JACQUES CARTIER BRIDGE
RE-DECKING PROJECT

The Jacques Cartier and Champlain Bridges Inc., Longueuil, QC

1. INTRODUCTION

1.1 Construction

Design started in 1924 by the joint engineering firms of Montsarrat and Pratley of Montreal, and J.B. Strauss of Chicago. Construction took place from 1925 to 1930. Fabrication and erection of the structural steel portions of the bridge, representing more than 30,000 tonnes, was carried out by Dominion Bridge Limited.

The trusses forming the approach spans are conventional Warren type, spaced at 12 m centres and vary in depth with the span. The floor system is carried above the trusses by floor beams that rest on and cantilever over the top chords. The floor beams are at 7.6 m centres.

The main span of the bridge (Fig. 1) is a symmetrical cantilever having an overall length of 590 m. The centre span is 334 m centre to centre of main piers and provides a clear navigation channel of 305 m. The navigational clearance in the channel is 47 m on a central length of 152 m. The trusses of the anchor and cantilever arms are of the K-design so successfully introduced in the Quebec Bridge (current world record span for a cantilever type bridge). They are 49 m in depth at the main piers, reducing to 15 m at the end of the anchor arm. The top chord curvatures were carried through into the suspended span for the sake of appearance. The suspended span has a length of 115 m.

The original construction included three curves in the roadway alignment, one curve is located at St. Helen’s Island Pavilion, a second curve is located near the north end of the main span and a third curve is situated along the North Approach spans above Montreal’s well-known St. Catherine Street.

The roof of the St. Helen’s Island Pavilion also acts as the bridge deck in this location. The steelwork of the pavilion is of simple design, the floor of the bridge being carried on the roof of the pavilion by means of heavy girder construction.

1.2 Traffic

The bridge had tolls since its opening in 1930 until 1962. In the early 1960’s, traffic was in the order of 17 million transits per year, but has since grown to about 43 million transits per year. Considering the bridge carries five traffic lanes, the traffic density on a per lane basis makes this bridge one of the busiest in North America.

High traffic volumes on the bridge is one of the main factors which drove the Owner, The Jacques Cartier and Champlain Bridges Limited, a Crown corporation and subsidiary of The Federal Bridge Corporation Limited, to retain a precast deck replacement system for this project.

2. DECK INVESTIGATIONS AND ASSESSMENT

The Owner had concerns about the condition of the existing deck because of its age (many sections are 72 years old) and because of deterioration resulting from the combined effects of de-icing salts used intensively since the 1960’s. These factors and the ever increasing number and weight of heavy trucks using the bridge since its inauguration in 1930, prompted the Owner to undertake a thorough investigation and assessment of the deck in order to address its concerns and to identify the most appropriate rehabilitation strategy.

In 1992 and 1994, two extensive bridge deck assessments were conducted which combined several state-of-the-art non destructive testing methods. These methods included ground penetrating radar, infrared thermography, half cell potential measurements, corrosion rate measurements using linear polarization, chloride content profiling using samples taken at four depths in the slab, as well as other conventional assessment methods such as chain drag, coring and ground truth testing, the latter which consisted in the removal of the asphalt layer in a few selected areas in order to expose the top deck surface.

The assessments carried out on this deck are, to the authors' knowledge, the most extensive bridge deck assessments ever to be carried out in Canada.

The combination of chloride content measurements, half cell potential readings and delamination surveys permitted an estimation of the time remaining before each section of the deck would reach a critical level of deterioration which was quantified by the use of a condition index. These studies clearly demonstrated that a large percentage of the deck surface would reach critical levels of deterioration by the year 2000 and consequently, that a complete deck replacement should be considered as the most appropriate rehabilitation strategy.

3. PROJECT HIGHLIGHTS, STRUCTURE AND DELIVERY METHOD

The Jacques Cartier re-decking project encompassed several noteworthy features, both in terms of procurement, contract administration, and design.

The project delivery method was structured as a design-build using a two-stage tendering process. The first stage consisted of a public tender for prequalification in which three consortiums were eventually qualified to submit technical and financial proposals for the project in separate envelopes.

The tender documents included a base case design supplied by the Owner as well as detailed specifications covering all facets of the project with particular emphasis placed on the need to maintain traffic and hence ensure full service to users during rush hour periods. A selection committee was formed to review submissions in both stages and eventually recommend a contract award to the consortium whose proposal offered the overall best value.

The contract incorporated a performance bonus (1M $) as well as penalties (1.65M $) attached to specific milestones in order to create incentives to complete the project on time. Important penalties were also built into the project to ensure that traffic lanes were opened with no delays on a daily basis.

The services of an independent engineer were integrated into the project structure and served to review the Contractor's design proposals.

Traffic analysis indicated that the bridge could be completely closed at night since other adjacent south shore crossings had reserve traffic capacity to handle the 10 % of total traffic volume normally crossing during the evening hours. It was, therefore, possible to allow closure of the bridge between 8:30 p.m. to 5:30 a.m. during each weekday while re-decking operations were carried out. Night traffic of motor vehicles was diverted to adjacent bridges that had sufficient reserve capacity. Night-time closure of the bridge was inspired from the fact that the bridge was closed some 10 times per year in the past for special events such as the International Fireworks Competition.

The project to re-deck the bridge was organized so that half of the bridge's length would be closed to traffic at night during the first year of construction and the remaining half closed at night for the second year of construction. This was in order to allow maximum efficiency for the Contractor, yet still accommodate the tourism needs from the presence of the La Ronde amusement park operating on St. Helen's Island situated approximately midway along the length of the bridge.

Challenges in the project also arose from the fact that works had to be carried out over major roadways, shipping channels and ports, urban zones (particularly along the North approach), as well as major public utilities including a 500 mm diameter natural gas main.

In order to achieve the Owner's overall durability objectives, the project also incorporated the following design requirements :

- Design life in excess of 50 years.

- High performance concrete with a compressive strength of 60 MPa, a minimum water/cement ratio of 0.32 and a chloride permeability (diffusion) to be less than 500 Coulombs on average.
- A rubberized asphalt waterproofing membrane.
- Post-tensioning in both directions with the requirement that no tension exists in the top fibre of the deck at joints between panels.
- Galvanized rebars in those areas directly exposed to de-icing salts.
- An improved drainage system, including increased cross-falls and new watertight expansion joints.

The project also called for the improvement of the geometry of the Craig curve section of the bridge (Fig. 1) where the existing curve radius was increased from 76 m to 180 m and where a new 2% super-elevation was provided to greatly improve upon the former transverse profile which was flat.

Finally, a new 2.7 km long bikeway cantilevered on the upstream side of the bridge was integrated into the prefabricated construction and on the downstream side, a new pedestrian sidewalk of equal length was also incorporated into the new deck units.

4. DESIGN

A full range of deck replacement options were initially identified and assessed against project requirements. A precast concrete replacement deck system was selected to meet both durability objectives and the need to maintain rush hour traffic across the five lanes of the bridge. Lightweight deck replacement systems were not favoured because the superstructure provides adequate capacity for a heavier concrete deck system. The following additional project objectives were identified:

a) Reduce risks to both the Owner and the Contractor
b) Reduce critical path construction work
c) Reduce temporary works/measures
d) Improve roadway geometry

A base case conceptual design was developed that addressed these objectives and broadly reflected the Owner's preferred deck replacement system. The concept consisted of precast panels that were composed of high-performance concrete, post-tensioned in both directions to provide high durability.

For the approach spans, the size of the precast panels was limited longitudinally by the 7.6 m floorbeam spacing and transversely, a four-panel arrangement was used to optimize the number of construction operations. The sidewalk and new bikeway were integrated with the roadway portion of the deck to better protect the supporting structural steelwork from roadway discharge. The deck cross-fall was increased with respect to the former to improve drainage. A cross-section of the base case concept for the South Approach spans of the bridge is shown in Figure 3. The concept for the North Approach spans is similar. The overall structural system for the Approach spans is also shown in Figure 4.

The Main span stringers are oriented transversely unlike the South Approach spans where the stringers are oriented in the longitudinal direction. Accordingly, the precast panel arrangement for the Main span was predicated by the need to straddle the transverse floorbeams and to keep the number of panel supports atop of the longitudinal beams to a reasonable number to avoid complex leveling operations. In the longitudinal direction, the Main span precast panels were approximately 2.2 m wide while transversely, a two-panel arrangement was used. The sidewalk and bikeway are separate from the roadway portion of the bridge deck owing to the planes of truss adjacent to the roadway. The new Main span sidewalk and bikeway consist of precast slabs with integral ribs. A cross-section of the base concept for the Main span of the bridge is shown in Figure 5. The concept for the Seaway span is similar.

5. FABRICATION AND CONSTRUCTION

Deck replacement work involved six principal types of construction activities which included: i) steel works incorporating floor beam repair, strengthening and installation of new bearing assemblies to support the panels; ii) precasting of HPC (high performance concrete) deck panels; iii) removal of existing deck sections; iv) installation of new panels; v) joint mortar placement and post-tensioning works and, vi) installation of expansion joint armours, cast-in place expansion joint dams, and waterproofing and paving work. Several photographs documenting the construction work can be consulted at the Owner's web site (www.jccbi.ca).

Because of the size of the project which required the installation of 1,680 precast deck panels during two construction seasons, the Contractor chose to construct a temporary precasting plant near the south approach of the bridge.

Built specifically for the project and certified to the requirements of CSA A23.4, the precasting plant occupied an area of about 175 m x 150 m and was constructed in a three-month period at a cost of approximately $ 6.5M Canadian. The plant encompassed five main areas for prefabrication, including a concrete batch plant, an area for preassembly of the reinforcing steel cages, an area dedicated to casting of the panels and prestressing operations, a temperature and humidity controlled maturity chamber and an exterior area for stockpiling of panels which was equipped with a 40-tonne overhead crane.

In the prefabrication process, reinforcing cages including prestressing strands (for the Approach-span panels) were preassembled (Fig. 6), then deposited into steel molds as complete units. Strands were tensioned against the steel molds which were specifically designed for this purpose.

HPC concrete was placed in the molds using concrete buckets and the concrete was consolidated into place using both external vibration of the molds and internal vibration applied locally in congested areas. Concrete surface was finished using a vibrating truss screed and a broom finish was also applied to improve tire traction while the bridge was operated, prior to placement of the asphalt wearing surface. Accelerated curing was used which permitted releasing of the prestressing strands and stripping of forms 13 to 16 hours after casting once the concrete had attained a compressive strength of 25 MPa.

Panels were transported over a distance of 1 km from the plant to the bridge site, using tractor-trailers which had trailer beds specially modified to support and transport the panels without damage.

On the bridge, the existing deck was removed by saw cutting the deck into sections which were similar in dimensions to the new panels to be installed. Existing deck sections, which included the slab, steel stringers, barriers and railings were removed using two 55-tonne self-propelled telescopic cranes placed at opposite ends of a panel.

During the same lifting sequence and using the same cranes, the new panels (weighting typically between 20 and 38 tonnes) were lifted from the transport truck and lowered (Fig. 7) onto the new bearing assemblies which were installed by other crews working in advance during the day.

At peak productivity, the Contractor was able to replace 6 concrete deck panels per crew per night and employed two crews, allowing for replacement of 500 m² per night. Joints between panels were filled using a very rapid setting.

The last major step in the re-decking process involved the installation of new expansion joint armours and casting of expansion joint dams, installation of a rubberized asphalt waterproofing membrane and the laying of a polymer modified asphalt wearing surface.

Structural systems for the Main span, Seaway span and South abutment spans are different. Installation of deck panels for the Seaway span and South abutment span are illustrated in Figures 8 and 9 respectively.

In order to erect precast panels for the outboard bikeway and sidewalk sections located along the main span, the Contractor designed and installed an efficient rail system (Fig. 10). The rail system enabled 79 sidewalk and bikeway panels, representing some 1,900 m² of deck to be installed in winter months between the period of December 23, 2001 and April 1, 2002.

6. MITIGATION MEASURES AND COLLABORATION WITH PARTNERS

The challenge, and yet also the success of an infrastructure rehabilitation project of this size and nature, resides in establishing the user as the number one priority. To this end, the Owner committed itself to completing the project within a two-year timeframe with no disruption to rush hour traffic. Faced with the fact that this commitment would entail complete night-time bridge closures and the occasional weekend closures, the Owner had no other alternative but to ensure that all messages concerning any bridge or lane closure were accurately communicated.

From the onset of the project, the Owner met individually all partners who would be impacted by the deck reconstruction work. This group of partners included no less than 18 separate organisations, each having their own concerns. This group included representatives from the cities of Montreal and Longueuil, public security forces (ambulance, fire departments, provincial and municipal police forces), public transit officials, regional transportation bodies, trucking associations, cyclist group, community groups and major event organising committees (Grand Prix of Montreal, La Ronde Amusement Park, International Fireworks Competition).

Several mitigation measures were implemented during the first construction season which included the installation of strategically placed variable message signs, both along immediate approaches to the bridge, as well as along major roadways in the region. These messages provided real time information about occurring and upcoming events on the bridge. Moreover, close ties were made with traffic reporters and the media in general by providing them with timely information about the project and construction progress, including tours of the work site. In order to mitigate impacts to cyclists, a dedicated phone line (INFO-VELO) was created. Furthermore, a shuttle service was implemented to enable cyclists to cross the work site (during full closures) with their bicycles via a vehicle that navigated through the work site.

The Corporation created and maintained a fully bilingual web site dedicated to the project (www.pjcci.ca). This site was updated regularly and provided web users with information about the project. Internet users were able to receive real time information about traffic conditions by accessing video images originating from lane surveillance cameras mounted on the bridge.

To help explain the project to both media and the general public, 3D computer generated animations were created, clearly depicting the installation sequence on the bridge.

Lastly, by carefully planning all facets of the project and by putting into place appropriate mitigation measures including those to address noise and dust issues, the Owner was able to minimise inconveniences to both users and local residents, including those residents residing within metres of this major urban bridge.

7. CONCLUSIONS

Faced with the difficult challenge of having to reconstruct the ageing deck of this major bridge without disrupting normal rush hour service to users and without impacting negatively upon the Montreal economy, the Owner had little choice but to develop a unique project structure and to seek a durable and efficient deck replacement system.

This challenge was met by selecting a deck system composed of precast, high performance concrete panels post-tensioned together and built under a design-build method of delivery. As a result of careful planning, collaboration with partners, the implementation of appropriate mitigation measures, and by constantly keeping the user in mind, this unprecedented re-decking project was successfully completed on time.

8. FIGURES

Fig. 1 – Main span and North approach

Fig. 2 – Seaway span and South approach

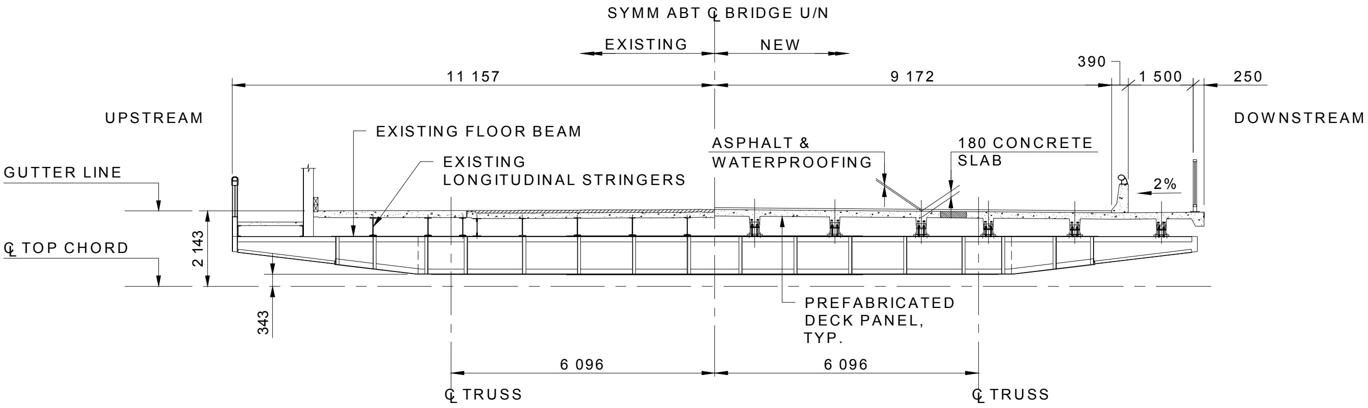

Fig. 3 – Typical Approach span cross-section (base case concept)

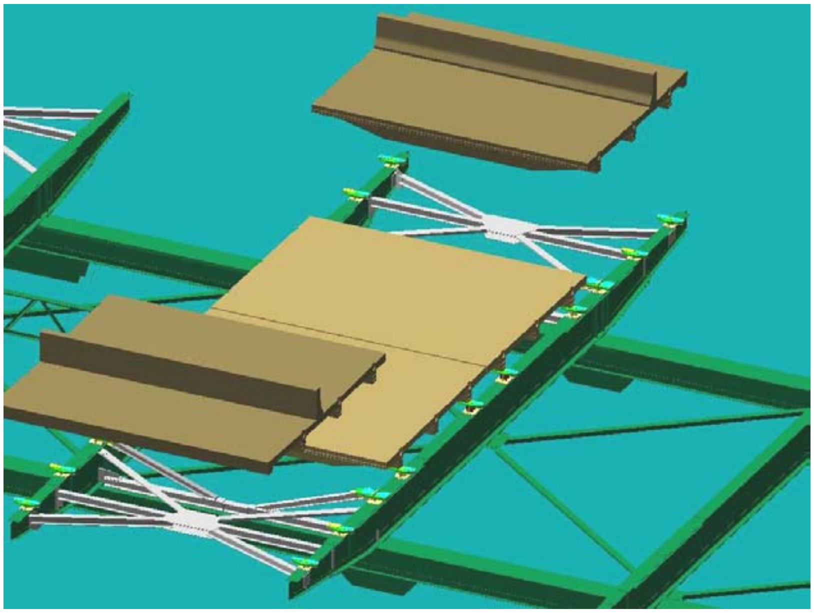

Fig. 4 – Approach span – Structural system for deck

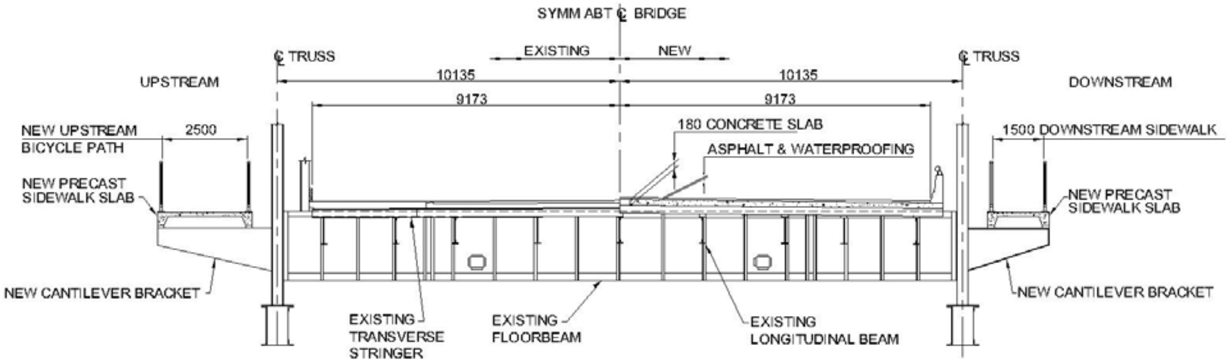

Fig. 5 – Main span cross-section (base case concept)

Fig. 6 – Fabrication of Approach span deck panel

Fig. 7 – Installation of Approach span deck panel

Fig. 8 – Installation of Seaway span deck panel

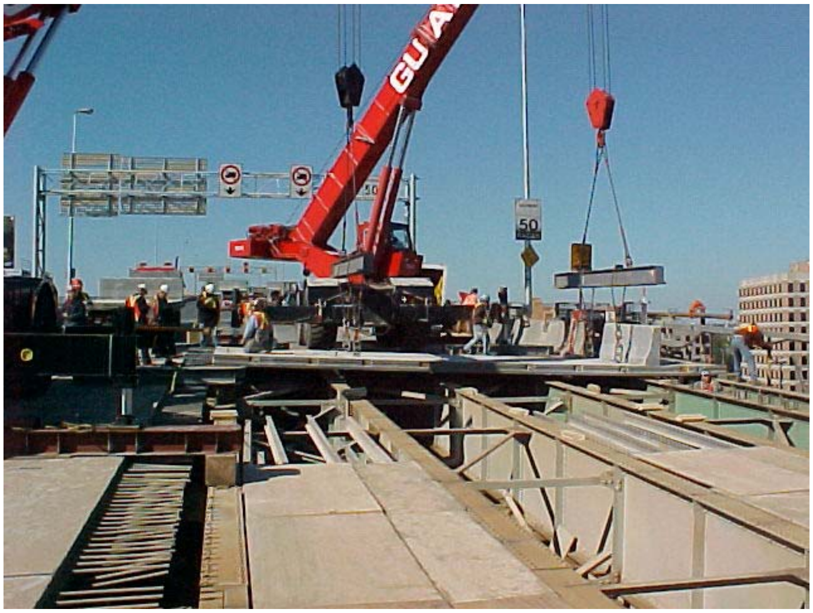

Fig. 9 – Installation of South abutment span panel

Fig. 10 – Installation of new precast bikeway panel