Engineering for **people**

Restoration of the Heritage Félix-Gabriel-Marchand Covered Bridge

2023 Quebec Consulting Engineering Awards Grand Prizes

Category - TRANSPORTATION

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30 YEARS

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Project summary

The project involved the design of major restoration work on the longest covered bridge in Quebec, and second-longest covered road bridge in the world. The team designed innovative solutions and ensured that the heritage appearance of the Félix-Gabriel-Marchand Bridge was respected to the extreme satisfaction of the client.

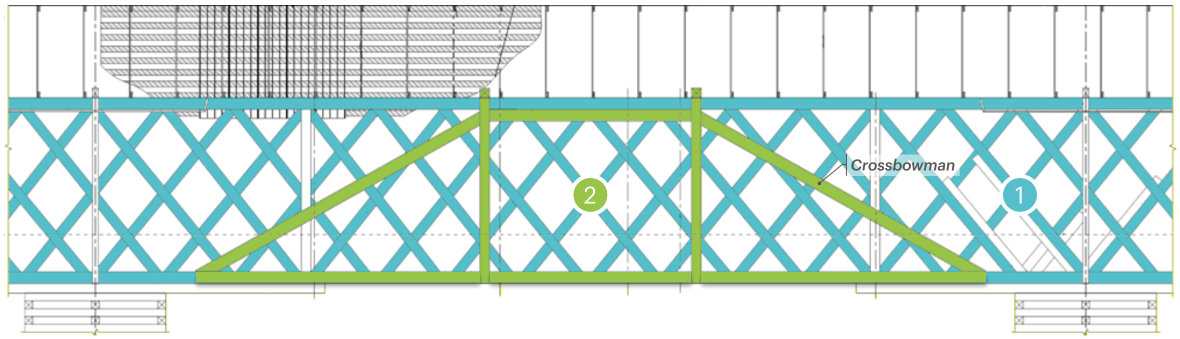
Innovation

The extraordinary Félix-Gabriel-Marchand Covered Bridge has stood for 125 years in the Outaouais, gracefully combining two superimposed structural systems – an unprecedented achievement in Quebec.

Despite its resiliency, the integrity of the Bridge was severely tested in 1979, when a log jam knocked it off its bearing seats. It was returned to service after an emergency intervention but closed again in 2014, when CIMA+ performed an inspection which revealed destabilization and significant vertical deformations ranging up to 200 millimetres.

Second longest covered bridge in the WORLD and longest in Quebec

> Built in 1898
> 151.7 metres long
> Designated a National Historic Site of Canada in 1998
> Classified as a heritage building
> Town-type lattice structure (crisscrossed planks) 1 combined with a double-post structure (Queen post) 2
> Insertion of a military bridge as a temporary support inside the covered bridge



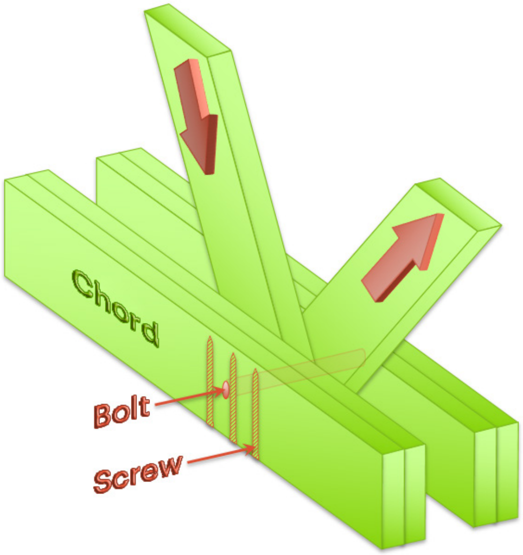
Innovation (continued)

Ductile connections and assemblies using engineering screws

CIMA+ employed a creative solution to overcome the age-old problem of brittle fractures: the use of European screws 3 that can exceed of 1,500 millimetres in length, not accessible in Canada until recently.

These specially-designed screws limit the development of cracks in wood near bolts, making it possible to reach the plastic limit of the connections and increase their capacity tenfold.

Dramatic increase in strength of bolted connections to some 1000%



Innovation (continued)

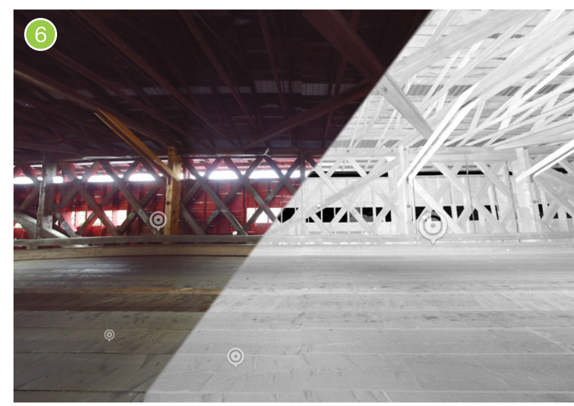
Corbeaux doubles

The reduction in the width of the piers by 40 per cent in 1997 led to an effective increase in spans and left the queen post truss bearing points unsupported. In response, the team extended the depth and length of the existing single sacrificial timber corbels 4 by doubling them to provide doubled structural corbels with increased rigidity that transferred the unsupported bearing loads of the queen post truss to the piers again. By re-engaging the queen post truss and reducing the effective spans, the global deflection issues were resolved.

3D digitized modeling of the structure

Considering the major distortions in the vertical and horizontal alignment of the Bridge, obtaining measurements proved to be a complex matter. In light of this, the CIMA+ Geomatics and Virtual Reality Capture team scanned the entire Bridge using a 3D 5 scan that generated a point cloud, 6 thus enabling the production of actual section drawings using appropriate software.

The «virtual bridge» was shared with stakeholders where it was possible to move within the point cloud and take the necessary measurements accurately.



Complexity

The load distribution of a covered bridge is indeterminate and complex. This complexity is further amplified in that case of this bridge because of its long spans, its two combined structural systems, the irregularities and defects in the timber and geometry, historical structural damage and the desire to respect the heritage of the structure.

Structural instability

Following inspections carried out by CIMA+ in 2014, which led to the Bridge being closed, it was determined that the weakening of the Bridge caused by the 1979 log jam and the various subsequent interventions decreased the stability of the structure.

The closed Bridge, which had become unstable even under its own weight, was given a new lease on life thanks to major structural reinforcements, straightening of the structure and replacement of damaged or defective parts.

A prefabricated bridge 7 was inserted inside the overall structure to ensure additional stability during construction. This temporary support considerably reduced the risks and maximized worker safety.

Complexity (continued)

3D structural analysis (based on 3D modeling)

Using modern finite-element modeling tools and powerful computers, CIMA+ created a 3D mode 8 l of the entire structure, taking into account the relative rigidity of the components. This sophisticated analysis simulated the anticipated deformation and load distribution for each member based on proper load sharing between the Town-type lattice beams and the double-post system. Such a complex analysis would have been inconceivable only a few decades ago.

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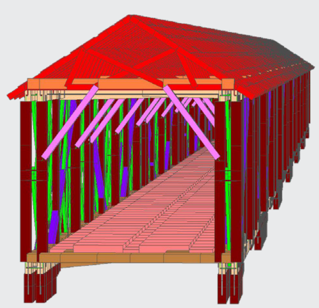

Complex structure recognized by the Ministère des Transports et de la Mobilité durable (MTMD)

Social or economic benefits

Social and economic perspective

- Key tourist attraction that is part of the regional circuit, photographed many times by the 4 million visitors per year in the Outaouais region
- This bridge is a source of pride for the two municipalities it connects and is recognized as an iconic symbol of the region
- Dozens of regional workers were involved in carrying out the restoration work benefiting from the economic spinoffs of this $6.5 million investment
- Waterway kept open for 4 years of work and linking the 240 km of the Coulonge River to the Ottawa River
- Canada Post issued a stamp 9 and a post card during the construction work
- The work made it possible to solidify the structure and restore the road link between the shores
- Certification provided by the Canadian Construction Materials Centre based on an assessment by the National Research Council of Canada

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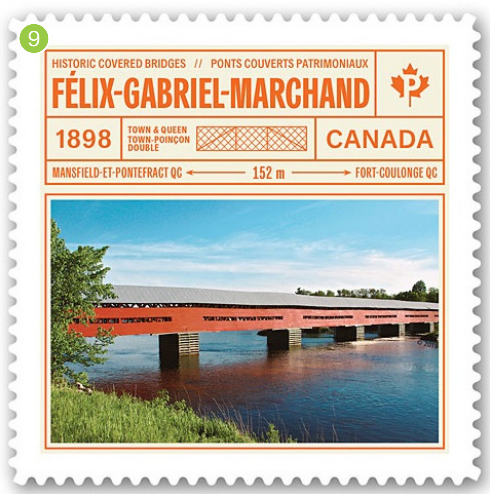

Social or economic benefits (continued)

Heritage value

> This unique Bridge is named after Félix-Gabriel Marchand, Premier of Quebec in 1897. Designated as a National Historic Site of Canada in 1988, and classified as a heritage building by the Ministère de la Culture et des Communications du Québec. The MTMD's heritage assessment gives it the highest heritage value in Quebec, i.e. 100%

> To ensure that the historical appearance of the Félix-Gabriel-Marchand Bridge would be respected, Michael Grayson, Eng., a Canadian expert on heritage bridges, was included as a part of the team


1948


1979


1948

Environmental benefits

Environnement

- Maintain existing piers without having to increase the footprint at the bottom of the river
- Insertion of a reusable and portable temporary support with prefabricated Bailey-type structure (military engineering design) inside the Bridge to avoid the environmental impacts of traditional supports on the river bottom
- Raising of the bridge deck by 400 mm, allowing for a 10% increase in clearance height in the case of extreme flooding – thus increasing climate change resiliency and providing clearance in excess of 65%. This improvement is an effective long-term strategy in keeping with the sustainable development framework with a view to anticipating problems before they arise

Environmental benefits (continued)

Sustainable development

- Use of sustainably harvested Canadian timber products
- Most of the removed components of the bridge were reused and repurposed by local residents and some are now on display at the George Bryson House Museum in Mansfield-et-Pontefract, providing a significant reduction in waste
- 50-year lifespan extension

Satisfying the client's requirements

The MTMD was satisfied about CIMA+'s creative work on the Félix-Gabriel-Marchand Bridge, that combined European, military, and Canadian engineering while conserving and showcasing the heritage elements of this Quebec jewel.

The MTMD's objectives were achieved thanks to the design of innovative and effective technical and technological solutions to :

> Resolve stability issues, restore double punch structure and ensure public safety by correcting existing defects

> Straighten the bridge frame laterally and vertically using a temporary military structure

> Respect the heritage aspect of the bridge, thanks to the engineering screws that avoided the addition of steel parts

> Respecting the MTMD's commitments with respect to user safety with a design that meets codes and standards

«I would like to begin by expressing my satisfaction with your design for restoring the Félix-Gabriel-Marchand Bridge.

You have more than adequately responded to our request for innovation in terms of achieving a level of conservation that is appropriate for a true restoration.

I would be remiss if I did not mention the exceptional collaboration of CIMA+ with Michael Grayson, Eng., the covered bridge expert, throughout the process of preparing the drawings and specifications and during the execution of the project. By applying innovative techniques, revisiting traditional methods and using high-quality materials, you have made a significant contribution toward ensuring that the work would respect the great heritage value of the Félix-Gabriel-Marchand Bridge.» (Translate) - Christine Dandois, Eng., M.Sc., Structures Directorate, MTMD

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