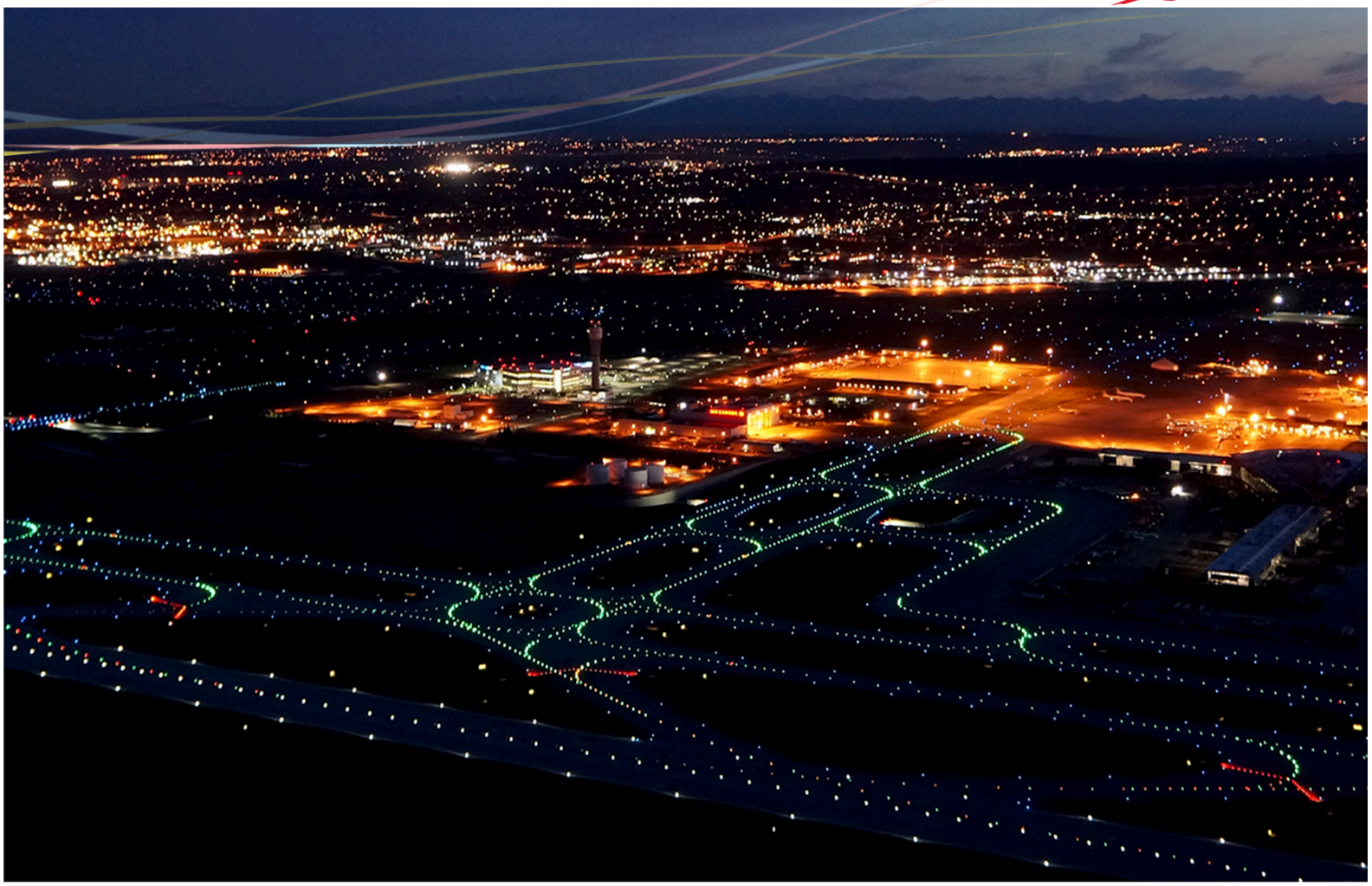
Canadian Consulting Engineering Awards 2015

Calgary International Airport Runway and Tunnel

Smart systems open roads and open skies

Calgary, Alberta



CALGARY AIRPORT RUNWAY AND TUNNEL

Lead Engineering Consultants:	Associated Engineering and CH2M HILL
Program Managers:	AECOM and Hatch Mott MacDonald
Owner/Clients:	The Calgary Airport Authority and The City of Calgary
Other Consultants:	Thurber Engineering Ltd., ADP Engineering Ltd., and CNSS Engineering
Contractor:	PCL Contraction Inc., Parson Corporation and Dufferin Construction

Associated Engineering — Global perspective. Local focus.

CH2MHILL

AECOM

Hatch Mott MacDonald

ASSOCIATION OF CONSULTING ENGINEERING COMPANIES | CANADA
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Executive Summary

The Calgary International Airport has experienced significant growth in the past two decades. In 2010, with its runway operating at capacity, the Calgary Airport Authority retained Associated Engineering and CH2M HILL as its prime consultant as well as AECOM and Hatch Mott MacDonald as its program manager to deliver its $620 million Runway Development Project.

Concurrently, the City of Calgary saw the Runway Development Project as an opportunity to improve the road network improvements to service northeast Calgary lands. The City engaged Associated Engineering and CH2M HILL to complete a new $295 million tunnel under the runway.

In simultaneously completing these two major projects, the Project Team designed the longest, most technically advanced runway in Canada. The runway features a Category IIIa runway lighting system, which allows aircraft to land in low visibility. Use of energy efficient LED lights—a first in the Americas—improves energy efficiency and performance of the lighting system. Advanced controls and monitoring systems incorporated into the runway lighting system enhance safety.

Custom designed concrete mixes for the runway and tunnel improve performance and durability in Calgary's unique climatic conditions.

Collaboration between Associated Engineering and CH2M HILL, the Calgary Airport Authority, AECOM and Hatch Mott MacDonald, the City of Calgary, and Construction Manager mitigated issues and risks, and fast-tracked design and construction, resulting in the successful completion of these projects on time and on budget.

The runway and tunnel allow more local and international travellers to Calgary, encourage surrounding development, and create jobs, boosting our economy.

Calgary International Airport Runway & Tunnel

- Longest runway in Canada
- Largest airfield electrical and lighting project
- Most ambitious concrete paving operation
- Largest number of runway and taxiway underpasses
- First CAT IIIa runway in North America with runway LED lighting
- First six-lane public road tunnel under runway
- Smart systems that enhance safety

Introduction

For more than 20 years, the Calgary Airport Authority has experienced steady growth at the Calgary International Airport. With demand exceeding the runway's capacity, particularly at peak times, and planning showing continued growth, the Calgary Airport Authority embarked on developing a new, parallel runway. Working with the Program Manager, AECOM and Hatch Mott MacDonald, the Calgary Airport Authority retained Associated Engineering and partner CH2M HILL for the engineering design and construction of the $620 million runway development project.

With expected increases in travellers going to and from the airport terminal, the City of Calgary wished to construct new roads around the airport to improve access to the terminal, and support the road network east of the airport. With work on the new runway closing major roads near the airport, the City saw the opportunity to construct a tunnel to extend one of the roads, Airport Trail under the new runway, an important component of its roadworks expansion. With Associated Engineering and CH2M HILL already working on the design of the runway, the City of Calgary retained this team to complete design and construction of the $295 million Airport Trail Tunnel.

Project Objectives

The Calgary Airport Authority needed a new parallel runway at the Calgary International Airport to provide additional capacity and accommodate larger, long-haul aircraft used on international flights. In addition, the Airport Authority wanted to improve the runway landing system to allow landing in low visibility weather conditions.

The City of Calgary wished to extend the key arterial airport access road, Airport Trail, to the east to improve traffic flow around the airport, provide access to areas east of the airport, and accommodate light rail transit to the terminal in the future. This required constructing a section of Airport Trail under the new runway.

Each project was a major design and construction effort on its own; delivering both projects together increased the level of complexity for the engineering team. Design

of the runway was already underway when the City awarded the tunnel project to our team. Notwithstanding, segments of tunnel had to be constructed within a tight schedule so that the runway and taxiways could be built on top.

Solution

The runway and tunnel projects feature a 4,270 metre long by 60 metre wide runway and a six-lane, 620 metre long tunnel –the longest runway and longest tunnel of its kind in Canada.

The new parallel runway is designed for the largest Code F aircraft (Airbus A380 and Boeing B747-8) and the most advanced, Category IIIa runway landing system. The new runway landing system allows uninterrupted aircraft operations at visibility limits down to 200 metres.

Other elements include fifteen new taxiways, two taxiway underpasses (166 metre and 61 metre lengths), aircraft parking apron, Field Electric Center and 11 kilometres of service roads.

With a tight schedule for the runway and tunnel, project management, technical excellence, and collaboration between the Associated Engineering/CH2M HILL team, the AECOM/HMM team, The Calgary Airport Authority, Construction Manager, and City of Calgary were keys to successfully completing these two major projects.

Fast-track design and contract packaging allowed construction to begin in select areas of the project, while design was ongoing. Careful sequencing and scheduling of the contract packages was required to complete segments of the tunnel at critical deadlines, which allowed runway and taxiway construction to proceed on top of the tunnel.

Innovation

The team employed smart systems and controls to improve design and construction efficiency, enhance safety, reduce energy use, and reduce overall costs.

Airfield Lighting

The design of the Category IIIa system includes more than 5,000 runway and taxiway lights with over 700 kilometres of airfield power cables and 40 kilometres of fibre optic cables originating in the Field Electric Center.

During construction in 2013, designers identified that LED runway edge and runway centerline airfield lighting had become available. The team recommended

substituting energy-efficient, high intensity LED lights for the specified runway lighting, marking the first use of inset and elevated edge LED lights for a Category IIIa runway in Canada and the United States.

The design team developed a sophisticated lighting control system, required to certify a Category IIIa precision approach runway. To minimize risk and enhance safety, key runway and taxiway wiring is interleaved with adjacent lights operating on different circuits.

To enhance safety and prevent runway incursions during low visibility conditions, approximately 500 airfield lights are individually powered, controlled and monitored by the Surface Movement Guidance and Control System.

Pavement sensors are installed to detect aircraft. Individual alarms appear if any of the lights are not functioning properly. During the low visibility conditions, the system runs on a 900 kilovolt amps diesel generator, backed up by the local energy provider.

The complex power transition system must switch between power sources in less than one second, ensuring that aircraft safety is not compromised during critical landing operations.

Tunnel and Underpass Structures

Determining structural design loads for the tunnel and underpass structures was a challenge since this information is not part of Canadian codes and standards and few structures are exposed to such high loads. The team evaluated aircraft weights and wheel base loads in various configurations to determine the design load.

Using complex finite element analysis models, the reinforced concrete structures, consisting of over 85,000 cubic metres of concrete and 16,000 tonnes of reinforcing steel, were designed to support the worst case static and dynamic loading scenarios from the aircraft traveling along the taxiway.

Approach slabs and granular backfill transition slopes were used to prevent concentrated vertical differential settlement to mitigate potential long-term runway and taxiway pavement surface smoothness irregularities.

To satisfy safety requirements in the tunnel, special systems were designed for fire protection, smoke and fire detection, and ventilation. To enhance fire protection, additional concrete cover was provided. An additional cementitious product was sprayed on the ceiling to insulate the concrete from high temperature damage resulting from vehicle fires or explosion.

Also, an innovative Very Early Smoke Detection Apparatus system was installed in the tunnel to monitor air quality at various detection points. The system automates the exhaust fan controls. Closed circuit television cameras were installed throughout to enable

the Airport Authority and City operations staff to assist with motorist incidents, support emergency responders and provide additional security.

For the tunnel, an innovative formwork system was used to achieve the aggressive fast track schedule. The system consisted of four separate sets of travelling forms, capable of being moved on rollers, each weighing more than 170 tonnes. Two custom designed rolling tent hoarding structures protected the concrete from inclement conditions, rain, and excessive sun or wind.

For the Taxiway J Underpass, special consideration was required to protect the existing airport aircraft fuel tank farm facilities. To maintain stability, protect the foundations and prevent settlement damage, a temporary secant pile wall using ground anchors was built along the north side of the tank farm prior to retaining wall construction.

To mitigate airport vehicle traction concerns during icy conditions and freezing temperatures due to the steep, 4% ramp gradient, an in-slab ramp snow-melt de-icing system covering approximately 4,300 square metres and consisting of a 150 millimetre thick concrete overlay embedded with 28 kilometres of glycol lines was used.

The de-icing system is the largest ramp heating system in Canada. At the connected heating plant, an innovative heating system using condensing boilers and a custom heating control sequence was installed to optimize thermal efficiency and maximize moisture removal from the combustion exhaust gases.

Energy efficient airfield lighting system and custom control systems make the Calgary International Airport one of the safest and most sophisticated in Canada.

Complexities

Delivering two, large and complex projects at same time, on the same site for two different clients required strong project management and collaboration to develop technically advanced solutions, manage risks, and meet the tight schedule. The team addressed the following key issues:

- The Project Team proactively engaged all stakeholders to discuss design options in a collaborative environment. Our team prepared more than 45 discussion papers to identify design criteria, options,

constructability issues, and risks, allowing the Calgary Airport Authority and the City of Calgary to efficiently make decisions.

- To meet tight, 38-month construction schedule for the runway, we accelerated design and developed contract packages. The work packages were developed within a Work Breakdown Structure that established work sequencing to accommodate the release of design and construction work packages to achieve the overall schedule and milestone dates.
- Segments of the tunnel had to be constructed within key milestones so that the airfield including runway and taxiways could be built on top. Fast-tracked design and work packaging permitting construction to commence within three months of project award.
- To suit Calgary's climate, we developed a custom concrete pavement mix for the runway. The concrete mix produces a pavement with reduced permeability, so it is not prone to segregation or degradation from freeze-thaw. An important part of the mix design was that it could be placed using high production, slipform equipment, which would achieve maximum pavement quality. We specified that the contractor use uniform slipform paving and pour the 435 millimetre thick concrete slab in a single layer, up to 12.5 metres wide—the most ambitious concrete paving operation ever performed in Canada. This approach maximizes strength of the concrete, helps fast-track construction, and was the most cost effective. This methodology results in a concrete pavement that provides improved

performance for aircraft take-off and landing. Within the overall 400,000 cubic metres concrete paving, over 300,000 cubic metres was completed during a five month period; and 55,000 cubic metres was completed in 3 weeks during the summer 2013 to achieve the project schedule. On our record paving day, over 5,000 cubic metres was placed during a 24 hour period – more production than any other concrete paving project in Canada.

- To achieve the tunnel schedule, a custom concrete mix was developed to allow for form removal after three days. To enhance effectiveness of cooling the concrete mix in warmer weather, a system was built onsite to inject liquid nitrogen into the drum of the concrete mixer truck, so that the temperature of the concrete could be reduced prior to placement. This helped ensure the very high rate of concrete delivery required to meet the deadlines.
- To manage 8.1 million cubic metres of earthworks for runway and tunnel construction, we developed an advanced earthwork model to optimize the use of on-site materials and minimize imported materials. All earthwork remained onsite, with no export of native earth. Crushed

concrete was re-used on site instead of importing crushed granular materials for maintaining roadways and construction haul routes.

- Pavement Life Cycle Cost Assessment was carried out to evaluate pavement system alternatives for the new runway and taxiway. The assessment was based on initial capital cost, discount rate for present worth calculation, lifetime maintenance and rehabilitation costs, savage value and user negative benefits (i.e. aircraft delays during rehabilitation), the results indicated that although the initial capital cost of a rigid Portland cement concrete structure was 6.6% higher than the equivalent flexible asphalt pavement structure, the 40 year life cycle cost of the rigid structure was 10% less, and 74% less materials were transported to the airport site.
- Value engineering for the airfield pavement design optimized the overall paving layout, steel reinforcement, and grade elevations to maximize the use of slipform paving equipment. Recycled Asphalt Pavement materials were used in shoulder and service road asphalt mixes. RAP was used for Runway End Safety Area and service road surfaces. Value engineering identified cost efficiencies and accelerated schedule without compromising the level of service.
- The original concept for drainage used large diameter pipes requiring 300 days to manufacture, jeopardizing schedule. Our alternate drainage design met project schedule and saved $5 million.
- Canadian codes and standards did not include design loads for the tunnel. We developed design load, considering aircraft weight, landing gear configuration, and load arrangements.
- Wet weather, in particular the 2013 floods, challenged construction. We worked with contractors to develop plans to maintain progress and pavement quality. Together with the Program Manager and the Construction Manager, our team developed a Winter Work Plan that facilitated earthworks movement and concrete pours during the cold winter months, critical to maintaining the project schedule.
- To address variable, unpredictable geotechnical conditions, we worked with the contractors to adapt equipment and techniques to maintain excavation schedule and pavement quality. Issues included settlement, subsurface moisture, unstable rock, slope stability, and variable subsurface groundwater conditions. At times, specialized surface mining equipment was used to achieve the schedule and excavate the rock, which also made it possible to produce a by-product that was used for fill embankment, thus saving time, hauling distances as well as the associated emissions and costs.

- Significant groundwater flows and potential for airfield drainage around tunnel required high performance waterproofing layer, engineered backfill and drainage system to minimize hydrostatic loading on tunnel walls.
- Close coordination was required with teams involved in other concurrent major projects including the $1.4 billion Calgary Airport International Facilities Project, as well as the Nav Canada Air Traffic Control Tower, which consist of a new 300 foot tower adjacent to the new runway and Category IIIa Instrument Landing System facilities. The Project team designed and oversaw construction of Nav Canada's airfield infrastructure. Comprehensive integration and interface coordination was required to complete the work to suit the Nav Canada technical and operational requirements on time and within budget.
- A Project Risk Matrix was established to identify risk elements, assess the level of risk exposure and monitor/mitigate risks throughout the project including availability of construction materials, capacity of the industry, availability of trucking, water requirements during construction, size and location of laydown areas, contract interface issues and earthworks management.

Effective teamwork, careful scheduling and risk management key to overcoming complex challenges.

Social & Economic Benefits

The Calgary International Airport is an important economic engine for the city, region, and province, generating more than $6 billion in economic activity.

The new Category IIIa runway increases the aircraft take-off and landing capacity of the existing airfield, meeting current and future demands so the Calgary International Airport will be able to keep pace with the passenger and cargo traffic growth well into the future.

The runway and tunnel projects provided construction employment for more than 600 workers on an average daily basis, more than a total of 2.5 million person hours, and stimulated additional employment in the Calgary region, including major land development projects.

The team incorporated state-of-the-art systems in the tunnel design to improve safety for travellers. To enhance fire protection, the tunnel walls were designed with additional concrete cover and a cementitious ceiling coating for insulation. Tunnel air quality is maintained by 32, 100-HP exhaust jet fans.

An innovative Very Early Smoke Detection Apparatus system samples and tests tunnel air for smoke and gas. Automated alarms connect

to the City's Traffic Management Centre. Closed circuit television cameras and incident detection software enable operators to assist with motorist incidents and support emergency responders.

Given the large temperature variations in Calgary, devices were installed in the tunnel to measure ambient and structure temperature and movement across expansion joints. Researchers will use data to advance tunnel design in the future.

For travellers and commuters, the tunnel improves access to the airport and connectivity to lands being developed to the east of the airport. Built to accommodate light rail transit, the tunnel paves the way for additional modes of transport to the airport.

The new, longer runway increases aircraft capacity and accommodates larger aircrafts, making way for longer, direct international flights. Aircraft idling time is reduced, benefitting travellers and the environment.

The new Category IIIa airfield lighting system ensures safe and efficient aircraft movements during poor weather, low visibility conditions. The runway development increases travellers to and from Calgary, stimulating the local and provincial economy.

To foster beneficial relationships with the local community and enhance the 'Team Culture", the Project Team supported a local charity on an annual basis. Fundraising activities were organized and carried out throughout the year to collect donations for the local groups such as INN from the Cold, Sonshine Centre, The Boys and Girls Club of Calgary, The Children's Cottage Society of Calgary and Discovery House. The Project Team donated more than $70,000 to these charities.

Improvements in both air and land accessibility will contribute to the economic engine of southern Alberta.

Environmental Benefits

The Project Team developed and implemented a Comprehensive Study, following requirements of the Canadian Environmental Assessment Agency. Environmental monitoring and inspections were completed during construction.

A project specific Sustainability Matrix reporting tool was setup to establish sustainability targets, which were scored to evaluate implementation versus plan. The Sustainability Matrix was updated periodically to ensure the effectiveness of the sustainability initiatives and, ultimately, sustainable, environmentally responsible project delivery.

The environmental footprint of the runway and tunnel projects was reduced by recycling and reusing existing materials. Asphalt millings from the existing Barlow Trail NE were reused as pavement for the 11 kilometres of new Airside Service Road.

Where possible, excavated rock was ground and used as the road base for the Airside Service Road, significantly reducing quantities of imported granular material, and the need to truck away unused materials. All earthwork remained onsite with no export of native earth off site.

During the excavation for the tunnel, the contractor used equipment that is typically used in surface mining. This equipment made it possible to produce a by-product that was used for fill on the runway and the tunnel, saving time, hauling, and associated emissions and costs.

A dry pond was created for sedimentation control during construction. The sedimentation pond protected the natural watershed from silt-laden stormwater, especially during 2013 floods. Post-construction, drainage from the tunnel continues to be pumped to the pond. The City and the Airport Authority have agreed to long-term monitoring of the dry pond to assess its performance to mitigate sediment leaving the airport's pond.

The alternative runway drainage design reduces potential soil erosion.

Using LED lights for all airfield lighting reduces energy consumption by more than 50%, increases performance, and significantly increasing service life.

The choice of concrete as the pavement surface will have a positive impact on the runway's maintenance life cycle costs. The use of rigid Portland cement concrete pavement versus flexible asphalt pavement resulted in a lower environmental impact as 74% less material was transported to the airport site.

Planning, setting targets, and evaluating results ensured sustainable, environmental responsible design, and construction.

Meeting Client's Needs

The Airport Trail Tunnel and the Calgary International Airport's parallel runway opened in Spring 2014, marking the completion of these projects on time and on budget. Completing these high profile, complex, technically challenging projects at the same time, on the same site for two clients is a testament to the project management and technical expertise of the Project Team, and their strong collaboration with the Calgary Airport Authority and the City of Calgary.

The tunnel improves connectivity to the lands now being developed east of the airport. Designed to accommodate light rail transit, the tunnel provides the opportunity to expand travel options to and from the airport.

The new runway expands capacity of the airport. With the ability to land new, larger aircraft, the new runway boosts local, provincial and the Canadian economy, bringing local and international travellers, encouraging surrounding development, and creating jobs.

"It's the longest runway in Canada. It can handle the world's largest aircraft. You won't get a better runway than this one." Garth Atkinson, President and CEO, Calgary Airport Authority.