

Leveraging the Operational and Cost Advantages of Hot In-place Recycling for a Single-Runway Airfield Pavement Rehabilitation Project at Kelowna International Airport

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ABSTRACT

In 2011, the City of Kelowna tendered the Rehabilitation of Runway 16-34, Taxiways A, B and C. The tender included the resurfacing of Runway 16-34, widening and resurfacing of Taxiway C, and resurfacing of Taxiways A and B at their existing dimensions. The tenders received were about 40 percent over budget, and the project was subsequently cancelled.

SNC Lavalin Inc. then completed a project review and developed a revised 2012 Work Plan for the project including a less operationally disruptive resurfacing approach, eliminating some requirements that were perceived as onerous by Contractors, and removing non-contiguous work elements.

In January 2012, the runway resurfacing project was re-tendered as a stand-alone Hot In-place Recycling (HIR) project. The Taxiway A, B and C rehabilitation work was re-tendered separately in May 2012.

Because of these and other changes, the cost of the runway and taxiway rehabilitation projects was reduced from the 2011 low-bid tender of \$6.256 Million, to a new, combined cost of \$2.893 Million. Both projects were completed in the summer of 2012, ahead of schedule, under budget, and with no operational disruptions.

This paper provides an overview of the project from inception to completion.

RÉSUMÉ

En 2011, la ville de Kelowna a effectué un appel d'offres pour la réhabilitation de la piste d'atterrissage 16-34, et des voies de circulation A, B et C. L'appel d'offres incluait le surfacage de la piste 16-34, l'élargissement et le resurfacage de la voie de circulation C, et le resurfacage des voies de circulation A et B dans leurs dimensions actuelles. Les propositions reçues étaient environ 40 pourcent au-dessus du budget, donc le projet a été annulé.

SNC Lavalin Inc. a par la suite revu le projet et a développé un plan révisé en 2012 pour le projet en incluant une approche de surfacage qui nuit moins aux opérations, en éliminant quelques obligations qui étaient perçues comme trop dispendieuses par les contacteurs et en éliminant des travaux non contigus.

En janvier 2012, un appel d'offres pour seulement le recyclage en place à chaud (HIR) de la piste a été soumis. Les travaux de réhabilitation des voies de circulation A, B et C ont été inclus dans un autre appel d'offres en mai 2012.

Pour cette raison, et aussi à cause de certains autres changements, le coût de la réhabilitation de la piste et des voies de circulation a été diminué, comparativement à l'offre la plus basse de 2011 de \$6,256 millions, à un coût combiné de \$2,893 millions. Les deux projets ont été complétés à l'été 2012, plus rapidement que prévu, à un coût moindre, et sans interruption du trafic.

Cet article propose une présentation globale de ce projet.

1.0 INTRODUCTION

Resurfacing asphalt-paved runways at busy airports with commercial air traffic is always a challenge for airport owners and operators, designers and contractors.

When airfield pavement resurfacing work is required at single-runway facilities, the difficulties are compounded by severely restricted working hours and security requirements with virtually all runway and most taxiway resurfacing work being carried out at night in order to assure work can be completed without adversely affecting air traffic operations.

2.0 AIRPORT LOCATION AND CONTEXT

Kelowna International Airport (YLW) is the busiest single-runway airport in Canada, and the 11th busiest airport in Canada, with about 1.4 Million passenger movements annually. Servicing a City population of over 110,000 people and a Metro population of about 180,000 people, it is a vital component of the economy of the central Okanagan region. There are regularly scheduled flights to and from Calgary, Edmonton, Toronto, Vancouver, Victoria, and Seattle, as well as seasonal service to Los Angeles, Las Vegas, Phoenix, and Mexico.

Typical daily aircraft movements include 64 scheduled passenger flights, mostly comprised of 737 and Dash 8 (Q400), along with 20 to 30 cargo/freight movements. A local flight training school with 15 aircraft and a vibrant general aviation community also utilize the airport. In addition, a major aircraft maintenance company capable of performing scheduled checks and repairs on a range of aircraft up to 757 operates out of the facility, while the provincial air medevac agency overnights and maintains a number of its aircraft at YLW.

Kelowna is located near Okanagan Lake in the Okanagan Valley, in the southern interior of British Columbia, Canada. It is about 400 kilometres northeast of Vancouver (Figures 1 and 2).

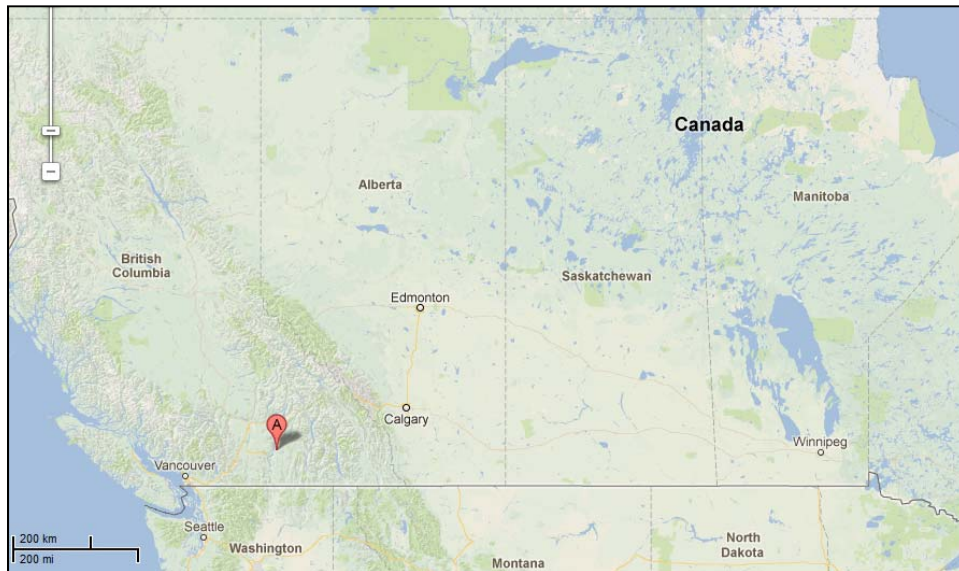


Figure 1. Location - Kelowna, British Columbia, Canada



Figure 2. Runway 16-34 and Taxiways, Kelowna International Airport

Kelowna's climate is semi-arid with dry sunny summers, cold cloudy winters and four distinct seasons. The coldest recorded temperature is -36°C . Summers are hot and sunny, with daytime temperatures often exceeding 35°C . The hottest recorded temperature at the airport was 39°C while the highest temperature ever recorded in the city was 41°C . The city averages about 380 mm of precipitation per year, with about one third of the precipitation falling as snow, the majority in December and January. June is the wettest month of the year. Kelowna averages 300.5 hours of bright sunshine in July. As such, in the summer months, Kelowna is typically a very good climate for paving activities, and the risk of weather-related delay is minimal.

3.0 PROJECT BACKGROUND

3.1 History of Runway 16-34

Runway 16-34 (designated Runway 15-33 at the time) was originally constructed by the City of Kelowna in 1957 as a 550-metre long, 30-metre wide, gravel strip, consisting of 130 mm of crushed base gravel. In 1959, the runway was extended to a total length of 1,631 metres, widened to 61 metres throughout and paved with Hot Mix Asphalt (HMA). The pavement structure (1959) consisted of 280 mm of granular sub-base, 150 mm of crushed granular base and 90 mm of HMA. In 1977, the entire existing runway was overlaid with 85 mm of HMA.

The runway was last overlaid with HMA in 1986. The 1986 overlay thickness ranged from 80 mm to 200 mm, placed in multiple lifts, with 80 mm placed at the outer edges, increasing to 200 mm at the centreline (to increase the transverse slope to the centerline crown).

Due to stripping observed prior to the 1986 overlay, the overlay specifications required that hydrated lime be incorporated as an anti-stripping additive at 1.5 percent by weight of dry aggregate. This thick overlay, combined with the addition of the hydrated lime, likely contributed to the long service life achieved (26 years).

In 1990, the runway was extended by a further 600 metres to the south. The runway extension included 110 mm of HMA, over 300 mm of crushed granular base, and 400 mm of granular sub-base. Again, hydrated lime was specified as an anti-stripping additive at 1.5 percent by weight of dry aggregate.

In 2008, the runway was lengthened again by 450 metres to the north.

The Pavement Load Rating (PLR) documented in the Transport Canada Airport Pavement Load Rating Chart as at March 2000 was 10, with a corresponding International Civil Aviation Organization (ICAO) Pavement Classification Number (PCN) Code of 54/F/C/W/T. There was no published Tire Pressure Limit restriction, since it exceeded 1.0 MPa [1]. In summary, this means that the existing, overall pavement was structurally adequate based on the current design aircraft, and that the asphalt pavement layer thickness exceeded the minimum thickness required to avoid restrictions due to design aircraft tire pressures (i.e., pavement strengthening was not required).

4.0 THE 2011 RUNWAY REHABILITATION PROJECT

In May 2011, the City of Kelowna publicly tendered the “T11-014, Runway 16-34 Rehabilitation” project for the resurfacing of Runway 16-34 including Taxiways A, B and C [2].

The scope of the 2011 tender based on the (B.C.) Master Municipal Contract Documents (MMCD) 2000, Gold Edition [3] included the following key work elements:

1. Cold-milling to 65 mm and inlay of 75 mm, using HMA on the centre (keel) section (19 m wide) along with Hot In-place Recycling (HIR) to 50 mm of both of the outer edges (each at 21 m wide) of Runway 16-34, and each at a length of 2,187 m.
2. Cold-milling to 50 mm and inlay of 50 mm using HMA on Taxiways A, B and C, along with a small portion of full-depth, (“complete” pavement structure with associated utility work) taxiway widening (~50 m²) on Taxiway C.
3. Localized repair of runway asphalt surface involving milling, removal and reinstallation of four inset lights on the threshold of runway 16, followed by asphalt reinstatement.
4. Installation of a runway pavement sensor, Remote Processing Unit (temperature sensor).
5. **Optional work** including: construction of an Annual Aircraft Parking Area on Taxiway D; construction of asphalt parking area adjacent to Apron I North; and, construction of a (small) concrete slab for a pavement sensor unit.

Pay adjustments were to apply to runway and taxiway inlay HMA compaction only, based on the B.C. Ministry of Transportation’s End Product Specifications [4].

There would be a penalty of \$10,000 per hour imposed on the Contractor if he failed to return the runway and all taxiways to a useable condition by 05:55 AM each morning. The \$10,000 penalty would be

imposed at 05:56 and again on the hour for every hour thereafter that the runway and/or taxiways were not returned to useable condition.

A bonus of \$10,000 per calendar day to a maximum of \$100,000 would be paid for completing all work (1. to 4. above) before 5:55 AM on August 10, 2011. Conversely, a penalty of \$10,000 per calendar day to a maximum of \$100,000 would be assessed upon the Contractor for each additional day commencing at 5:55 AM and after August 10, 2011. The penalty cost would be in addition to any liquidated damages incurred as part of the Contract, for late completion. Conditions related to Changes, Extra Work and Delays, including delays caused by abnormal weather would have no bearing on or adjustment to, the Bonus/Penalty Provision date.

To accommodate aircraft movements, runway and taxiway closures were to be limited to a single, five-and-a-half-hour period per 24-hour day, seven days per week; there would be no contractor access to the runway until 12:00 AM each night. All construction equipment was to be off airside in a secured, gated compound, and all affected airfield pavement surfaces were to be swept and cleaned by 5:30 AM each morning. The Contractor was responsible for communicating this 'readiness' condition to airport staff through the Consultant to allow the airport to conduct the necessary inspections of the runways and taxiways in advance of 5:55 AM, for the first flight departure at 6:00 AM in the morning.

Severe penalties would be imposed for any flight delays caused by the construction work, including late cleanup, or in the event of any weather-related reopening delays.

Notice to Proceed was to be provided June 3, 2011 with Substantial Performance by August 31, 2011 and Total Performance by September 21, 2011.

Tenders were publically advertised, and closed in April 2011.

Two compliant bids were received by the City of Kelowna, both of which were from local contractors, and were opened in public. The total bid prices, based on the scope previously outlined, *excluding optional work and taxes*, were as follows [5]:

Bidder No. 1:	\$6,256,695.00	Low Bid
Bidder No. 2:	\$6,593,642.43	--

The 2011 low bid tender at \$6,256,695.00 significantly exceeded the budgeted (2011, by others) cost (by about 40 percent) for the Work. The project was consequently cancelled.

5.0 THE 2012 RUNWAY REHABILITATION PROJECT

In summer 2011, the City of Kelowna issued, to pre-qualified Consultants, a new Request for Proposals (RFP) [6]. The deliverables outlined in the RFP included:

- "Provide a Value Engineering Review of T11-014 Tender for Runway 16-34 Rehabilitation issued in May 2011;
- Evaluate runway rehabilitation options and make recommendations on construction methods and alternatives and provide a Class "A" Construction Cost Forecast;

- Review and revise existing detailed design drawing and related documents to incorporate accepted recommendations including any optional items;
- Produce and distribute to the City of Kelowna a tender-ready package;
- Review and evaluate tenders and make a recommendation on the preferred proponent; and
- Provide professional engineering field services including but not limited to contract administration and inspection services for the runway rehabilitation project and other optional works.”

The detailed Consultant Scope of Services was divided into three phases as follows:

Phase One Services:

Tender Review of T11-014 (2011), including:

- a) Conduct visual review of the general condition of the runway and sections of taxiways scheduled for rehabilitation.
- b) Review the existing T11-014 tender documents and provide observations and recommendations related to the project as originally tendered, including:
 - i) Instructions to Tenderers;
 - ii) Schedule;
 - iii) Quantities;
 - iv) Contract drawings and agreements;
 - v) Plan of Construction Operations (PCO);
 - vi) Milestone dates including allowable hours of construction and days of work;
 - vii) Project specifications; and
 - viii) Other special provisions and supplementary specifications.
- c) Review the tenders received as a result of T11-014, provide observations and recommendations including:
 - i) Schedule of quantities and pricing as they relate to the original cost forecast;
 - ii) Proposed construction schedule;
 - iii) Effect of restrictive work conditions (closure hours);
 - iv) Penalty clause associated with late runway opening;
 - v) Effect of restrictive project schedule (start and completion dates);
 - vi) Penalty/Bonus clause associated with date of substantial completion; and
 - vii) Effect of no asphalt cement escalation/de-escalation clause in the tender.
- d) Consider specific pavement resurfacing, construction and rehabilitation methodologies and provide comments or alternative recommendations.

Phase Two Services:

Prepare Detailed Design and Tender Ready Package, including:

- a) Meet with airport staff to confirm project scope, including optional items;
- b) Prepare a revised PCO;
- c) Prepare Master Municipal Construction Documents (MMCD 2000, Gold Edition) tender documents, specifications and supplementary specifications;
- d) Prepare design drawings for Runway 16-34 rehabilitation, related taxiways and optional items;
- e) Prepare Class “A” Construction Cost Forecast;
- f) Submit drawings, specifications and Class “A” Construction Cost Forecast;
- g) Meet with airport to discuss revised work package;
- h) Complete design drawings to Issued for Tender (IFT) status;
- i) Complete MMCD tender documents and supplemental specifications to IFT status;
- j) Complete PCO drawings(s) and documents to IFT status; and
- k) Tender Services - Tendering of the project and award were the responsibility of the City of Kelowna Purchasing Branch. Consultant to work cooperatively with Purchasing during the tender period.

Phase Three Services:

Engineering Field services to include:

- a) Contract administration;
- b) Inspection during construction;
- c) Issuing of Final Certificates, Deficiency lists and Holdback release; and
- d) Prepare and submit Record Drawings and Documents.

In September 2012, SNC Lavalin Inc. (SLI) was selected as the Consultant for the 2012 Project. Pertinent background and related project documents were collected, and the review process commenced.

6.0 THE 2012 PROJECT APPROACH

6.1 Phase One Process - Key Elements

The following provides a summary of key elements completed by SLI during Phase I:

1. Completed a visual review of Kelowna airport runway and taxiway pavements; provided observations and comments addressing type, severity and extent of existing surface defects.
2. Reviewed last (March 2000, Transport Canada) Airside Pavement Inventory, Airfield Pavement Construction History and Airport Pavement Load Rating Chart.
3. Reviewed most recent (2007) Airfield Pavement Condition Survey report [7].
4. Reviewed 2011 tender and bid documents, including tender costs.

5. Met with local contractor bidders regarding the 2011 tender, and other interested bidders, sought feedback, and discussed concerns related to 2011 tender to understand the contractors' concerns and perceived issues.

Based on this work, the Consultant reported several important observations:

- The greatest impact on tender pricing was related to the short duration, daily operating window. Contractors estimated they would be able to achieve as little as 1.5 to 2 hours of effective production time per shift given the number and sequence of operations necessary for cold-mill and inlay repaving and HIR, including time for the pavement surface to cool, cleanup and apply temporary line paint before re-opening. However, all personnel would still have to be paid for a full production shift regardless of hours worked.
- Penalty clauses for late finish (daily) and for the construction completion deadline added significant risk to contractors; these risk costs were factored into bids accordingly.
- Contractors would incur significant "lost opportunity" costs with many resources occupied seven days per week for an extended period, but with very limited production.
- Standby requirements were onerous as back-ups were necessary for all equipment, including cold-milling plant(s), HIR train, asphalt paver(s), rollers and an HMA plant. Bidders included costs to have a competitor's plant and crew available on standby for every shift in the event of supply disruption or breakdowns.
- Contractors had to forego other bidding opportunities in order to bid the airport project, including a large city paving project for which tenders closed at the same time, on the same day.
- Contractors expressed concern with the "tone" of the specifications and pre-tender meeting discussions, indicating a potential for limited cooperation during construction.
- Weather would not be considered as justification for delayed daily works, or for late project completion, with a high risk that significant monetary penalties would be triggered.
- Course of Construction insurance added considerable cost, in spite of limited risk.
- Contractors indicated a willingness to bid on a revised work program in the proposed time frame (February 2012 tender, June-August 2012 construction).
- Extended time between tender and construction increased the risk of escalation in asphalt cement prices. An "asphalt escalation" clause could be included to protect contractors from increased cost risk that would otherwise be factored into tender prices.

The conclusion from these observations was that strict work constraints resulting from airport operations added a significant cost premium to executing the 2011 project as tendered.

Based on past experience, the Consultant then undertook a detailed examination of a full width HIR application to assess whether the intended project objectives could be achieved with improved productivity, with similar constraints as were included in the 2011 tender. This examination included:

- A review of condition and performance-to-date, of other [8] HIR runway and taxiway resurfacing projects completed throughout B.C.;

- A review of the condition of a stand-alone HIR application completed on Taxiway A at Penticton Airport in 1994 [9] as part of a larger airfield pavement rehabilitation project, at 17 years old (Figure 3);
- A review of the 2011 tender resurfacing methodology;
- A review of the costs, benefits, associated risks, together with medium to long-term maintenance and repair implications; and
- A review of the pros and cons of several alternative pavement resurfacing approaches, including:
 - 2011 as-tendered, cold-mill and HMA inlay (centre 19 m keel section) combined with HIR (outer 21 m, both sides);
 - Stand-alone HIR, full length and full width; and
 - HIR full length and width, followed by placing a HMA overlay, full length and full width.

Each alternative was considered to minimize the potential for operational disruption, together with expected functional service life, and estimated probable construction costs. The results were presented as a commentary and report, with alternative recommendations and associated risks, initial costs, and medium to long-term maintenance and repair consequences. A revised Work Plan was then recommended.



Figure 3. Stand-alone Hot In-place Recycled Surface - Taxiway A at Penticton Airport at 17 Years

7.0 HISTORY OF HIR ON CANADIAN AIRFIELDS

HIR has been used extensively on asphalt paved runway and taxiway pavement resurfacing projects in B.C. [10] (and to a lesser extent, Alberta [11]) for more than 20 years. These past applications have included projects funded by Transport Canada and several projects funded through Transport Canada’s Airport Capital Assistance Program (ACAP) along with others funded directly by airport owner-operators. It is important to note however, that in the vast majority of the past airfield resurfacing applications, the 40 to 55 mm HIR treatment had been immediately followed by placing a HMA overlay, typically ranging from 50 to 75 mm thick. While this has been a sound approach, and one that has been demonstrated through various applications in B.C., the cost to adopt the combined HIR/HMA overlay approach was estimated at a significantly higher cost than the available City of Kelowna funds.

8.0 2011 PROJECT REVIEW AND 2012 PROJECT RECOMMENDATIONS

Based on the data and information gathered through Phase One, a number of recommendations were provided to the City of Kelowna. Recommendations included consideration of internal (design and airport operations) discussions, information and data gathered, 2011 bids, past airfield pavement rehabilitation experiences and construction logistics, and contractor feedback, together with important elements to be considered in contract, specifications, and tendering strategy, including regional market conditions and project timing. Key review recommendations and results are provided in Table 1.

9.0 THE 2012 PAVEMENT REHABILITATION PROJECTS

9.1 2012 Runway 16-34 Rehabilitation Project

Having confirmed the applicability of HIR and presenting the expected advantages to the City of Kelowna, the Scope of Work was simplified to make the project appealing to regional HIR contractors. It should be noted that three HIR contractors exist in B.C., each with more than 15 years of HIR experience.

The final tender quantities included HIR (140,000 m²), added HMA (5,200 tonnes), rejuvenating agent (cash allowance \$175,000), standby time (cash allowance \$15,000) and temporary and permanent painted lines and markings (lump sum). Tenders were opened in public. Three compliant tenders were received.

In January 2012, the runway rehabilitation project was re-tendered as a stand-alone HIR resurfacing treatment. The contract reflected the changes previously noted. All of the changes were intended to share risk, increase bidder appeal, simplify the project scope, minimize the potential for operational disruption, and minimize the overall project cost.

Tender results including all Scheduled Pay Items and Cash Allowances, excluding taxes, were as follows:

Bidder No. 1:	\$2,312,100.00	Low Bid	ARC Asphalt Recycling Inc.
Bidder No. 2:	\$2,417,105.00	---	---
Bidder No. 3:	\$3,560,000.00	---	---

The Contract was awarded to ARC Asphalt Recycling Inc. (ARC) at the tendered amount of \$2,312,100.00 plus taxes. A Notice of Award was issued by the City of Kelowna in February 2012.

Table 1. Key Review Recommendations and Actions from Phase I Project Review

Objective	Key Recommendations	Actions
Category A Simplify the Works to allow improved Contractor productivity	Airport staff to meet with stakeholders to increase duration of daily (nightly) work window/closures; late completion (liquidated damages) to remain based on standard Master Municipal Contract Documents 2000 (MMCD 2000), Gold Edition, contract language.	Accepted. One extra hour provided daily: (11:00 pm to 5:55 am daily; option for 7 day/week work) Liquidated damages to remain, per MMCD
	Adopt ‘hard’ airfield closures, allowing only critical medical emergencies (medevacs) on a ‘prior notice’ basis; issue project Notice to Airmen (NOTAMs) accordingly.	Accepted
	Remove taxiway A, B and C rehabilitation works into a stand-alone, separately tendered project, while eliminating use of different resurfacing methodologies and equipment from the runway rehabilitation project. Work scope ‘packaged’ to suit regionally-based contractors’ in-house capabilities.	Accepted
Category B Reduce scope and risk premiums to provide economies to Contractor and Owner	Remove non-essential work scope, including <i>Optional Work</i> , from tender. Tender separately, as and when needed.	Accepted
	Defer Taxiway C widening until scheduled use by larger aircraft is confirmed. This element of the work was not a statutory requirement with current aircraft fleet mix operating at YLW.	Accepted
	Eliminate Course of Construction insurance requirement, due to the very limited risk.	Accepted
	Eliminate onerous financial penalties, including daily and substantial completion delay charges; allow weather related contract extension, subject to proof and Terms of Contract, while retaining liquidated damages for late completion.	Accepted
	Eliminate non-contiguous work elements (runway resurfacing).	Accepted
	Remove End Product Specification (EPS) and related pay adjustments. Contractor to provide QC testing, owner to provide QA testing.	Accepted
	Issue Runway Rehabilitation tenders early in new year; directly contact eligible bidders when Invitation to Tender is released.	Accepted. Runway rehabilitation to be tendered in Jan. 2012.
	Revise estimate of probable construction costs, based on two separate projects, and agreed-to changes.	Accepted
Simplify runway rehabilitation project work scope such that the project includes only HIR treatment, added HMA, and temporary and permanent paint and line markings.	Accepted	

Table 1 Continued. Key Review Recommendations and Actions from Phase I Project Review

Objective	Key Recommendations	Actions
Category C Homogenize and optimize the construction approach to deliver economies to Contractor and Owner within project constraints while achieving the same quality of output	Tender runway resurfacing project with HIR applied to the entire width and length of the runway surface (61 m by 2,187 m), eliminating higher operational disruption risk (mill and inlay) work on the centre 19 m; increase HIR 'cut' depth to 50 mm plus the addition of 30% added, plant-produced HMA (65 mm total resurfacing treatment depth); include mandatory use of a liquid anti-stripping additive in the added HMA.	Accepted
	Include detailed contractor Quality Control (QC) testing requirements; require mix design(s) to be fully developed by contractor, including added HMA and HIR mix, to meet specifications; Provide Quality Assurance through development of a project-specific Supplementary Specification for HIR with added HMA.	Accepted. Pre-tender (2011) core data [12] to be included as "information only"
	Airport staff to visit Penticton airport to view 1994 Taxiway A, stand-alone HIR surface condition and performance to date.	Accepted
	Modify Taxiway A, B and C rehabilitation project. Reconstruct a portion of Taxiway A to sub-grade (failed) and thicken asphalt layer; remove and thicken asphalt pavement layer only, on Taxiway A and C (failed areas), increase mill and inlay depth to 65 mm on remaining Taxiway A, no change to Taxiway B (50 mm mill and inlay); tender work to be carried out in same date window as runway rehabilitation, with the same work hour restrictions.	Accepted
	Revise estimate of probable construction costs, based on two separate projects, and agreed-to changes.	Accepted

It is worth noting that acceptance of the recommendations in Category C (application of HIR) enabled the consultant to simplify the work and reduce the project risks (as noted in Categories A and B).

9.2 2012 Taxiway Rehabilitation Project

The Tender for the revised scope 2012 Taxiway Rehabilitation at Kelowna International Airport, reflecting the recommended changes was issued in May 2012 and closed May 29, 2012. A Notice of Award was issued in mid-June 2012.

Key changes to the 2012 Taxiway Rehabilitation at Kelowna International Airport - T12-053 (compared to the 2011 combined project tender, taxiway only work) are summarized in Table 2.

The Taxiway Rehabilitation project was to be completed in the same period as the 2012 Runway Rehabilitation project, with the same workdays and work hours, duration, and the same contract language changes with respect to bonus/penalty and late completion.

Table 2. Key Changes to Taxiway Rehabilitation Work Scope, 2011 Versus 2012

2011 Tender Work Scope (taxiway elements only)	2012 Taxiway Rehabilitation Tender Work Scope (including repair improvements)
Taxiway A, B and C: cold-mill and inlay all areas to 50 mm depth using HMA. Total Taxiways A, B and C: 700 tonnes HMA (5,500 m ²)	Taxiway A: reconstruct 1,600 m ² of existing to sub grade (failed). Excavate 1,010 mm, replace with 600 mm granular sub base, 300 mm granular base and 110 mm HMA (2 lifts) – to match 2008 runway extension pavement structure
	Taxiway A: remove 1,800 m ² including 100 mm existing asphalt pavement and 40 mm granular base; replace with 140 mm HMA (2 lifts)
	Taxiway A: cold-mill and inlay 1,400 m ² , Taxiway A to 65 mm depth using HMA
	Taxiway B: cold-mill and inlay to 65 mm depth using HMA
	Taxiway C: cold-mill and inlay 2,300 m ² to 50 mm using HMA
Widen taxiway C (50 m ²), including: excavate to 680 mm depth, replace with 310 mm granular sub base, 270 mm crushed granular base, 100 mm hot-mix asphalt, along with various utility works (PVC storm pipe, perforated sub-drains, type 'L' manholes (3), fill abandoned manholes with concrete), topsoil and seeding.	Deleted

Tender results, including all Scheduled Items and Cash Allowances, excluding taxes (with *no optional work*) were as follows:

Bidder No. 1:	\$ 581,120.70	Low Bid	Peter's Bros. Construction Ltd.
Bidder No. 2:	\$ 727,245.30	---	---
Bidder No. 3:	\$ 786,698.00	---	---
Bidder No. 4:	\$ 803,127.60	---	---

The compliant bid documents and tenders were reviewed. No irregularities were noted. The consultant recommended the contract be awarded to Peter's Bros. Construction Ltd. at the tendered amount of \$581,120.70, plus taxes. Notice of Award was issued in mid-June 2012.

Based on the foregoing, a comparison of the costs of the 2011 low bid tender and the two 2012 project low bid tenders, including both, project by project and combined costs are shown in Table 3.

Table 3. Project Cost Comparisons, 2011 Versus 2012

2011 Runway Rehabilitation Tender (T11-014)	
2011 Runway Rehabilitation Project, Low Bid (combined runway and taxiway projects <i>excluding optional work and taxes</i>) (A)	\$ 6,256,695.00
2012 Runway and Taxiway Tenders (T12-010 and T12-053)	
2012 Runway Rehabilitation Project Low Bid (B) (Hot In-place Recycling)	\$ 2,312,100.00
2012 Taxiway Rehabilitation Project Low Bid (C) (revised scope)	\$ 581,120.70
2012 Combined Rehabilitation Projects, Low Bids (B+C)	\$ 2,893,220.70
Cost Difference (savings), 2012 Projects versus 2011 Project (A - (B+C))	\$ 3,363,474.30

By re-tendering the project as a full length, full width HIR project, together with other changes, it was possible to eliminate unnecessary risk premiums, enable the contractors to achieve higher productivity with similar operation restrictions, and lower material and construction costs. As a result, the City of Kelowna was able to realize approximately 50 percent cost savings (Table 3).

It should be noted that the scope changes from the combined 2011 “as tendered” work to the combined 2012 “as tendered” work were relatively small. The elimination of the 2011 Taxiway C widening (50 m²) is considered to have been offset by scope increases in the 2012 work. The original 50 mm of mill and inlay depths for all taxiway repair areas in 2011 was changed to include a combination of full depth repairs on Taxiway A (partial reconstruction to sub-grade, partial full depth pavement removal and deepening to 140 mm, and the remainder 65 mm inlay) in 2012. The Taxiway C mill and inlay depth was changed from 50 mm (2011) to 65 mm (2012), while also including a portion of 190 mm of pavement removal and replacement.

The remainder of this paper focuses on the 2012 Runway Rehabilitation Project.

10.0 2012 RUNWAY REHABILITATION (HIR) PROJECT

10.1 HIR Equipment Requirements

A project-specific Supplementary Specification was developed for HIR for the 2012 Runway Rehabilitation project. This Supplementary Specification was based on earlier specifications (evolving from 1988 through 2011) adopted on other B.C. airport runway HIR projects (which in nearly all cases, was followed by a HMA overlay), and was then further modified to reflect the application of HIR as a stand-alone, finished product process, including the addition of a virgin, plant-produced HMA.

The essence of the HIR specification required heating the existing asphalt surface using one or more pre-heaters, followed by a series of self-propelled infrared heaters and milling drums, rejuvenator applicators, pug mill mixer(s), scarifiers, a paver and rollers. The specified requirement was to remove by milling, in at least two stages, the existing asphalt, to a depth of 50 mm. Added mix was specified to be included at a rate of 30 percent based on the milled portion, resulting in an average 65 mm of reprocessed surface depth. Proof of previous work performance was required before mobilizing equipment to the Work site.

Equipment was specified to be capable of heating the top 50 mm of the runway pavement in stages, to an average temperature of 120°C measured immediately behind the screed. Moisture content was to be reduced to a level at or below one percent and the specified degree of compaction (98 percent of 75-blow Marshall density) was to be consistently achieved, demonstrated by core specimen testing related to average daily Marshall mix quality control test samples. The finished runway surface was to have no irregularities exceeding 5 mm when checked with a 4.5 m long straightedge measured in any direction.

10.2 HIR Aggregate and Mixture Design Requirements

The specification required the production, delivery, addition and remixing of the equivalent of 15 mm (an additional 30 percent based on initial removal depth) of virgin, plant-produced HMA (“added mix”) and an asphalt recycling agent/rejuvenator at an approximate rate of 0.5 litres per square metre (paid for by cash allowance). The Contractor was responsible for the development of a combined HIR asphalt mix design conforming to the requirements of the specifications. The specifications included requirements for aggregate quality and gradation for the added mix, as well as the gradation of the resulting, combined, HIR asphalt mixture. The added mix was intended to provide an increase in the maximum aggregate particle size (12.5 to 19 mm) and a higher aggregate fracture content, while incorporating a softer grade of asphalt cement and a liquid anti-stripping additive. A “leaner” added mix was expected. This in turn, would be expected to increase void space and allow the addition of the required rejuvenating agent.

The Contractor was required to obtain a sufficient number of cores from the upper 50 mm of the runway surface to develop the project mix design (Job Mix Formula), and was required to submit the final mix design for review. A total of 43, 10 and 15 cm diameter cores were obtained from the runway surface by the Contractor in April 2012. The upper 55 mm of each core was removed by saw cutting then logged, photographed, and tested for bulk specific gravity. Little to no evidence of stripping was observed in the top 55 mm of the core specimens. These cores were later used for laboratory Marshall mix design trials.

Pre-tender runway pavement core test results (2011 Technical Memo) were provided as part of the Tender Package as “information only.” The information included average values of the following: asphalt cement content; aggregate gradation; percent fracture (two faces); penetration of recovered asphalt cement; maximum relative density; and in-situ air voids. The memo also provided general comments on the type of added mix that may be required, given existing runway pavement characteristics (from the outer 21 m of each side of the runway only).

A 150-200, Group A (CAN/CGSB-16.3-M90, Asphalt Cements for Road Purposes) asphalt cement was specified for use in the added, plant-produced HMA. An asphalt anti-stripping agent was required as a component in the added HMA, at a rate of not less than 0.5 percent by weight of asphalt cement, or as otherwise recommended by the producer/manufacturer. A minimum Tensile Strength Ratio (TSR) of 80 percent was also included in the specification.

The aggregate gradation requirement for the combined HIR mixture (existing plus added mix) is shown in Table 4.

Table 4. Combined Hot In-place Recycled (HIR) Mixture Aggregate Gradation Requirement

Sieve Size / Designation	% Passing, Combined HIR Mixture
19 mm	100
12.5 mm	85 - 95
9.5 mm	70 - 85
4.75 mm	50 - 65
2.00 mm	35 - 50
0.425 mm	15 - 28
0.180 mm	7 - 15
0.075 mm	3 - 7

The specified requirements for the combined HIR mix properties (existing plus added mix, based on a 75-blow Marshall mix design) are provided in Table 5.

Table 5. Combined HIR Mix Design Property Specification Requirements

Property	Property Specification – Airfield Pavement
Marshall Stability at 60°C, N, minimum	12,000
Flow Value, mm	2 - 4
Air Voids in (combined) Mixture, %	2.5 - 4.5
Voids in Mineral Aggregate, % minimum	14
Index of Retained Stability, % minimum	75
Tensile Strength Ratio (TSR), % minimum	80

11.0 PROJECT EXECUTION

11.1 The ‘Standard’ ARC HIR Train

The ‘standard’ HIR train used by ARC is an Ecopaver 400 (manufactured by Ecopave Systems Inc. of Kamloops, B.C.). The train configuration is shown schematically in Figures 4 and 5.

Typically, the train includes a single, truck-towed, propane-fuelled pre-heater, followed by two propane-fuelled, radiant heating, heater-miller units, and a remix hopper with pickup conveyor unit and a twin-shaft pug-mill/re-mixer connected to a conventional asphalt paver. This is followed by a series of rollers, including pneumatic, combination pneumatic/steel, and tandem steel, the latter two of which are vibratory-equipped. The asphalt paver includes an electronic sensor actuated boom and a joint matcher ski for lay-down thickness control.

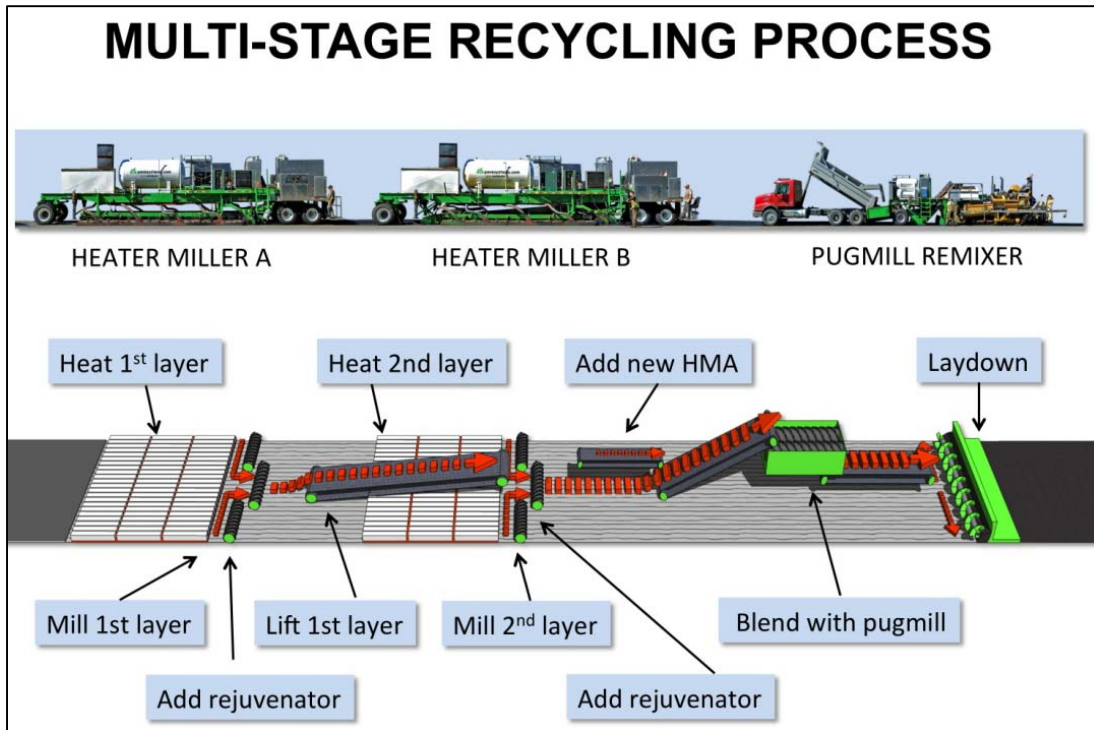


Figure 4. 'Standard' Ecopaver 400 HIR Train Schematic

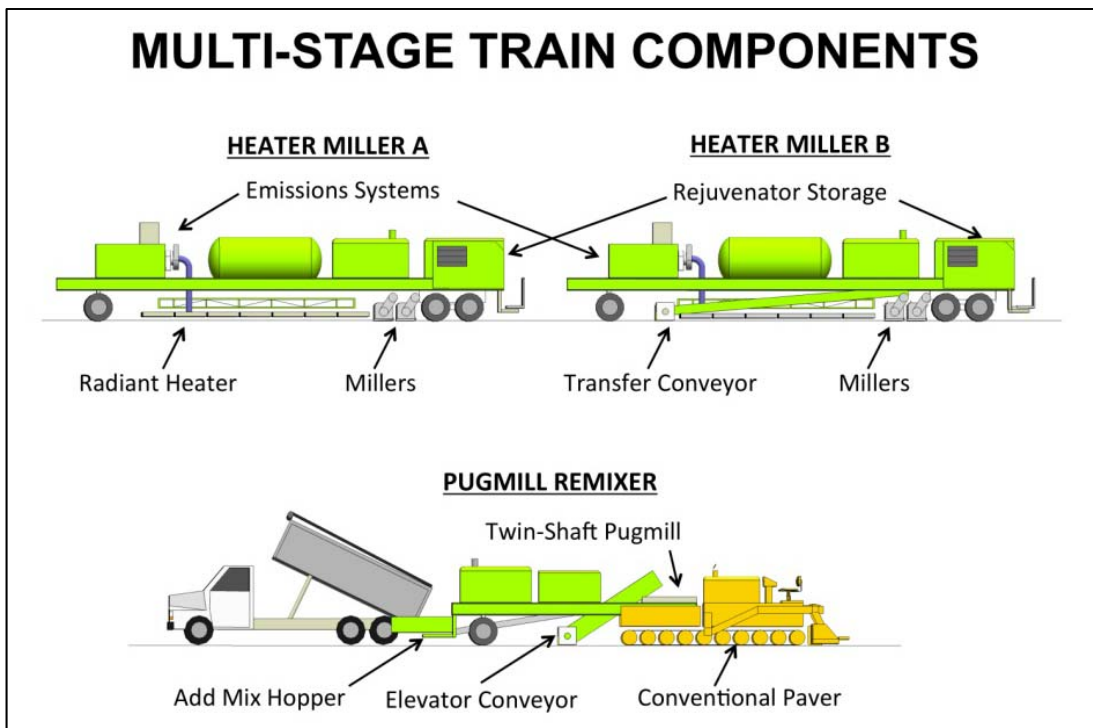


Figure 5. Layout and Processing Schematic of 'Standard' Ecopaver 400 HIR Train

Each of the two heater-miller units (A and B) radiantly heats then removes by milling, about one-half of the total required milling depth. Both heater-miller units include rejuvenating agent storage tanks and adjustable dispensing systems. This allows for earlier (versus B unit only) addition of the rejuvenating agent (Golden Bear Specialty Oil, Cyclogen L™ was used), which provides for some initial ‘fluxing’ time when the milled asphalt is in the windrow while dividing the additive addition into two roughly equal addition points, providing improved rejuvenator distribution and uniformity.

The combined milled asphalt, asphalt rejuvenator, 30 percent added mix (consisting of a 150-200 Group A, [versus 120-150 Group A] asphalt binder and a liquid anti-stripping agent additive) are combined and remixed in a twin-shaft, pug-mill mixer, and after mixing, loaded into the paver hopper, conveyed to the paver, placed, spread and compacted similar to a conventional HMA paving operation.

In addition to the HIR equipment, ARC mobilized a mobile Terex 150 (150 U.S. TPH) counter-flow, drum mix asphalt plant with a bag house and four cold feed bins, and a 40 U.S. ton storage silo (Figure 6) to produce and store the required added mix. The asphalt plant was permitted and erected in a nearby gravel pit about 1.5 kilometres from the airport. This allowed ARC to produce the added mix without reliance on a sub-contracted HMA supplier, while keeping truck haul distances to a minimum and maintaining short haul truck turnarounds. Custom added mix aggregates were sourced from a nearby aggregate producer about 5 kilometres from the asphalt plant site, after pre-qualification tests were completed.



Figure 6. ARC's Terex 150 TPH, Portable Drum Mix Asphalt Plant

11.2 Use of the 'Modified' ARC HIR Train

The total area of the HIR treatment on the runway was about 61 m wide and 2,185 m long, for a total area of about 133,300 m². This would consist of treating two, 30.5 m wide runway 'halves.'

The HIR treatment could commence at either end of the runway at a processing width of approximately 3.65 m (with small width variations and overlaps to fit the overall 30.5 m width on each side of the centreline crown). The runway would require nine passes on each side of the centreline, and 18 passes in total, for a single-lane area of about 7,980 m². Isolated and secured contractor equipment lay-down areas were established within the airport property opposite each end of the runway on the east side, at about 100 to 150 m away from the runway edge. This helped to reduce the distance the train was required to travel at the start and end of each work shift.

Given the short duration (about six and one-half hours of gross working time less mobilization and demobilization and cleanup time) of the nightly work window, ARC modified the 'Standard' HIR train configuration, hoping to complete about two thirds (or more) of the runway length of each lane, per shift. To accomplish this, a second pre-heater, and a third 'A'-type unit heater-miller was added to the train in advance of the usual 'A' and 'B' units.

The extra pre-heater was expected to provide additional initial surface heating and drying, and a warmer and drier surface in advance of the heater-millers, while increasing the processing efficiency and progress of the heater-miller units that followed. The additional heater-miller was expected to improve production through an extra stage of heating and milling, while allowing for greater overall productivity. The rejuvenator would be dispensed at the second 'A', and the 'B' unit and the remainder of the train would operate as usual. The Kelowna airport 'Modified' ARC HIR train configuration and processing system layout is shown schematically (Figure 7).

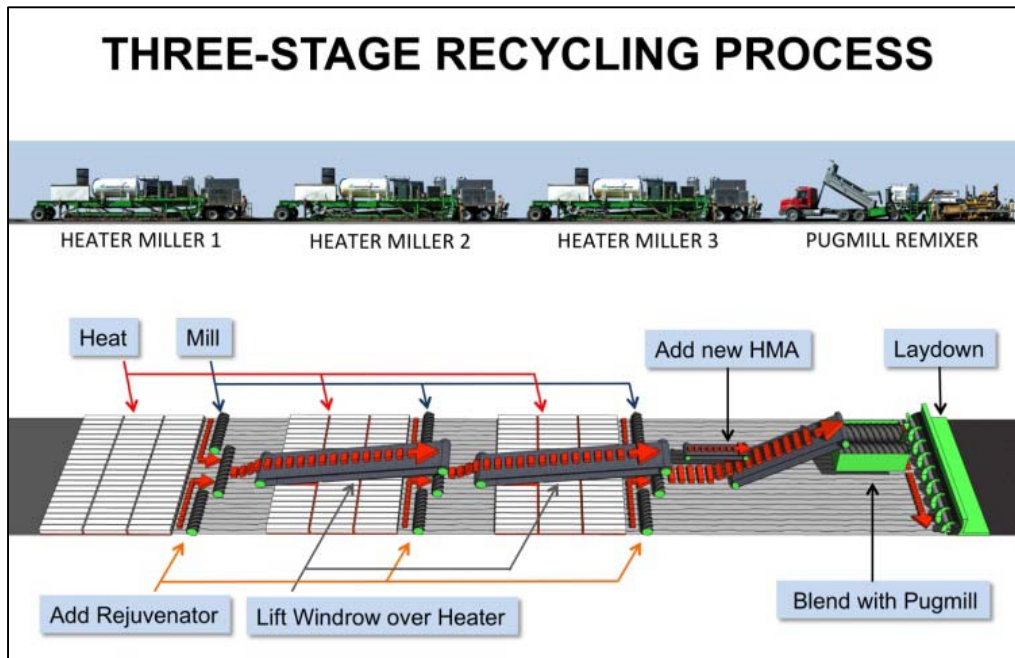


Figure 7. The Kelowna Airport 'Modified' ARC Hot In-Place Recycling (HIR) Train

11.3 The “Rubber” Hits the Runway

Following pre-construction meetings, and some delay in finalizing the mix design for the combined HIR mixture, ARC commenced with the first shift of processing on the north end and east side of the runway on June 9 (evening) and finished on the 10th (morning).

The Kelowna airport project was the first project of the 2012 construction season for ARC, following the typical off-season equipment teardown, component rebuild, maintenance and repair works. As a result, some equipment issues (mostly electrical) arose in the early stages of the project. In addition, unusually cool and wetter than average weather conditions in early to mid-June resulted in some cancelled, and some lost work shifts (six and one half-shifts). Cooler daytime and night-time temperatures and lower pavement surface temperatures slowed production rates.

Processing began on the easternmost edge lane (outer 3.65 m) of the runway, where any potential irregularities would be well outside of critical aircraft manoeuvring surfaces. Additional mix adjustments and corrections could be made to HIR processing and added mix blending with minimal impact.

Initial Quality Control (QC) suffered from slow turnaround but was corrected by the Contractor in the first week of production.

11.4 Runway HIR Treatment Methodology and Progress

Generally, the runway HIR treatment followed a typical methodology each night. This included starting a lane pass at either end of the runway and progressing as far as production and shift duration (allowing time for surface cleaning) permitted. The more common approach, which was dictated primarily by air temperature, pavement surface temperatures, HIR mixture temperature and the HIR production that followed, included progressing to about one half to two thirds of the total lane length, then stopping. This resulted in a transverse transitional (temporary) joint, usually only once in each lane.

The following shift, the train would begin processing at the opposite runway end working toward and overlapping well into (10 to 15 m) the previous shift transition joint. The rejuvenator and the added mix were shut-off for the last portion of the initial pass. For the completion joint tie-in pass, the rejuvenator and added mix continued into the untreated transition zone by 10 to 15 m, ensuring rejuvenator and added mix application continued until meeting the opposing lane ‘head’. Equipment was then shut down, lifted, and walked to the contractor lay-down area nearest to the starting position for the following shift.

All permanent start-up transverse joints and overlap transition joints were hand-treated using Golden Bear Specialty Oil CRF® Crackfiller / Restorative Seal emulsion applied using a paint roller, then lightly sanded and rolled using a rubber tire roller.

During the initial cooler weather period in mid to late-June, the typical shift included completing approximately 50 percent of a full-length runway pass. The remaining 50 percent of the pass length was completed on the following shift. The Contractor chose to work seven days per week, subject to daily decisions based on expected weather conditions, for the entire duration of the project. Photographs of the ARC HIR train are included in Figures 8 through 10.



Figure 8. HIR Train From Back of Paver



Figure 9. HIR Train From Back of Paver



Figure 10. ARC Train Work In Progress on BC Highway Project

HIR processing progressed from the outer easternmost edge of the runway working inward toward centreline. The final lane pass on the east half of the runway centreline extended about 15 to 20 cm beyond centreline, to allow a 15 to 20 cm overlap on the eventual, final centre lane pass, and to allow the final pass to be aligned directly over the geometric centreline (and the crown-line) of the runway.

The eastern half of the runway was completed on the morning of July 4th; 26 days from the start date with six and one half shifts lost due to poor weather or equipment issues. The east half required 20 shifts to complete the nine lanes at 66,673 m². This resulted in a shift average of approximately 3,333 m² (about 915 lineal metres at 3.65 m wide) per five-hour average net working time per shift.

Temporary centreline paint lines (nine 30 m long evenly spaced stripes every 60 metres for the full length of the runway) were then applied at the end of the two shifts on the final pass on the east side of centreline (as required by Transport Canada).

HIR processing of the western half of the runway began at the westernmost edge of the runway, with processing progressing from west to east toward centreline, on the July 4/5 shift.

The general approach to the HIR processing remained the unchanged from the eastern half of the runway.

Weather conditions and daytime and night-time temperatures were much more seasonal during processing of the west (2nd) half of the runway. Daytime high temperatures of 32 to 37°C were common and pavement surfaces were much drier, and remained warmer through the shift. This assisted production significantly, such that two, full runway-length passes could be completed in three working shifts.

The remaining half of HIR processing was completed on July 19th; 15 days from the west edge-pass start date, with no shifts lost. The west half of the runway required 15 shifts to complete the nine lanes of HIR processing at a total of 66,673 m² resulting in a shift average of approximately 4,445 m² (about 1,218 lineal metres at 3.65 m wide) per five-hours average net working time per shift. An aerial image of the completed runway and taxiways is included as Figure 11.



Figure 11. Runway 16-34 and Taxiways A (left), B (centre) and C (right), at Project Completion

12.0 QUALITY PROCESSES

The Contractor was required to provide a Quality Plan, including a detailed Materials Sampling, Inspection and Testing Plan, for review and approval prior to commencing the Work. The City of Kelowna appointed and retained a materials testing firm who provided Quality Assurance (QA) testing at a reduced frequency (10 to 25 percent of QC frequency).

12.1 Quality Control

Project specifications included a detailed table outlining the minimum requirements for ongoing contractor QC inspection and testing activities. The QC testing was required during added mix aggregate production and of added HMA and HIR mixture and aggregates during processing and finished pavement testing (cores, straightedge and flood testing).

The majority of the QC testing was completed in an on-site (at the nearby asphalt plant) portable testing laboratory. The contractor used a thin-lift nuclear gauge to monitor compaction each shift. Cores from the area processed during the previous night shift were obtained at the start of the following shift.

The bond between the HIR processed layer and the underlying asphalt was very strong, resulting in the need for every core to be drilled through the entire pavement thickness. This was followed by saw cutting

the cores at a depth of 65 mm, then testing. All core holes were cleaned, dried, tack coated, filled with recycled HMA and compacted using a pneumatic hammer with a footplate attachment.

The QC testing generally included the following daily testing:

- Added mix aggregate: aggregate gradation (washed) and percent fracture during aggregate production (minimum one per day);
- HIR mix: Marshall and mix volumetrics testing, including maximum theoretical density, briquette density, stability, flow, VMA and asphalt cement content (two 'sets' per day, and not less than one 'set' per 750 tonnes processed);
- Added mix: aggregate gradation (washed) and percent fracture, asphalt cement content, and moisture content (one 'set' per day of added mix production);
- Monitoring of compaction using a nuclear gauge, followed by coring and core testing, including noting apparent bond strength of HIR to underlying asphalt layer (none, poor, fair, good or excellent): minimum one core per 1,000m² of HIR treatment per shift. No less than three cores per HIR processing shift);
- Surface planeness (straightedge testing) using a 4.5 m long straightedge (one transverse measurement per 50 lineal metres, one longitudinal test per 200 lineal metres for both in-process (hot un-compacted mat), and finished surfaces; and
- Flood testing to identify any ponding issues (one flood test to be completed every 200 lineal metres).

12.2 HIR Processing - Field QC Activities

In the field, ongoing QC monitoring was completed (and documented) at the HIR train. The primary field QC monitoring tasks included:

- Collect weigh scale delivery tickets, calculate and mark surface based on the targeted length each load of added mix should yield (based on processing width, length, depth and mix density). Actual yield distance was measured versus target yield distance and added mix addition rates were adjusted accordingly;
- Rejuvenating agent addition rate was monitored regularly. Dosage rate was adjusted based on actual versus target addition rate (litres/metre²) at the end of each shift;
- Milling 'cut' depth was monitored at each heater-miller on each side of HIR train; ongoing adjustments were made as required;
- Automatics (added mix hopper and auger feeds) were visually monitored, lay-down joint matching and surface texture (loose and rolled) was monitored for uniformity (segregation), on the loose and rolled mat surfaces;
- Temperatures were monitored with infrared thermometers at all stages of the process, as well as at the rear of the paver, including incoming added mix at truck box/added mix hopper;
- Lay down compacted thickness was monitored visually, relative to adjacent completed HIR pass, and untreated adjacent surface; adjusted as required; and

- 4.5 m straightedge used to check loose and compacted HIR surface cross-section and joint matches.

At shift end, added mix loads were tallied and application rates for added mix and rejuvenating agent (tanks dips at start and end) were determined, and formally reported the following work shift.

13.0 SUMMARY OF QUALITY CONTROL TESTING

13.1 Discussion of QC Average Lot Test Results

QC test reports were provided at the start of the following shift, except core test results, which were provided at the start of the shift one additional day later. QC reports were reviewed daily, and the need for adjustments was discussed with the Contractor at the start of the following work shift. The results of the combined HIR mixture Quality Control tests, on a Sample Lot basis, are summarized in Table 6.

As shown, some of the average lot test results were outside of the specification limits. Most notably, the air voids averaged only slightly above the minimum air voids, with the lowest lot averaging 1.4 percent. Many mix adjustments were made to increase air voids, including the removal of significant amounts of fines through the asphalt plant bag house and incremental reduction of the asphalt cement content in the added mix. Consequently, the rate of addition of the rejuvenating agent was maintained in the range of 0.4 to 0.5 litres per m² (versus the target of 0.5 litres) throughout the project.

Table 6. Summary of Combined HIR Mix Requirements and Average QC Lot Test Results

Test Description / Specification Limits	Asphalt Content (% dry aggregate) 6.1 ± 0.3	Stability (N) > 12,500	Flow (mm) 2-4	Air Voids (%) 2.5 - 4.5	Compaction (%) > 98.0
Upper Limit	6.4	N/A	4.0	4.5	N/A
Lower Limit	5.8	12,000	2.0	2.5	98.0
Highest Lot Test	6.5	16,400	4.0	4.9	99.0
Lowest Lot Test	5.3	10,225	2.0	1.4	97.4
Job Lot Average (33 Test Lots) (Note 1)	5.9	12,668	3.5	2.7	98.3

Note 1: Table 6, Average Quality Control Lot Test results extracted from Metro Testing Laboratories Ltd. Project Summary Report dated July 23, 2012.

The majority of the low air void mix was experienced on the outer 15 m of the runway on the east side. Since little or no aircraft travels beyond approximately 9 m of the runway centreline this was not considered a major issue. In this regard, a 1997 paper [13] notes, among other findings:

1. “Performing HIR pavements were characterized by low construction Marshall air voids, low pavement air voids and low recovered asphalt penetrations relative to the values that would be typical for virgin asphalt concrete mixtures.
2. Based upon the observed performance to date of the HIR sections included in this study, HIR mixtures can be designed at lower Marshall air voids than normally specified for conventional virgin asphalt concrete mixtures when recovered binder properties indicate penetration values are

lower than those typical of conventional mixtures. Marshall mix design volumetric criteria developed for conventional virgin mixtures are not totally appropriate for HIR mixtures.”

The lower air voids mix, when in lower-travelled areas, would be expected to remain very durable. Some moderate flushing was observed on the east side of the runway, but for the most part, disappeared after several days. Upon project completion, no flushing was observed.

It is further noted that Marshall stability test results were generally high, with an average lot value of 12,668 N, and the lowest lot value remaining reasonable at 10,225 N. Compaction was very good, achieving over 98 percent average compaction on nearly all lots, with the exception of one lot with an average of 97.4 percent compaction.

13.2 Runway Friction Test Results, 2012 - 2011

Runway friction testing was completed on the runway in June 2011 prior to runway resurfacing, and again in October 2012 following resurfacing, as a part of an annual testing routine. Friction testing was completed using a trailer-mounted version of the International Civil Aviation Organization (ICAO) listed, Federal Aviation Authority (FAA), Transport Canada approved Scandinavian Airport and Road Systems (SARSYS) friction measurement instrument (Figure 12). Full length friction measurement runs were made at 6 m Left (L) and 6 m Right (R) offsets from centreline, along with the normal 3 m Left and 3 m Right offsets used in previous friction surveys. The results of this testing are summarized in Table 7 [14].



Figure 12. Saab Friction Testing Equipment

Table 7. Runway Friction Test Results, 2012 - 2011

Runway (Offsets from centreline)	Average Runway Friction Index		Minimum 100 m Runway Friction Index	
	October 2012	June 2011	October 2012	June 2011
16-34 (3 m)	81	81	74	58
16-34 (6 m)	81	81	74	58
16-34 (15m)	83	95	72	85

The report stated that Transport Canada guidelines for tests under these conditions indicate that remedial action should be programmed for a facility when the overall Runway average Friction Index falls below 60 or any 100 m section falls below 40.

The runway-average Runway Friction Numbers for the October 2012 test series were as follows:

- Runway 16-34 (3 m and 6 m offsets): well above the Transport Canada maintenance planning level.

The minimum 100 m Section Runway Friction Numbers for the October 2012 test series were as follows:

- Runway 16-34 (3 m and 6 m offsets): well above the Transport Canada maintenance planning level.

The minimum 100 m section values in these areas remained in the 70-80 range, or well above the corresponding Transport Canada maintenance planning level of 40.

14.0 OBSERVATIONS AND CONCLUSIONS

The stand-alone, Runway 16-34 HIR resurfacing project at Kelowna airport, a single-runway site, is believed to constitute the first primary runway surface treated using HIR with added mix, in Canada and possibly, North America.

The application of HIR resurfacing offered many benefits to the City of Kelowna (airport). Those benefits included, in part, the following:

- Reduced risk of airport operational disruption (due to equipment breakdowns and unexpected weather events), while working in a short, night-time work window;
- Limited need for commercial air-carrier schedule modification;
- Significant reduction in runway resurfacing cost;
- Reduction in the use of non-renewable resources;
- Reduction in trucking (of resurfacing materials) to and from the airport site;
- Improved nearby road and highway traffic safety (less trucking and shorter hauls);
- Very smooth longitudinal profile achieved (HIR processing rarely stops forward movement);

- Limited surface irregularities (abrupt elevation changes) during and after each HIR pass; and
- In the event of an emergency, equipment can be lifted, and quickly removed from the runway, the treated surface compacted, leaving no deep reveal, such as with cold-milling and inlay, or lengthy transition ramps, as required with a conventional overlay.

Post construction average runway friction test results showed the finished surface to be well above the Transport Canada maintenance planning level.

The contractor was an important element in the success of the project. An ongoing commitment to a safe and high quality project was demonstrated throughout the Work. Past experience, integrity, professionalism, and a high level of skill were evident at all levels of the company.

There are many aspects of such a project that must be very carefully considered before embarking on a runway resurfacing program utilizing HIR. It is also important to note that an advantage of treating an airport runway using HIR is that quality control on (previous) airfield pavement resurfacing works is extensive, and comprehensive. As a result, existing asphalt pavement materials are generally very consistent, and of high quality.

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