CSCE Annual Conference
Growing with youth – Croître avec les jeunes

Laval (Greater Laval)
June 12 – 15, 2019

THE NEW CHAMPLAIN BRIDGE'S EXPANSION JOINTS AND SHM SYSTEM – SUPPLY, INSTALLATION, IMPLEMENTATION

Moor, G.[3], Baillés, B.[2], Lauzon, A.[1,4], Paciacconi, A.[3] and Treacy, M[3]
[1] Mageba International, Canada
[2] Mageba International, USA
[3] Mageba CH, Switzerland
[4] alauzon@mageba.net

Abstract: The long-term performance of Montreal's New Champlain Bridge will depend on many factors, including, for example, the performance and durability of the key structural components that have been used in its construction, and the provisions that are made for inspecting and maintaining it throughout its long service life. This paper relates to a key example of each of these factors – the expansion joints that will accommodate the bridge's movements and rotations, and the structural health monitoring (SHM) system that will provide valuable data to support long-term inspection and maintenance work.

1 INTRODUCTION

Construction of the New Champlain Bridge in Montreal is currently approaching completion, at which point it will replace an existing structure that carries approximately 160,000 vehicles per day across the St. Lawrence River. The new bridge is being built as the main element of a $4.2 billion project which also includes the new Île-des-Soeurs Bridge. A consortium consisting of SNC-Lavalin, ACS and Hochtief is responsible for design, construction, financing, operations, maintenance and rehabilitation of the associated infrastructure, under a public-private partnership agreement with the Government of Canada. Overall design and construction is being undertaken by SNC-Lavalin, Dragados Canada, Flatiron Constructors Canada and EBC Inc., with design of the New Champlain Bridge the responsibility of SNC-Lavalin, TY Lin International and International Bridge Technologies. The Owner's Engineer is headed by Arup Canada, and Independent Engineer services are provided by Stantec and Ramboll. The care that has been taken by the bridge constructors to design and build the bridge in a way that will ensure good long-term performance, with minimum disruption to bridge users due to maintenance and renovation work, is demonstrated by the selection and use of key components and technology in the bridge's construction – as described below.

2 THE BRIDGE'S EXPANSION JOINTS

The bridge was designed with expansion joints at eight axes – joints of the modular type that will enable the bridge's superstructure to optimally accommodate movements and rotations. These joints were designed with between three and ten individual movement gaps each, thus facilitating longitudinal movements of up to 800 mm (as well as transverse and vertical movements and triaxial rotations as may be required). Since the bridge has separate superstructures for eastbound and westbound road traffic, it has two expansion joints at each axis, one per carriageway. The lengths of the individual expansion joints range between 17.5 m and 26.8 m.

In selecting the expansion joint solution for the bridge, particular attention was taken by the bridge design and construction team to ensure good long-term performance, thereby minimizing the need for repair and replacement work, and thus also minimizing not only life-cycle costs of these key structural components but also the impacts on bridge traffic while such works are carried out. This is demonstrated, in particular, by the demanding requirements specified in relation to laboratory testing of any expansion joint type proposed for use on the structure. This testing was based on the requirements of AASHTO's LRFD Bridge Construction Specifications, Appendix A19, including extensive fatigue testing, the Opening Movement and Vibration (OMV) test and the Seal Push-out (SPO) test (Spuler et al. 2013). Some of this testing, as conducted on the selected Tensa-Modular expansion joint, is shown in Figure 1. The responsible engineers could take special confidence from the way in which the fatigue testing was conducted, as described by Moor et al (2017), with an unprecedented level of independent testing done in the infinite life regime. This testing was conducted to provide a much higher degree of confidence than necessarily required by the standard, with testing designed to allow only 5% probability of failure as opposed to the standard 50%. Further confidence could also be gained from the demanding seismic testing to which the joint type had been successfully subjected; although such seismic conditions are not expected to arise, the testing nonetheless demonstrates an impressive degree of robustness and insusceptibility to damage that will serve any expansion joint well in the long term.

Figure 1: On left, Opening Movement and Vibration [OMV] test; on right, fatigue testing – one of the ten required test specimens, each subjected to six million load cycles

Design and manufacture of the expansion joints, for a design life of at least 30 years and to incorporate a specified seismic performance, is primarily in accordance with CAN/CSA-S6-06 and AASHTO LRFD Bridge Construction Specifications, with welding in accordance with CAN/CSA-W59-13 and galvanizing per ASTM A123 and A153. The design of the joints, as illustrated in Figure 2, will prevent damage by snow clearing vehicles, with vertical steel plates to the surface of the fully concreted joint anchorages, and also with the surface of the joint slightly below the connecting surfacing in accordance with best practice as shown by Lachinger and Hoffmann (2015).

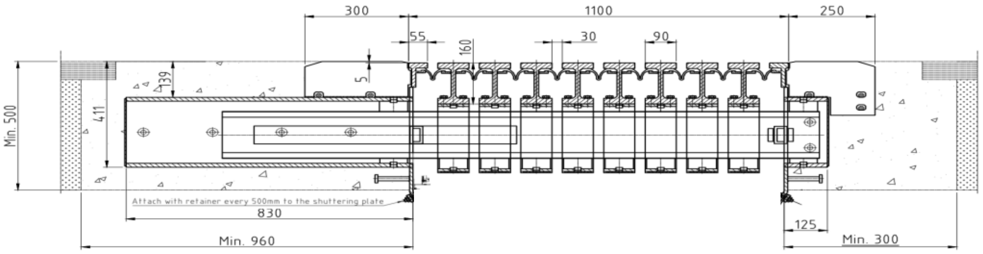

Figure 2: Typical cross section of a nine-gap Tensa-Modular expansion joint as installed

To ensure proper installation of the expansion joints (a very important factor in ensuring good long-term performance), the bridge constructor made sure to have an appropriate level of expertise available whenever required – for example, in ensuring proper pre-setting of width at the time of connection to the main structure (Figure 3).

Figure 3: Installation of a 7-gap joint, ensuring proper pre-setting of width at time of connection to the main structure in order to ensure that all future movements can be properly accommodated

3 THE BRIDGE’S STRUCTURAL HEALTH MONITORING SYSTEM

In order to optimize long-term bridge inspection and maintenance work, a Robo-Control SHM system is currently being installed, covering both the new Champlain Bridge and the nearby Île-des-Soeurs Bridge. This system will provide, on an ongoing basis, instant data which will enable the bridges’ performance, maintenance and rehabilitation to be optimized and their service lives to be extended. The system includes 26 Data Acquisition Units (DAUs) which act as substations within the SHM network. Each DAU receives data from a cluster of sensors, and is positioned accordingly. The DAUs, in turn, are connected to the Master Station by fiber optic cabling. All SHM data is transferred to the Champlain Bridge’s west abutment maintenance facility where the Master Station is located, which is linked to the city’s comprehensive Traffic Management System. When fully installed, in accordance with a schedule that is dictated by the bridges’ construction process, the system will incorporate approximately 250 sensors, as follows:

- 141 strain gauges (48 embedded and 93 surface-mounted)
- 44 displacement sensors (at expansion joints and bearings)
- 15 accelerometers (on deck / piers and cables)
- 6 tilt meters (on pylon and piers)
- 22 corrosion sensors within reinforced concrete elements
- Global Positioning System (GPS) units (one at tower base, two at tower tops, one at base station)
- Weather stations and pyranometers (at top of tower and on superstructure of main span)
- 18 temperature sensors (8 for pavement, 10 for structure)

Many of the required sensors (strain gauges, structural temperature sensors and corrosion sensors) required to be embedded in the structure’s concrete, and thus had to be installed at a much earlier stage in the bridge construction process than normally arises. An example of the installation of a corrosion sensor, for instance, is shown in Figure 4. Thanks to the strong recognition of the importance of long-term durability in the case of these bridges, such corrosion sensors have been incorporated at critical locations in the reinforced concrete structures to provide early indication of corrosion well before it becomes a potential problem.

Figure 4: A corrosion sensor (left), and strain gauges of different types (center and right), as installed

The corrosion sensor shown in Figure 4 (left) tracks both chloride penetration and carbonation, simultaneously measuring corrosion rates at four different depths within the concrete. Since these probes are positioned next to steel reinforcement bars, the progress of corrosion ingress from the concrete surface to the rebar depth can be determined. Strain gauges, both embedded and surface-mounted (also shown in Figure 4), have also been installed at selected locations, enabling strain (and hence stress) behavior under various loading scenarios to be understood. Of course, the presence of embedded sensors such as those shown necessitates great care during placing of concrete, and close coordination is required between the involved parties to ensure that sensors are installed at the optimal time.

A range of other sensors have yet to be installed at the time of writing, including displacement sensors, accelerometers and tilt meters. All of these will provide valuable information enabling a good impression to be gained of overall structural condition and performance at any time. For instance, if a bearing or an expansion joint begins to exhibit more (or less) movement than expected (e.g. based on measurements to date), or if a pylon or a pier tilts more than expected, this may be a useful sign of an issue that needs to be examined – a process which can be further supported by the programming of the system to provide alert messages to the responsible engineers when pre-defined threshold values have been reached. In the case of the displacement sensors, installed on selected bridge bearings and expansion joints, the data from these sensors can also provide the accumulated movement experienced over time by the sliding materials of these key components, facilitating efficient and effective planning of critical replacement work for these wear materials which might be expected to require replacement during the main structure's service life (Islami et al, 2016).

4 CONCLUSIONS

The specification and use of key components and technology in the construction of the New Champlain Bridge – its expansion joints and its SHM system – demonstrate the importance attributed to long-term performance throughout the structure's service life. By ensuring the long-term durability and performance of the proposed expansion joint solution – not only with respect to very demanding testing but also considering performance on actual bridge structures over a period of decades – the bridge construction team could make an important contribution to minimizing life-cycle costs and traffic disruption on the bridge. And the design and use of such an extensive SHM system, that will efficiently and automatically provide detailed, precise information on many key factors relating to the bridge's condition and performance, will help optimize bridge inspection and maintenance work – also reducing long-term costs and avoiding unnecessary impacts on traffic. The SHM aspect of the project, in particular, also demonstrates how close coordination between bridge designers, contractors and suppliers can enable the appropriate equipment to be integrated wisely in the construction process, ensuring that full advantage may be taken of all potential benefits, right from the start of the bridge's life cycle.

REFERENCES

Islami, K, Meng, N., and O'Suilleabhain, C. 2016. Smart bridge components (expansion joints, bearings and seismic devices) for intelligent infrastructure. *19th IABSE Congress*, Stockholm, Sweden.

Lachinger, S. and Hoffmann, S. 2015. Level Crossing. Bridge Design & Engineering # 79, London, UK.

Moor, G., Hoffmann, S. and Baillés, B. 2017. Fatigue testing of modular expansion joints in the infinite life regime according to AASHTO specifications. *39th IABSE Symposium*, Vancouver, Canada.

Spuler, T., Moor, G. and Meng, N. 2013. Testing of modular expansion joints – America's leading role. 36th IABSE Symposium, Kolkata, India.