CHIEF PEGUIS TRAIL EXTENSION - ROTHESAY ST. OVERPASS

RAPID DESIGN & CONSTRUCTION OF AN INTEGRAL ABUTMENT BRIDGE WITH MSE WALLS & CELLULAR CONCRETE BACKFILL

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ABSTRACT

The Rothesay Street Overpass is one component of a significant Public Private Partnership (P3) project, the Chief Peguis Trail (CPT) Extension, in Winnipeg, Manitoba. Due to changes in the P3 Contractor's design/construction team, the overpass subcontractor was required to hire a design engineer for the Rothesay Street Overpass, and had less than one year to complete the design and construction of the structure. In the preliminary stages of the CPT project it was decided to raise the overpass 3 m from the original at-grade design in order to eliminate a costly lift station that would have been required for land drainage with a 6 m deep underpass. The overpass is in a congested urban/residential location, and raising the structure required the addition of narrow approach embankments over poor soil conditions between residential housing.

The P3 Contractor owns the CPT facility for 30 years, after which ownership reverts back to the City of Winnipeg. As a result, the schedule, cost, constructability, durability, future maintenance and stringent hand-back criteria were critical factors affecting the design and construction. To minimize structure depth, maintenance costs, and increase durability, a two-span precast box girder overpass with integral abutments was selected. Due to the compressed schedule, Mechanically Stabilized Earth (MSE) retaining walls were selected to create the narrow approach embankments, abutment backwalls, and grade changes required to fit the structure into the project's right-of-way. To compensate for the poor underlying soils and high anticipated settlement, lightweight cellular concrete backfill, up to 5 m in depth, was required. The use of cellular concrete around integral abutments provided unique challenges, and innovative details were developed to allow performance of the integral abutments in a relatively rigid backfill.

Preliminary design through to construction completion and overpass opening on December 1, 2011, took approximately 11 months, and the design and construction was completed on budget and on schedule. This project demonstrates that: (1) Construction schedules can be significantly compressed even when utilizing new and innovative materials and designs. (2) The combination of an integral abutment overpass, MSE abutments and retaining walls, and lightweight cellular concrete backfill is a viable alternative when site conditions, the construction schedule, and/or construction costs dictate that a more traditional structure will not achieve the project goals. (3) MSE retaining walls are very quick to erect, and backfill with cellular concrete can accelerate the construction, however, procurement of construction materials can have a significant effect on the schedule. (4) A comprehensive Quality Management Program, including third party reviews, is essential to the success of the design and construction of a P3 project. (5) P3 projects are inherently an economical and cost effective solution for providing new and replacement infrastructure, even if they are not "mega" projects. 6) Selection of an appropriately skilled design-build team is critical to the success of an innovative and fast-track design-build project.

PROJECT BACKGROUND

Introduction

The Rothesay Street Overpass (Overpass) is one component of a significant Public Private Partnership (P3) project, the Chief Peguis Trail Extension, in Winnipeg, Manitoba. The Chief Peguis Trail (CPT) Extension Project included construction of a new 3.7 km long section of four-lane divided roadway between Lagimodiere Boulevard and Henderson Highway in northeast Winnipeg. The CPT Extension connects the previously existing section of Chief Peguis Trail from Main Street to Henderson Highway, which served approximately 25,000 vehicles per day, to Lagimodiere Blvd., a major north/south regional/arterial route serving east Winnipeg. As part of the P3 arrangement, the builder/owner is DBF2 Ltd. (DBF2), who is responsible for the Design, Build, Financing, and Maintenance (DBFM) of the facility for the next 30 years. Following this 30 year period, ownership of the facility reverts back to the City of Winnipeg (City).

Originally the CPT Extension Project was to include an at-grade intersection at Rothesay Street and Chief Peguis Trail. Prior to construction of this new segment of Chief Peguis Trail, Rothesay St. served as an important north/south collector and local connection between the residential communities on either side of the CPT right-of-way green corridor. The nearest crossing locations of the CPT right-of-way are Henderson Highway, located 0.9 km to the west, and Gateway and Raleigh, located 1.2 km to the east. Rothesay St. is a heavily utilized vehicle and transit bus route, and is also extensively used by both cyclists and pedestrians, including many school children. The residential neighbourhoods on either side of the CPT right-of-way include many nearby schools, churches, parks, and a fire station. During the bidding phase of this P3 project, the City determined that a grade separation should be included as part of the current scope of work, rather than being a future addition due to concerns from the local community and users of Rothesay St.

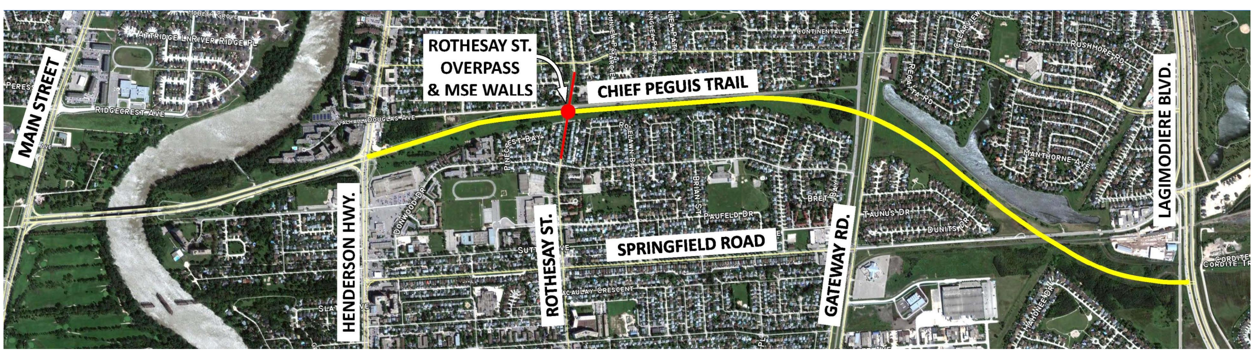

Figure 1: Chief Peguis Trail Extension from Henderson Highway to Lagimodiere Boulevard.

Evolution of Design Concept and Project Team

The initial concept for the grade separation at Rothesay St. and CPT included an underpass on CPT, approximately 6 m below existing grade. The intent was for Rothesay to remain at its existing grade as a simple flyover, crossing CPT without any on/off ramps or other connection to CPT. This would maintain the connectivity of the community across the CPT right-of-way; would not alter the traffic in the local community by eliminating or adding traffic entries/exits between Rothesay and CPT; it would maintain a safe condition for local vehicles, cyclists and pedestrians; and it would allow the new higher speed CPT Extension to flow without interruption from Gateway Road to Henderson Highway. During the negotiation stage for the P3 project between the City and DBF2, it was proposed to raise the grade separation at Rothesay approximately 3 m above grade. This was proposed in order to reduce the depth of the underpass and eliminate the need for a costly lift station for the land drainage water, which would otherwise collect in the 6 m deep underpass.

The DBF2 team was required to provide a conceptual/preliminary design for the raised Overpass in a relatively short time frame during the proposal stage. The concept initially proposed by others for the raised overpass structure did not meet the long term maintenance strategy of DBF2 or the City, and as a result a new design was required in an even further compressed time frame to meet the accelerated construction schedule for 2011.

As a result, DBF2 entered into discussions with Gateway Construction & Engineering Ltd. (Gateway) to provide a design-build alternate for the new Overpass. Gateway was originally a part of the DBF2 team as the overpass contractor, but the design was to be completed by others. When Gateway became the design-build contractor for the new overpass, they approached AECOM to provide the design for the new structure. The geotechnical engineer for the overpass was exp. (formerly Trow Consulting Engineers Ltd.) who was also the geotechnical engineer for the overall CPT Extension Project. The roadway geometry for the CPT Extension being spanned, and the Rothesay St. Overpass and its approaches, was provided by Morrison Hershfield (MH), the roadway designers for the overall CPT Extension Project. (Note that exp. and MH were under contract directly to DBF2, and as such a significant level of coordination and cooperation was required between the Gateway/AECOM team and DBF2/exp./MH team.) As design of the project progressed, Atlantic Industries Canada Ltd. (AIL) also contributed to the Gateway/AECOM team as the designer and supplier of the Mechanically Stabilized Earth (MSE) retaining walls and its components.

As part of the original DBF2 design/construction team, Gateway had reviewed preliminary design drawings and had priced the original Overpass design concept, which was a single span, rigid frame structure with cast-in-place concrete beam-girders and inverted tee beams. With the late change that saw Gateway become the design-build contractor for the overpass, and DBF2's desire to change the design to a two-span structure with conventional precast girder units, Gateway and AECOM were given less than one year to complete both the design and construction of the structure. At the time the proposed construction costs for the new design-build structure were negotiated between DBF2 and Gateway, there was no preliminary design completed, only preliminary sketches prepared by Gateway's project manager showing the required spans and clearances. With the overpass in a congested urban/residential location, raising the structure required the addition of narrow approach embankments between residential housing properties, over poor soil conditions. The resulting site geometry required extensive use of retaining walls along both Rothesay St. and CPT. Several conventional cast-in-place retaining wall options were reviewed, as this was Gateway's preferred option for the purposes of reducing schedule and to avoid the reliance on additional designers and suppliers. Through the analysis of several conceptual wall geometries and backfill material combinations, it was determined that cast-in-place cantilever and/or gravity walls were too costly due to the requirement of additional foundation components (piles) to address difficult geotechnical issues related to Winnipeg's typically poor soil conditions. An MSE retaining wall system, which is a lighter and more flexible structure, was selected to address these issues.

Pre-loading the overpass approaches to allow for settlement of the existing subgrade soils was not an option due to the compressed schedule. Numerous options for a lightweight backfill material were investigated, including: dacite pumice stone from British Columbia with a unit weight of 750 kg/m^3; moulded expanded polystyrene (EPS) blocks with a unit weight of 22 kg/m^3; and lightweight cellular concrete with a unit weight of 475 kg/m^3. It was determined to use the lightweight cellular backfill, up to 5 m in depth, to mitigate the high anticipated settlements. The existing soil at the depth of the retaining wall foundations is a soft to firm clay, with an undrained shear strength of 35 kPa, and an ultimate bearing capacity of 180 kPa.

The decision to use cellular concrete as the lightweight backfill for the Rothesay St. approach embankments and the integral abutments provided unique challenges, and innovative details were developed to allow performance of the integral abutments in a relatively rigid backfill.

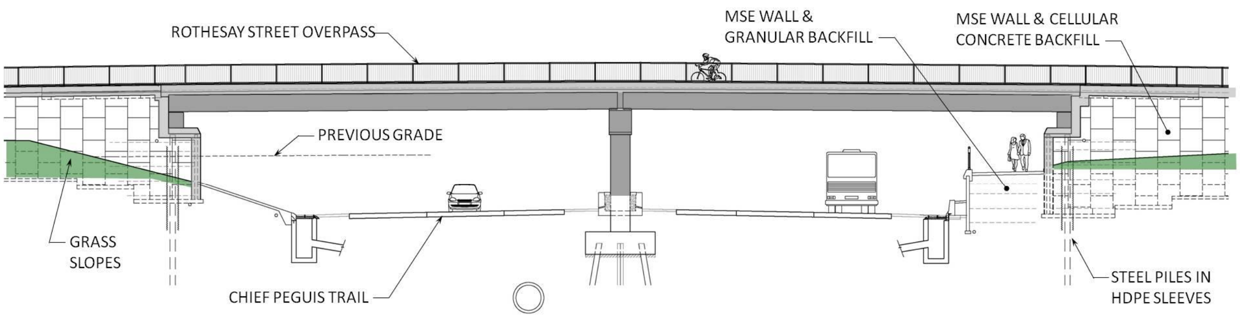

Figure 2: Rothesay Street Overpass East Elevation.

Compressed Schedule

In accordance with the P3 arrangement between the City and DBF2, the 3.7 km long four-lane CPT Extension, including the Rothesay St. Overpass, was required to be completed and open to traffic by November 2012. However, DBF2 had set an internal deadline for opening of the entire facility to traffic in 2011, a full year ahead of schedule. In addition, due to the changes in the design concept and the late addition of Gateway/AECOM as a design-build team, the design of the Overpass structure commenced later than originally scheduled. As a result, the schedule for the completion of the Overpass was compressed from both ends.

Preliminary design through to construction completion for the Overpass component of the CPT Extension Project took approximately 11 months. Preliminary design of the overpass structure commenced in January 2011, and the Overpass was opened to traffic on December 1, 2011, with the CPT Extension from Henderson to Lagimodiere opening the next day.

Photo 1: CPT Right-of-Way, April 2011.

Photo 2: Rothesay St. Overpass and CPT, Dec. 2011.

PRELIMINARY AND DETAILED DESIGN

Design Process in a P3/Design-Build Project

The CPT Extension Project, which includes the Rothesay St. Overpass, will be maintained by DBF2 for 30 years, at which time the facility will be handed back to the City. Design and construction of a highly durable structure was in the best interest of all parties involved. While this is inherent to the design of most permanent facilities, there is an added emphasis to reduce construction and maintenance costs when a structure will be privately owned and operated. In addition, when the design engineer is employed directly by the contractor in a P3 or design-build relationship, innovation is encouraged and more easily facilitated. The constant design development with the designer and contractor working together allows for rapid decision making and optimization during the design process.

For the Overpass, the design development process was driven by both the requirement for optimized construction and maintenance costs, as well as the need to meet the compressed schedule. The entire design team from DBF2 and Gateway/AECOM held weekly meetings to facilitate the rapid design development and decision making process. Throughout the preliminary and detailed designs, many options were explored for the Overpass and retaining wall structures. These options were flushed out quickly so that decisions could be made and detailed design could commence on critical path items. This in turn allowed these components to proceed to fabrication and construction, as the design of other components continued. Similar to other P3 and design-build projects, issued for construction drawings were issued in stages to allow the project to proceed in a rapid but organized fashion. Somewhat unique to this project however was that components such as the retaining walls were still in a preliminary design phase when other components such as the girders and integral abutments were already issued for construction. This was necessitated by the highly compressed schedule. The experience, good engineering judgement, and collaboration of the design and construction team members was critical to mitigate the risks inherent with such a process.

Precast Pre-stressed Concrete Box Girder Structure Type

Precast pre-stressed concrete box girders were selected almost immediately in the design process to produce the most efficient, durable and rapid superstructure construction available for the estimated span lengths and available structure depth. The roadway profile of Rothesay and CPT had already been determined earlier by the roadway designer, and as a result the superstructure was required to fit within this given vertical space with only minor adjustments. A two-span structure was selected to minimize the overall structure length, depth, cost, and to keep the structure and abutment slopes within the limits of the right-of-way. The selected overpass superstructure consists of two spans 24 m in length over the six-lane CPT (four current lanes expandable to six in the future) and a 3.7 m wide multi-use pathway. The design team committed to these span lengths based on several iterations of the CPT cross-section, the estimated widths required for TAC vehicle clearances, and the yet-to-be determined retaining wall type/width between the CPT roadway and Overpass abutments.

The Overpass consists of a two-lane roadway over the structure with 1.8 m sidewalks on each side. The concrete box girder forms were available locally, they could be rapidly fabricated, and the local fabrication experience with this type of girder resulted in a minimal learning curve, accelerated production, and reduced risk to the project schedule. The erection of the precast box girders is also a relatively rapid process due to the local experience and placement of girders immediately adjacent to each other. The girders are pre-stressed longitudinally and post-tensioned together laterally which optimizes the load capacity, performance and durability.

A 200 mm thick concrete deck was cast on top of and composite to the girders to provide structural continuity for live load over the pier, to increase the section's capacity, and to provide a monolithic slab with increased durability. The raised sidewalks were also cast monolithically with the main deck to accelerate construction and eliminate any horizontal joints which might cause leakage or maintenance issues in the future. A significant benefit of the box girders to the schedule was the greatly reduced deck formwork requirements, as only the narrow cantilevers required formwork. The girders also utilized high strength low permeability concrete to increase capacity and durability. The box girders result in a smooth profile underneath the overpass, which minimizes the surface area for future maintenance.

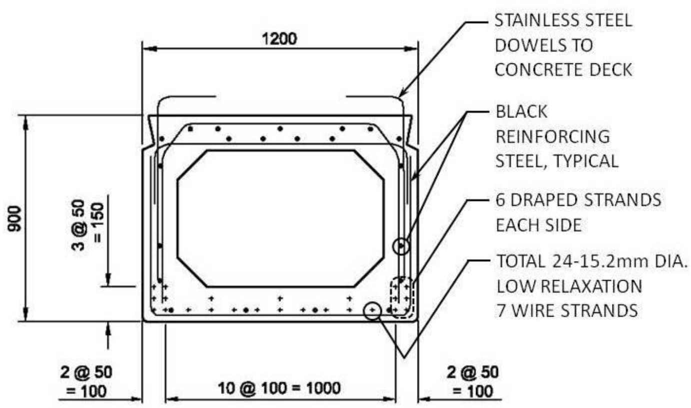

Figure 3: Precast Box Girder Section at Midspan.

Photo 3: Erection of Precast Concrete Box Girders.

The concrete deck, traffic barriers/curbs, abutment backwall/end diaphragm and pier diaphragms utilize galvanized reinforcing steel for increased durability. The box girders however are reinforced with 7 wire pre-stressing strands and black reinforcing steel. To ensure electrical isolation between the black and galvanized reinforcing steel and prevent premature corrosion of the galvanized deck steel, dowels from the girders to the deck were stainless steel. Any other locations requiring isolation between reinforcing steel types were epoxy coated.

Photo 4: Erection of Precast Concrete Box Girders.

Photo 5: Underside of Overpass.

Integral Abutments

To further increase durability and reduce costs of the overpass, it was designed using integral abutments. Traditionally integral abutments have not been extensively used in Manitoba, however they eliminate the need for expensive and high maintenance expansion joints, typically modular boxed cells, at the ends of the structure. Integral abutments utilize a single row of piles supporting an abutment pile cap, and the piles are designed to move longitudinally with the bridge to accommodate seasonal thermal expansion and contraction forces. The approach slabs are connected to the overpass deck, so that all thermal movement occurs at the end of the approach slabs and on the roadway, well beyond the actual limits of the overpass structure. The joint between the approach slab and the roadway can be a maintenance issue, as either a single box seal formed joint assembly is required, or regular maintenance of the asphalt roadway surface is required. DBF2, as the P3 owner, will have an extensive maintenance program for the entire CPT Extension facility, and it was determined that regular maintenance on a simple hot-poured joint in the asphalt would be less costly then installation and maintenance of a more sophisticated joint assembly.

The continuous overpass structure over the bridge pier and abutments eliminates any joints that could allow moisture and chlorides to attack the girders, bearings, and other structural elements below the overpass deck as the joint assemblies deteriorate and fail with time. This results in significant long-term savings, as indicated by many older overpass and bridge structures in Manitoba requiring rehablitation at the girder ends wherever expansion joints are located. With respect to initial construction costs, the integral abutments also eliminate the need for massive concrete abutment components, wingwalls, and intricate bearing assemblies; and the single row of piles greatly reduces the total quantity of piles, which reduces both the costs for the piling and the time for installation of this critical path item.

Rothesay Approach Embankments and Mechanically Stabilized Earth Retaining Walls

The Rothesay St. Overpass is located at the narrowest cross section of the CPT Extension right-of-way in a congested urban/residential location. Raising the structure above grade to eliminate the need for a pumping station at this location required lengthy and narrow approach embankments over existing utilities and weak existing soils. This required the construction of several hundred meters of retaining walls along both Rothesay St. and CPT. Typically in Winnipeg, conventional cast-in-place cantilever retaining walls with piled foundations have been used, however after reviewing numerous design options this type of wall was considered too costly if a deep foundation system was required. In addition, cast-in-place retaining walls are considered rigid structures, requiring a 3:1 Factor of Safety (FS) for their design. With an ultimate bearing capacity of only 180 kPa for the existing clays, the allowable bearing pressure for this type of wall was only 60 kPa. Due to the rigidity of a cast-in-place cantilever retaining wall, global stability was also an issue. A Mechanically Stabilized Earth (MSE) retaining wall system, which is considered to be a more flexible structure requiring a bearing FS of 2:1, was selected to address these issues.

The MSE retaining wall system consists of precast concrete wall panels held back with galvanized steel tie-back mats or straps. The precast wall panels have a textured “fractured fin finish” to soften the appearance of the concrete and make the surface less prone to vandalism or graffiti. The first row of panels is erected on a relatively narrow and thin concrete levelling pad. This pad is not required to distribute the bearing load of the wall to the soil, rather the entire “stabilized” soil mass works as one large bearing unit. Each subsequent row of panels is erected on top of the previous row, with vertical pins providing alignment and a shear

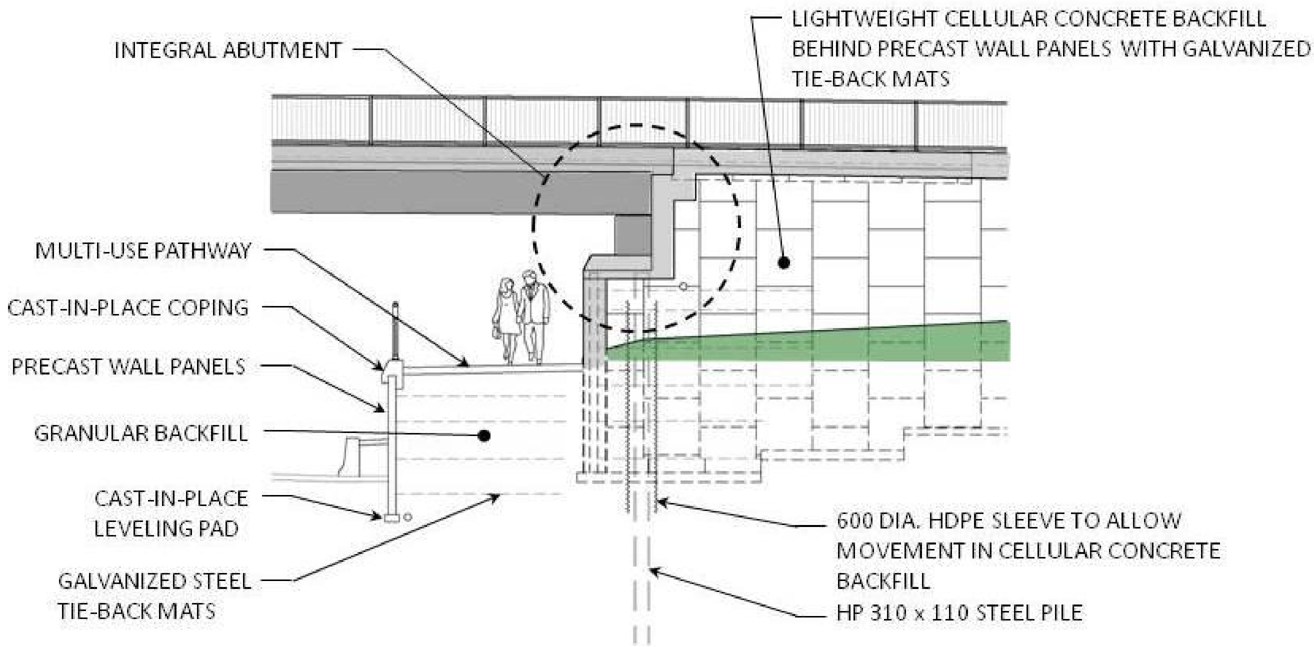

Figure 4: Cross Section and Elevation of MSE Walls on CPT and Rothesay St.

connection between panels. The lower panels and tie-back mats are backfilled to the underside of the next layer of mats, and the process continues until the design wall height is achieved. Traditionally MSE retaining walls are backfilled with regular compacted granular backfill, the only requirement being that the electrochemical analysis of the backfill material meets the requirements of the tie-back material. The system must be designed for: bearing pressure under the levelling pads and granular backfill; pullout of the tie-backs from the granular backfill; and the sliding, overturning, and global stability of the entire system.

Initial settlement calculations for the 3 m high approach embankments were estimated to be in the order of 200 mm using conventional compacted granular material, so innovative designs were investigated to reduce the anticipated settlement and its effects on the roadway and existing utilities. As the design proceeded it was determined that to minimize the settlement to acceptable levels some form of a lightweight fill was required. Three different lightweight backfill material options were investigated, a lightweight granular aggregate, Expanded Polystyrene (EPS) blocks, and lightweight cellular concrete. Lightweight granular aggregate, in the form of pumice stone, is not available locally in or near Manitoba and would have required rail shipment from a source in British Columbia. Considering the large volumes which would have been required for the Rothesay approach embankments, this would have been cost prohibitive, and could have negatively impacted the schedule.

It was determined that a lightweight material in the range provided by either EPS blocks or cellular concrete was required for the Rothesay embankments to reduce the settlement to acceptable levels. The MSE retaining wall system relies on tie-backs from the precast wall panels into a “stabilized mass” behind the panels. Due to the 5 m height of the Rothesay embankments, the load on the tie-backs is significant, and this load could not be effectively transferred to the EPS blocks. As a result, to meet the strength and stability requirements of the relatively high back-to-back retaining walls along Rothesay St., cellular concrete, supplied by Cematrix Canada Inc. was selected for this project. Cematrix cellular concrete consists of regular ready-mix slurry (cement, flyash and water) with a foaming agent added. The foaming agent creates a material that resembles self compacting concrete, without the aggregates, and with visible air bubbles, increasing the volume of the supplied slurry by 380%. This results in a low strength concrete backfill which is approximately half the weight of water. The cellular concrete was pumped into place in 380 mm lifts (tie-back layers were 760 mm apart), and successive lifts could be poured one day apart. Combined with the erection of the MSE wall panels, the MSE wall construction is a very rapid and efficient process once the wall materials are delivered to the site.

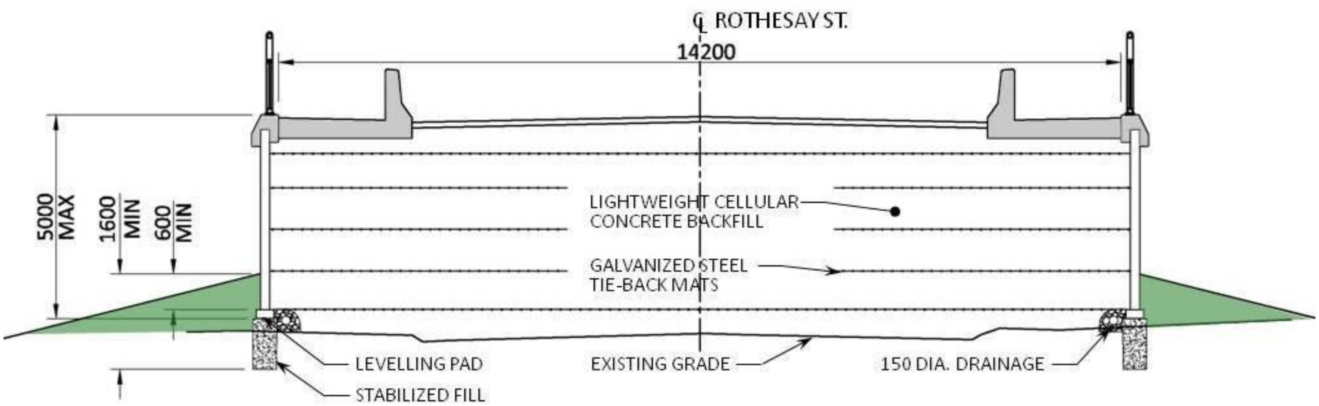

Figure 5: Cross Section of Rothesay St. Approach Embankments and MSE Walls.

Based on a constant supply of slurry, the Cematrix unit supplied was able to produce up to 500 m^3 of cellular concrete per day. Formed pour areas of a maximum size of 100 m^3 were prepared, as any pours larger would result in the fresh poured Cematrix material compressing the previously placed material and damaging the air void structure. This would result in a material with a higher density than the desired design value of 475 kg/m^3. The maximum depth of pour for the foaming agent used was 600 mm. Deeper pours can be achieved, but an alternate foaming agent is required.

Photo 6: Pouring Cellular Concrete Behind Abutment Piles.

Photo 7: Stepped Cellular Concrete Embankment on Rothesay.

The MSE wall panels were erected using a combination of cranes and a zoom boom. Due to the rapid design-build process, and the time required for the design, production and delivery of the MSE wall components, the overpass girders had been erected prior to receiving the abutment panels. As a result, erection of the front face of the abutment MSE wall, as well as the lower section of the CPT retaining wall in front of the abutment panels below the Overpass, had to be erected utilizing a zoom boom. The majority of the remainder of the panels were erected using various different sized cranes. On average approximately 30 to 35 panels were erected per day, depending on their location.

Photo 8: Galvanized Tie-Back Mats on Hardened Cellular Concrete.

Photo 9: MSE Wall Construction Along CPT.

Cellular concrete backfill is poured in a liquid state, and cures to be a very low strength but rigid backfill. The combination of this rigid cellular concrete backfill behind the integral abutments, which rely on thermal expansion of the overpass into the backfill, was a design concern which has not been encountered on past projects. As a result, a design detail was developed behind the abutments to incorporate a 600 mm wide vertical column of low density insulation, which can compress when the overpass abutments expand thermally. In addition, the steel piles are surrounded by cellular concrete, and they also require the ability to deflect longitudinally to allow for the thermal expansion and contraction of the overpass superstructure. Each steel pile was encased with an HDPE sleeve filled with Styrofoam pellets to provide a void surrounding each pile. This allowed for the deflection of the pile with the thermal movement of the overpass, without affecting the cellular concrete embankment, the MSE wall in front of the abutment pile cap, or negatively affecting the Overpass structure.

Photo 10: Liquid Cellular Concrete around Abutment Piles in HDPE Sleeves.

To the knowledge of the design team, this project is the first combination of an integral abutment overpass structure with MSE retaining wall abutments and lightweight cellular concrete backfill in North America. To date the components of the structure have behaved well together, and the expansion and contraction of the structure has performed as anticipated.

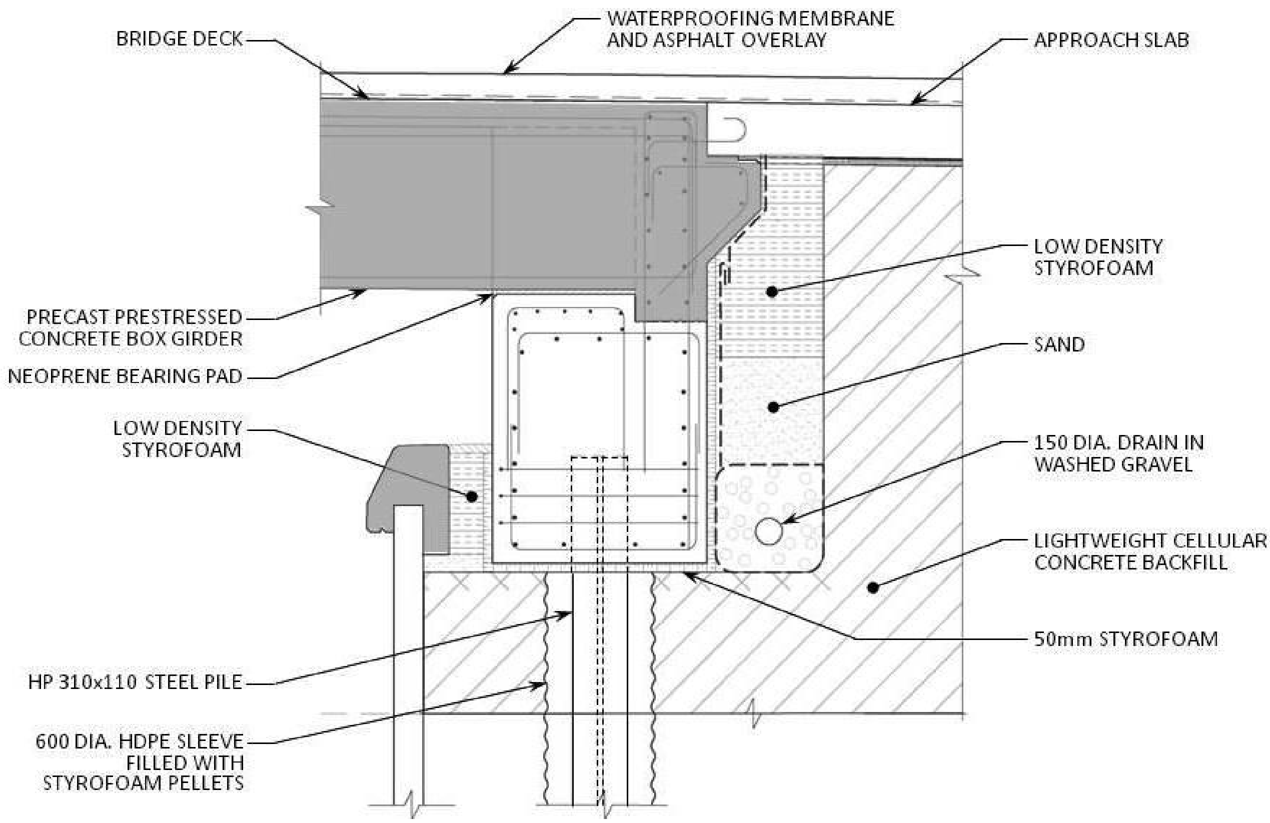

Figure 6: Details to allow Thermal Expansion/Contraction at Integral Abutment and Cellular Concrete Backfill.

Chief Peguis Trail Mechanically Stabilized Earth Retaining Wall

For the MSE retaining walls along CPT granular backfill could be utilized. These MSE walls are below the existing grade so the backfill is replacing excavated material and does not load the existing soils as significantly as the Overpass approaches. The granular backfill was required to meet electro-chemical parameters due to the galvanized restraining mats utilized in the MSE wall design. As the design progressed it was also determined that a significant length of the wall along CPT did in fact exceed the allowable bearing capacity. This area required improvement of the bearing zone directly under the MSE wall. As a result a layer of weak underlying soil was removed and replaced with 500 mm of compacted granular to achieve the required bearing capacity.

Durability and Maintenance of Secondary Components

The designs of several secondary components were optimized during the design process. The durability of concrete traffic barriers was considered an important element for durability and long term maintenance due to the exposure to chlorides and freeze-thaw action. A high strength low permeability concrete (CSA category C-1 with a corrosion inhibitor added) was utilized with the addition of polymer fibres to reduce both short and long term cracking. The performance of traffic barriers on various structures in Winnipeg was reviewed, and it was decided to provide shorter traffic barrier segments on the Overpass to prevent cracking due to deflection of the superstructure. Longer traffic barrier segments were used off the Overpass where they are not subjected to the deflections of the superstructure. This decreased the number of joints and associated construction and maintenance costs. Details for the barrier construction and crack control joints were researched and a hybrid joint was derived and adopted, compared to the usual joints used on City structures.

The Overpass deck has an asphaltic waterproofing membrane with an asphalt overlay which has an expected design life of 15 to 20 years. The alternative overlay, which has become a City standard, was a high performance concrete (HPC) overlay which has a longer return period for rehabilitation, but would have increased both the 2011 construction costs and schedule. It was determined that the long term costs would also be lower with regular crack sealing in the asphalt, and two scheduled replacements of the asphalt overlay and waterproofing in 30 years rather than the HPC overlay. In addition, the replacement of an HPC overlay would require a future temporary closure of the overpass to vehicular traffic. To add to the durability of the concrete deck, a wick drain detail from the Province of Alberta was adopted which will assist with removing moisture from between the asphalt overlay and the waterproofing membrane should moisture penetrate the asphalt.

A comprehensive list of maintenance items was developed during construction to ensure inspections and maintenance are performed at regular intervals to the long term benefit of the structure. In most bridge and overpass projects in Manitoba the owner dictates the maintenance items and schedule, however on this project the designer's and contractor's input (AECOM and Gateway) was a key part of the development of the maintenance program for DBF2.

Utilities

The Rothesay St. Overpass involved very complex geometric, geotechnical and structural design and construction challenges. The CPT right-of-way is quite narrow where it crosses Rothesay St., and Rothesay itself is a two-lane residential street with houses and sidewalks on both sides. There is a significant array of public and private utilities running through the site, including: gas lines; telephone, cable and other communication lines; land drainage and waste water sewers; a major 1800 mm diameter interceptor sewer serving the northeast portion of the City; and a 600 mm high pressure water feedermain which supplies water to the entire northeast portion of the City. Most of these utilities required relocation in the summer of 2011 at the commencement of construction. The major exceptions were the interceptor sewer and the feedermain, which could not be compromised in any way during or after construction. The overpass and retaining wall structure foundation design, as well as the approach embankment settlement, was to avoid any impact on these utilities. The construction of protection works to "bridge" the feedermain south of the overpass was required so that it would not be affected by future settlement of the embankment and protect the approach against washout in the event of a failure of the high pressure feedermain.

Risk Mitigation

Quality management is the key component of risk mitigation for the design and construction of any P3 project. The quality systems instituted for P3 projects are typically much more rigorous than for traditional design/bid/build projects due to the inherent risks of rapid design and construction, and the strong desire to be innovative and improve economics. The entire CPT Expansion Project had a stringent quality management program developed and implemented by Morrison Hershfield (MH) for DBF2 in order to meet the City's requirements. This included multiple levels of review, quality checks and sign-offs for every project deliverable, including design drawings and specifications. All designs were also subject to independent design reviews by third party firms. Dillon Consulting Ltd. provided the third party review for the Overpass, and Thurber Engineering provided the third party review for the MSE retaining walls and overall Overpass global stability. The quality program was also audited by MH during the design and construction process for the Overpass. An effective quality management program such as the one used on the CPT Expansion Project greatly reduces the risks on a P3 project, and this was of great importance when considering the rapid pace of design and construction.

<u>Social and Environmental Impact</u>

The entire CPT Extension Project will have a significant social and environmental benefit for the City of Winnipeg as it is a key connection in the development of the City's Inner Ring Route and Active Transportation Network. In the short term CPT now extends from Main St. west of the Red River to Lagimodiere Blvd. on the east side of the City. This is the first direct east/west connection inside the perimeter in northeast Winnipeg, and it will reduce the commute time and associated environmental impact for east/west traffic. The CPT Extension has also alleviated much of the traffic congestion in the area by diverting much of the residential through traffic and truck traffic from surrounding streets to CPT. In the long term the Inner Ring Route will have an even greater positive impact, as CPT extends further around the north and east sections of Winnipeg, and the efficiency of travel within Winnipeg improves.

The most significant social impact of the Rothesay St. Overpass is that communities north and south of the CPT Extension will continue to function as they have for the past 40 years. A major four-lane divided arterial has been added to their community with minimal impact to the traffic in the predominantly residential area, without an at-grade intersection that would have increased the possibility of vehicular and pedestrian collisions.

Photo 11: Multi-Use Pathway under Construction.

Photo 12: Aluminum Handrail and Noise Walls.

Another feature of the CPT Extension Project is the Active Transportation Corridor (ATC) multi-use pathway which has been added to the north side along CPT, which extends from Henderson to Gateway. The pathway travels under the north span of the overpass which was designed specifically to accommodate it. The pathway is also connected to Rothesay St., which allows pedestrians and cyclists on Rothesay to utilize CPT as a walking and cycling route.

Lowering CPT along this narrow section of the right-of-way reduced noise impacts to the adjacent residents. The MSE retaining walls of the overpass embankments also tie into aesthetically pleasing noise attenuation walls to further minimize visual and noise impact. The noise walls and pedestrian handrails along the multi-use pathway are strategically located so that pedestrians and cyclists do not accidentally have direct access to CPT, which further improves the safety of the facility.

CONSTRUCTION

Rothesay St. Overpass, Embankments and Traffic Barriers

The Rothesay St. Overpass construction presented problems in that construction began while the drawings and specifications were still in various stages of preparation. Due to the busy construction season in the City of Winnipeg and Province of Manitoba in 2011, procurement of some materials was exceptionally difficult. In particular galvanized reinforcing steel had a five to six week delivery period from the time of shop drawing approval. This created issues with the scheduling of construction works on site, and at times limited the ability to keep experienced site personnel actively working on critical path items.

Due to the late decision to use the cellular concrete as the lightweight backfill material for the Overpass abutment and approach retaining walls, the design and subsequent supply of the precast panels and tie-back mats were delayed until late summer 2011. The completion of the Overpass was affected by the delayed construction of the MSE retaining walls on the approach embankments and abutments, as the approach slabs were constructed off the overpass structure, on the backfilled approaches. This location coincided with the deepest sections of cellular concrete and MSE wall panels, further compounding these problems. The delay in construction of the approach slabs affected the construction of the concrete traffic barriers on the approach slabs, and subsequently the placement of the asphalt overlay on the Overpass.

While it is possible to heat and hoard for concrete works such as the approach sidewalks and concrete traffic barriers, the supply and placement of asphalt is much more weather dependant. The asphalt on the approach slabs and overpass was placed in early November of 2011, within days of the end of the asphalt paving season in Winnipeg. In order to pave the Rothesay approaches and roadway in time for a 2011 opening, the roadway paving was actually completed prior to the completion of the adjacent concrete structural sidewalks and traffic barriers. The asphalt was placed and compacted beyond the final edge of pavement, and then sawcut to provide a straight edge of pavement. The structural sidewalks were then cast against the edge of the pavement, rather than the asphalt being placed against the concrete sidewalks. This minimized the volume of asphalt that needed to be placed right at the end of the season, and reduced the corresponding risk that the paving works would not be completed for opening of the entire CPT facility in 2011.

The forming and placing of the concrete traffic barriers on the Rothesay approaches and along CPT in front of the pathway MSE walls was greatly aided by a change in design from the typical City standard. The standard calls for multiple independent barriers with dowels between the sections, thus necessitating that they be formed and poured in a “checkerboard” pattern. Details for the traffic barriers joints off the Overpass and its approach slabs were adopted and modified from previous P3 projects in western Canada and a City project done by Gateway in 2010/11. The change to pour long continuous sections of traffic barrier with crack inducers at every 5 m+/- allowed Gateway to significantly decrease the amount of time required to form and place the nearly 560 m of traffic barriers off the Overpass structure. The traffic barriers on the Overpass were still formed and poured to the City standard in 3 m +/- sections due to the thermal expansion/contraction, deflection and vibration of the bridge.

Photo 13: Rothesay Embankment Construction.

Photo 14: Rothesay Overpass and Roadway.

MSE Retaining Walls

One of the major issues encountered in the construction of the MSE retaining walls was the availability of materials on site due to the delays in finalizing the MSE wall and cellular concrete design. The MSE precast panels were supplied from a precast plant on Vancouver Island, British Columbia, while the galvanized wire mats were supplied from Texas. The casting and shipping of the precast panels was scheduled based on which panels were required first. However, due to the geometry of the walls, and the fact that it made sense to fabricate all the "similar" panels (same dimensions and mat/strap attachments) at the same time, there were days where Gateway did not have any precast panels to erect. This in turn affected the quantity and locations in which the cellular concrete could be poured, and had a negative ripple effect on the schedule.

Typically, the top of the 150 mm x 300 mm leveling pads for the MSE wall panels is 600 mm below final grade, to allow the toe of the walls to be buried. Due to the depth of frost penetration in Winnipeg, it was decided to extend the levelling pads to a minimum depth of 1.6 m below finished grade to accommodate the deeper frost penetration. Because the cast-in-place levelling pads were thickened to achieve this grade change rather than lowered, additional dewatering measures below the MSE wall panels and levelling pads were avoided.

Schedule

The design and construction schedule was an enormous challenge for this project. The detailed design of the overpass began in February of 2011, without the benefit of a conceptual or preliminary design phase. A high level of coordination was required between the entire team including: DBF2, the proponent and design-build owner; Gateway, the overpass and retaining wall contractor; AECOM, the overpass designer and MSE retaining wall geometric designer; Morrison Hershfield, the roadway and embankment designer; exp., the geotechnical designer; Atlantic Industries Limited (AIL), the MSE retaining wall supply/designer; Genivar, the municipal designer; Smith Carter, the landscape architect; and the City of Winnipeg, the eventual owner of the facility.

DBF2 had made an internal commitment to open the CPT Extension in 2011, one year ahead of the schedule required by the DBFM Agreement. Significant financial targets would not have been met if the CPT Extension Project was not completed and opened to traffic in 2011. AECOM and Gateway were required to make rapid decisions on the overpass and retaining wall structure types, overpass span lengths, depths and details, retaining wall geometry and material types.

Completing the detailed design as the fabrication of components and the construction progressed, with the knowledge of a year-end deadline for opening the structure to traffic, resulted in increased pressure and coordination with the contractor and the entire DBF2 team. This was compounded by the use of innovative designs and construction materials necessitated by the geotechnical and physical constraints of the site. In particular, the combination of an integral abutment overpass with MSE retaining walls was new to Manitoba, increasing the required time for reviews by Gateway, the DBF2 team, and the City. In addition, the need to use lightweight cellular concrete as the backfill for the MSE walls along Rothesay in order to make the selected design work in the space and time allowed required additional research, design and review hours. The combination of all of these components allowed for this unique grade separation to be constructed quickly and efficiently in a very constricted area with poor soil conditions.

Typically the design and construction of such a unique structure would require several years to complete due to the complexity of the design, the approvals and comfort level required by the owner for new and innovative materials and structures, and the additional construction time required for learning to work with new materials and procedures. Rather than requiring an extended design and construction period, this complex overpass was completed in 11 months from the commencement of design to the opening of the overpass to vehicular traffic. This is considered to be by far the shortest duration for design and construction of a roadway and overpass facility of this size and scope in Manitoba.

Construction Cost

Rothesay St. crosses CPT at the narrowest section of the right-of-way, and by raising Rothesay 3 m and lowering CPT 3 m the most efficient grade separation geometrically possible has been provided within a very narrow space. This improves the economics of the structure and allowed for the shortest possible overpass span. This reduced the initial capital cost of the overpass, and thus also reduces the long term maintenance cost as there is less structure to maintain.

Because this project is a privately funded P3, the financial details of various components of the work are not available to the public. However, due to the rapid construction and opening of the CPT Extension a year ahead of schedule, the final costs for the entire facility have been identified by the City as being below their budget. Specific to the Rothesay St. Overpass and MSE retaining walls portion of the work, the final cost has been estimated to be less than the anticipated cost of a more traditional structure incorporating the 6 m underpass of CPT. (A complete preliminary design and costing of alternates was not completed due to the compressed schedule and late changes to the scope of work, so precise costs of alternatives in 2012 dollars are unknown.) In general, a traditional overpass design, with CPT depressed by 6 m as originally intended, would have included approximately $5 Million for a lift station and associated underground works, as well as significantly longer and higher retaining walls along CPT. Various global stability and bearing pressure issues which were encountered with the as-constructed Rothesay and CPT MSE Wall designs would have also affected a deeper structure, so it is believed that overall costs of the Rothesay St. Overpass and MSE walls would have been greater with the original concept of the overpass at-grade. Finally, a more traditional structure type may not have allowed for such rapid construction, and missing the 2011 opening would have added significant costs to the project.

With respect to maintenance costs, P3 projects such as the CPT Extension and Rothesay St. Overpass are inherently economical. The successful Proponent owns, operates and maintains the facility for an allotted term, in this case 30 years, and there are stringent handback criteria for the facility regarding its condition to ensure the City inherits a facility that will meet the 75 year design life. As a result there was a significant focus on designing a durable structure with minimal maintenance costs and optimized replacement of components. This results in a high quality structure which will be well maintained to optimize the economics and life of the structure for the first 30 years and beyond. The facility will also not be subject to an inappropriate decrease in maintenance budgets, or the delay and/or elimination of timely repairs, which can occur with publicly owned structures.

Conclusions and Recommendations

Significant knowledge was gained on the CPT Rothesay St. Overpass project through the challenges and successes of several design and construction innovations. Recommendations are provided regarding design and construction for similar projects as follows:

1. This project demonstrates that construction schedules can be significantly compressed even when utilizing innovative materials and systems. A highly co-ordinated design process between all parties is critical to the success of using innovative materials in such a rapid design process. A supportive owner is also essential to this process. All ongoing issues must be continuously advanced until solutions are obtained in order to meet such an aggressive schedule.

2. The combination of an integral abutment overpass, MSE abutments and retaining walls, and lightweight cellular concrete backfill is a viable alternative when site conditions, the construction schedule, and/or construction costs dictate that a more traditional structure will not achieve the project goals.

3. The MSE retaining walls are very quick to erect, and backfill with cellular concrete can accelerate the construction even further. However, delays in receiving construction materials, including the precast panels and galvanized tie-back mats, can have a significant effect on the schedule. Consideration must be given to the delivery schedule of these items, which can delay major components of the work at critical time periods, thereby minimizing the positive effects of the rapid wall assembly.

4. A comprehensive Quality Management Program, including third party reviews, is essential to the success of the design and construction of a P3 project. This mitigates the risks associated with innovative and rapid design and construction.

5. The Chief Peguis Trail Extension Project is a P3 project, and as such is inherently an economical and cost effective solution for providing new and replacement infrastructure. Many jurisdictions across Canada have been moving to the P3 delivery model in order to allow major infrastructure projects to be designed and constructed when public funding is otherwise not immediately available. This is an effective method of delivering projects, even if they are not “mega” projects.

6. The complimentary engineering and construction skill set of the design-build team was a key to the success of the Rothesay St. Overpass project. Gateway, as the contractor, has several engineers on staff, including their project manager for this project who has a background in bridge design. In addition, Gateway's site superintendent assigned to this project has over 20 years of bridge experience, including a number of City bridge projects with very tight schedules. AECOM, the engineering consultant, has extensive design and construction experience with similar innovative structures in other jurisdictions, completed by local Winnipeg staff, and a strong background in P3’s and design-build projects.

In general the design and construction of the Rothesay St. Overpass provided many challenges which were overcome through various innovative design and construction techniques, including modifications following problems in the field. The final product showed that with proper considerations in the original design and a committed effort by all parties during construction, very challenging design, construction and schedule obstacles can be effectively overcome. Despite the many challenges encountered, this project was completed successfully, within the project budget, and the overpass was opened ahead of schedule.

Photo 15: Rothesay St. Overpass and CPT Extension Open to Traffic.

Photo 16: Rothesay St. Overpass and CPT Extension June, 2012.