ -	$ -	0.00
B1 EARTHWORK						$ -	$ -	0.00
B11 Excavation and Backfill	1.000	401	m2	$ -	$ -	$ -		0.00
B12 Environmental	1.000	401	m2	$ -	$ -	$ -		0.00
B2 ROAD REALIGNMENTS						$ -	$ -	0.00
B21 Road Realignments	1.000	401	m	$ -	$ -	$ -		0.00
B3 SITEWORK FINISHES						$ -	$ -	0.00
B31 Soft Landscaping	1.000	401	m2	$ -	$ -	$ -		0.00
B32 Landscaping Fittings and Fixtures	1.000	401	m2	$ -	$ -	$ -		0.00
B4 ANCILLARY WORK						$ -	$ -	0.00
B41 Bridge Demolition	1.000	401	m2	$ -	$ -	$ -		0.00
B42 Site Reinstatement	1.000	401	m2	$ -	$ -	$ -		0.00
NET BRIDGE SUBTOTAL - INCLUDING SITE AND ANCILLARY WORK						$ 3,798	$ 1,523,000	65.33
Z GENERAL REQUIREMENTS AND ALLOWANCES						$ 2,015	$ 808,180	34.67
Z1 GENERAL REQUIREMENTS AND FEES						$ 1,006	$ 403,595	17.31
Z11 General Requirements and Overheads		15%			$ 228,450	$ 570		9.80
Z12 Contractors Profit		10%			$ 175,145	$ 437		7.51
Z2 ALLOWANCES						$ 1,009	$ 404,585	17.36
Z21 Design and Pricing Allowance		10%			$ 192,660	$ 480		8.26
Z22 Escalation Allowance		0%			$ -	$ -		0.00
Z23 Construction Allowance		10%			$ 211,925	$ 528		9.09
TOTAL CONSTRUCTION COST (HST EXTRA)				$5,813 per m2			$ 2,331,200	100.00

Element	Quantities		Unit Rates	Sub-totals

BRIDGE STRUCTURE

A21 Shop Fabrication

Element	Quantities		Unit Rates	Sub-totals
PHASE 1				
1 Supply Stringers				
▪ Fabricate new steel stringers	11900	kgs	$ 6.00	$ 71,400
▪ Fabricate shims	5000	kgs	$ 6.00	$ 30,000
2 Deck Grating				
▪ Supply galvanized steel grating (125mm deep)	190	m2	$ 860.00	$ 163,400
▪ Miscellaneous connections	1	sum	$ 10,000.00	$ 10,000
PHASE 2				
3 Supply Stringers				
▪ Fabricate new steel stringers	14900	kgs	$ 6.00	$ 89,400
▪ Fabricate shims	5000	kgs	$ 6.00	$ 30,000
4 Deck Grating				
▪ Supply galvanized steel grating (125mm deep)	190	m2	$ 860.00	$ 163,400
▪ Miscellaneous connections	1	sum	$ 10,000.00	$ 10,000
A21 Shop Fabrication Subtotal	**401**	**m2**	**$ 1,415.46**	**$ 567,600**

A23 Site Installation

Element	Quantities		Unit Rates	Sub-totals
PHASE 1				
1 Secure Bridge				
▪ Traffic control	1	day	$ 1,500.00	$ 1,500
▪ Chain bridge down	1	day	$ 2,900.00	$ 2,900
2 Establish Traffic Lane				
▪ Traffic control	5	days	$ 1,500.00	$ 7,500
▪ Supply precast jersey barriers	75	no	$ 300.00	$ 22,500
▪ Temporary traffic lights	1	sum	$ 15,000.00	$ 15,000
▪ Miscellaneous signage	1	sum	$ 10,000.00	$ 10,000
▪ Install jersey barriers	75	no	$ 185.00	$ 13,875
▪ Traffic lane maintenance	1	sum	$ 20,000.00	$ 20,000
3 Deck Replacement				
▪ Remove decking, sills, stringers	190	m2	$ 550.00	$ 104,500
▪ Remove and reinstall span locking mechanism	1	sum	$ 50,000.00	$ 50,000
▪ Refurbish existing steel structure	1	sum	$ 25,000.00	$ 25,000
▪ Install stringers, shims, galvanized steel grating	190	m2	$ 1,100.00	$ 209,000
▪ Supply timbers curbs	1	mfbm	$ 3,000.00	$ 3,000
▪ Miscellaneous connections and hardware	1	sum	$ 1,000.00	$ 1,000
▪ Install timber curbs	1	sum	$ 5,000.00	$ 5,000
▪ New X-bracing	1	loc	$ 10,000.00	$ 10,000
PHASE 2				

Element	Quantities		Unit Rates	Sub-totals
4 Establish Traffic Lane				
▪ Relocate jersey barriers	75	no	$ 275.00	$ 20,625
▪ Traffic lane maintenance	1	sum	$ 25,000.00	$ 25,000
5 Deck Replacement				
▪ Remove decking, sills, stringers	190	m2	$ 650.00	$ 123,500
▪ Refurbish existing steel structure	1	sum	$ 30,000.00	$ 30,000
▪ Install stringers, shims, galvanized steel grating	190	m2	$ 850.00	$ 161,500
▪ Supply timbers curbs	1	mfbm	$ 3,000.00	$ 3,000
▪ Miscellaneous connections and hardware	1	sum	$ 1,000.00	$ 1,000
▪ Install timber curbs	1	sum	$ 5,000.00	$ 5,000
▪ New X-bracing	1	loc	$ 10,000.00	$ 10,000
6 Balance/Commission Bridge				
▪ Re-balance counterweight, commissioning	1	sum	$ 75,000.00	$ 75,000
A23 Site Installation Subtotal	401	m2	$ 2,382.54	$ 955,400
General Requirements and Fees				
Z11 General Requirements and Overheads				
▪ Contractor's Overheads			15%	$ 228,450
Z11 General Requirements and Overheads Subtotal	15	%		$ 228,450
Z12 Contractor's Profit				
▪ Contractor's Profit			10%	$ 175,145
Z12 Contractor's Profit Subtotal	10	%		$ 175,145
Allowances				
Z21 Design and Pricing Allowance				
▪ Design and Pricing Contingency			10%	$ 192,660
Z21 Design and Pricing Allowance Subtotal	5	%		$ 192,660
Z23 Construction Contingency				
▪ Construction Contingency			10%	$ 211,925
Z23 Construction Contingency Subtotal	15	%		$ 211,925

ELEMENTAL COST SUMMARY

Option 3 FRP Panel Deck

PROJECT:	DECK REPLACEMENT - OPTIONS ANALYSIS	DATE:	MARCH 2, 2020
LOCATION:	LASALLE BRIDGE, KINGSTON, ONTARIO	CLASS:	D - FEASIBILITY
CLIENT:	PUBLIC SERVICES & PROCUREMENT CANADA	FILE	13003
DESIGNER:	PARSONS INC	GDA: m2	401

GROSS BRIDGE DECK AREA 401 m2

ELEMENT	RATIO TO GDA	ELEMENTAL QUANTITY	ELEMENTAL UNIT RATE	ELEMENTAL AMOUNT	RATE PER GDA	TOTAL AMOUNT	%
A BRIDGE					$ 5,558	$ 2,228,800	62.49
A1 BRIDGE SUBSTRUCTURE					$ -	$ -	0.00
A11 Foundations	1.000	401 m2	$ -	$ -	$ -		0.00
A12 Bridge Abutments	1.000	401 m2	$ -	$ -	$ -		0.00
A13 Approaches	1.000	401 m2	$ -	$ -	$ -		0.00
A2 BRIDGE STRUCTURE					$ 5,558	$ 2,228,800	62.49
A21 Shop Fabrication	1.000	401 m2	$ 2,725.19	$ 1,092,800	$ 2,725		30.64
A22 Shop Assembly	1.000	401 m2	$ -	$ -	$ -		0.00
A23 Site Installation	1.000	401 m2	$ 2,832.92	$ 1,136,000	$ 2,833		31.85
A3 BRIDGE MECHANICAL					$ -	$ -	0.00
A31 New & Refurbished Components	1.000	401 no	$ -	$ -	$ -		0.00
A32 Mechanical Site Installation	1.000	401 no	$ -	$ -	$ -		0.00
A4 BRIDGE ELECTRICAL					$ -	$ -	0.00
A41 Supply New Components	1.000	401 m2	$ -	$ -	$ -		0.00
A42 Electrical Site Installation	1.000	401 sum	$ -	$ -	$ -		0.00
A5 BRIDGE TESTING & COMMISSIONING					$ -	$ -	0.00
A51 Testing & Commissioning - Shop Assembly	1.000	401 m2	$ -	$ -	$ -		0.00
A52 Testing & Commissioning - Site Assembly	1.000	401 sum	$ -	$ -	$ -		0.00
NET BRIDGE SUBTOTAL - LESS SITE AND ANCILLARY WORK					$ 5,558	$ 2,228,800	62.49
B SITE AND ANCILLARY WORK					$ -	$ -	0.00
B1 EARTHWORK					$ -	$ -	0.00
B11 Excavation and Backfill	1.000	401 m2	$ -	$ -	$ -		0.00
B12 Environmental	1.000	401 m2	$ -	$ -	$ -		0.00
B2 ROAD REALIGNMENTS					$ -	$ -	0.00
B21 Road Realignments	1.000	401 m	$ -	$ -	$ -		0.00
B3 SITEWORK FINISHES					$ -	$ -	0.00
B31 Soft Landscaping	1.000	401 m2	$ -	$ -	$ -		0.00
B32 Landscaping Fittings and Fixtures	1.000	401 m2	$ -	$ -	$ -		0.00
B4 ANCILLARY WORK					$ -	$ -	0.00
B41 Bridge Demolition	1.000	401 m2	$ -	$ -	$ -		0.00
B42 Site Reinstatement	1.000	401 m2	$ -	$ -	$ -		0.00
NET BRIDGE SUBTOTAL - INCLUDING SITE AND ANCILLARY WORK					$ 5,558	$ 2,228,800	62.49
Z GENERAL REQUIREMENTS AND ALLOWANCES					$ 3,336	$ 1,337,781	37.51
Z1 GENERAL REQUIREMENTS AND FEES					$ 1,473	$ 590,632	16.56
Z11 General Requirements and Overheads		15%		$ 334,320	$ 834		9.37
Z12 Contractors Profit		10%		$ 256,312	$ 639		7.19
Z2 ALLOWANCES					$ 1,863	$ 747,149	20.95
Z21 Design and Pricing Allowance		15%		$ 422,915	$ 1,055		11.86
Z22 Escalation Allowance		0%		$ -	$ -		0.00
Z23 Construction Allowance		10%		$ 324,235	$ 809		9.09
TOTAL CONSTRUCTION COST (HST EXTRA)			$8,894 per m2			$ 3,566,600	100.00

Element	Quantities			Unit Rates		Sub-totals
BRIDGE STRUCTURE						
A21 Shop Fabrication						
PHASE 1						
1 Supply Stringers						
▪ Fabricate new steel stringers	11900	kgs	$	6.00	$	71,400
2 Deck Grating						
▪ Supply FRP deck panels with integrated curbs	190	m2	$	2,400.00	$	456,000
▪ Miscellaneous connections	1	sum	$	10,000.00	$	10,000
PHASE 2						
3 Supply Stringers						
▪ Fabricate new steel stringers	14900	kgs	$	6.00	$	89,400
4 Deck FRP Panels						
▪ Supply FRP deck panels with integrated curbs	190	m2	$	2,400.00	$	456,000
▪ Miscellaneous connections	1	sum	$	10,000.00	$	10,000
A21 Shop Fabrication Subtotal	401	m2	$	2,725.19	$	1,092,800
A23 Site Installation						
PHASE 1						
1 Secure Bridge						
▪ Traffic control	1	day	$	1,500.00	$	1,500
▪ Chain bridge down	1	day	$	2,900.00	$	2,900
2 Establish Traffic Lane						
▪ Traffic control	5	days	$	1,500.00	$	7,500
▪ Supply precast jersey barriers	75	no	$	300.00	$	22,500
▪ Temporary traffic lights	1	sum	$	15,000.00	$	15,000
▪ Miscellaneous signage	1	sum	$	10,000.00	$	10,000
▪ Install jersey barriers	75	no	$	185.00	$	13,875
▪ Traffic lane maintenance	1	sum	$	10,000.00	$	10,000
3 Deck Replacement						
▪ Remove decking, sills, stringers	190	m2	$	550.00	$	104,500
▪ Remove and reinstall span locking mechanism	1	sum	$	50,000.00	$	50,000
▪ Refurbish existing steel structure	1	sum	$	25,000.00	$	25,000
▪ Install stringers	190	m2	$	420.00	$	79,800
▪ Install FRP deck panels	190	m2	$	400.00	$	76,000
▪ New wearing surface	190	m2	$	200.00	$	38,000
▪ Supply & install deck drains	3	no	$	2,500.00	$	7,500
▪ Adjust back wall to deck	2	no	$	7,500.00	$	15,000
▪ New X-bracing	1	loc	$	10,000.00	$	10,000
PHASE 2						
4 Establish Traffic Lane						

Element	Quantities		Unit Rates	Sub-totals
▪ Relocate jersey barriers	75	no	$ 275.00	$ 20,625
▪ Traffic lane maintenance	1	sum	$ 10,000.00	$ 10,000
5 Deck Replacement				
▪ Remove decking, sills, stringers	190	m2	$ 650.00	$ 123,500
▪ Refurbish existing steel structure	1	sum	$ 30,000.00	$ 30,000
▪ Install galvanized steel grating deck	190	m2	$ 850.00	$ 161,500
▪ Install stringers	190	m2	$ 420.00	$ 79,800
▪ Install FRP deck panels	190	m2	$ 400.00	$ 76,000
▪ New wearing surface	190	m2	$ 200.00	$ 38,000
▪ Supply & install deck drains	3	no	$ 2,500.00	$ 7,500
▪ Adjust back wall to deck	2	no	$ 7,500.00	$ 15,000
▪ New X-bracing	1	loc	$ 10,000.00	$ 10,000
6 Balance/Commission Bridge				
▪ Re-balance counterweight, commissioning	1	sum	$ 75,000.00	$ 75,000
A23 Site Installation Subtotal	401	m2	$ 2,832.92	$ 1,136,000
General Requirements and Fees				
Z11 General Requirements and Overheads				
▪ Contractor's Overheads			15%	$ 334,320
Z11 General Requirements and Overheads Subtotal	15	%		$ 334,320
Z12 Contractor's Profit				
▪ Contractor's Profit			10%	$ 256,312
Z12 Contractor's Profit Subtotal	10	%		$ 256,312
Allowances				
Z21 Design and Pricing Allowance				
▪ Design and Pricing Contingency			15%	$ 422,915
Z21 Design and Pricing Allowance Subtotal	5	%		$ 422,915
Z23 Construction Contingency				
▪ Construction Contingency			10%	$ 324,235
Z23 Construction Contingency Subtotal	15	%		$ 324,235

ELEMENTAL COST SUMMARY

PROJECT: DECK REPLACEMENT - OPTIONS ANALYSIS
LOCATION: LASALLE BRIDGE, KINGSTON, ONTARIO
CLIENT: PUBLIC SERVICES & PROCUREMENT CANADA
DESIGNER: PARSONS INC

Option 4 - Timber Sidewalks

DATE: MARCH 2, 2020
CLASS: D - FEASIBILITY
FILE 13003
GDA: m2 401

GROSS BRIDGE DECK AREA 401 m2

ELEMENT	RATIO TO GDA	ELEMENTAL QUANTITY		ELEMENTAL UNIT RATE	ELEMENTAL AMOUNT	RATE PER GDA	TOTAL AMOUNT	%
A BRIDGE						$ 377	$ 151,125	65.34
A1 BRIDGE SUBSTRUCTURE						$ -	$ -	0.00
A11 Foundations	1.000	401	m2	$ -	$ -	$ -		0.00
A12 Bridge Abutments	1.000	401	m2	$ -	$ -	$ -		0.00
A13 Approaches	1.000	401	m2	$ -	$ -	$ -		0.00
A2 BRIDGE STRUCTURE						$ 377	$ 151,125	65.34
A21 Shop Fabrication	1.000	401	m2	$ -	$ -	$ -		0.00
A22 Shop Assembly	1.000	401	m2	$ -	$ -	$ -		0.00
A23 Site Installation	1.000	401	m2	$ 376.87	$ 151,125	$ 377		65.34
A3 BRIDGE MECHANICAL						$ -	$ -	0.00
A31 New & Refurbished Components	1.000	401	no	$ -	$ -	$ -		0.00
A32 Mechanical Site Installation	1.000	401	no	$ -	$ -	$ -		0.00
A4 BRIDGE ELECTRICAL						$ -	$ -	0.00
A41 Supply New Components	1.000	401	m2	$ -	$ -	$ -		0.00
A42 Electrical Site Installation	1.000	401	sum	$ -	$ -	$ -		0.00
A5 BRIDGE TESTING & COMMISSIONING						$ -	$ -	0.00
A51 Testing & Commissioning - Shop Assembly	1.000	401	m2	$ -	$ -	$ -		0.00
A52 Testing & Commissioning - Site Assembly	1.000	401	sum	$ -	$ -	$ -		0.00
NET BRIDGE SUBTOTAL - LESS SITE AND ANCILLARY WORK						$ 377	$ 151,125	65.34
B SITE AND ANCILLARY WORK						$ -	$ -	0.00
B1 EARTHWORK						$ -	$ -	0.00
B11 Excavation and Backfill	1.000	401	m2	$ -	$ -	$ -		0.00
B12 Environmental	1.000	401	m2	$ -	$ -	$ -		0.00
B2 ROAD REALIGNMENTS						$ -	$ -	0.00
B21 Road Realignments	1.000	401	m	$ -	$ -	$ -		0.00
B3 SITEWORK FINISHES						$ -	$ -	0.00
B31 Soft Landscaping	1.000	401	m2	$ -	$ -	$ -		0.00
B32 Landscaping Fittings and Fixtures	1.000	401	m2	$ -	$ -	$ -		0.00
B4 ANCILLARY WORK						$ -	$ -	0.00
B41 Bridge Demolition	1.000	401	m2	$ -	$ -	$ -		0.00
B42 Site Reinstatement	1.000	401	m2	$ -	$ -	$ -		0.00
NET BRIDGE SUBTOTAL - INCLUDING SITE AND ANCILLARY WORK						$ 377	$ 151,125	65.34
Z GENERAL REQUIREMENTS AND ALLOWANCES						$ 200	$ 80,194	34.67
Z1 GENERAL REQUIREMENTS AND FEES						$ 100	$ 40,048	17.31
Z11 General Requirements and Overheads		15%			$ 22,669	$ 57		9.80
Z12 Contractors Profit		10%			$ 17,379	$ 43		7.51
Z2 ALLOWANCES						$ 100	$ 40,146	17.36
Z21 Design and Pricing Allowance		10%			$ 19,117	$ 48		8.27
Z22 Escalation Allowance		0%			$ -	$ -		0.00
Z23 Construction Allowance		10%			$ 21,029	$ 52		9.09
TOTAL CONSTRUCTION COST (HST EXTRA)				$577 per m2			$ 231,300	100.00

Element	Quantities		Unit Rates	Sub-totals
BRIDGE STRUCTURE				
A23 Site Installation				
1 Establish Traffic Lane				
- Relocate jersey barriers	75	no	$ 275.00	$ 20,625
- Traffic lane maintenance	1	sum	$ 5,000.00	$ 5,000
- Remove traffic control systems	1	sum	$ 20,000.00	$ 20,000
2 Sidewalk Replacement				
- Miscellaneous scaffolding, access	1	sum	$ 15,000.00	$ 15,000
- Sidewalk removals	49	m	$ 200.00	$ 9,800
- Supply steel angles for sidewalk frames	750	kg	$ 10.00	$ 7,500
- Supply timber stringers	2	mfbm	$ 10,000.00	$ 20,000
- Supply timbers decking	4	mfbm	$ 3,000.00	$ 12,000
- Miscellaneous connections and hardware	1	sum	$ 2,000.00	$ 2,000
- Install timber sidewalk stringers and decking	49	m	$ 300.00	$ 14,700
3 Sidewalk Guardrail - Modify				
- Refurbish existing guardrailing	49	m	$ 500.00	$ 24,500
A23 Site Installation Subtotal	401	m2	$ 376.87	$ 151,125
General Requirements and Fees				
Z11 General Requirements and Overheads				
- Contractor's Overheads			15%	$ 22,669
Z11 General Requirements and Overheads Subtotal	15	%		$ 22,669
Z12 Contractor's Profit				
- Contractor's Profit			10%	$ 17,379
Z12 Contractor's Profit Subtotal	10	%		$ 17,379
Allowances				
Z21 Design and Pricing Allowance				
- Design and Pricing Contingency			10%	$ 19,117
Z21 Design and Pricing Allowance Subtotal	5	%		$ 19,117
Z23 Construction Contingency				
- Construction Contingency			10%	$ 21,029
Z23 Construction Contingency Subtotal	15	%		$ 21,029

ELEMENTAL COST SUMMARY

Option 5 FRP Panel Sidewalk

PROJECT: DECK REPLACEMENT - OPTIONS ANALYSIS
LOCATION: LASALLE BRIDGE, KINGSTON, ONTARIO
CLIENT: PUBLIC SERVICES & PROCUREMENT CANADA
DESIGNER: PARSONS INC

DATE: MARCH 2, 2020
CLASS: D - FEASIBILITY
FILE 13003
GDA: m2 401

GROSS BRIDGE DECK AREA 401 m2

ELEMENT	RATIO TO GDA	ELEMENTAL QUANTITY		ELEMENTAL UNIT RATE	ELEMENTAL AMOUNT	RATE PER GDA	TOTAL AMOUNT	%
A BRIDGE						$ 1,043	$ 418,375	62.49
A1 BRIDGE SUBSTRUCTURE						$ -	$ -	0.00
A11 Foundations	1.000	401	m2	$ -	$ -	$ -		0.00
A12 Bridge Abutments	1.000	401	m2	$ -	$ -	$ -		0.00
A13 Approaches	1.000	401	m2	$ -	$ -	$ -		0.00
A2 BRIDGE STRUCTURE						$ 1,043	$ 418,375	62.49
A21 Shop Fabrication	1.000	401	m2	$ -	$ -	$ -		0.00
A22 Shop Assembly	1.000	401	m2	$ -	$ -	$ -		0.00
A23 Site Installation	1.000	401	m2	$ 1,043.33	$ 418,375	$ 1,043		62.49
A3 BRIDGE MECHANICAL						$ -	$ -	0.00
A31 New & Refurbished Components	1.000	401	no	$ -	$ -	$ -		0.00
A32 Mechanical Site Installation	1.000	401	no	$ -	$ -	$ -		0.00
A4 BRIDGE ELECTRICAL						$ -	$ -	0.00
A41 Supply New Components	1.000	401	m2	$ -	$ -	$ -		0.00
A42 Electrical Site Installation	1.000	401	sum	$ -	$ -	$ -		0.00
A5 BRIDGE TESTING & COMMISSIONING						$ -	$ -	0.00
A51 Testing & Commissioning - Shop Assembly	1.000	401	m2	$ -	$ -	$ -		0.00
A52 Testing & Commissioning - Site Assembly	1.000	401	sum	$ -	$ -	$ -		0.00
NET BRIDGE SUBTOTAL - LESS SITE AND ANCILLARY WORK						$ 1,043	$ 418,375	62.49
B SITE AND ANCILLARY WORK						$ -	$ -	0.00
B1 EARTHWORK						$ -	$ -	0.00
B11 Excavation and Backfill	1.000	401	m2	$ -	$ -	$ -		0.00
B12 Environmental	1.000	401	m2	$ -	$ -	$ -		0.00
B2 ROAD REALIGNMENTS						$ -	$ -	0.00
B21 Road Realignments	1.000	401	m	$ -	$ -	$ -		0.00
B3 SITEWORK FINISHES						$ -	$ -	0.00
B31 Soft Landscaping	1.000	401	m2	$ -	$ -	$ -		0.00
B32 Landscaping Fittings and Fixtures	1.000	401	m2	$ -	$ -	$ -		0.00
B4 ANCILLARY WORK						$ -	$ -	0.00
B41 Bridge Demolition	1.000	401	m2	$ -	$ -	$ -		0.00
B42 Site Reinstatement	1.000	401	m2	$ -	$ -	$ -		0.00
NET BRIDGE SUBTOTAL - INCLUDING SITE AND ANCILLARY WORK						$ 1,043	$ 418,375	62.49
Z GENERAL REQUIREMENTS AND ALLOWANCES						$ 626	$ 251,119	37.51
Z1 GENERAL REQUIREMENTS AND FEES						$ 276	$ 110,869	16.56
Z11 General Requirements and Overheads		15%			$ 62,756	$ 156		9.37
Z12 Contractors Profit		10%			$ 48,113	$ 120		7.19
Z2 ALLOWANCES						$ 350	$ 140,250	20.95
Z21 Design and Pricing Allowance		15%			$ 79,387	$ 198		11.86
Z22 Escalation Allowance		0%			$ -	$ -		0.00
Z23 Construction Allowance		10%			$ 60,863	$ 152		9.09
TOTAL CONSTRUCTION COST (HST EXTRA)				$1,670 per m2			$ 669,500	100.00

Element	Quantities		Unit Rates	Sub-totals
BRIDGE STRUCTURE				
A21 Shop Fabrication				
A21 Shop Fabrication Subtotal	**401**	**m2**	**$ -**	**$ -**
A23 Site Installation				
1 Establish Traffic Lane				
- Relocate jersey barriers	75	no	$ 275.00	$ 20,625
- Traffic lane maintenance	1	sum	$ 5,000.00	$ 5,000
- Remove traffic control systems	1	sum	$ 20,000.00	$ 20,000
2 Sidewalk Replacement				
- Sidewalk removals	49	m	$ 250.00	$ 12,250
- Supply & install FRP panel sidewalk	112	m2	$ 3,000.00	$ 336,000
3 Sidewalk Guardrail - Modify				
- Refurbish existing guardrailing	49	m	$ 500.00	$ 24,500
A23 Site Installation Subtotal	**401**	**m2**	**$ 1,043.33**	**$ 418,375**
General Requirements and Fees				
Z11 General Requirements and Overheads				
- Contractor's Overheads			15%	$ 62,756
Z11 General Requirements and Overheads Subtotal	**15**	**%**		**$ 62,756**
Z12 Contractor's Profit				
- Contractor's Profit			10%	$ 48,113
Z12 Contractor's Profit Subtotal	**10**	**%**		**$ 48,113**
Allowances				
Z21 Design and Pricing Allowance				
- Design and Pricing Contingency			15%	$ 79,387
Z21 Design and Pricing Allowance Subtotal	**5**	**%**		**$ 79,387**
Z23 Construction Contingency				
- Construction Contingency			10%	$ 60,863
Z23 Construction Contingency Subtotal	**15**	**%**		**$ 60,863**

Appendix B:
Selected Correspondence

From: Michael Broglie <mbroglie@sbengineering.net>
Sent: Monday, February 10, 2020 3:57 PM
To: Charron, Jean-Bernard
Cc: Harvey, Peter; John Williams
Subject: [EXTERNAL] RE: La Salle Bascule Bridge Deck Replacement Study -Mechanical and Electrical considerations

My responses are below in red.

Regards,

Michael P. Broglie, PE
Associate III

Stafford Bandlow Engineering, A Division of WJE
800 Hyde Park, Doylestown, PA 18902

Direct: 267.576.7006
Main: 215.340.5830
Mobile: 267.614.3443

www.sbengineering.net [sbengineering.net]
Visit our parent company: www.wje.com [wje.com]

From: Charron, Jean-Bernard <Jean-bernard.Charron@parsons.com>
Sent: Wednesday, February 5, 2020 12:20 PM
To: Michael Broglie <mbroglie@sbengineering.net>
Cc: Harvey, Peter <Peter.Harvey@parsons.com>
Subject: FW: La Salle Bascule Bridge Deck Replacement Study -Mechanical and Electrical considerations

Sensitive

Good Afternoon Mr. Broglie,

We are currently working on the Bascule Bridge deck replacement feasibility study and we would need your input on the balancing, mechanical and electrical aspects. Based on John Williams' July 24, 2017, Memorandum to Maurice Mansfield, we are aware that the existing mechanical systems are overloaded when analyzed with CHBDC S6-14. A maximum wind speed of 69 km/h has to be respected in order not to overload the systems. The client has asked us to consider options to replace the deck and to perform this exercise thoroughly we need to evaluate options that would increase weight such as cast in place concrete deck and options that would increase the wind surface such as closed FRP deck like Composite Advantage's deck system. We will only keep options that reduce the deck weight or augment it by no more than 5%. As for wind loading, we understand that going from an open deck system such as the grating to a closed deck would increase the wind load by 18% (as per CHBDC section 13.6.4.6). If my interpretation of the pressure/wind speed relationship is correct, in order to maintain the wind loads at the level they are actually with a new closed deck, the maximum wind speed at which the bridge can be operated would be ((240 Pa * 0.85)/0.05)^0.5 = 63.9 km/h, instead of the current limit of (240/0.05)^0.5 = 69.3 km/h. This doesn't seem to be a large reduction is the permissible wind speed. However we were reluctant to do anything that would change the current conditions and potentially create problems to a structure that has so far performed well, despite being substandard according to the current codes. Our questions are:

-What is your opinion on the impact of changing the open steel grating for a lighter closed deck on the mechanical and electrical components of the bridge? Using a closed deck has many benefits and the client is well aware of it, so we need a good substantiation to discard lightweight closed deck options if we do. Do you think the 18% surface increases could be managed by reducing the maximum permissible wind speed? This would allow to maintain the theoretical loading status quo, but the current code deviation explained in Mr. Williams' 2017 Memo would still be required.

From a mechanical standpoint, there are some clear problems with increasing the weight of the bridge deck. The goal to only assess options with a reduced deck weight or limit increase in weight doesn't eliminate issues because the machinery experiences both static and dynamic loads. We have very limited information about the heel trunnion bearing bushing material due to limit information on the original drawings and the arrangement requires full disassembly of the heel trunnions for any inspection or testing. The original design drawings call the material out as phosphor bronze, but during the era that the bridge was built there were many common and proprietary varieties of phosphor bronze without a common standard for bronzes used on movable like there are today. As part of the trunnion and previous work on the bridge we evaluated the heel trunnion bearing stresses. These stresses are higher than anything we would design for today and higher than the allowable for any of the bronze alloys in the CHBDC for this application. All outward indications from the bearing is that it is very good condition, specifically the very low friction as compared to other Strauss bridge. This supports our recommendations to not modify the bearings in an effort to bring them up to code. Given the high stresses that we do know and the many unknowns about the bushing, it is our strong opinion that adding weight and/or dynamic stresses from wind loads bearing is not recommended.

We also need to confirm that the proposed FRP is actually lighter than the existing open grid deck. The literature on Composite Advantage's website lists a unit weight of 16 to 20 psf. I do not have any information on the grid deck currently installed on the bridge, but I've encountered steel open grid decks with a unit weight below 20 psf. As mentioned above, any additional weight to the span is not recommended and if there is negligible weight difference that benefit is negated by the increased loading from wind.

Additionally, the analysis behind the wind restriction memo utilized the capacity of the existing span drive machinery along with the existing structure. The resulting recommendation was to replace the motors with the same capacity as the existing ones and then to apply the wind speed limitation during operation. This ensured no additional loads to the machinery than what it has previously operated reliably in. Although your math matches closely with mine on how the allowable wind pressure/wind would reduce with a closed desk versus the existing open deck, I don't believe the recommendation is this straightforward. Changing the structure and it's resulting behavior would warrant additional analysis as opposed to simply imposing the operational wind restriction to the existing structure as with the memo. This again reverts back to our desire to not apply any additional loads to the heel trunnions mentioned above. Also, further reducing the wind speed restriction may cause an issue for Transport Canada or other authorities.

Finally, you mention that the client is well aware of the many benefits of a closed grid deck. I do not have much experience with FRPs, but John Williams has expressed that he's aware of issues related to them including many problems for maintenance personnel. This is something that should be discussed further if it is something we would recommend.

-If fully closed deck options aren't feasible because of limitations of the mechanical and electrical system, we are considering noise mitigation measures to improve the current situation. Those measures could take the form of 4 – 2' wide strips of FRP deck directly in the wheel path. This would increase the wind surface by approximately 6% if my calculations are correct and would require a maximum operating wind speed of ((240/1.06)/0.05)^0.5 = 67.3 km/h to maintain the wind loading as it is at this moment. What are your thoughts on this approach?

I have seen many open grid deck bridges that have a partial concrete fill for the wheel paths. FRP could be a possible option, but it still presents some of the issues mentioned above.

-What would be the cost bracket for the replacement of all substandard mechanical and electrical components to be code compliant with a closed deck of lighter or equal weight than the actual deck? We only require an order of magnitude to compare options that would require such a comprehensive rehabilitation.

It is not possible to make all of the mechanical and electrical systems fully code compliant without complete replacement. My understanding from the trunnion study is that it is also not feasible to make the structure fully code compliant. A replacement bridge is the better option versus attempting to bring the bridge to compliance with the code. To simply replace the span drive machinery to become code compliant, I would estimate $10 million.

Regards,

Jean-Bernard P. Charron, ing., P.Eng., SPRAT 3
Senior Bridge Engineer
Gordie Howe International Bridge Project
Owner's Engineer - Main Bridge – CM Canadian Side

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STAFFORD BANDLOW ENGINEERING, INC.

July 24, 2017

Via E-Mail
Maurice.Mansfield@parsons.com

Mr. Maurice Mansfield
Parsons
1223 Michael St., Suite 100
Ottawa, ON K1J 7T2

Maurice,

As part of the LaSalle Causeway Bridge motor and drive rehabilitation design, the existing machinery and prime mover were evaluated with regard to the 2014 edition of the CAN/CSA S6 Canadian Highway Bridge and Design Code (CHBDC), Section 13 requirements. It was determined that the current prime mover, which consists of two 50 HP at 585 RPM motors operating together, were overloaded by a factor of 1.50.

The existing gears, shafts, keys, and bearings were evaluated with regard to the current prime mover using the information provided by the original and 1966 rehab drawings. There was sufficient legible to evaluate the capacity of the gears, shafts and bearings. It was determined that these existing machinery components are appropriately sized for the existing prime mover. However, there is little reserve capacity in the existing gears and therefore increasing the capacity of the prime mover as part of the motor and drive replacement project is not possible unless the scope of the replacement work is increased to include virtually all of the existing gearing.

It should be noted that there is limited legible information on the key sizes and lengths on the available drawings. As such any evaluation of the existing keys is considered preliminary until such time that the existing key dimensions can be verified at the bridge.

Although the existing prime mover is overloaded per Code requirements, the bridge is routinely operated on a single motor and there are no reported issues of the existing motors (individually or operating as a pair) failing to operate the bascule leaf in the recent past or over its' history of operating since circa 1915. As such, it would appear to be reasonable to maintain the current capacity of the motors with the replacement motors which would provide for reliable operation without exceeding the capacity of the existing machinery.

The loads on the prime mover during operation of a bascule leaf are caused by imbalance, friction, inertia, wind and ice as follows per Article 13.7.14.7.2 of the CHBDC:

(a) Maximum starting torque (Ts) shall be determined for span operation against static frictional resistance, unbalanced conditions (if any), a wind load of 0.48 kPa (10 psf) on any vertical projection, and an ice loading of 0.12 kPa (2.5 psf) on the area specified in Clause 13.6.4.5 and shall include inertial resistance due to acceleration.

(b) Maximum constant velocity torque (Tcv) shall be determined for span operation against dynamic frictional resistances, unbalanced conditions (if any), and a wind load of 0.12 kPa (2.5 psf) acting normal to the floor on the area specified in Clause 13.6.4.5.

Maximum starting torque is the limiting case for sizing the prime mover. Imbalance, friction, inertia are not practical to modify. As such, limitations on wind pressure (and therefore maximum wind speeds) must be modified if the prime mover does not have adequate capacity to fully comply with CHBDC requirements. The existing (and proposed new) prime mover has sufficient capacity to operate the span with a wind pressure of 0.24 kPa (5 psf).

Wind loads for movable bridge operation are given in the Code as a wind pressure. The commentary on Annex CA3.1 – Climate and environmental date in CAN/CSA S6-14 provides a formula describing the relationship between the reference pressure, q (in Pa), and the corresponding mean hourly wind speed, v (in km/h):

$$q = 0.05\, v^2$$

Using this formula, the wind speed corresponding to the Code required design wind pressure (480 Pa) is 98 km/hr and the wind speed corresponding to the proposed maximum permissible wind pressure (240 Pa) is 69 km/hr.

In order to implement the wind speed restrictions for the bascule leaf operation it would be necessary to revise operating procedures to check wind speeds. This may be done using dedicated wind speed monitoring equipment installed at the bridge (which does not presently exist), or by checking wind speeds at a nearby weather station via the internet.

Please advise if it is acceptable to deviate from CAN/CSA S6-14 Canadian Highway Bridge and Design Code requirements and design the new motors and drives with the same capacity as the existing prime movers at the bridge which will require implementation of operating restrictions to periods when the wind speeds are less than 69 km/hr and adopting new operating procedures for verifying acceptable wind speeds.

If you have any questions or would like to discuss any of the above in further detail, please do not hesitate to contact me at (215) 340-5830.

Sincerely,

John Williams, P.Eng.

LaSalle Causeway Bascule Bridge

Steel Deck Grating Replacement Study – Phase 1 Feasibility Assessment (Rev.1)

PSPC Project Numbers: R.09736.004 and R.089507.003

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