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Only single-lane traffic can use the bridge

Construction has just begun on a project which will improve access for traffic to one of the largest natural gas reserves in British Columbia. **Raj Singh**, **Ken Rebel** and **Brian Taylor** report

A vital crossing of the Fort Nelson River which can currently only accommodate single-lane traffic is being upgraded to eliminate the bottleneck in an important transportation route for Canada's natural gas industry. The bridge crosses the Fort Nelson River in a remote region of the northern Rocky Mountains in British Columbia. It was originally built in 1984 and at the time was one of the longest bridge structures of its kind in the world. It is part of an important transportation route for the natural gas industry, but the fact that it is a single lane crossing has increasingly caused delays for traffic travelling to and from the Liard natural gas basin, one of the largest reserves in British Columbia. Vehicles often have to wait for traffic to clear in one direction before making their way across the 430m-long bridge.

The existing structure is a temporary steel Acrow bridge which has a timber deck and seven permanent piers, and was originally built from an ice bridge. In addition to the restrictions on traffic flow that the structure presents, it also has safety issues that need resolving. A condition inspection by consultant McElhanney in 1992 revealed an ongoing problem with top chord reinforcing bolts breaking, most likely the result of overtightening that caused tensile failure. The existing timber deck and cross-ties were estimated to have two or three years of remaining lifespan. The superstructure was found to be generally in good condition, as were the pier caps, pipe piles, concrete infill diaphragms, and abutments. The deficiencies revealed in the 1992 inspection were addressed by ongoing maintenance

A decision was made to strengthen the substructure and replace just the superstructure, and a key challenge was to ensure that the new bridge could be built within the short construction season of the northern climate. Durability and longevity of the bridge components were also important considerations in this climate, as maintenance demands have a high influence on the lifecycle cost.

To address the first challenge, the design approach was to minimise the extent and duration of field activities through a high degree of shop fabrication, and configuring components with repetitive details for ease of assembly and on-site installation. Another consideration in proportioning and selecting the bridge components was the location in relation to potential fabrication shops, as well as possible access routes, transportation limitations, and traffic restrictions.

A number of superstructure replacement options were evaluated for cost and constructability, as well as their suitability for northern conditions, durability, and risk. Steel girders were found to be more cost-effective than concrete girders for this particular span arrangement and site location. Given the relatively long multi-span bridge and limited in-stream access conditions, incremental launching was chosen as the preferred erection method rather than conventional crane erection which would have to be carried out from a temporary access bridge or ice bridge. Furthermore, steel plate girders with constant depth, or steadily changing depth to accommodate existing pier elevations, were found to be the best option in terms of weight and cost efficiency for the site.

Various options for the number of girder lines were also evaluated, in order to determine the optimal arrangement. While a four-girder option had the benefit of a shallower depth, this was not the preferred option as it would have required approximately 25% more steel. The optimal arrangement in terms of structural steel efficiency, as well as adding redundancy against collapse, was a three-girder line option. The resulting girder spacing provided sufficient room for inspection and maintenance access, which is a high priority for bridges in remote locations in the north.

With respect to the bridge deck, partial-depth and full-depth precast options were assessed, with the latter selected as the preferred solution. This method has the advantage that fabrication in a certified plant environment ensures a high quality product while minimising concrete cover, reducing the weight. Panels can also be produced and installed year round, ultimately increasing installation speed and significantly reducing on-site labour requirements.

At detailed design phase, an incremental launch erection procedure was set out, in which the girders and diaphragms would be assembled in a launch bed at one end of the bridge and progressively pushed over the piers to the opposite bank. Several options for launching the steel superstructure were considered, but the chosen method will be to make use of a relatively long launching nose. During assembly of the first few girder segments, based on the erection sequence assumed for design, a tapered nose will be assembled at the tip of the first girder segment to minimise the cantilever deflection, reduce construction stresses on the permanent girders, and provide clearance for the cantilever tip to land on the rollers atop each pier. The maximum deflection anticipated at the leading end of the first permanent girder, where the launching nose is connected, is 900mm.

Since the new bridge will follow the same alignment as the existing bridge, a solution was developed to eliminate the need to excavate a large section of the road to accommodate a launch bed. The two spans at the north end of the bridge cross land rather than water, and this means that crane access is possible for these two spans. Once they are in position, they will be used as an elevated launch bed. During construction it is proposed that additional temporary bents will be built at the most northerly span to support the girder segments as they are assembled; this could change depending on the contractor's preferred erection method.

The three steel plate girders will have a constant depth of 3m over the majority of the bridge, with the end spans transitioning to 1.1m to align with the top of existing abutment seats and the most northerly pier. The change in substructure elevations is due to the existing bridge switching from a double depth truss on the long spans to a single depth truss at the end spans. The three plate girders will have a constant spacing of 3.33m over the entire length of the bridge.

The fact that the two spans at the north end and one at the south will be configured with variable depth girders are a challenge for construction. Variable-depth girders are relatively challenging to launch and it is proposed that the end spans be installed by conventional crane erection. The raised height of the northernmost pier of the bridge will also demand a specific vertical jacking sequence when the girders are launched over the first two piers.

The launch procedure requires the underside of the bottom flange to be level over the full length of the bridge and the use of precast deck panels requires that the top flange be level over the full length. This eliminates the need to vary the haunch height in the field, but requires more effort fabricating the webs and flange-to-web welds in the fabrication shop.

Several specific details were incorporated into the girder design to simplify temporary equipment and allow the superstructure to be incrementally launched without overstressing the permanent components. Design details included a constant-width bottom flange to simplify the guide roller designs; a gap in the bottom flange splice plate to allow the rollers to pass through; a relatively stocky bottom flange to accommodate the high compressive stresses during the launch, and a constant-depth girder.

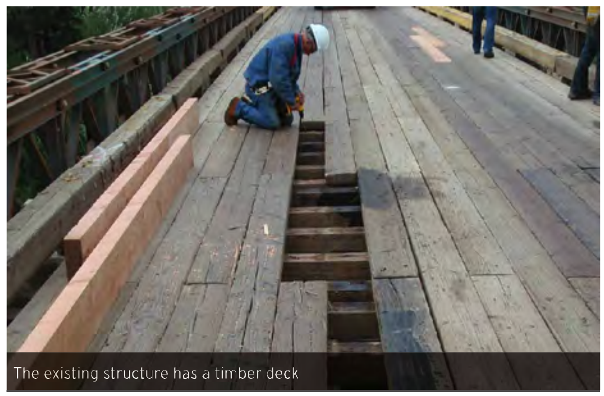
To tie in with the existing roadway alignment at the north end of the bridge while accommodating an increased design speed, it was necessary to begin the roadway spiral on the otherwise straight bridge. This required a variable super-elevation over a small portion of the bridge deck on a constant deck profile. To simplify both precast panel fabrication and girder fabrication, the super-elevation was accommodated by providing a vertical kink in the upstream girder at the start of the super-elevation change and casting a higher bearing pedestal at the northerly pier and the north abutment. This enabled all three girders to have similar haunch heights while avoiding the need to build special formwork for thicker precast deck panels or to form excessively high haunches that could become unstable during construction.

In keeping with the design philosophy of minimising on-site labour-intensive activities such as concrete casting, the deck was designed with mild-steel reinforcing without any prestressed or post-tensioned steel. A waterproofing membrane was also specified for the deck surface with two layers of asphalt and a stainless steel top mat of rebar. A wick drain will be installed beneath the asphalt wearing surface to allow any water to drain via small pipes embedded in the precast panels.

The new bridge superstructure, including the deck, will be continuous over its entire length, with expansion joints only at the abutments. This continuity will protect the girder system from the weather and improve the durability of the bridge while enhancing user comfort. Minimising joints further reduces the maintenance effort and thereby the lifecycle cost of the bridge. Additionally, disc bearings were deemed the most feasible bearing type because of their compact size, simplicity, relative lack of maintenance requirements, and ease and cost of replacement.

The articulation scheme was developed to minimise longitudinal pier deflection under braking loads, minimise restraining forces arising from expansion and contraction during temperature changes, and simplify bearing replacement. Piers two to five will be fixed in the longitudinal direction, making the point of fixity for longitudinal movement offset slightly from the middle of the bridge towards the south, and causing slightly larger displacements at the north abutment than at the south. The existing piers are extremely flexible in the longitudinal direction, requiring the engagement of four piers to resist the external longitudinal loads. The predicted longitudinal displacement at piers two and five, resulting from the extreme temperature differential, will be easily accommodated with minimal stress in the pier piles. The design also incorporates a bridge jacking and a bearing replacement scheme. Jacks will be placed in line with the girder centrelines for bearing replacement as opposed to jacking on the pier diaphragm.


The bridge was built in 1984 across the Fort Nelson River


The existing structure has a timber deck

The bearings will need to be slid upstream or downstream for replacement; since there is limited space on the existing piers outside of the exterior girders, the bearing design enables them to be removed towards the inside of the pier cap. The centre girder will not be restrained transversely at any of the piers.

Overall, the design process considered the site's extreme northern conditions in developing a cost-effective solution that incorporated an advantageous erection scheme. Maximising the use of shop manufactured modular components for faster on-site installation will ultimately result in a higher quality bridge with improved durability and reduced maintenance. Further, the bridge has a mild steel reinforced, full-depth precast deck which is continuous over its entire 430m length – one of only a few applications of its kind in British Columbia. The tender process for the Fort Nelson River Bridge took place last year, with client BC Ministry of Transportation & Infrastructure awarding the US$23 million contract to Forbes Industrial Contractors. Construction has just started and it is anticipated that the substructure strengthening and superstructure replacement work will take approximately two construction seasons to complete

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