Twinning of Stoney Trail over the Bow River in NW Calgary

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Abstract
Calgary's growing population led the Government of Alberta and the City of Calgary to begin planning for the Calgary Ring Road (Stoney/Tsuut'ina Trail) in the 1970s to improve community access to Calgary's roadway network. The recent opening of the last section of the Ring Road creates a 101km-long free-flow circuit around Calgary that reduces traffic congestion and improves commuter access to major road arteries to and from greater Calgary communities. The completion of the Ring Road included the twinning of the original 1997 Stoney Trail bridge over the Bow River which completed the northwest section of the road.

This paper will discuss the project to twin Stoney Trail over the Bow River which involves both road and bridge components, including the construction of a new five-span river crossing - a 470m-long bridge over the Bow River, directly west of the existing Stoney Trail bridge. The new bridge was segmentally cast-in-place using a balanced cantilever method. This means the superstructure was built out from each of the piers and abutments in six separate sections and joined together at completion.

Other aspects of the project include a single lane interchange bridge at Tuscany/Scenic Acres, associated collector-distributor roadway, and adding a lane to existing SB mainline to increase capacity. This work was to connect the newly twinned Bow River Bridge to existing sections of Stoney Trail to the north of Crowchild Trail with 3 lanes Southbound.

Figure 1 - New SB Stoney Trail Bridge over the Bow River

(photo credit – Stantec)

Introduction

In the 1970s, the Government of Alberta (Alberta Transportation and Economic Corridors [TEC]) and The City of Calgary (The City) began planning the Calgary Ring Road (Stoney/Tsuut'ina Trail) to accommodate Calgary's growing population. When completed, The Ring Road created a 101 km-long free-flow freeway around Calgary, reducing traffic congestion and improving access to major road arteries. The twinning of the Bow River Bridge completed the northwest segment of The Ring Road and provides an essential link to the southwest quadrant, which was the last component of The Ring Road to be completed around The City.

This project involved two components: design and construction of a collector-distributor road and bridge between Crowchild Trail NW and Scenic Acres Link NW, and the construction of a new five-span, 470m-long bridge over the Bow River, directly west of the existing Stoney Trail bridge (as shown in Figures 1 and 2). The new bridge used a segmentally cast-in-place, balanced cantilever method. This means the construction of the bridge's superstructure required cantilevering segments out from each of the piers to join opposing segments mid-span. Ninety-eight segments were cast and sequenced over a two-year construction period for the bridge superstructure. The bridge also required in-river work to build the foundations for two of the piers, as well as detours to the City of Calgary's pathway network to facilitate pier and abutment construction.

In addition to planning, design, and administering the construction of the bridge, the design team also provided hydrotechnical, geotechnical, and environmental support throughout the project. Working closely with the construction joint venture (Flatiron-Aecon Joint Venture [FAJV]) and the owner (TEC), bridge construction was completed over a 4-and-a-half-year period.

Figure 2 - New SB bridge open to detour traffic October 2023

(photo credit – Stantec)

The design of this project provided a methodical approach to the planning, design, and construction based on a thorough understanding of the overall project requirements and associated risks. This included careful consideration of all environmental constraints with clear objectives and managing project intangibles such as stakeholder engagement within established parameters.

A large infrastructure project such as this goes beyond servicing the community and City by providing a critical link in the provincial economic corridors system. Locally, the project connects the communities on each side of the river with enhanced pathways and improved access to Bowness Park, a highlight of Calgary's natural beauty.

First presented at the 2023 - International Bridge Conference in Washington D.C., this project has gone on to win awards from the Alberta Chapter of the American Concrete Institute (ACI) for the 2024 Award of Excellence in concrete, as well as the Consulting Engineers of Alberta Showcase Awards. This project also received the Alberta Transportation Minister's Awards for Transportation Innovation in Construction Innovation.

Completing a quality-built bridge of this complexity, especially during the COVID-19 pandemic, is evidence of the success the combined team brought to the project – some sense of the size of the site is shown in Figure 3. Over 750,000 hours were spent without a lost-time incident, high quality standards were maintained with limited re-work and claims, and with no significant impacts to the travelling public.

Figure 3 - SB bridge under construction September 2023 - four tower cranes!

(photo credit – Stantec)

Roadworks

This project twinned a final section of The Ring Road and widened an adjacent section of Stoney Trail to 3 lanes. To accomplish this, Component 1 removed the detour that southbound (SB) traffic had been using on the original bridge – traffic on the new bridge is shown in Figure 4. Additionally, a section of the southbound carriageway was built to tie to the new Highway 1 interchange. Component 2 involved the construction of a new collector distributor road from north of Crowchild Trail to Scenic Acres Link / Tuscany Boulevard, and the widening of the mainline SB to three lanes. This was accomplished with the addition of a one-lane bridge over Scenic Acres Link.

Further work was required to temporarily detour pathways on both sides of the river, resulting in a permanent set of stairs being built on the south side that was popular during the pandemic.

Road design was completed using guidelines[1] listed in references 1 through 3

Figure 4 - Looking South to new TransCanada Highway Interchange, October 2023

(photo credit – Stantec)

Foundations

The new Bow River crossing is a five-span bridge, with four piers that were founded on augered cast-in-place piles. Abutments were founded on a combination of driven steel piles and augured cast-in-place piles. The project required temporary realignment of the main river channel to install an in-stream cofferdam at pier two and a work berm for pier three – the berm and cofferdam at Pier 2 is shown in Figure 5. Hydraulic modelling determined the ideal placement of the piers and optimized the river channel for in-stream constrictions by factoring in seasonal flow fluctuations, flood, and ice events.

As part of the initial design investigations, a test pile program was used to confirm bearing capacities in the substrata below the bridge. This program allowed for a reduction in number of piles required for the final design.

A 3m deep pile cap is built at each pier to distribute the pier loads onto the piles. Each pier column was built above the pile cap in five lifts to achieve the 30m height. Both the pile caps and pier columns required cooling to meet mass concrete requirements. The cooling water was allowed to adjust to ambient temperature in ponds on-site before being released into the Bow River.

The abutments for the bridge were built with a roof slab section to allow for access into the superstructure and an approach slab to address long-term settlement in the approach roadway structures.

Figure 5 - Temporary berm and cofferdam facilitating the construction of Pier 2

(photo credit – Stantec)

An additional tangent pile retaining wall was built into the south slope of the river above pier 1. This wall was built using tiebacks and was used as part of the construction phasing but was ultimately installed to reduce the lateral loading from the south slope onto the pier 1 structure and is completely buried in the final grading.

Environmental

Working in the environmentally sensitive Bow River basin required working with TEC, diverse regulators including the Department of Fisheries and Oceans, Alberta Ministry of Environment and Protected Spaces and Transport Canada – Navigable Waters, as well as FAJV and their group of consultants. It took a multi-disciplinary team working across sectors to complete the numerous pre-construction deliverables for regulatory approvals. Key accomplishments included guiding FAJV through final revisions of their Environmental and Construction Operations (ECO) Plan and assisting FAJV in making the construction site compliant with regulatory approvals and authorizations.

We are always at the mercy of nature and its challenges. Obstacles included multiple stakeholders, timelines within which construction had to start, environmental and regulatory timelines (for example, only short timeframes were available to install and remove temporary in-stream berms) and fluctuating early spring weather conditions. One of the biggest challenges was the complexity of the site, working in the Bow River basin, an environmentally and publicly accessible location in one of The City’s most sensitive areas. A true test was the first unexpected external audit in which the project site and personnel did extremely well, proving our efforts paid off.

The new bridge is designed to keep roadway water (including de-icing salts and grit) from draining directly into the river; we also modified the existing bridge during the deck rehabilitation to remove deck drains that had been draining roadway water directly into the river. We were able to direct the roadway water from both bridges into a stormwater pond that will allow grit to settle and salts to dissipate. The City of Calgary has implemented a monitoring and remote-control system for the stormwater ponds, allowing for remote closing of the outfall gates and preventing accidental hazardous material from flowing into the river.

The balanced cantilever construction method minimized impacts to the river ecosystem and provided a reduced construction footprint, leading to less ecological restoration required when construction was complete. To compensate for the loss of fish habitat from the in-stream construction of berms and caissons, an existing snye (backwater) was improved to promote fish activity and breeding.

In the 2022 flood season, the Bow River flows were forecast to overtop the construction berms, and as a precaution, all equipment was moved to higher ground proving emergency plans were effective and implementable to protect the environment. By finding unique solutions to environmental challenges, such as using a circular cofferdam which required nearly zero de-watering, we helped set new standards for future projects of its type—those with massive concrete construction in an environmentally sensitive setting.

Superstructure

With spans over 100m, six-meter-deep trapezoidal girder sections were required for this bridge. The existing structure used similar trapezoidal girders but was incrementally launched with temporary piers to reduce the launch cantilever. During design development, possible construction methods were reviewed with five contractors and the cast-in-place segmental balanced cantilever method was selected instead of launching, as the bridge was too short to be economical for precast segmental construction. Ultimately a balanced cantilever method was used to cast the superstructure in place.

Once the piers were constructed to the underside of the superstructure, the first sections of the superstructure were built over the piers, referred to as the "pier tables". The pier tables were temporarily supported by large pipe columns referred to as stability props, to provide a wider base of support for the balancing of the cantilevered superstructure sections – as shown in Figure 6.

Figure 6 - Stability props at pier 3, Summer 2022

(photo credit – Stantec)

The balanced cantilever construction method used is rare for Alberta, as the technique is optimal for the construction of multiple 100m span bridges; note – most 2-span interchange bridges in Alberta are 100m. The concrete superstructure segments were cast in a balanced sequence over each pier, with each un-cast segment supported by a form-traveller formwork system that was launched after the previous segment was cured and post-tensioned. This process was repeated until each opposing segment met at mid-span and was joined; the sequential stressing of both transverse and longitudinal post-tension tendons was a critical aspect of the structure construction and segmental sequencing. The casting of each of the 98 segments was completed in one monolithic pour; the bottom slab (soffit) was cast first and allowed to set, thus creating a "plug" to support the subsequent vertical webs cast in even lifts, followed by the deck slab. Each segment required approximately 100m^3 of 55 MPa High-Performance Concrete. Once the opposing cantilevers were built out to within a last segment of each other, steel girders were attached to both sides of the closure pour to provide stability to the section while the concrete cured. Once at strength, the full span was post-tensioned to provide continuity to the superstructure.

Designing the sequential staged construction for each step of the balanced cantilever process was a challenge that required detailed analysis and innovative thinking to manage principal tension in segment webs, bearings and deck movements, and alignment correction forces. Construction challenges required continuous survey of geometry to control and adjust formwork settings to ensure cantilevered segments stayed within tolerances and unbalanced loading was managed prior to each concrete segment pour. Managing mass concrete hydration temperatures required an innovative approach for cooling the mass concrete pours for the pile caps and piers. An environmental sustainability manifold and re-circulation of river water system was implemented, explained in detail below.

During design, significant efforts were made to analyze and design the structure for both temporary and permanent loading conditions. During construction, surveys of pre-pour, opposing cantilevered, and post-pour segments were completed daily with survey data factored and adjusted to account for temperature effects on steel stability props at the piers to ensure that each cantilever alignment (vertical, horizontal, and twist) was managed as the cantilevered segment extended up to 50m to mid-span where it would tie into the opposing segment within a 25mm tolerance – Figure 7 shows one of these aligned closure pours.

Figure 7 - Preparing for closure pour, span 4 - Summer 2022

(photo credit – Stantec)

With limited time for construction each year (as winter construction of the segments was not economical), cycling of the formwork and segment pours remained a critical path item throughout the two-year superstructure construction phase. To maintain the schedule, four cantilevers (extending from two piers) with two concrete segment pours were cycled each week from March to October – Figure 8 shows a view of the traveller formwork from inside the adjacent segment. Additionally, to maintain schedule, FAJV received buy-in from the various suppliers to work 24 hours per day utilizing day and night crew shifts – with day shifts preparing formwork and advancing segments and night shifts pouring concrete. An interconnected system of smart thermometers and sensors was used to monitor concrete temperatures during the curing of segments in cold weather conditions and in mass concrete. Overall monitoring reports were generated at the end of each week to manage and monitor quality.

Figure 8 - Inside the Traveller Formwork

(photo credit – Aecon)

Because this project was unusual, it allowed for advancements in engineering and construction experience in Alberta. The sheer size and magnitude of the Bow River Bridge required a joint venture between two large contractors to execute the work, plus the involvement of a cantilevered bridge specialist who has constructed balanced cantilever bridges all over the world. The specialist provided critical guidance such as advising on the critical steps in geometry control during the pre and post concrete casting of cantilevered segments. A view of the cantilever over the river is shown in Figure 9. The design team also supported the client through a four-year design development process that required extensive coordination with multiple consultants planning and constructing this important link in the Stoney Trail Ring Road.

Design of the bridge structure was based on codes[4] listed in references 4 through 9.

Figure 9 - Span 3 at maximum cantilever over the river in late summer 2022

(photo credit – Stantec)

Restoration of the existing northbound (NB) Bridge

Once the new SB bridge was complete, NB traffic was detoured onto it, along with 2 lanes of SB traffic. During this detour, modifications to the existing NB bridge were made. The median barrier was removed to facilitate northbound only traffic, and deck drains were removed to prevent road drainage from entering the Bow River directly. Lastly, the Polymer Modified Asphalt (PMA) wearing surface was removed. Because the PMA was only 50mm thick, a thinner waterproofing layer was required, and a 4-part methyl methacrylate (MMA) system was installed. The existing bridge deck surface condition was too rough for the MMA, significant cleaning of the deck was required. Patching of the rougher sections required significant unexpected work but ultimately led to a satisfactory preparation that allowed for the MMA and asphalt wearing surface to be installed.

Figure 10 - Traffic shifted to new SB bridge to facilitate restoration of NB deck - October 2023

(photo credit – Stantec)

Conclusion

This project began in 2014 with a Request for Proposals from TEC. Once selected, the design team began the process to get to the bridge we see today. This process included budgetary decisions that led to a few starts and stops, but ultimately led to Tender closing in 2019. Construction started soon after and was complete in November 2023, as shown in Figure 10. Plainly put, this project took a long time to design and build. The design of a cast-in-place balanced cantilever superstructure is complicated, and building it is even more complicated in our northern climate.

With such a long development period our team unexpectedly evolved. The design team embraced these changes and viewed them as opportunities for improvements rather than setbacks. The team was able to transfer knowledge while maintaining clear lines of communication ultimately benefited the project, even as personnel retired, changed careers, and moved to other opportunities. Staffing changes remained a challenge throughout the project but were navigated successfully and bolstered by those individuals who were involved in the project from the beginning of its design and construction, providing stability and continuity. Partnering was a big part of the success and in March 2024, this project was awarded a Partnering Award at the Minister's Awards Ceremony as part of the Transportation Connects Conference in Edmonton.

Meeting the client's key objectives for the construction of a twin bridge posed considerable challenges to match an aesthetic similar to the existing structure while adhering to their specific criteria. The goals were to emulate pier spacing, minimize impact on river hydraulics, and create a larger trapezoidal girder section without deviating noticeably from the original bridge. The design team successfully designed a twin bridge so closely resembling the original that, without knowledge of existing bridge construction details, one would assume they were constructed simultaneously – as shown in Figure 12.

The project faced formidable hurdles, including a lengthy schedule, a significant budget, and environmental limitations, compounded by access challenges through Bowness Park and the use of a rare construction method. Unforeseen complications arose during construction when the owner initiated an interchange project south of the Bow River Bridge, not accounted for in the initial 2018 design tendered in 2019. The design and construction team adapted to these changes to ensure a comprehensive roadway connection for the new TransCanada highway interchange.

Figure 11 - Detoured traffic on new SB bridge, looking downstream on the Bow River towards downtown Calgary

(photo credit – Stantec)

Notably, the project navigated the unique challenges posed by the COVID-19 pandemic, implementing strict protocols for the safety of hundreds of workers involved in the construction, from shifts in lunch trailers to health checks and monitoring protocols. In the realm of infrastructure projects, the distinct challenges faced and conquered by this endeavour, including pandemic-related obstacles, contribute to its standout status within the field of bridge engineering.

On a personal level, the most meaningful aspect of the project for those who worked on it often lies in its unique engineering elements, particularly the rarity of bridges with girders of such magnitude. Walking inside the bridge evokes a sense of awe, emphasizing the project's size. Despite the complexity of managing multiple simultaneous work zones, such as constructing four cantilevers simultaneously for two seasons, the site maintained exemplary safety standards and was successfully closed without a lost-time incident. The gratification of opening lanes to traffic and achieving a major portion of an over 50-year municipal vision, coupled with the memorable experience of waving to the first cars on the new bridge, further emphasizes the personal and broader significance of this infrastructure project and the communities it touches – the prominence in the Calgary landscape is evident in Figure 11. The traveling public will see a tangible efficiency gain in the Calgary roadwork network, as the twinned bridge facilitates the speed limit to be safely increased to 100kph through this section of The Ring Road.

Figure 12 - Twinned bridges from pathway view - October 2023

(photo credit – Stantec)

References

[1] Alberta Transportation, “Highway Geometric Design Guide” (2004)
[2]Transportation Association of Canada, “Manual on Uniform Traffic Control Devices for Streets and Highways” (2009(
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[9]Post Tensioning Institute (PTI) and American Segmental Bridge Institute (ASBI), "PTI/ASBI M-50.3-12 Guide Specification for Grouted Post-Tensioning", U.S.A. (2012)