Circle Drive Widening

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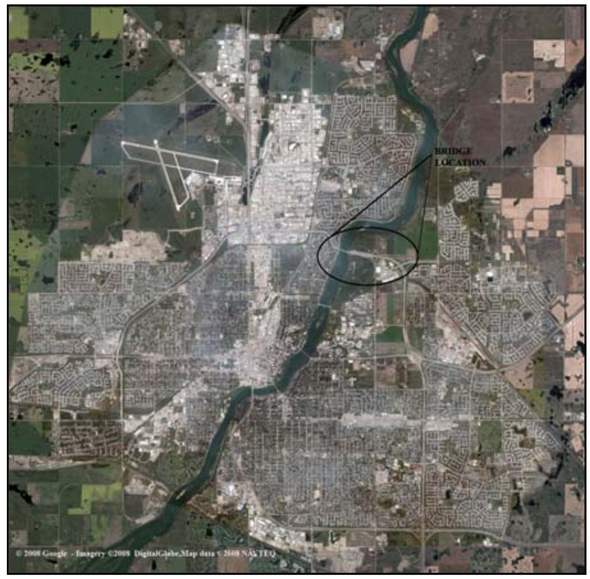
1.0 Project Overview



Circle Drive from College Drive to Millar Avenue, including the Circle Drive Bridge was opened to traffic in 1983. Since the opening, the City of Saskatoon has experienced considerable growth especially with residential development in the northeast combined with employment growth in the northwest areas. This development has caused increased traffic demands on the existing northern section of Circle Drive including the Circle Drive Bridge. In order to accommodate this growth, the City implemented a considerable number of improvements along the Circle Drive network that include interchanges at:

- Circle Drive at College Drive;
- Circle Drive at 22nd Street;
- Circle Drive at Attridge Drive; and
- Circle Drive at 8th Street.

These capacity improvements have improved traffic flow, however, with each improvement; shortcomings of the remaining network became more apparent.

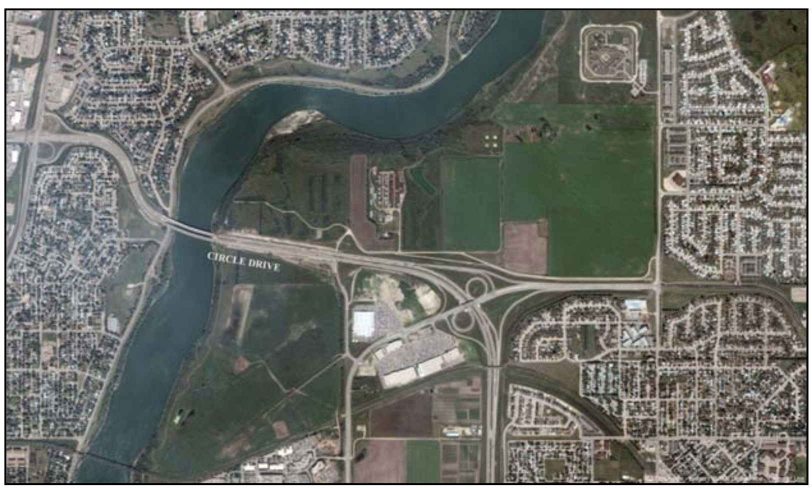


Figure 1.1 – Project Location

The objectives of this project were to provide an additional lane of traffic in each direction from Millar Avenue to Attridge Drive which would complete the capacity improvements available on the Circle Drive network in this area. Challenges presented to the City in attaining this goal included:

- Widening a major river crossing (Circle Drive Bridge); and
- Completing the project while minimizing the impact construction would have on the traveling public.

The Circle Drive Bridge is one of 5 major river crossings in the City of Saskatoon. The structure configuration consists of twin 5 span steel girder structures with a total span length of 275 metres supporting 2 lanes of traffic plus a sidewalk in each direction, Figures 1.2 and 1.3. In 1983, future capacity improvements had been expected and had been included in the original design by providing additional pier and abutment elements plus connection points between the two structures to permit in-filling of the space as shown in Figure 1.4.

2.0 Technical Challenges

Current traffic patterns and growth projections along Circle Drive from Attridge Drive to Millar Avenue were analyzed to provide an understanding of how this section of roadway was performing. Results suggested that a large percentage of the traffic enter and exit Circle Drive between the Warman Road and Attridge Drive Interchanges. It was identified that widening to the outside would allow the direct connection of the ramps of these two interchanges, eliminate the need for major changes to the roadway pavement markings, provide for cleaner traffic accommodation during construction and avoid interruption to the existing median drainage. However, since the bridge was designed with provisions to widen to the middle, the drawbacks inherent to widening the road to the middle were considered inevitable during the preliminary stages of the project.

Figure 1.2 – Circle Drive Bridge

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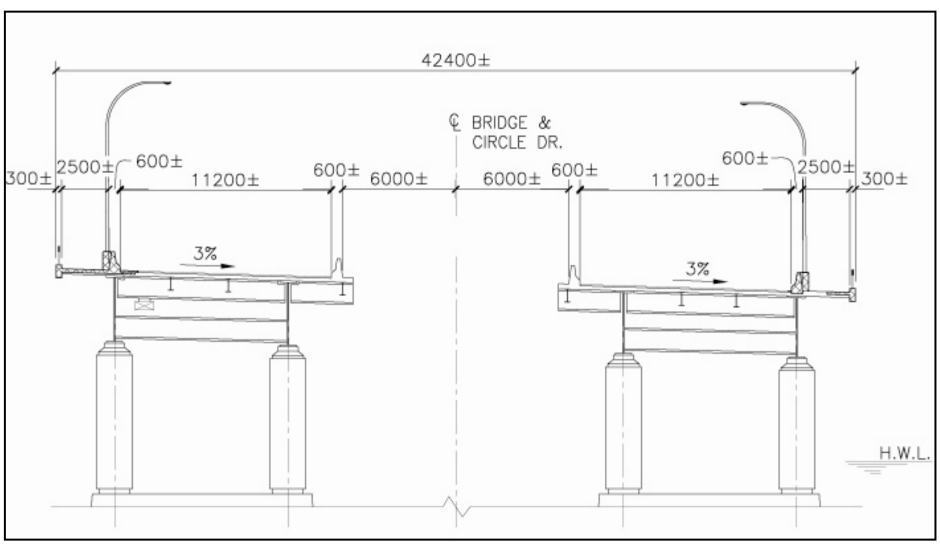

Figure 1.3 – Circle Drive Bridge – Existing Cross Section

2.1 EXISTING CONDITIONS

The Circle Drive Bridge had been in service since 1983 and during this time no significant maintenance or rehabilitation had been completed except for a partial mill and replace of the wearing surface in the traveled lanes in 2003. Therefore, an extensive visual inspection of the bridge structure was completed in order to identify any issues that may exist which should be addressed with the work required to widen the structure. In addition to the visual inspection results, a structure assessment report completed in 2004 was available which provided insights into the state of the structure and its age relative to its remaining service life.

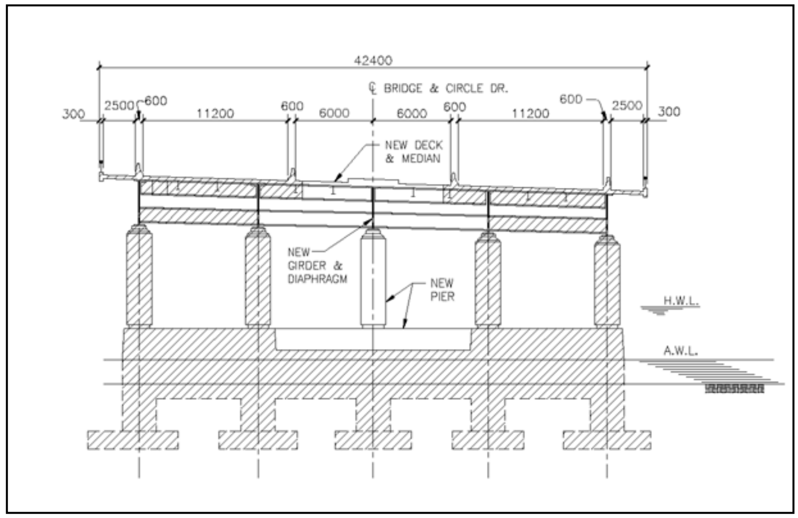

Figure 1.4 – Original Widening Proposal

Detailed visual inspections covered all accessible portions of the structure but focused on areas adjacent to the proposed expansion, that is, the space between the two structures. Visual inspection results painted a picture of a structure showing early signs of deterioration consistent with the age and design of the structure that included:

- White stained cracks on the deck soffit in the negative bending moment regions;
- Extensive delaminations on the traffic barriers and curbs;
- Misaligned deck joints;
- Expansion joint trip seals split and torn in many locations;
- Teflon sliding surfaces debonded on the eastbound structure pier bearings at Pier 1 South Bearing and Pier 3 North Bearing; and
- Regular transverse asphalt cracks evident in the shoulders.

Figure 2.1 – Existing Condition

A detailed deck condition survey had been completed on this structure in 1999 and 2004 as part of an annual deck testing program conducted by the City of Saskatoon. The intent of this program was to identify the rate at which chlorides were impacting the structure and to develop potential rehabilitation strategies that would maximize the service life of the structure.

Testing completed in 1999 and 2004 included:

- Half cell equipotential surveys;
- Delamination testing;
- Chloride testing at the 12.5, 50, and 100 mm depths; and
- Rebar cover measurements.

Visual and test results suggest the membrane is reaching the end of its service life as chloride levels had increase between the 1999 and 2004 measurements and white stained cracks were evident on the structures soffit. Corrosion activity also appeared to be increasing parallel with the chloride contamination. However, this observation was felt to be misleading due to the presence of an epoxy coating on the reinforcement which can cause regions of apparent high negative potential due to the insulating effects of the undamaged epoxy.

2.2 SERVICE LIFE ASSESSMENT

With the capital expenditure being considered in widening the bridge, a complete service life assessment was deemed necessary in order to confirm the rehabilitation strategy for the existing structure and to ensure that widening would not affect the overall performance of the bridge. Service life models used in the evaluation were based on a combination of a multi-mechanistic model and the Alberta Infrastructure Service Life Model both of which were modified to address the variability related to service and life cycle cost prediction.

Modifications to the service life models were limited to identifying ranges of expected remaining service lives rather than single point estimates. Estimates for repair timing, remaining service life, repair costs, and repair quantities were developed using the modified models, expert opinion and knowledge gathered from recent research compiled on service life estimation.

Timing and cost ranges developed were then input into a life cycle costing model linked to a Monte Carlo simulation environment. This simulation process allowed multiple combinations of service life and cost to be combined in a probabilistic manner thereby allowing relative risk to be assessed between options over a wide range of scenarios. Simulations included calculations for 5,000 different combinations of cost, timing, and repair quantity with analytical results graphically presented below in the form of a cumulative probability distribution curve. Analysis conclusions suggest the widening project would not significantly change the rehabilitation strategy for the bridge which currently identified a major membrane replacement and deck rehabilitation for 2014.

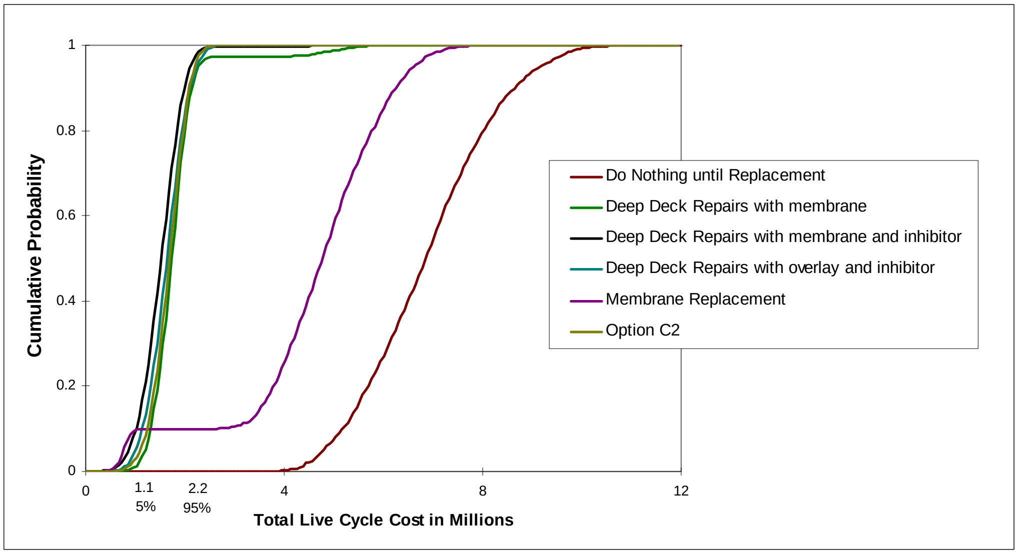

Figure 2.2 – Monte Carlo Simulation Results for Widening Rehabilitation Scenarios

2.3 WIDENING OPTIONS

The bridge structure, prior to widening, consisted of two girder lines per structure (total of four girder lines) with transverse floor beams spaced at approximately 10 metres on centre. The original design allowed for the addition of a fifth girder between the two structures as the abutment, pier, and deck were designed to accommodate the additional girder line without significant modification requirements, refer to figure 2.3.

Initially, the plan for widening was to complete the original design intent by infilling between the two existing bridges. However, preliminary budgets developed as part of the planning process suggested that widening to the interior would exceed the project budget by a considerable amount. The primary reason for this unexpected cost increase was related to the price of structural steel which had recently increased drastically.

Combining this budget issue with traffic analysis conclusions that indicted the majority of widening users would prefer a lane widening to the outside of the bridge provided the design team an opportunity to re-consider the original design intent of widening the bridge between the two structures. Therefore an alternative plan was developed that evaluated the potential for converting the existing sidewalk space into the required third lane.

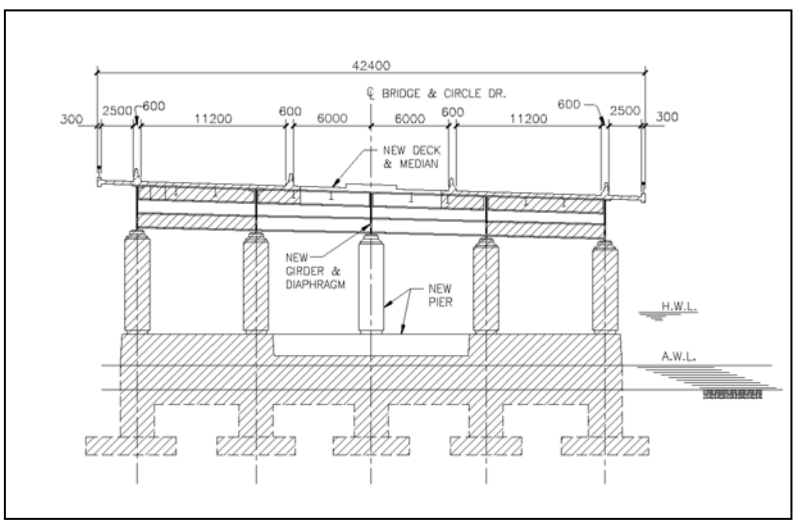

Figure 2.3 – Original Widening Geometry

This alternative plan had distinct

advantages over the original plan as a new longitudinal girder and pier column was not required thereby minimizing the work within and over the river. Additionally, roadway alignment approaching the structure from the east would be greatly simplified both in terms of design and construction phasing. However, the use of sidewalks as a driving surface created two issues that required an assessment related to:

- The load capacity of the existing cantilevered sidewalks as initial evaluations revealed the current sidewalk capacity was insufficient for the loads induced by vehicles; and

- Providing alternative pedestrian accommodation as the Circle Drive Bridge was the only crossing point over the South Saskatchewan River for pedestrians within the north end of the City.

Sidewalk strengthening was accomplished by adding transverse floor beams and longitudinal stringers. However, the pedestrian accommodation required the construction of a new walkway.

Initially, two base configurations were evaluated as shown in Figure 2.4 and Figure 2.5. The main difference between these options was the level at which the walkway would be positioned relative to the roadway surface. The first option, Walkway at the Road Level, required transitioning ramps to elevate pedestrians from the adjacent walkways to the Circle Drive elevation. The second option eliminated this additional structure by allowing pedestrians direct access to the walkway from the adjacent Meewasin Valley Trail.

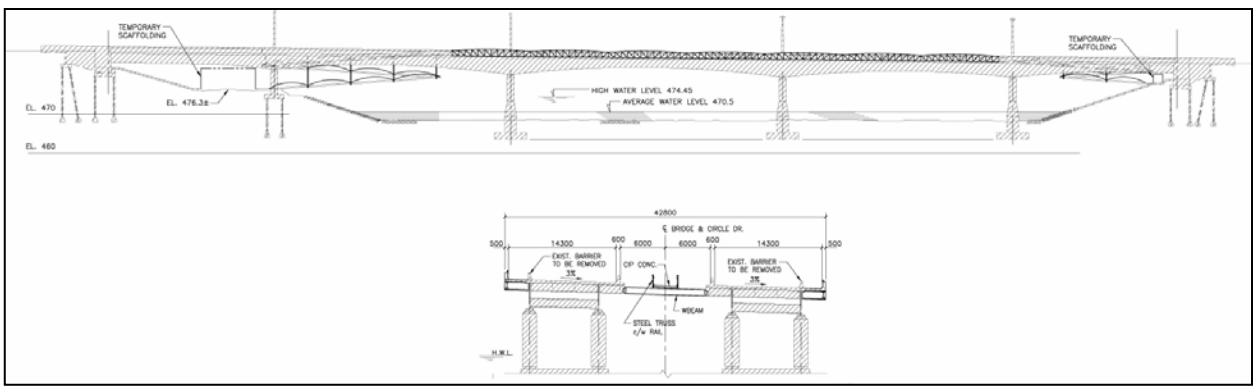

Figure 2.4 – Walkway at Road Level

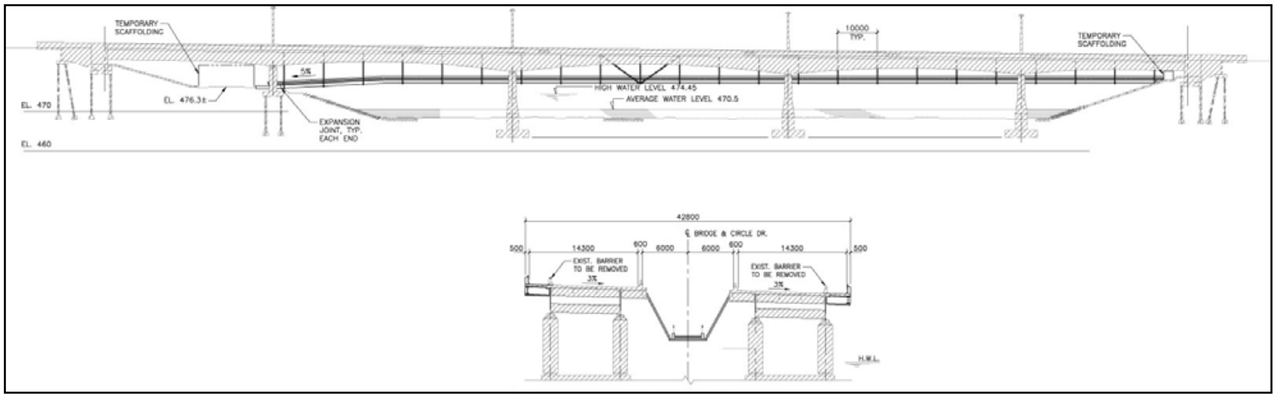

Figure 2.5 – Walkway Below Road Level

The first option was initially preferred as it was similar to the existing arrangement where pedestrians accessed ramps on each side of the bridge to transition from the Meewasin Valley Trail to the level of the bridge deck. As well, this option was considered to provide a safe environment for pedestrians due to the proximity of the walkway to the driving surfaces.

The second option provided an improved geometric alignment for connecting the Meewasin Valley trails which paralleled both sides of the river. Additionally, removing pedestrians from the roadway elevation would improve the walking experience for pedestrians as they would be placed in an environment that was isolated from traffic and exposed to the natural setting provided by the river below.

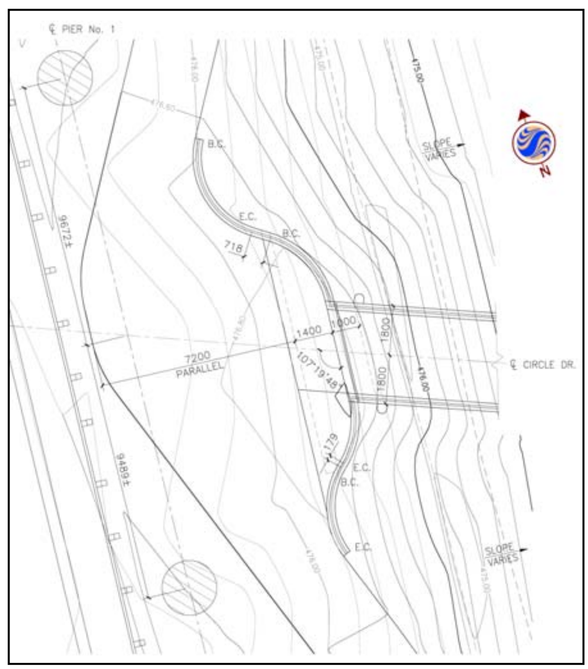

Figure 2.6 – Proposed walkway to trail transitions.

Preliminary costs were developed for the two walkway alignments assuming the existing structure had sufficient capacity to accept the additional lane of traffic and the new pedestrian walkway without modification. These costs suggested that a walkway at the lower elevation, while more costly per square metre produced the least project cost as the length was considerably shortened. When preliminary pedestrian bridge costs were combined with the bridge widening costs it became apparent that the option for widening the vehicle bridge into the existing sidewalks and constructing a separate pedestrian crossing would result in approximately $3,000,000 in project savings.

Once the apparent cost savings related to this revised widening scenario had been identified, a detailed assessment of the existing bridge structure was completed to determine if any additional strengthening was required to the main structure and if so what the cost implications would be to the project. Conclusions of this assessment indicated the existing structure had sufficient capacity in terms of strength and fatigue to support the new loads imposed by the widening and separate pedestrian structure scenario. Therefore, the apparent cost savings of widening the structure by modifying the existing sidewalks and providing a new pedestrian crossing between the structures could be realized.

2.4 CRIME PREVENTION THROUGH ENVIRONMENTAL DESIGN (CPTED)

Due to the high profile nature of the widening project and changes created when a separate pedestrian walkway was required, the City initiated a CPTED study for the site. CPTED is a collaborative, multi-faceted approach to reducing opportunities for crime, improving perceptions of safety, and strengthening community bonds. For this project, CPTED was used to evaluate the existing pedestrian linkage at the Circle Drive Bridge, identify elements that work well so they could be incorporated into the new design, and to capture elements that require improvement so that the new pedestrian walkway would not repeat mistakes from the past.

The CPTED study included visual inspections during different times of the day so that issues related to pedestrian and cyclists patterns could be identified which were then supplemented by a user survey. Study findings identified several features of the proposed structure geometry that required consideration during design in order to mitigate any potential issues in the use of the facility. These findings included:

- Transitions from the pedestrian bridge to the adjacent Meewasin Valley Trail would need careful consideration in order that sufficient space is provided for pedestrians and cyclist to safely transition, Figure 2.6;
- The walkway should have sufficient width to ensure pedestrians and cyclists could co-exist without conflict; and
- Rails and protective shelters should be designed to prevent a tunnel effect for users of the facility.

Figure 2.7 – Preliminary Pedestrian Bridge Renderings

The findings were incorporated into the final design as discussed in the next sections.

2.5 PEDESTRIAN BRIDGE

Until this point, the majority of engineering assessment had focused on the existing structure and how to accommodate the new lane of traffic required in each direction. Once the decision had been made to modify the existing sidewalks to accommodate vehicle traffic the design team changed their focus to the pedestrian bridge and how best to provide an economical solution.

Before any significant engineering work was completed a preliminary rendering showing the walkway at a level below the roadway was produced that outlined the proposed geometry and aesthetic requirements of the structure, Figure 2.7. This rendering was used as the basis for discussion with the City and other regulatory groups in order to generate feedback related to the look and feel of the pedestrian bridge. The development of this rendering was considered fundamental to the development of the proposed bridge as previous experience had demonstrated the value this presentation material provided when describing a complex project to non-technical groups.

Figure 2.8 – Pedestrian Bridge Support at Pier

While the rendering was reviewed by interested groups the design team turned to the challenges of developing a reasonable design and construction plan for the proposed suspended structure. Fortunately, the existing geometry of the adjacent structures provided regular support points for the new sidewalk at approximately 10 metre spacing. However, the existing bridge was constructed on a horizontal curve which created a slightly different skew angle and connection geometry at each support point. These varying dimensional features of the existing geometry created significant logistical issues related to providing a solid base for erection while allowing flexibility for the different geometry at each panel and the inevitable field adjustments.

Figure 2.9 – Pedestrian Bridge Support Between Piers

These challenges were overcome with the use of three rigidly supported panels at each pier location combined with adjustable hanger rods between the piers, Figures 2.8 and 2.9. Once set, the three starting points provided a solid base from which one end of each subsequent panel could be placed. The opposite end could then be suspended from adjustable hangers spaced at approximately 10 metre intervals from the adjacent structure, Figure 2.10. Since the hangers were adjustable, each panel could be positioned vertically and horizontally to permit the best position for the new panels which

Figure 2.10 – Pedestrian Bridge Connection Details

complemented the geometry of the adjacent structures with the new sidewalk. Once each panel was positioned, it formed the rigid base for erection of the next panel until the mid-span panel was placed which completed the longitudinal continuity of the structure.

Once the basic framing system and construction phasing was developed, detailed assessments of the system could be completed in accordance with Canadian Highway Bridge Design Code (CHBDC) to ensure all limit states were evaluated. Strength, flexibility, and fatigue issues were easily accounted for in the overall design. However, since the structure was suspended from adjustable hangers from the adjacent structures, structural dynamics of the system were found to govern the overall design.

3.0 Innovative Design Features

Technical challenges identified during the preliminary design phase required additional thought during the design phase to ensure an economical solution was developed. Due to time constraints, two contracts were established to ensure delays in the widening construction did not occur due to the pedestrian bridge design.

During the preliminary assessment of the existing structure, it was noted that the existing sidewalks did not have sufficient capacity to support the load increases caused by the widening. Therefore, structural capacity improvements were developed for the main structure that included modification of the sidewalk to deck transitions and installation of transverse floor beams and longitudinal stringers.

Careful phasing of demolition and re-construction work was also required as removal of traffic barriers and concrete to facilitate tie in of the new floor beams and stringers would effectively remove the top reinforcement continuity necessary to support the cantilevered slabs. To address this issue demolition and reconstruction work was staged by:

- By removing barriers to the existing deck top to maintaining top reinforcement continuity;
- Limiting full depth concrete removal at floor beam locations to allow installation of the floor beam and exterior stringer; and
- Placing concrete overtop of the floor beams and stringers to ensure continuity of the new structural steel with the sidewalk prior to removing the top layer of concrete for final transitioning of the new to existing deck.

Significant conflicts existed at the connections between the transverse floor beams and main girder due to congested reinforcement and existing connection plates which attached the interior floor beam to the main girder. Dealing with this congestion was avoided with the use of high strength threaded bars fastened to the existing floor beam close to the underside of the bridge deck which was then passed through the main girder and attached to the new floor beam, Figure 3.1. High strength threaded bars were sized to resist all temporary loads induced during construction as well as permanent and vehicle loads. Stud anchors were introduced to ensure

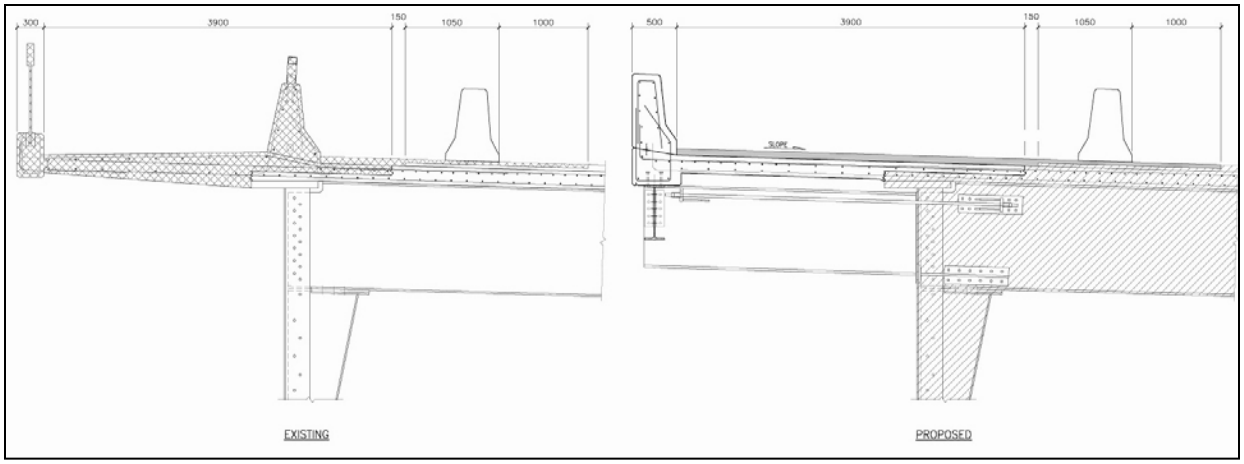

Figure 3.1 – Cantilever Sidewalk Strengthening and Demolition Details

the new floor beam and stringer would perform compositely with the deck and original structure.

The pedestrian bridge installation proceeded smoothly based on the design concept developed during the preliminary and detailed design phases. Erection of each sidewalk unit was attained using a moveable work bridge which spanned between each structure while suspending each new sidewalk panel, Figure 3.2. The selection of modular units during the design phase combined with the use of a work bridge allowed for minimal impact to the traveling public as lane closures were held to a minimum during off-peak hours.

Figure 3.2 – Pedway Construction

4.0 Conclusions

The Circle Drive Widening project required an innovative approach to provide additional east and west bound lane at the least possible cost to the City while maintaining 2 lanes of traffic in each direction for the duration of the construction phase. Initial budget assessments revealed the original widening plans could not be completed within the established project budget so an innovative solution was required.

The selected solution consisted of converting the existing sidewalks into driving surfaces and constructing a new walkway between the existing structures set at a lower elevation. This solution resulted in a lower project budget, improved traffic alignments at both approaches to the bridge, while improving the overall walking experience for any pedestrians using this important crossing of the South Saskatchewan River.

Normally, when budget constraints require a re-design of the project the general outcome is a project which loses some of its aesthetic appeal or functional improvements. For the Circle Drive Widening project, the design team was successful in addressing the budget challenges while providing an improved product for both drivers and pedestrians. The outcome of this project is a testament to the team approach embraced by all groups involved.

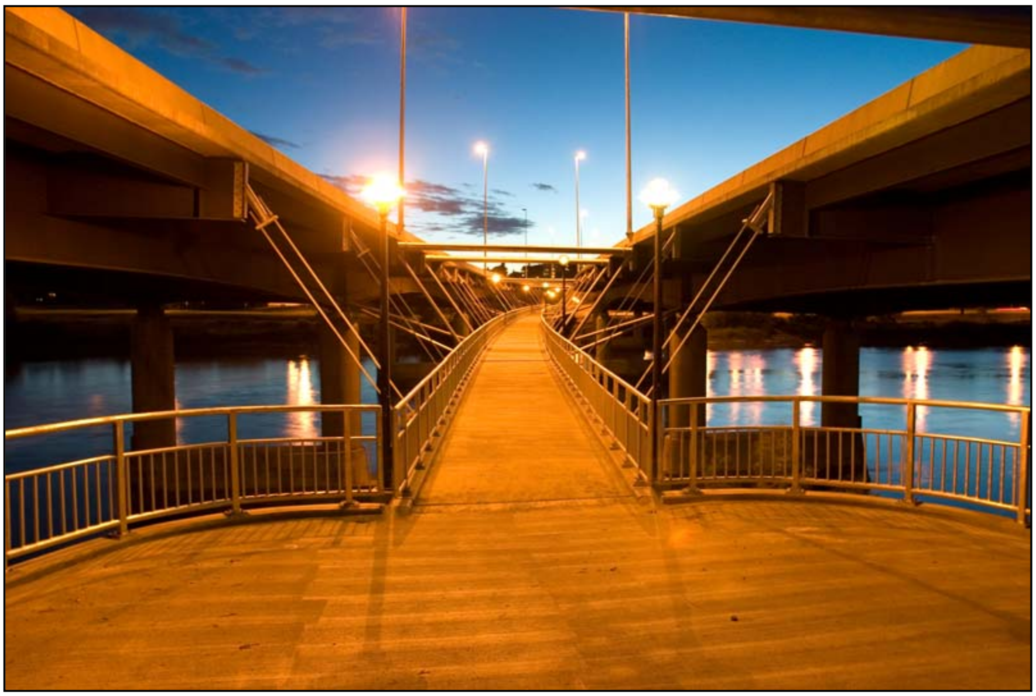

Figure 4.1 – Finished Pedestrian Bridge