Submitted by McElhanney

Piece-by-Piece

The Deconstruction of the old Port Mann Bridge

Prepared for the Canadian Consulting Engineering Awards 2016
Entry Category: B. Transportation

Contents


The old Port Mann Bridge was built in 1964

The arch and edge girders were cut in the middle first to make a cantilever system.

Piece-by-Piece

The Deconstruction of the old Port Mann Bridge

1. Innovation

In 2012, the Government of British Columbia completed the massive upgrade of Highway 1 east of Vancouver including the construction of the new 10-lane Port Mann Bridge over the Fraser River. As part of this landmark project, the old Port Mann Bridge, a 586m-long, three-span steel tied-arch crossing which formerly carried the highway, needed to be removed.

Often when a bridge requires removal, it is simply demolished with explosives. In this case, the decommissioning needed to be controlled to prevent detrimental impacts to the river environment and to the adjacent newly constructed bridge.

The McElhanney team was retained as the lead construction engineer by Kiewit-Flatiron Joint Venture (KFJV) in late 2012 to engineer and prepare a step-by-step manual for removing the 50 year old bridge. This involved using a cable-stayed system that essentially converted the tied-arch into a cantilever bridge and allowed for orderly removal, piece-by-piece starting with the centre and progressing to the sides. The entire deconstruction sequence was custom engineered for this particular bridge and site.

The 1963-64 construction process could not simply be reversed as several changes had been introduced to the bridge itself and the surrounding site over the years. Also, technology and equipment have changed considerably and therefore new methodology was needed.

After five decades of fatigue stressing, corrosion, and various modifications to the bridge, it was impossible to accurately predict what stresses might be released by cutting into the structure. Therefore, a scheme was devised that incorporated layers of redundancy for safety, plus the ability to fine-tune the support systems so the team could adjust to the behavior of the old structure in real time. The McElhanney-led team designed temporary towers and stay cables to support the bridge during deconstruction (see concept sketch on page 9).

One of the most unique innovations was the use of "crowsnest" control centres on top of the temporary towers from which the ironworkers could precisely orchestrate the cantilever by stressing or destressing the cables in quick order.

The team developed creative means and methods to safely cut the first arch ribs and edge girders. Use of ultra-sensitive strain gauges and hydraulic jacks confirmed the arch force was truly relieved prior to cutting. Once the edge girders were cut, they were immediately "caught" by an assembly of high strength steel bars.

Deconstruction of the bridge started in December 2012 and the last pieces of steel were taken away for recycling in fall of 2015.

2. Complexity

"This project presented a greater technical challenge than engineering a new cable-stayed bridge." — David Jeakle, PEng, PE, McElhanney's principal engineer on this project. He has worked on the design of multiple cable-supported bridges throughout his career.

To develop the detailed plan for deconstruction, McElhanney held discussions with the designer of the original bridge (Gerritt Hardenberg of CB Engineering) and studied archive erection plans such as temporary works, construction photos, design plans, and shop drawings. This included studying the 300 original drawings to plan every step for removing 400 individual pieces of steelwork. The majority of sections weighed less than 35t, however some pieces were as heavy as 100t, or about the weight of a Boeing 757-200 aircraft. Where possible, the original construction process was reversed but several crucial aspects required wholly new solutions. For example, due to railway expansion under the south sidespan, temporary supports could not be built as the original constructor had done. This added significant complexity in balancing the south half of the bridge.

Cables were affixed to 58m-tall temporary towers to support the bridge. It was impossible to accurately predict what locked-in stresses might be released by cutting into the structure. This made for some very "stressful" cuts. *Cutting the arch put the entire weight of the bridge onto this cable system. This partial structure was extremely vulnerable to construction stage demands. This aspect presented the biggest engineering challenge; in layman's terms, a false move could lead to a "house of cards" type failure.*

3. Social and/or Economic Benefits

Economic — The project resulted in removing an aging redundant bridge, which would have required seismic upgrading, construction of ship collision protection measures, and high ongoing costs for maintenance to tax payers had it remained in use.

Throughout the deconstruction, the team maintained uninterrupted shipping and rail traffic adjacent to the bridge. Also, traffic continued to flow over the new bridge as the old one was deconstructed so as not to impede commerce.

Social — When built in 1964, the old Port Mann Bridge was hailed as the longest arch bridge in Canada. It was an integral and beloved part of the urban skyline for many years. Instant removal through explosives might have been disturbing to locals who admired it. Throughout the project, many commuters and bridge enthusiasts watched the iconic bridge's methodical removal with interest and nostalgia. The project was featured regularly in the local press and McElhanney engineers published articles on the project in *Bridge Design & Engineering* and *World Highways* magazines to further share the experience with the bridge community.

Unlike a new piece of infrastructure that the community interacts with, the engineering success here is less tangible but certainly no less important. The safe completion of this complex feat required rigorous planning and precise execution. The project demonstrates pragmatic yet innovative engineering, even when a structure is "un-built."

McElhanney

Pieces of the bridge were carefully removed by crane and lowered onto a barge for recycling. Note the proximity to the new bridge.

4. Environmental Benefits

The presence of lead-based paint and asbestos in the old bridge's wearing surface demanded that the dismantling works be tightly controlled to eliminate the risk of any harmful substances entering fish habitats in the Fraser River.

Fifty years ago, or in other parts of the world, this bridge might have been demolished instantly with explosives. With Canadian society demanding higher and higher environmental standards, the project team devised a way to safely remove the bridge, without harming the fish-bearing Fraser River.

In total, 9,000t of steel were sent for recycling rather than to a landfill. The temporary works were also made of recyclable material.

Temporary cable-stayed cantilever system.

5. Meeting Client's Needs

The prime consideration for KFJV, above all else, was to design a sequence that would be safe – for the workers, for the environment, and for the new bridge and its travelers.

KFJV needed to execute the deconstruction to a tightly planned schedule to control costs. Design of the deconstruction project was far behind schedule when the McElhanney team was hired to take over responsibility from a previous consultant. Thanks to McElhanney's aggressive efforts and innovation, the contractor was able to recuperate the time lost and complete the project on time and on budget.

The cost of deconstruction was approximately $50M. It was completed in 24 months. McElhanney provided prompt office and onsite engineering support throughout the removal process.

"The dismantling of the old Port Mann Bridge was an extraordinary challenge. Solutions developed by McElhanney were innovative yet practical, cost effective, and worked well during execution." — Paul Hopkins, Site Superintendent for Flatiron Constructors.

This high-profile project was featured in *World Highways Magazine* (top), and *Bridge Design & Engineering Magazine* (bottom).

McElhanney

Concept Sketch

Stressful Cut #1 — The Arch

1,600 tonne arch force had to be relieved before cutting the bridge apart. Several investigative steps confirmed that the arch force was truly relieved; including use of ultra sensitive strain gauges and hydraulic jacks. Still, cutting the bridge made for some stressful moments!

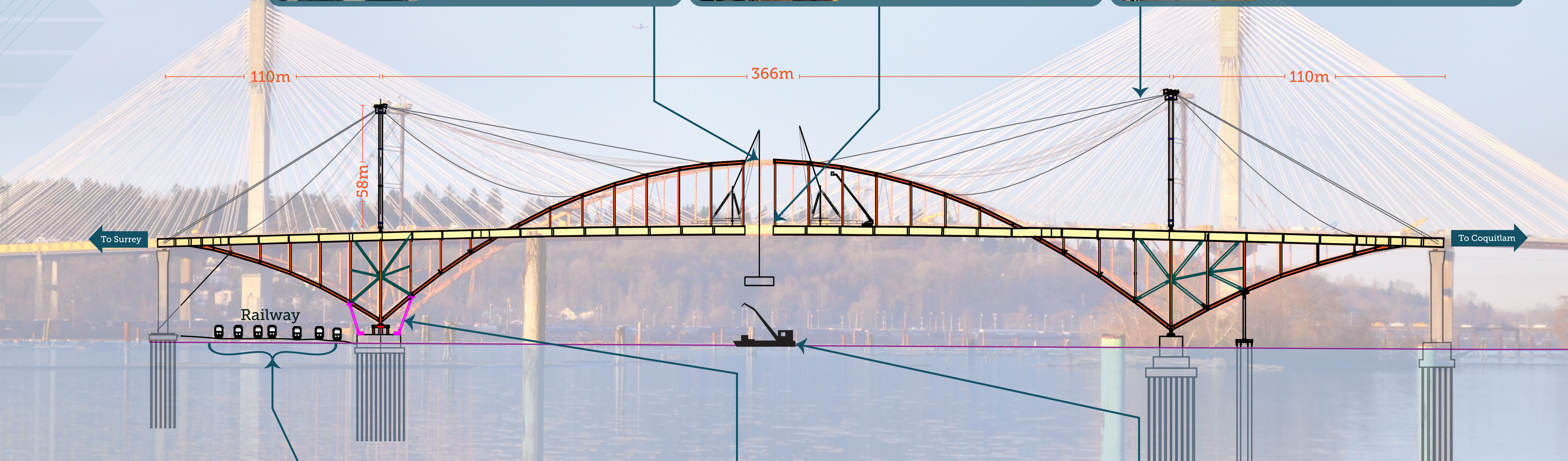
Stressful Cut #2 — The Edge Girders

The first cuts to the edge girders were made while each girder was carrying 700 tonnes of tension. This tension was immediately 'caught' by an assembly of high strength steel bars. The bars were then relieved of tension using hydraulic jacks as a 9-inch gap opened up between the tips.

Controlling a House of Cards

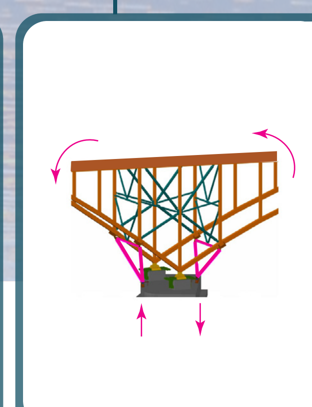
Cables were installed to carry up to 900 tonnes each. Cutting the arch put the entire weight of the bridge onto the cable system.

From a 'crowsnest' control centre on top of each tower, the ironworkers could manipulate the bridge like a puppet master pulling carefully on different cables as necessary.



Crowded Out

Due to railway expansion under the south sidespan, temporary supports could not be built as the original constructor had done. This added significant complexity in balancing the south half of the bridge.



Balancing the Bridge

Without temporary support under the sidespan, the entire south half of the bridge had to be stabilized on the limited footprint of this pier. Tailor-made triangular frames were designed to connect the bridge joints to the available support points.

Piece-by-Piece

Regular cranes would have been too heavy to sit on the cantilevered sections so custom built derricks were installed to pick and lower the 400 pieces of steelwork to waiting barges. The Bremerton barge crane was brought in to finish off the final sections.

McElhanney