Calgary's Airport Trail Tunnel

Calgary, Alberta

Submitted to: Canadian Consulting Engineering Awards
Category G: Project Management

Photo credit: Brad Heninger

Confirmation Receipt

Full Project Description

ch2m

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Calgary's First Vehicular Tunnel

On Saturday, May 24, 2014, more than 5,000 Calgarians strolled through the The City of Calgary's Airport Trail Tunnel, celebrating the opening of Western Canada's only general vehicle traffic tunnel under an active runway. Opened to traffic at dawn the following morning, the 620m long, cast-in-place concrete tunnel carries six lanes of traffic under the Calgary Airport Authority's (YYC) new parallel runway, part of an ambitious $2B program of developments at Canada's third largest airport.

The opening of the tunnel marked the culmination of 3 years of intense effort on the part of The City and the Airport Trail Tunnel team. As the team's Prime Consultant and Consultant Project Manager, CH2M was responsible for leading the multidisciplinary engineering and detailed design of all disciplines, including structural design of the tunnel, contract administration, and services during construction. CH2M had also served as Project Manager for the functional planning of the tunnel, assisting The City in establishing the budgets, design parameters, and timelines that would govern the project.

CH2M was supported by a strong, collaborative group of subconsultants that included Associated Engineering Ltd. (roadway, electrical and mechanical design; drainage; and lift station design), Thurber Engineering Ltd. (geotechnical engineering), and ADP Engineering Ltd. (east-side streetlighting design). The City engaged PCL/Parsons/ Dufferin Joint Venture (PPD) as Construction Manager to provide constructability and schedule input, and to tender and manage the onsite construction work.

Stepping Up to the High-Profile Project

When Barlow Trail had to be closed between McKnight Boulevard and Airport Road to facilitate construction of the new runway and taxiways, The City was presented with both an opportunity and a challenge.

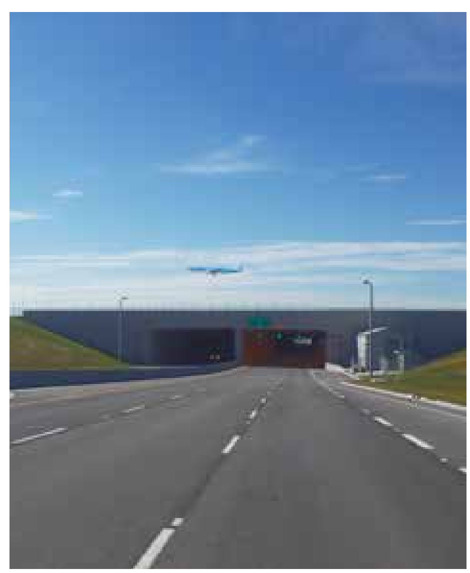
The opportunity was clear:
Enhance roadway network connections to the airport by extending Airport Trail from Barlow Trail to 36 Street NE, paving the way for further extension to the east and providing for a light rail transit line to the YYC terminal in the future

The challenge was more daunting:
Complete the tunnel work quickly, on the same site, without disrupting the runway's construction or delaying its scheduled opening date of June 2014

Barlow Trail is a significant roadway and commuter route for many Calgarians, especially northeast residents, as well one of two major access routes to the airport for travellers from all over the city. The tunnel had been a key point of debate in the 2010 municipal election and would be under greater public scrutiny than other infrastructure projects. The pressure was on – and the clock was ticking.

A Winning Project

- *Alberta Construction* Magazine's 2013 Top Projects Award (Civil Over $50M)
- 2013 American Concrete Institute (Alberta Chapter) Award of Excellence (Civil)
- 2014 Canadian Society of Safety Engineering Award (Calgary Chapter) CSSE Special Project Award
- 2014 Project Management Institute: Southern Alberta Chapter, PMI-SAC Project of the Year (Finalist)
- **2015 Consulting Engineers of Alberta Award of Excellence - Project Management**



Two Projects, Two Owners, One Location, One Hard Deadline

Meeting the fast-track schedule while addressing the tunnel's technical requirements and coordinating construction with the runway was the Airport Trail Tunnel Team's most significant challenge. With the runway's deadline looming, tunnel construction had to get started quickly, leaving little time for a typical design and review process.

To meet the Runway Development Program timeline, the tunnel project schedule was broken down into the following milestones, key points at which the tunnel sections were "handed over" to YYC so their work on the runway could proceed:

- August 31, 2012: Complete the construction of half of the tunnel immediately under the runway, along with the gravel fill required to build up the base of the runway structure, so that **runway construction over the tunnel could begin**
- October 31, 2012: Complete the construction of 85 percent of the length of the tunnel so that **construction of three new taxiways associated with the new runway could get underway**
- June 30, 2013: Complete construction of the full length of tunnel so that **the remaining airfield work could be completed**

As soon as The City's municipal processes allowed, CH2M initiated the design of those aspects of the project that would allow a contractor to begin site work as soon as a lease agreement was in place with YYC. Just 3 months after the design was initiated, design and construction were underway simultaneously. The work was staged to focus first on the excavation, which would allow the structural work to begin, and then completing the excavation while the structural work was in progress. To manage the simultaneous design and construction progress, the team separated the scope of work into 15 work packages, many with more than one trade contractor, and in several instances, multiple trade contractors providing similar and interdependent scopes of work.

To monitor and ensure progress, the project was broken down into measureable components for excavation, underground utilities, structure, and backfill. Careful planning resulted in achievable milestones and allowed for contingency to account for any unexpected conditions that might be encountered. The specific milestones, design, and construction work packages were time-bound to achieve the outcome.

"The project managers and work crews have done an outstanding job in completing this complex project and in meeting many tight deadlines over the past three years."

Mac Logan, General Manager – Transportation,
The City of Calgary
Press Release May 24, 2014

Quick facts about the tunnel

- More than 600,000 m³ of excavated earth and rock
- More than 2.5 km of water and stormwater utilities
- Approximately 45 kms of electrical conduit
- 12,000 tonnes of reinforcing steel
- More than 60,000 m³ of concrete
- 32 100-horsepower exhaust jet fans
- 1,380 lighting fixtures

Photo credit: Brad Heninger

Calgary's Airport Tunnel Timeline

2011

February

City Council approves construction of the Airport Trail tunnel

Design begins April

July

Excavation begins

October

Start of watermain and storm sewer installation

November

Casting of first tunnel footings

2012

February

Concrete pour of the first of 50 tunnel walls and roof sections

May

Start of excavation for storm water lift station and tank

May 27

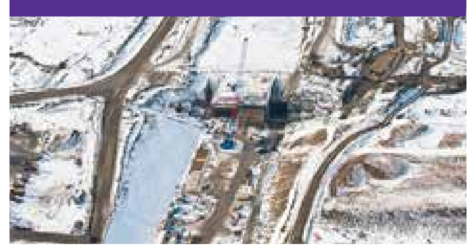
Start of backfill operations under the future runway

August 31

Hand over to YYC the area above the tunnel under the future runway

October

Completion of tunnel concrete work and hand over to YYC the area above the tunnel under the taxiways



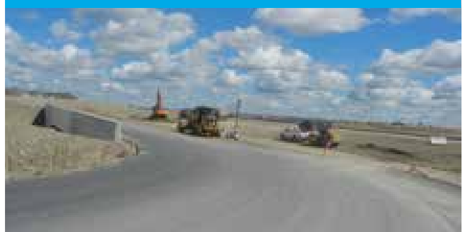
Calgary's Airport Tunnel Timeline

May

Completion of storm tank structure

July 31

Hand over to YYC the area above the tunnel under west perimeter service road



May 2

Smoke test with Calgary Fire Department – proves automated smoke detection and exhaust fan control

2013

2014

June 1

Delivery of West control building

February

Commissioning of lift station pumps

May 24

Airport Trail Tunnel Opening Event

June 30

Hand over to YYC the area above the tunnel under east perimeter service road

August/September

Completion of exhaust fan installation

May 25

Tunnel open to traffic

Timely, Quality Delivery of Design and Construction

The size of the project team varied, with an integrated core project management team of about 25 City, CH2M, and PPD personnel supported by more than 100 staff for various durations throughout the project.

Construction manpower represented about 2,200 workers over the course of the project – a maximum of about 200 onsite at any one time.

Because of the logistics involved in managing the tunnel's simultaneous design and construction process, while coordinating with the Runway Expansion Program, the tunnel project could easily have been derailed by differences of opinion regarding how it should proceed. With skillful project management, it became an opportunity to use creative teamwork and an open communication process to build the framework for success.

The project also benefited from the involvement of the team's accomplished senior project managers, engineers, and technical specialists who brought expertise in key areas and specific experience in the fast-track delivery of challenging assignments. Under the leadership of CH2M as Project Manager and PPD as Construction Manager, the team adopted a multidisciplinary approach that involved having all the designers and the Construction Manager's team at the table at the same time – and building constructability into the design from the beginning. This allowed the team to focus on specific elements of the design that were on PPD's critical path, with a view to understanding how the design of those elements would affect the overall project. The result was a design that was optimized for constructability, which was imperative to maintaining the schedule and to delivering a quality project on budget.

This inclusive approach was also reflected in the team's open, flexible communication style. Many of the decisions were made and documentation created at meetings and via e-mail, then followed by formal documentation to reflect the contractual requirements. Co-locating CH2M and PPD team members on the site opened up opportunities for communication and rapid transmission of information. Regular meetings with the Tunnel's major external stakeholder – YYC's runway project – allowed for clear communication regarding each project's site constraints and how the impacts were to be mitigated. The City of Calgary – Transportation Infrastructure was an integral part of all of these meetings, as the scope, schedule, and budget for the project were under their ultimate control.

With construction started before design was complete, and the runway and tunnel projects both underway in the same location, decisions often had to be made quickly – which demanded open communication grounded in trust.

Owner: THE CITY OF CALGARY TRANSPORTATION INFRASTRUCTURE

Prime Consultant: ch2m

Construction Manager: PCL, PARSONS, Dufferin Construction

Subconsultants: *Associated Engineering Ltd., Thurber Engineering Ltd., ADP Engineering Ltd.*

Navigating the Tunnel's Many Challenges

Coordinating the construction of two major projects in the same place at the same time inevitably leads to challenges, especially when when two Owners are involved. CH2M maintained a firm hand on the project management side, while the team as a whole addressed the many technical challenges presented by the tunnel's design and construction. In addition to diligence and careful planning, this required expertise, advanced technical knowledge, and considerable innovation on the part of the Airport Trail Tunnel Team.

Legend

Meeting Fast-track Schedule · **Management of Risk** · **Degree of Difficulty** · **Benefit to Society** · **Environmental Value** · **Technical Excellence** · **Innovation** · **Added Value** · **Advancement of Technology**

Effective Management for On-Time, On-Budget Delivery

CH2M led weekly design meetings, with the Construction Manager as a key contributor to decision-making. Because design and construction were an integrated process, these meetings continued for almost 18 months.The budget was managed through constant tracking of tendered costs, construction budget, and contingency funds to ensure that expanded scope was still within The City's budget. Most decisions were schedule-driven. Meeting The City's milestones while addressing technical challenges sometimes meant that work was underway around the clock. The project was delivered to meet The City's budget of $294.8 million.

Comprehensive Tracking to Manage Risk

The Construction Manager (PPD) created and maintained a risk register that identified anticipated and encountered risks and ranked them according to criticality with respect to schedule and cost impacts. The register also included proposed mitigation measures, and risk items were all tracked through to close-out. Discussions among The City, PPD, CH2M, and, YYC often revealed anticipated risks, which enabled the tunnel team to put measures in place to mitigate them.

The choice of contract type also contributed to effective risk management. The City assumed more risk in unit-price contracts, while trade contractors assumed more risk in lump-sum contracts. Decisions regarding risk management choices often followed convention – for example, roads contracts are often unit price based.

A Built-in Commitment to Quality

Quality management was the result of a fully collaborative approach among CH2M and the technical subconsultants, PPD, and the trade contractors. Each played a role that ensured multiple reviews of many aspects of the complex project. Generally speaking, the trade contractors were responsible for maintaining their proposed quality control (QC) program, as approved by CH2M, who provided quality assurance (QA) for the project with a shadow program of testing and review. PPD was responsible for ensuring that contractor QC was achieving the requirements, both in workmanship and inspection and in testing, and for coordinating the QA requirements with construction progress. PPD compiled and maintained the complete set of QA and QC data for hand-over to The City and YYC.

Excavating in unpredictable geotechnical conditions

The excavation was complicated by highly variable and unpredictable geotechnical conditions, as well as difficulty with slope stability. As a result, the crews had to adjust their equipment and techniques frequently, depending on the conditions. At one point, they were working 24 hours/day, 7 days/week to achieve the schedule. To manage these changing conditions, the contractor used equipment that is typically used in surface mining. This equipment, made it possible to produce a by-product that could be used for fill applications on both the runway and the tunnel, saving time, hauling distances and the associated emissions, and costs.

Determining the design loads required to support the aircraft above

Determining the design loads for the tunnel was a particular challenge, since this information is not part of Canadian codes and standards to date. In developing the calculations, CH2M's design team had to consider both the weight of the plane and the configuration of its landing gear – that is, the distribution of the plane's weight across the tunnel. The heaviest planes did not necessarily impose the biggest load on the tunnel, and dozens of landing gear configurations had to be considered. The design load also had to factor in accidental situations, such as a plane straying from the runway and imposing load on the tunnel structure without the benefit of an overlying pavement structure. In the end, the tunnel is designed for loading from an Airbus A380, which weighs more than 600-tonnes.

Devising the innovative formwork system to meet the fast-track schedule

The formwork system used to hold the reinforcing steel and wet concrete as it sets and cures could have been cast with one set of forms. To achieve the aggressive schedule, four separate sets of travelling tunnel forms were used, each weighing more than 170 tonnes. Starting in the middle and working outward, the tunnel segments were cast concurrently using a 'leap frog' method of construction, with the lead segments cast in isolation and infill segments cast with a second set of forms. The tunnel required more than 50 large concrete pours each using 850 m3 of concrete and taking more than 15 hours to complete. To simplify and speed up the process, the concrete formwork was moved on rollers. Two custom-designed rolling tent-hoarding structures protected the concrete from winter conditions, rain, and excessive sun and wind – one of them used for segments on the east side and the other west side.

Creating the large-scale cast-in-place concrete structure

More than 60,000 m3 of concrete was placed in 12 months in order to meet the required hand-over schedule. This work demanded precision, particularly with respect to temperature. All concrete delivered to the site had to be maintained at or below 20 degrees Celsius, which required up to 76,000 kg of ice per tunnel segment. To enhance effectiveness of the cooling in warmer weather, a system was built onsite to inject liquid nitrogen into the drum of a concrete mixer truck, so that the temperature of the concrete could be reduced prior to placement. Using this system in conjunction with the ice at the batch plant helped to keep up with the very high rate of concrete delivery required and assisted in meeting deadlines. Project scheduling requirements also called for a specially-designed concrete mix that would allow for form removal after 3 days. The concrete expertise demonstrated on this project was recognized with the 2013 Award of Excellence (Civil) from the Alberta Chapter of the American Concrete Institute.

Customized backfill to meet site groundwater requirements

The space created between the excavation and the tunnel wall is often backfilled with the excavated material itself. Because of the site's significant groundwater flows, as well as the potential for ingress from the airfield drainage ditches above, a modified engineered material was used instead. This material had similarities to a crushed road base granular product, but the fines were partially removed to allow for water to drain through the gravel. A perforated pipe was installed at the base of each tunnel footing (outside and center tunnel walls), to collect all water passing through the backfill material, enabling the structural design to minimize the hydrostatic loading from water retained behind the tunnel walls.

Waterproofing to enhance the tunnel's durability

One of the biggest threats to the durability of concrete is the deterioration caused by the chlorides transported by water. To protect the concrete structure and suit cold weather and "green" concrete conditions, a waterproofing layer was applied to the tunnel's exterior surfaces, which were then covered with backfill. The sheet-laid waterproofing layer was applied soon after stripping the concrete formwork and produced more consistent results than many of the liquid applied waterproofing alternatives. The exposed, mostly interior, surfaces of the tunnel were treated with a pigmented sealer whose elastomeric properties allow it to stretch over the microscopic cracks that develop during the life of concrete. This significantly reduces the concrete porosity, slowing the deterioration from chlorides.

Improving tunnel design in the future

The City of Calgary and CH2M realized early in the tunnel design process that the structural behaviour of tunnels is not well understood. Given the large variations in temperature that Calgary experiences, it was decided to monitor the long-term behaviour of the tunnel structure. Remote data monitoring has been implemented to measure the ambient temperature, concrete structure temperature, and movement across expansion joints and at dozens of locations throughout the tunnel. The measured data is collected using wireless technology and sent via cellular telephone networks to a monitoring centre outside of Calgary. This data will be used by local academic researchers to confirm some of the design concepts used for the tunnel, and potentially improve upon these concepts for future tunnels.

Ensuring the Safety of Tunnel Users

Because tunnels must comply with requirements typical of building codes (smoke and fire detection, emergency egress, smoke ventilation), safety was a prime consideration. To enhance fire protection, the tunnel walls were designed with additional concrete cover, a simple step that saved the costs, labour, and time associated with fire protective layers. An additional cementitious product was sprayed on the ceiling to insulate the concrete from the brunt of the temperature imposed by a fire.

Tunnel air quality is maintained by 32, 100-HP exhaust jet fans, each weighing 570 kg. The air is constantly sampled using an innovative Very Early Smoke Detection Apparatus (VESDA) system that draws air into eight detection points via perforated tubes mounted to the tunnel walls (noxious gas) and ceiling (smoke). The VESDA system allows for automation of fan control for smoke and gas exhaust. Manual control of fans is available to firefighters.

Automated alarms connect to The City's Traffic Management Centre (TMC), where operators have access to hundreds of traffic cameras. Closed circuit television (CCTV) cameras throughout the tunnel enable TMC operators to assist with motorist incidents and support emergency responders. Because of the tunnel's position under the runway, YYC has installed further CCTV monitoring to provide additional security. State-of-the-art incident detection software uses the CCTV feeds to determine when a vehicle stops in the tunnel (collision, mechanical breakdown, etc.), notifying TMC operators with a flashing alert on their monitors.

Protecting the Environment

The project presented several opportunities to protect the environment, such as using all excavated material from the tunnel on the runway and tunnel construction sites – thereby reducing greenhouse gases – and creating temporary ponds for sedimentation control during construction. However, the most constant environmental challenge was stormwater and groundwater management. The emphasis was on protecting the natural watershed from silt-laden water leaving the site, some the result of runway construction / grading increased the volumes and some from the tunnel construction site – particularly during the rains associated with the 2013 flood. Water from the tunnel construction was pumped to a runway dry pond that drains to a City sewer. It continues to be pumped by the tunnel's lift station and is treated by an additional underground device before discharge into the pond. The City and YYC have agreed to long-term monitoring of the dry pond to assess performance of these efforts to mitigate sediment leaving the airport's pond.

Benefiting All Calgarians

The high-profile project was completed on-time and on-budget, meeting the expectations of The City, the Calgary Airport Authority, and the travelling public, particularly those who live and/or work in the communities surrounding the Airport. Along with improved access to the airport terminal, the tunnel provides improved connectivity to the lands now being developed immediately east of the new runway. And when the opportunity arrives for The City to expand travel options to the airport, planning will be that much easier: the tunnel was designed to accommodate or allow for the implementation of a light rapid transit link to the airport terminal.

Calgary's Mayor Naheed Nenshi focuses on the crowd at the Airport Trail Tunnel Opening Event

"This is a big deal for many, many reasons. It represents the culmination of a lot of hard work by a lot of people in the community as well as a lot of my colleagues with The City of Calgary and our partners. I'm very proud of them for delivering this project on time and on budget."

Mayor Naheed Nenshi May 24, 2014

Photo credit: Brad Heninger