Canadian Consulting Engineering Awards 2013

Autoroute 30, Montréal | Beauharnois Canal Bridge and Serge-Marcil Bridge

Category B: Transportation

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ARUP

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Beauharnois Canal Bridge | Construction Over the St. Lawrence Seaway

Full Project Description

A | Project Information

Project Name

Autoroute 30, Montréal | Beauharnois Canal Bridge and Serge-Marcil Bridge
The project is a Public-Private Partnership (PPP) (signed in 2008) between the Ministère des Transports du Québec and the private partner Nouvelle Autoroute 30 s.e.n.c., a consortium involving companies owned by Acciona and ACS infrastructure.

Project Location

Montréal, Québec, Canada

Project Size

$1.5bn capital
Beauharnois Canal Bridge: 2.5km length, Serge-Marcil Bridge: 1.5km length

Completion Year

2012

Entering Firm

Arup

Role

Lead Design Firm for Highway Engineering, Bridge Design, Geotechnical Engineering, Tunnel Design, and Design Project Management

Project Leaders

Project Manager – Douglas Balmer, Associate Principal, Arup
Project Director – Don Phillips, Principal, Arup

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Installation of NEBT beams over the St. Lawrence River using a launching gantry

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Top: Completed Beauharnois Canal Bridge looking westward | Bottom Left: Post-tensioned piers providing nearly 40 metres of clearance over the Beauharnois Canal
Bottom Right: Work continues on the Beauharnois Canal Bridge through the night, to meet project milestones

Full Project Description

B | Project Summary

75 Word Summary

Ministry of Transports of Québec required a cost-and-time efficient way to complete the Beauharnois Canal and Serge-Marcil Bridges on Montréal's new Autoroute 30, to bypass the city and help to ease traffic congestion. As lead designer to the Nouvelle Autoroute 30 Construction Joint Venture, Arup used site-specific analyses, a unique construction launch sequence (Beauharnois) and designs that minimize footprints and optimize span lengths.

The result: safe and environmentally-sensitive crossings, constructed in short duration, and in challenging weather conditions.

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Beauharnois Canal Bridge in the foreground, with Serge-Marcil Bridge at the top left

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Lifting of steel haunch section at one of the monolithic main piers for Beauharnois Canal Bridge

Project Highlights | Innovation

The Serge-Marcil and Beauharnois Canal Bridges required innovative multi-modal response spectrum techniques to carry out a sufficient seismic performance analysis.

Innovation

In the case of the St. Lawrence Bridge, a relatively high bedrock level suggested the use of short and stiff piers as the most cost-effective means to support the bridge deck, which in turn compromised its seismic performance.

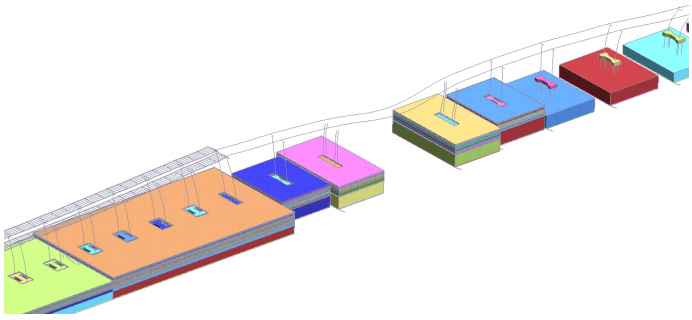
The challenge was then finding an inexpensive and efficient solution to effectively 'isolate' the superstructure from the foundations in the event of an earthquake. Friction pendulum bearings were the answer to this problem, requiring our engineers to undertake complex analysis routines to model the non-linear hysteretic behavior of these particular bearings.

The Beauharnois Canal Bridge is an irregular structure with differing span lengths and column heights, and significantly diverse soil conditions. In particular, the varying soil conditions warranted a special analysis since the amplification of the bedrock spectrum through the soil varies along the length of the bridge. These irregularities required Arup to undertake time history analyses using the finite element software LS-DYNA.

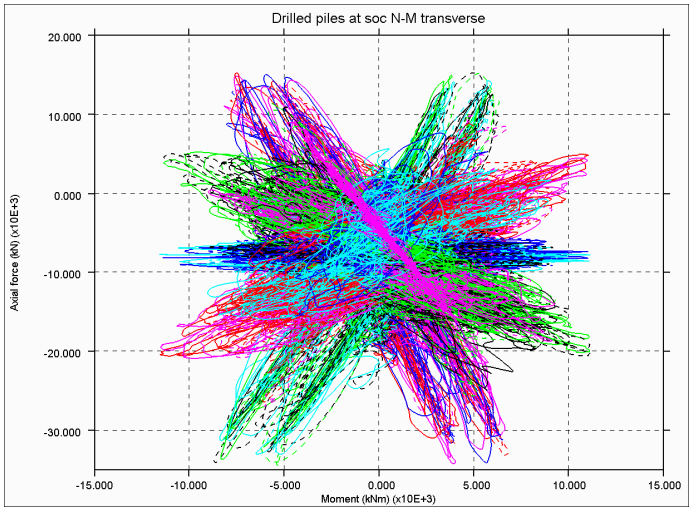
In both bridges, soil elements were modeled explicitly and included as part of a global analysis model. This presented a great advantage as ground motion could be directly applied at bedrock level and site response accurately analyzed, as opposed to being simply estimated from the site coefficients given in the Canadian Highway Bridge Design Code.

Non-linear soil column models were analyzed in isolation, with results being compared against the Arup in-house site response analysis software SIREN. This allowed Arup engineers to fully optimize the finite element soil mesh density and validate its behavior.

Five sets of design time histories were developed for each of the design response spectra using the software RSPMatch2005. Arup engineers could then take an actual recorded ground motion as input and modify its acceleration ground motion history, such that the corresponding response spectrum matched a target design spectrum.



Still image of the time history analysis animation model developed by Arup



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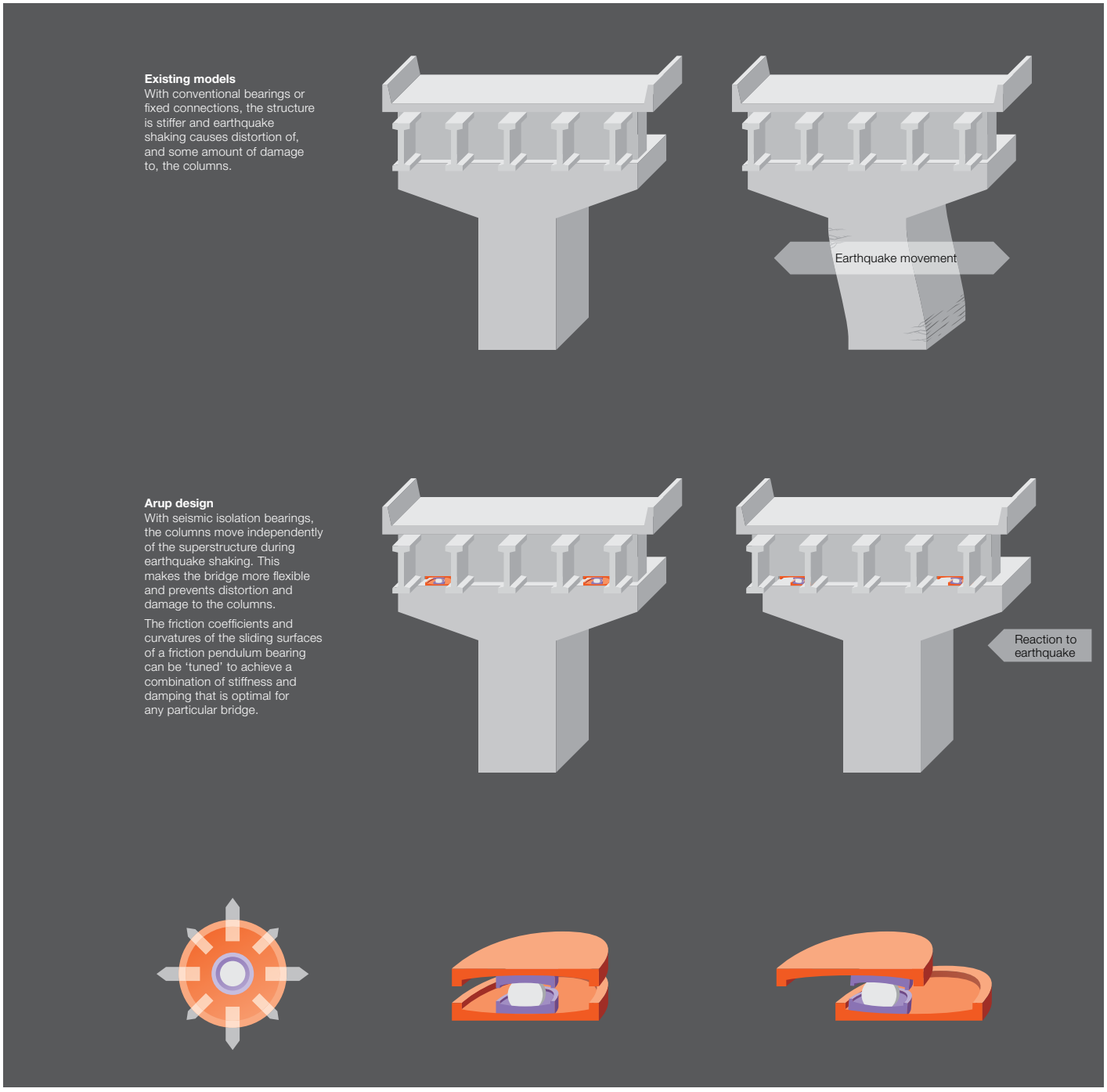
Axial force seismic response simulation plot for drilled shafts at Beauharnois Canal

Since RSPMatch2005 makes modifications in the time domain -as opposed to earlier programs which used approaches based on white noise-, it preserves the non-stationarity of the original seed record and does not add unrealistic energy content to the entire duration of the history.

Therefore, the use of in-house developed software interlinked with readily available packages constitutes a key factor differentiating Arup from other consultants. Instead of simply using the default code methodology, Arup engineers were equipped to effectively adjust their design to site specific seismic criteria.



Functioning of seismic isolation bearings used for the Serge-Marcil Bridge

Project Highlights | Complexity

Autoroute 30 (A30) crosses the St. Lawrence Seaway's Beauharnois Canal on a 2.5km bridge. This substantial length is dictated by the need to provide 38.5m of clearance above the Seaway for the safe passage of ships, and the maximum preferred gradient of 3.5% on the approaches required for significant truck traffic.

Complexity

The complexity of the final scheme was increased by the third party agreement between the Ministry of Transport of Québec (MTQ) and the St. Lawrence Seaway Management Corporation, forbidding construction activities above the Seaway, except during the winter season when it remains closed to shipping due to ice buildup in the river.

Faced with this constraint, the design team needed a suitable construction method to construct the 150m main span in a short duration and in harsh and freezing weather conditions. The solution was to incrementally launch a steel box girder over the main span.

The steel box girder was designed to be constructed off-site. Segments were then connected together in a staging yard on the east side of the canal before being placed on rails and launched over the canal. This allowed the bridge to be built safely and in a timely and cost effective manner - without affecting ships on the Seaway.

For socio-economic reasons, the footprint of the bridge had to be minimized to reduce head-loss in the canal, which might impact the efficiency of the downstream hydro-electric barrage. This was also an environmental requirement, to limit the loss of fish habitat. As a result, Arup optimized the span length to minimize the impact upon the canal and facilitate the launching of the bridge.

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Winter conditions add complexity to construction of the Beauharnois Canal Bridge

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Staging yard used to facilitate preparation for launching of the box girders.

Project Highlights | Social and Economic Benefits

Since its opening in December 2012, the new A30 has been commended in the press by local mayors and residents, road users from near and far, and businesses large and small.

Social and Economic Benefits

The proposal to construct a new highway in the Greater Montréal Area to connect the municipalities along the south shore of the St. Lawrence River was originally rooted in the 1960s. It was recognized then that the connection between key cultural and economic centres such as Montréal, Toronto and Ottawa needed to be enhanced.

The two main obstacles to the connection, however, had long been the crossing of the St. Lawrence River and that of the Beauharnois Shipping canal. By delivering an integrated and durable design that overcame these challenges, these cities can now realize the social and economic benefits of being more efficiently interconnected.

Additionally, the connection over the St. Lawrence River and the Beauharnois Shipping canal to the south of Montréal gives road users, and in particular road haulage companies, an opportunity to bypass the island of Montréal. Prior to the construction of the A30, the main routes from Toronto or Ottawa to eastern Quebec, the Maritimes or the United States (New York or Vermont) passed through the heart of Montréal on Highway 20 and 40. Both of these highways experience heavy congestion on regular business days.

With a total investment $1.5 billion (CAD 2008), the project also contributed to the local economy by not only stimulating local business activities through the presence of nearly 1,000 workers on-site during the project's construction phase, but also by awarding approximately 85% of its Canadian contracts to businesses of the Greater Montréal Area, most of which were small and medium sized businesses.

It will help reduce the driving time and overall driving-related costs of a population estimated at nearly 170 000 individuals. For example, it is estimated that a driver will save approximately 30 minutes of travel time between Boucherville and Vaudreuil-Dorion by using A30 instead of using Autoroute 40 through Montréal.

Project Highlights | Environmental Impact

The principal environmental impacts arising from the design and construction of the Serge-Marcil Bridge over the St. Lawrence River and the bridge over the Beauharnois Shipping Canal related to the works within water.

Mitigating Environmental Impacts

The pier spacing on both bridges was optimized to suit the environmental requirements whilst still satisfying the construction methodology agreed with the contractor.

The Serge-Marcil Bridge is a low level crossing over a relatively shallow river. The water levels in the river are also controlled by Hydro-Quebec, so at times the river ran almost dry.

In consideration of the variable nature of the river stage, a number of hydraulic scenarios were developed to assess the and mitigate the potential hydraulic and environmental implications of using temporary berms to provide access to the bridge during construction.

The design also mitigated the impacts upon an area of sensitive marshland, and a potential bird breeding area on the north shore of the St. Lawrence River. This influenced both the position of the abutment and piers, and the drainage design at this location, the drainage being designed such that runoff from the bridge was directed away from the protected area.

The design of the Beauharnois Canal Bridge also accommodated sensitive fish habitat by strategically locating and optimizing the piers within the canal, and also placing the massive pile caps above the water level. The latter also served to offer greater protection against ice loads during the winter months.

In addition, the reduction in overall journey times for through traffic will help alleviate some of the congestion and pollution in the heart of Montréal.

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Beauharnois Canal Bridge

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The bridges' role in bypassing Montréal centre will reduce traffic congestion and associated emissions pollution

Project Highlights | Meeting the Client's Needs

During the request for proposals stage, the modifications proposed to the two main bridges from the reference design helped to contribute to the Government of Québec's project-wide estimated value-for-money in the order of $750 million (CAD, 2008) by carrying out the project as a public-private partnership compared to a traditional procurement approach.

Meeting the Client's Needs

Our response considers both the needs of the project owner, MTQ and Nouvelle Autoroute 30, s.e.n.c. (NA-30), and the needs of our direct client, the NA-30 Construction Joint Venture. Ultimately our designs helped to realize a project that was opened on time, and provides relief to traffic passing through the greater area of Montréal.

With regards to our immediate client, Arup worked closely with the contractor to develop design solutions for the Serge-Marcil Bridge and the Beauharnois Canal Bridge which were aligned with their preferred objectives and construction methodologies. Arup mobilized significant local and specialist international resources to help the client meet its goals and open the road on time.

The team's flexibility in rescheduling designs to suit the contractor's requirements allowed early commencement of construction in key areas of the project. Arup has also performed value engineering studies at various stages of the project for the Nouvelle Autoroute 30 CJV to help fine-tune the design to accommodate local ground, weather and market conditions, minimizing construction cost and schedule.

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The A30 opens as scheduled

Image Cover: Beauharnois Canal Bridge, Montréal, © NA30 CJV

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