Bridge
DESIGN & ENGINEERING

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Remote control

Published: March 01, 2010

A major bridge crossing in Canada's remote Northwest Territories is set to move ahead again after being halted for an extensive and rapid redesign. Prabhjeet Raj Singh and Matthias Schueller report

Rendering of the completed Deh Cho bridge (Infinity Engineering Group)

Long after the first settlers arrived in Yellowknife in the 1930s, people still travelled either by horses in summer, or dogsleds in winter due to the absence of a proper road connecting the region to the highway system of Canada. A 530km-long all-weather road from the Alberta border north to Yellowknife was completed in 1968 and has been steadily upgraded over the past 25 years. This route is known as Yellowknife Highway; it offers connections to winter roads that service the gold and diamond mines of the north and is used by more than half the population of the province. Construction of the highway reduced travel times significantly, but the Mackenzie River remained as a major obstacle.

The river at Fort Providence is approximately 220km north of the Alberta border and is crossed by ferry from late spring to early winter and by an ice bridge during some of the winter months. Since 1987, the ferry has operated into January or February through a channel cut in the ice, until the ice bridge is strong enough for heavy vehicles. Ice bridges are susceptible to collapse and cause environmental harm; even when operating normally, they can add 30 minutes to the trip. But the link is totally broken for an average of five weeks during spring while the ice breaks up and for up to three weeks in the autumn due to low water levels and while the ice forms sufficiently to cut the ferry channel. During these periods of isolation, there is no road connection between the region and southern Canada so people can only travel by air. Freight traffic to the region is also interrupted – some is trucked to the river, transferred to slings and shuttled by helicopter across the river to trucks on the other side.

As well as creating a permanent road connection, the bridge crossing would be expected to provide considerable economic stimulus and offer direct cost savings to industries, businesses, government and consumers in the region.

The route to construction of the new bridge has been anything but smooth, although with detailed design now complete, construction of the superstructure is finally expected to start later this year.

Back in 2007, the Government of the Northwest Territories entered into a public-private partnership with the Deh Cho Bridge Corporation for the design and construction of a new bridge consisting of a 1,045m-long composite steel truss bridge with a cable-assisted main span of 190m. The two-lane bridge has nine spans; the main span is flanked on both sides by three spans of 112.5m length and one of 90m. The superstructure is formed of two 4.5m-deep Warren trusses spaced 7.3m apart. Two A-shaped towers at each end of the main span support two planes of cables, each of which consists of six cables connected to the main truss via an outrigger system. The US$160 million bridge will be tolled, and the government will also contribute the same amount as it currently pays to operate the ferry, which will be discontinued when the bridge opens.

The P3 proposal called for accelerated construction of the bridge, and as is typical with this sort of fast-track project, construction of the foundations and substructure started before the superstructure design was finalised. But an independent review of the original superstructure design by TY Lin International on behalf of the government identified numerous deficiencies and deemed it unbuildable. The lack of a feasible erection procedure and the inclusion of several details that would be difficult to fabricate and assemble were some of the shortcomings identified. They could have had a direct impact on the project schedule with potentially significant cost implications for the partnership.

Pressure was put on the P3 team to mitigate the schedule delay by resolving these design issues effectively and economically. The original designer resigned from the project and Infinity Engineering Group was appointed by the Deh Cho Bridge Corporation to propose solutions. As well as presenting options to eliminate the deficiencies of the original design, Infinity developed a redesign option and carried out a value engineering exercise which revealed that it would offer significant savings in cost and schedule while simultaneously improving safety, durability, and constructability. The owner and concessionaire opted for the redesign option.

The value engineering process led to several features that were different to the original design. Applying the principles of lightweight design, a conventional truss system was developed where the member profiles respected the selected construction method. The articulation scheme chosen allows a continuous and jointless deck for the entire bridge length; this 235mm-thick deck will be built from precast concrete panels with cast-in-place stitches. A waterproofing membrane with two layers of asphalt will be applied to the surface for sealing purposes, and compact locked-coil cables are proposed for the stay system with the locations of the anchor points in the main span being modified for improved structural and aesthetic quality. These cables have the benefit of simple, fully-approved anchorages that can easily be inspected and maintained.

The design also included the consideration of a feasible and verified erection scheme; this involves launching the approach trusses, a one-step simultaneous stressing procedure for all the cables and a heavy barge lift of the main span. The scope included ensuring compatibility of the redesigned superstructure with the existing substructures which were already under construction. At the time the redesign started, foundations for all of the bridge piers had been installed, and the substructure for four of these piers had been completed.

The process of ensuring compatability meant that the design team had to be closely involved with the construction of the substructures and had to address site issues at the same time as they were carrying out the redesign work.

The challenge was not limited to solving technical problems under an accelerated schedule of five months; the problems encountered on the original design had sparked a greatly-increased level of scrutiny from the owner, lender and the concessionaire. The owner and its technical advisory team – BP Tech and TY Lin International – were primarily interested in the technical adequacy of the design. Meanwhile the lender and its representative CH2M Hill were mostly concerned with progress and adherence to the schedule, while the concessionaire and its prime consultant Sargent & Associates focussed on auditing the quality aspects.

Understandably, a certain level of confidence had to be established between the P3 teams and the new designer. With the involvement of several teams, Infinity took the lead in steering progress meetings by developing agendas on behalf of the prime consultant, presenting the progress of the work and addressing comments. To instill confidence the designer chose to work transparently with all teams being given open access to drawings, calculations and progress reports.

Upon the award of the redesign, Infinity and Sargent & Associates developed a project-specific quality management system that included a quality control plan and a quality assurance plan. The merit of a design depends on the knowledge and experience of the design team and a well-structured and rigorously followed quality system ensures a product of the highest quality. The quality plan included a provision for an external peer review of the redesign by a long span expert, which Infinity subconsulted to URS Corporation's Tampa office. A web-based project portal was developed to allow easy access for the multidisciplinary team to easily access information including project inputs, drawings, specifications and progress reports, and to check prints and drawings from one common source.

In order to accommodate the accelerated design schedule, steps were taken to speed up the decision-making, review and approval processes. A living document 'additional design assumptions' was set up to record any assumption or decision made on design criteria that was not clearly specified in the project requirements. The design proceeded, using this amended design criterion unless instructed otherwise by the owner. Progress meetings were used as an opportunity to present and discuss the design drawings in their existing state of development with the reviewers, sometimes before an official submission. This offered reviewers a head start on the review process and an opportunity for the designer to discuss and understand their concerns and adapt the design accordingly.

Infinity's project management team worked with the Engineer of Record to develop a task list with priorities based on the deliverable schedule and a work plan was developed by allocating resources to each task for designing and checking. Internal weekly meetings served as an opportunity for the project management team to assess progress relative to the work plan and to update the plan accordingly.

It was important to illustrate to the lenders that the redesign deliverables were progressing on schedule. This job was made easier by a web-based time management system that was used to record work hours. The project management team set up the tasks based on the work plan and budget hours for each task on the time management system. As work progressed, the status of each task, deliverable and the overall project could be determined by comparing the recorded hours to the budget

hours. Detailed progress reports per task and overall summary charts were prepared and presented at the monthly progress meetings. Later in the schedule as submissions were spaced closer than the monthly progress meetings, the lender's consultant was invited to attend the internal weekly progress meetings and review the design progress personally.

The quality assurance plan led by SA required periodic audits of the design consultant's quality control system. Audits were performed at the 60% and the 100% stages of the redesign. The objective was to determine the state of compliance of the design consultant's work to the project quality plan, identify any gaps and make recommendations for addressing these. The quality management team at Infinity conducted internal audits to ensure compliance with the quality plan and resolve any comments arising from the external audits conducted by SA.

The redesign simplified and improved the constructability of the bridge as well as achieving more than 20% savings in tonnage in structural steel. The successful completion of the redesign required not only technical but also managerial and organisational competence from the consultant. Teams from several independent companies were involved, with each group interested in a certain aspect of the work. With the absence of a clear direction it was important for the design consultant to steer the process in order to derive maximum benefit for everyone involved.

Submission of the final 'issue for construction' drawings for the superstructure took place last month *(January)* putting the project back on track. The original contract with Atcon was terminated at the end of 2009. As *Bd&e* went to press, negotiations were under way to appoint a new contractor with the intention of completing the work on schedule before the end of 2011.

Owner: Government of Northwest Territories

Territorial advisors: BP Tech/TY Lin International

Concessionaire: Deh Cho Bridge Corporation

Prime consultant: Sargent & Associates

Engineer of record: Infinity Engineering Group

Peer reviewer: URS Corporation

Lender's consultant: CH2M Hill

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