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SECTION: Project Spotlight: Deh Cho Bridge

HEAD: Permanent Link across Canada's Longest River

DECK: Designing for faster and cheaper onsite construction and minimal repair in the field

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The Deh Cho Bridge near Fort Providence, which officially opened to traffic on November 30, 2012, is the first bridge to cross Canada's longest river, the Mackenzie, and the largest bridge project ever undertaken in the Northwest Territories. Before the kilometre-long 2-lane bridge opened, communities of the North Slave region, including Yellowknife, often endured days- or even weeks-long disruptions during winter freeze-up and spring break-up when crossing the river was hazardous or impossible and any supplies would have to be flown in.

Early estimated capital construction costs had been $55 million. In 2007, when the Deh Cho Bridge Corporation (DCBC) contracted with the Government of the Northwest Territories to design, construct, finance, and operate the bridge, cost estimates had risen to $167 million. Final costs came in at $202 million, in large part because of technical and financial difficulties, said Earl Blacklock, manager of public affairs and communications for the Government of Northwest Territories Department of Transportation.

Major construction began in the spring of 2008 with installation of the four southern piers. By April 2009, the four northern piers were completed. DCBC had scheduled a

2010 completion, but in early 2009 the original general contractor, New Brunswick-based Atcon Construction, was relieved of its management and on-site work coordination, and later filed for bankruptcy. DCBC's design did not meet Canadian bridge code standards, and its engineer left the project.

"That was the moment that we came on board," said Dr. Matthias Schueller of Infinity Engineering Group Ltd., which conducted a value engineering assessment for the bridge, and then took over the design of the superstructure, pylons, cables, and abutments. "When you keep the design as it is for aesthetic reasons and other reasons—for example, you don't want to take out the piers and build a new structure," Schueller observed, "—you have to deal with what you have." When Infinity got involved the eight piers in the river were mainly completed.

In spring 2010 the territorial government took over the project from DCBC, hiring Ruskin Construction, the sub-contractor principally responsible for construction during the first two seasons, to finish the job.

Founded on concrete spread footings cast into the Mackenzie River bed using cofferdams, each pier consists of a lower solid concrete cone reinforced with an outer steel shell protecting it against ice forces, and an upper steel head, which has a base and two inclined legs connected by a tie-beam. The lower concrete cone and the steel head are connected at the pier's bottle-neck, with post-tensioned high-strength bars to ensure that the critical connection stays tight and sealed for service loads.

Infinity's redesign was completed in six months. Using light-weight design principles, it designed an innovative composite extradosed truss bridge compatible with the alreadyconstructed piers. The main span is cable-assisted, and at its highest point reaches 27.2 metres above the Mackenzie River. Two A-pylons each support two cable planes, each of which comprise six cables connected to the main truss through an outrigger system.

The piers had been identified as very stiff and with a brittle failure mode. Only one pier could be equipped with longitudinally fixed bearings, but “you cannot hang the entire superstructure on only one pier because no pier alone could handle the significant wind load,” said Schueller. However, engaging more than one pier would result in expansion and contraction between those two piers. Infinity used an innovative technique called the Failure-Mechanism-Concept (FMC) to verify that the bridge’s 1045-metre-long superstructure could be built as a single continuous unit with expansion joints only at the abutments, eliminating the two complex and costly expansion joints originally proposed for the 190-metre-long main span. To allow forces such as dynamic wind or earthquake forces to be shared with other piers, the designers decided to employ “lock-up devices,” also called “shock transmission units,” which act like shock absorbers on a car. “This way we allow the superstructure to expand or contract due to temperature changes,” said Schueller, “but when the dynamic loads like gusting winds come, we have a system where several piers are engaged.” Such lock-up devices have been used for years in seismic regions or in very long structures like suspension bridges, but not typically in bridges like the Deh Cho Bridge.

Applying FMC took the bridge’s design beyond the traditional ultimate limit state design approach adopted by modern codes. Infinity recognized that the weakest pier section, the “pier bottleneck,” could be designed to act like a fuse in order to allow a controlled failure mechanism. “We redesigned the critical section so it can rotate; the joint simply opens up when you have a certain force and this way you can engage other piers,” said Schueller. “When the bridge goes to its limits, you want it to ‘announce’ the problem by showing unusual deformations and strains or members that fail but don’t automatically trigger a sudden collapse.”

Infinity determined that designing the superstructure for a high degree of repetition, effective assembly-line fabrication processes and rigorous shop trial assembly including quality control and quality assurance would lead to faster and cheaper onsite construction and minimal repair in the field. Its designers focused on fast-track methods, designing a Lego-like standardized system for the assembly-line fabrication and trial assembly of 55 truss segments. All prefabricated and partially preassembled components were designed so that they could be delivered to the site by road and rail via standard transportation means, avoiding oversized loads and special permits. Superstructure fabrication started in early 2010. On-site temperatures as low as -40 °C meant that most construction could only take place between June and December. Material delivery to the north shore depended on ferry or ice road service, and ice breakup in the spring required the removal of any work supported by temporary foundations in the river. Only abutments, curbs, and wearing surface were designed for conventional construction methods.

“We basically changed the superstructure in details but not in the big picture,” said Schueller. The new design saved about 25 per cent on steel and 30 per cent on deck concrete, and provided other significant cost advantages, including lower expected maintenance costs. The bridge is being financed by the savings from the elimination of the ferry and ice bridge services, $2 million annually (inflating) from the Government of the Northwest Territories and a bridge toll on commercial vehicles of between $75 and $291 based on the number of axles. Passenger vehicles are free.

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SIDEBAR: The Pile Driving

"So far north and with the extreme temperature and rural conditions, everything is a little more difficult," according to Dr. Matthias Schueller, but the pile driving "was pretty straightforward, nothing special: piles were driven into the fill of the approaches, which were built up to the base of the foundation for the abutment, far below the final profile grade line. Some were simple vertical piles and some were inclined, to have more resistance for horizontal loads. The profiles were rolled sections, typically used as beams. A small hammer drove them down to the anticipated elevation, and when they had enough resistance according to geotechnical specifications they stopped. The piles were then integrated into the foundation slab of the abutment."

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PULL QUOTES:

"You don't want to take out the piers and build a new structure—you have to deal with what you have."

"Applying FMC took the bridge's design beyond the traditional ultimate limit state design approach adopted by modern codes."

Both quotes, Dr. Matthias Schueller, Infinity Engineering Group Ltd.

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