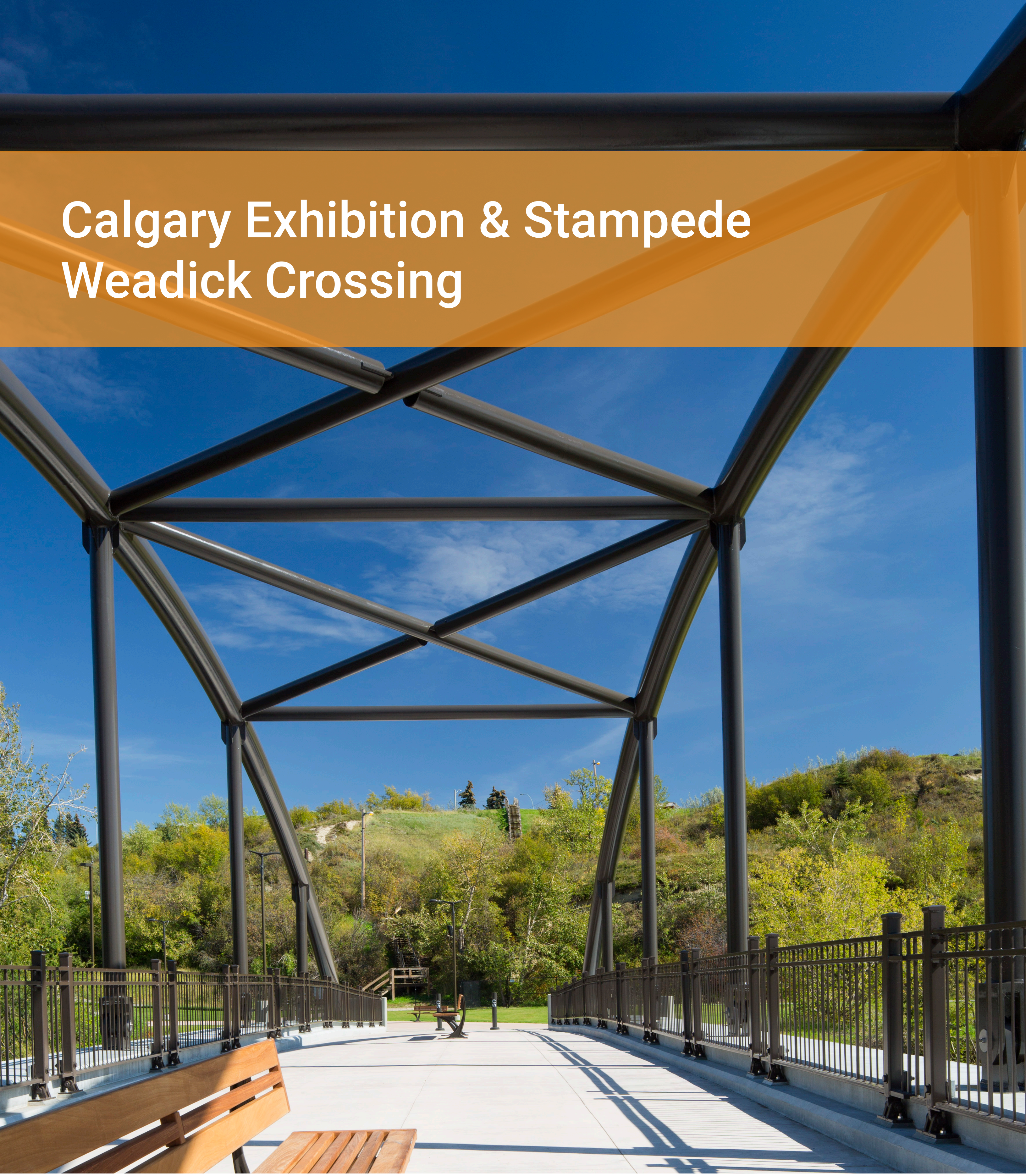
Calgary Exhibition & Stampede Weadick Crossing



Creative Thinking
Practical Results

rjc.ca

Submitted by:

Read Jones Christoffersen Ltd.
Calgary, AB

This project was completed in cooperation with:

Calgary Exhibition & Stampede
Owner

Read Jones Christoffersen Ltd.
Prime Consultant and Bridge Engineer

Lawson Projects
Project Manager

Amec Foster Wheeler
Hydrotechnical Engineer

Designcore Engineering Ltd.
Electrical Engineer

Graham Construction
General Contractor

Planning a New Gateway

Stampede Park is one of Alberta's most well-known and beloved cultural institutions. The Stampede grounds are a year round world class destination, with a wide variety of facility types supporting an even wider variety of events, culminating annually in the famous ten day Calgary Stampede!

The Stampede Board's vision for the Park's development is 'to continue to evolve Stampede Park into a year-round community hub in the heart of Calgary.' The Stampede has embarked on three key developments to support this vision, the Youth Campus, ENMAX Park, and the Agrium Western Event Centre.

The ENMAX Park project is a 30 acre parcel of land along the east bank of the Elbow River that Stampede Park plans to develop into a beautiful inner city park. From the moment visitors enter, the Stampede wants them to feel connected to Calgary's western roots.

One of the ways that visitors would be able to access this future park was by crossing the former Blue Bridge located behind the Saddledome. The Stampede wanted to increase pedestrian traffic across this bridge, and wanted to ensure people's safety, and that the crossing reflected the values and feelings of the Stampede.

Recognizing from inception of the plan that the previous Blue Bridge in its then current state would not suffice, Read Jones Christoffersen (RJC) was engaged by the Stampede to begin a project that would culminate in a new bridge, named after one of the Stampede's founder, Guy Weadick.

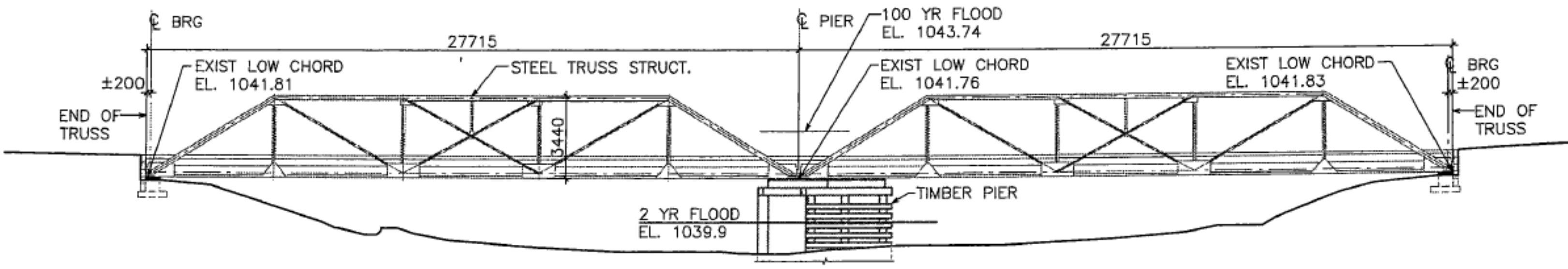
History of the Blue Bridge

The former Blue Bridge over the Elbow River was a pedestrian crossing used by Calgary Stampede employees to access a utility and maintenance building on the east side of the Elbow River. The bridge was also used by pedestrians (walkers and cyclists) using the pathway system on the east bank of the Elbow River.

The bridge spanned approximately 54 meters abutment to abutment and was a 2-span pony-truss bridge made up of riveted steel trusses, timber wood deck, timber pier with wood piles and timber lagging abutment walls with shallow concrete spread footings. All of the steel in the bridge dated back to the early 1900s, and many elements were repurposed from other locations, including the steel pony trusses and many of the large wood deck beams.

Investigation of the Blue Bridge

RJC's involvement began in 2011 with the structural investigation of the wood pier and wood piles of the Blue Bridge. The Stampede wanted the bridge investigated to determine its safety and any maintenance or repair strategies that should be completed. The investigation determined that the wood pier was deteriorated and at the end of its serviceable life. RJC recommended that load



restrictions be put in place, a sign communicating this was posted by the Calgary Stampede. The investigation also determined that the bridge required rehabilitation or replacement, with more robust construction to meet current standards and loading.

Rehabilitation of the Blue Bridge

RJC was engaged to produce contract documents for the restoration and rehabilitation of the Blue Bridge. Major consideration was given to flood forces as the bridge was located in the floodway below the 1:100 year flood level. Major regrading or access structures at the banks was not an option due to potential impacts to adjacent facilities, so the bridge had to remain at original elevation in the floodway and be upgraded to resist forces due to flood events.

The project sope included maintaining the existing pony truss, with structural upgrades to resist flood forces. This involved lateral bracing in the deck, combined with local bracing of the bottom chord of the pony truss. Replacement bearings were designed for 1-in-100 year flood loads. For the existing shallow footing abutments, added weight and area was recommended to resist flood loads.

A new in-stream concrete pier and concrete pile foundations were also recommended. The pier was designed to have a rounded nose to reduce resistance to flood flows..

The rehabilitation of the Blue Bridge went for tender in the early spring of 2013. Unfortunately, due to a review of available funding the Calgary Stampede was forced to halt the project during the tender with the intention of re-tendering the following year.

Due to the poor condition of the wood pier, RJC was engaged again to investigate and monitor the bridge on a regular basis and to advise if the bridge required closure at any time due to high river flow events. Visual inspections were conducted regularly of the pier and piles, as well as a review of survey

information checking for overall bridge movement. AMEC Earth and Environmental were also engaged to monitor water levels and alert RJC of high-flow warnings.

June 19, 2013

June 19, 2013 is a date many Albertans will remember for the rest of their lives, particularly those who were directly impacted by the flood waters that caused mass destruction that day. The entirety of the Calgary Stampede grounds, like much of downtown Calgary, was heavily flooded.

The existing Blue Bridge was washed out to be found wrapped around the pier of the Saddledome Access Bridge a few hundred metres downstream. The Blue Bridge's shallow concrete abutments remained in place, but the bridge had been lifted off its bearings. The wood piles at the midspan pier were sheared off close to the river bed.

With the 101st Calgary Stampede set to open in just two weeks, the Stampede was rapidly in repair and recovery mode for the entire park.

Weadick Crossing 2.0

After the 101st Calgary Stampede was celebrated (with a new theme 'Come Hell or High Water!') the Stampede

began looking at options for the replacement of the Blue Bridge. In the fall of 2013, RJC was engaged as the Prime Consultant and Bridge Engineer to begin developing concepts for the new bridge. Considerations for the new bridge included:

- A clear span across the Elbow River for 46.5 metres to avoid having a pier in the water
- A structure that would allow the elevation of the bridge deck to be as close as possible to out of the 1 in 100 year flood elevation – while still being code compliant for slopes for pedestrian access without major access structures.
- A structure with robust elements that could withstand flood impacts
- A design with some height and pageantry to compliment the festival and exhibition flare and style of the Calgary Stampede.
- A design that felt like a gateway between the ground and the new Calgary Stampede park space on the east bank of the Elbow River.

RJC developed numerous bridge concepts with these considerations in mind. The concepts included mobile, lifting and submerged type bridge structures. The concept selected is a steel through arch bridge supporting a concrete deck that would be partially submerged during flood events.

Gravity System

The bridge had to support a variety of uses including pedestrians, horses and riders, and maintenance vehicles. Because of people crossing the bridge on horseback, a 16 foot clearance to overhead structure was required. This resulted in relatively long, unbraced lengths for the tubular steel arch.

The arch design is extremely effective at balancing loads and minimizes flexural load effects. Under unbalanced loading such as moving pedestrian loads, construction loading etc., flexural load effects are maximized.

The bridge's concrete deck has a 5m clear width to accommodate pedestrians, horseback riders and maintenance vehicles. The deck is hung from the steel arch using tubular steel sections selected for their resilience against flood debris when compared to lightweight hanger rods or cables. The deck does not act as a tension tie for the arch as it is isolated at the locations where it passes through the deck. The horizontal thrust from the arch is taken out at the abutments. The one way slab spans transversely to continuous edge beams supported from hangers and the arch.

The 'clean' soffit profile of the concrete deck minimized depth and reduced resistance in the floodway. The resulting concrete deck was more challenging to

to construct than a typical concrete bridge deck supported on steel beams on hangers, but it was the right solution for Weadick Crossing given its floodway location.

The ends of the arch were designed as fixed moment connections. Anchors at these baseplates were tensioned for the resulting maximum flexural stress on the baseplate. This engaged the full stiffness of a moment connection – which was modeled in an analysis.

The foundations for Weadick Crossing are concrete abutments on deep large diameter concrete piles. The piles had to carry both gravity load as well as significant lateral force from the arch thrust, resulting in shear and flexure on the piles.

Lateral System

The lateral loading considers wind, flood and earthquake forces. The concrete deck and edge beams spanning between shear pins at each abutment create the main lateral resisting system. Wind load on the steel arch itself

is mostly shed to both the concrete deck and into the abutments, as well as directly into the moment connected baseplates at the abutment.

The concrete deck has a total of eight sliding neoprene bearings (neoprene with mirror finish sliding surface), four are on the abutments and four are on the arch itself. The bearings act as a true 'roller' support. Lateral movement is restricted by the steel arch and hangers, and through the use of the shear pin on each abutment. The shear pin is a short HSS embedded into the concrete abutment. It allows longitudinal thermal movement but limits lateral movement due to applied wind, flood or earthquake loading. The arch hangers have a pin connection to the deck allowing longitudinal movement due to temperature changes.

The longitudinal lateral resistance due to earthquake loading was a recognized challenge. The articulation of the deck was designed to allow longitudinal thermal expansion and contraction of the concrete deck. During longitudinal earthquake loading, the deck was projected to move upto 40mm in each direction before engaging a shear pin. This 40mm of longitudinal movement induces flexure in the hangers and the arch. The tensile and flexural stress on the HSS to HSS connections required reinforcing of the connection with stiffeners to prevent chord yielding.

Given the history of the previous bridge structure at this location, flood resilience was of absolute importance. To mitigate flood impact, the bridge deck is heavy and

streamlined. The ends of the arch are concrete encased, with added redundancy incorporated into the design by allowing for one broken hanger to not cause collapse. In addition, an innovative fold-down guardrail system was designed, in the case of flooding the guardrails fold down to help decrease resistance.

Design of the HSS arch was governed by the combined compression and biaxial bending of the HSS. The compressive capacity of the arch was reduced for its effective length. Determining the effective length of arch was a very similar process to what is used to determine the effective length of a pony truss. For Weadick Crossing, lateral support to the compression chord is provided by the stiffness of the out of plane flexure of the hangers and the flexural and torsional stiffness of the concrete deck. The arch was designed to be laterally stiffened by the HSS hangers in the out-of-place direction. Hangers were designed for moment due to bracing forces in the out of plane direction, while a pin allows for rotation in-plane for thermal expansion/contraction of the concrete deck and arch.

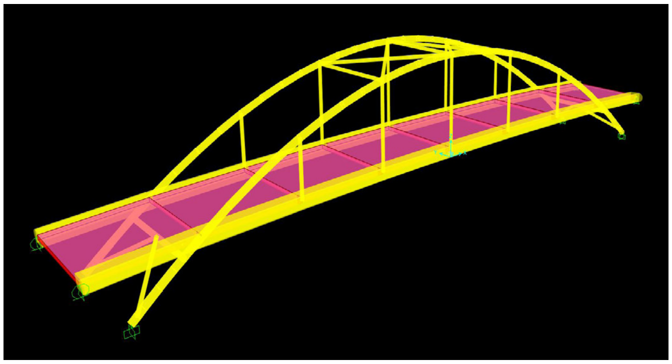
The effective length of the arch was determined from the Euler buckling load, determined using the non-linear buckling analysis in SAP2000, which provides a factor for each buckling mode. The compressive load on a member is multiplied by the factor to determine the Euler buckling load, with >1 indicating that buckling is not occurring. From this, the Euler buckling stress was determined. An equation for compressive resistance was applied to determine the compressive resistance of the section.

As the arch depends on the hangers and therefore the stiffness of the concrete deck for lateral stability, the temporary construction coordination was identified as a key challenge.

Construction

The project was tendered with the design at approximately 40% completion so that firm construction budgets could be carried in the Stampedes capital planning process. Graham Construction (Graham) were the successful contractor and were engaged to provide constructability input to the final design.

Construction for structure was more challenging than most because there was no concrete deck or edge beams to provide lateral support to the arch during construction. Because of this, its unsupported length was increased and its compressive capacity decreased. This was a challenge because it was still required to carry the full concrete deck dead load, the construction live load and limited wind



loading during construction.

The first consideration for erection of the arch was lifting it onto the abutments. A temporary tension tie cable was added from baseplate to baseplate on both arches, which acted to resist the outward thrust of the arches during the lift. Following landing on the abutments, the anchors were pre-tensioned as specified using a turn-of-nut hydraulic jack prior to the placement of the concrete deck.

RJC collaborated closely with Graham to carefully consider how to construct the concrete deck, various options were considered including to completely support the concrete pour off shoring on the ground. The pros and cons of this option were:

Pros:

- No construction loading applied to the arch, no specific requirements for strengthening the arch.
- Design of falsework remained in the contractor's scope of work

Cons:

- Required extensive berming into the Elbow River which would require permitting.
- When the falsework was removed, the arch would deflect under dead load to its in-service profile
- mposes deflections and stresses on the concrete deck and edge beams as they were cured at a profile prior to the arches deflection under dead load.

Together, the team determined that the preferred option should allow the arch to deflect under the weight of the wet concrete and for the concrete to cure its in-service profile.

Through multiple iterations with Graham and their temporary works engineer, a solution was reached. RJC designed temporary cabling and support elements to supplement the missing stiffness of the concrete deck; this system would maintain the compressive capacity of the arch to carry the temporary construction loads, even without the deck in place. This system was cost effective, and easy to install without interfering with Graham's concrete deck falsework system.

Graham worked with their temporary works engineer to design a falsework system that was supported off the arch hangers, therefore moving the arch as it deflected under the dead load. Unfortunately however, due to a restriction in the capabilities of the falsework system, shoring off the ground was required to be used in the end spans in order to support the deck pour.

To maintain a balanced loading on the arch structure, a 3 stage pattern concrete pour was used. Concrete was placed in Pour 1 first, at the centre of span, which deflected the centre downward and the outside of the arch upward, imposing the resulting flexural loading. On the same day, concrete was placed in Pour 2 at the abutment ends of the deck on the shoring required by Graham.

The concrete from pours 1 and 2 was required to develop seven day strength before the shoring was lowered in order to load the arch and balance the load of the concrete pour at midspan. The length of the Pour 2 was coordinated so that no cracking would result from supporting its own dead load. Following Pour 1and 2, Pour 3 was incrementally poured from 1 towards 2 in lengths no greater than two meters to control un-balanced loading on the arch.. Critical to success was making sure that the loading on the arch remained as balanced as possible to limit flexural stresses while the compressive load increased.

Weadick Crossing

Weadick Crossing opened in June of 2015, just in time to welcome the world to the 103rd Calgary Stampede. The new bridge meets all of the Stampede's requirements. It is more durable, flood resistant and environmentally friendly than the previous bridge. It also considers the Stampede's heritage and unique uses, with features such as the bracing members on the bridge being high enough above the bridge deck to allow horseback riders to comfortably pass below the bridge structure.

The bridge is a single span steel arch bridge spanning 46.5 metres, abutment to abutment. Since it is supported on each bank with no pier in the water, it is less invasive to the river and there is no obstruction for rafters who frequently float down the river on hot summer days. The design also respects the Elbow River's brown trout population; it is much more compatible to the fish and wildlife habitat than the former 'blue bridge.'

To resist the potential damage of flood impacts, the new bridge has a concrete filled steel tube below flood level to help combat impact damage on the steel arch section. The bridge deck is also slightly higher than the previous bridge deck. With the new bridge, the 2013 flood would have only touched the face of the deck edge beams, and with no pier in the river there is nothing for floating materials to get caught on. To further prevent flood impact, a unique feature of the bridge is the design of the deck and hand rails which allows them to fold down. This will allow floating debris to pass over the bridge and lessen the chance of materials in the river getting caught on the structure.


rjc
Creative Thinking
Practical Results