Advanced Pavement Technology – A Must for Airport Pavements – Case Studies

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ABSTRACT

The aircraft traffic loading continuously increases at Canadian airports. Climate change also has an adverse impact on pavement performance. Temperature increases may cause premature pavement deformations and shear failures. Pavement friction is another aspect that must be addressed. Conventional pavement technology is often not sufficient to meet the increasing quality demands for airfield pavements. Pavement materials and technologies successfully used on road pavements are often not suitable to meet the performance needs for airfield pavements.

The focus is mainly on hot-mix asphalt, including asphalt cement types, quality aggregates, and advanced mix designs. It is common to improve the subgrade soil characteristics; the application of geosynthetics has been noted to be very successful and has become a common solution for airside pavements.

This paper includes two case studies. The introduction of advanced HMA technology at Edmonton International Airport which significantly improved pavement performance, and reduced demands for maintenance interventions. The use of better quality asphalt cement, aggregates and overall asphalt mixes at Winnipeg International Airport for major runway rehabilitation.

1.0 INTRODUCTION

The increase in aircraft traffic loading is continuous in Canada in terms of both the number of aircraft movements and the load levels applied by individual aircrafts. Some of the newer aircrafts such as the Boeing 777 and Airbus 380, or some of the Antonov aircrafts, for example, apply very high stress levels to the pavements. In addition, climate change may also have an adverse impact on pavement performance. It may increase the rate of permafrost degradation and pavement failures. Furthermore, temperature increases may cause premature pavement deformations and shear failures.

In the design process of airport pavements, the focus must not only be on the condition of subgrade soil, the number and severity of applied loading, and the initial construction cost. Pavement friction is another aspect that must be addressed. In the Canadian climate, the potential for frost heaving and permafrost degradation must also be considered. Due to high performance requirements at Airports, maintenance demands are high. On the other hand, frequent maintenance or pavement rehabilitation activities may have significant adverse impacts on airport operations and drastically increase the cost.

Conventional road pavement technology is often not sufficient to meet the always increasing quality demands for airfield pavements. Pavement materials and technologies successfully used on road pavements are often not suitable to meet the performance needs for airfield pavements. The focus of developing new specifications for airfield pavements is mainly on hot-mix asphalt (HMA), including advanced asphalt cement types, very good quality aggregates, including their frictional characteristics, and advanced mix designs. The use of performance graded polymer modified asphalt cements is common. The quality of granular materials used in base and subbase layers typically must be improved in terms of their angularity, abrasion resistance, and permeability. It is common to improve the subgrade soil characteristics; the application of geosynthetics has been noted to be very successful and has become a common solution for airside pavements.

The focus in this paper in on the advanced asphalt technology implemented at Edmonton International Airport (EIA) and Winnipeg International Airport (WIA).

2.0 ADVANCED TECHNOLOGY AT EDMONTON INTERNATIONAL AIRPORT

Edmonton International Airport (EIA) is located in Leduc, Alberta and is one of the fastest growing airports in Canada and the largest in the area. EIA is owned and operated by the Edmonton Airports, a community based and financially independent corporation. The airport serves approximately 7 million passengers each year and additionally provides air cargo operations. The airside pavements at EIA consist of a total of two runways (Runway 02-20 and Runway 12-30), a network of taxiways including two parallel taxiways along each runway and multiple aprons. The development of a suitable multi-year rehabilitation and treatment strategy for the two runways and the taxiways required extensive cooperation and consultations between Edmonton Airports and the design and geotechnical consultants.

Prior to the development of the rehabilitation and treatment strategy, it was critical that the current pavement condition was documented and that the primary deficiencies were determined. The cause of these deficiencies had to be identified and addressed by the recommended pavement rehabilitation or treatment. A detailed visual condition inspection was carried out by Golder's pavement specialist on all airside facilities at different times, depending on pavement rehabilitation scope, to identify the primary types, severity and density of the distresses present on the runway pavements. EIA is also currently implementing Airport Pavement Management System (APMS). During the condition inspection it was observed that one of the primary deficiencies with some of the pavements was the significant amounts of stripping of the asphalt cement from the aggregates used in the asphalt mix. Photograph 1 shows an example of the stripping that was observed in a piece of the asphalt that was removed from the runway pavement. The figure shows that aggregate particles in the mix are completely stripped of asphalt cement. This is a clear indication that the asphalt mixes placed previously on the airfield facilities were severely susceptible to moisture damage, which successively occurred over the years that the runway pavement was in service. Through consultations with Edmonton Airports and based on Golder's experience with asphalt mixes used in the Edmonton area, it was our understanding the stripping in asphalt mixes was a common problem that had been encountered for a number of years.

Photograph 1: Asphalt stripping visible in a piece of the asphalt mat obtained from the runway pavement.

In addition to the issue associated with asphalt stripping, it was also observed that the old mixes used exhibited poor durability and resistance to cracking and some exhibited poor resistance to permanent deformation. Very extensive high to medium severity reflective cracking and shoving was observed on the asphalt surface. The reflective cracking was noted to be primarily from the joints and the cracks in the concrete slabs underlying the asphalt layers. At a number of locations, the cracks were significantly deteriorated and spalling of the asphalt mat adjacent to the crack was observed. Photographs 2 and 3 show examples of the typical medium and high severity cracking that was observed on the runway pavement.

Photograph 2: Typical medium severity reflective cracking on the runway pavement.

Photograph 3: High severity reflective cracking on the runway pavement.

The asphalt mixes had insufficient load bearing capacity to accommodate the very heavy aircraft loading that is applied to the pavements at the airport. During discussion with Edmonton Airports and based on reviews of past asphalt paving specifications, it was noted that the asphalt mixes used were often the same as the mixes that were placed on street pavements in Edmonton and adjacent areas and incorporated a large proportion of rounded particles. In localized areas of the runway pavement, particularly at locations experiencing very high horizontal forces applied by braking or turning aircrafts, high severity asphalt shoving and shear cracking was observed. Photograph 4 shows an example of the shear cracking and shoving observed at the threshold of one of the runways.

Photograph 4: Shear cracking and shoving of the asphalt surface at a threshold of Runway 12-30.

Based on the frequent occurrence of reflective cracking and its severity that was observed on the asphalt surface during the condition inspection, it was hypothesized that at numerous locations the underlying concrete slabs were in poor condition likely with poor load transfer at the joints and a number of cracked and shattered slabs. Finally, during the condition inspection it was noted that the asphalt longitudinal joints were also in poor condition due to deficient construction practice.

The investigation of the existing pavements identified that one of the primary issues with the existing pavements was the poor quality asphalt mixes that were placed on the airside pavements. Additionally, poor quality construction practices resulted in the deficiencies in the pavement such as longitudinal joint cracking, which in turn reduced the service life of the in-place pavement. To ensure that these deficiencies were addressed during the pavement rehabilitation, critical review of the previous specifications used for airside pavement construction was carried out. The purpose of the review was to identify key elements of the specifications that required improvements, to ensure that the rehabilitated pavements meet the service life expectations of the airport authority. Listed below are some of the key aspects of the specification that were customized to meet the needs of the airport.

- The physical property requirements for the aggregates to be used in the asphalt mixes was revised to ensure that only good quality aggregates available in the area were used in the asphalt mixes for the runway pavements. Some of the changes included reducing the maximum allowable Los Angeles abrasion, magnesium sulphate soundness, and the proportion of flat and elongated particles.

- Minimum required Polished Stone Value (PSV) for the aggregates in the surface course was specified to be 50.

- The aggregates used in the asphalt mixes were required to be 100 percent crushed as compared to the previous requirement of a minimum of 75 percent crushed particles.

- The amount of natural, non-manufactured sand that was allowed to be used in the asphalt mixes was drastically limited and only allowed at the discretion of the Engineer.

- Multiple adjustments were made to the requirements for the asphalt mix designs as listed below:

  - Requirement to use performance graded asphalt cement that is polymer modified rather than penetration graded asphalt cement used in the past;

  - The gradation envelope for the combined asphalt aggregates was tightened;

  - The minimum asphalt cement content required to be included in the mixes was increased for both the surface and base course mixes;

  - The minimum required Marshall stability was increased for both the surface and base course asphalt mixes; and

  - Both surface and base course asphalt mixes were required to be tested and achieve a minimum Tensile Strength Ratio (TSR) of 80 percent to ensure that the mixes were not susceptible to stripping in the presence of moisture.

- Multiple adjustments were made to the requirements for the paving procedures and acceptance of the asphalt paving as listed below

  - The Contractor was required to use a ShuttleBuggy® Material Transfer Vehicle (MTV) to transfer the asphalt mix from the trucks to the paver in order to eliminate the potential for thermal and gradation segregation;

  - The Contractor was required to use a minimum of two pavers in echelon to minimize the number of cold longitudinal joints;

  - The requirements for the amount of Quality Assurance (QA) testing, testing turnaround times, and construction monitoring was increased to allow for problems to be identified and resolved in a timely manner;

  - Requirement for the minimum compaction of the asphalt mat was tightened compared with the minimum compaction required for highway/road pavement construction. The increased asphalt compaction would also reduce the potential for moisture damage of asphalt;

  - In addition to the asphalt mat compaction, the compaction of the longitudinal joint was also required to be tested and was to be no lower than the 1.0 percent of the mat compaction;

  - The tolerances for the plant produced asphalt mix properties, as compared to the asphalt mix design, were tightened; and

  - Smoothness testing was required to be carried out after completion of the surface course paving.

The pavement rehabilitation on the runways at EIA typically includes the milling of the existing asphalt and placing new asphalt on the centre 14 m of the runway. Photograph 5 shows construction of new slabs on Runway 02-20 and Photograph 6 shows a cross stitched crack. The pavement rehabilitation on Runway 02-20 included concrete slab removal in Row 1 on both sides of the centerline and localized slabs in other rows.

Photograph 5: Construction of new slabs on Runway 02-20.

Photograph 6: Example of cross stitched crack in concrete slabs.

After approval of the laboratory produced mix designs, a trial batch is prepared for each of the mixes to ensure that the designed mix could be satisfactorily produced in the plant within the tolerances included in the specification. The mix properties for the trial batch production for both mixes are reviewed and approved prior to placement of any mix on the runway.

It was noted in the past that even in areas where there was a sufficient thickness of remaining asphalt, the quality of the remaining asphalt was very poor. Essentially, there appeared to be no remaining adhesion in the existing asphalt and it was easily dislodged from the underlying concrete by the passage of the milling machine. Due to the condition of the existing asphalt and due to the variability in thickness, it was considered prudent to increase the milling depth such that the entire thickness of asphalt in all the areas was removed and replaced with new HMA. Removal of the entire thickness of the existing HMA also allowed for a thorough inspection of the underlying concrete slabs for the purpose of determining which slabs need to be removed and replaced, and which slabs should be cross stitched. Photograph 7 shows an example of the prepared surface of the underlying concrete prior to the application of tack coat and placement of the new hot mix asphalt. The surface of the existing concrete was slightly scarified to improve the bond with the overlying asphalt.

Photograph 7: Prepared surface of the concrete on Runway 12-30 prior to tack coat application and placement of new HMA.

Asphalt paving on the runway was carried out with three pavers in echelon and two ShuttleBuggies® remixing the material and transferring asphalt mixes from the trucks to the pavers. Photograph 8 shows an example of the paving operation that was carried out Runway 02-20. The figure shows two of the three pavers in echelon and one of the two ShuttleBuggies®. This allowed the elimination of cold joints in the newly placed mat thereby eliminating the weakest point in the pavement. Due to the increased width of the mat being placed, a significantly large number of rollers were required to ensure that compaction was being achieved prior to a reduction in the temperature of the placed mix. In order to achieve the tightened compaction requirement of 94 percent of Maximum Relative Density (MRD), whenever possible, the rollers were kept as close as possible to the pavers, as shown in

Photograph 9. Quality Control (QC) and QA testing of compaction was carried out continuously during paving and the Contractor was immediately notified if the required compaction was not being achieved. Compaction requirements for the mat and the joints were met on both runways.

Photograph 8: Asphalt paving operation on Runway 02-20 included three pavers and two ShuttleBuggies®.

Photograph 9: Compaction operation on Runway 12-30.

The smoothness is initially measured with a 3 m straight edge. Final smoothness is evaluated using an Inertial Profiler. Photograph 10 shows the final asphalt mat on Runway 02-20. The quality of the mat including compaction and smoothness was excellent.

Photograph 10: Paved surface on Runway 02-20.

3.0 TECHNOLOGY IMPROVEMENTS AT WINNIPEG INTERNATIONAL AIRPORT

In the past conventional pavement technology was used at Winnipeg International Airport (WIA) [1 and 2]. The recent improvements of the pavement/asphalt technology were based on local experience, successful application of pavement technology advancements at EIA, improvements in Federal Aviation Administration (FAA) paving specifications in the USA [3] and Golder’s extensive experience with airport pavements. In 2019 WIA carried major pavement rehabilitation on Runway 13-31. The existing pavement structure on the runway was very complex, as shown in Figure 1. Runway 13-31 intersects with Runway 18-36 and has a number of other intersections with taxiways. The surface of the pavement was asphalt and concrete. The distresses included concrete cracking, asphalt low to high severity cracking and localized ravelling, patching, and aggregate polishing. Typical distresses are shown in Photographs 11 to 13. Also, localized depressions and reflective cracking were observed. It was decided that the entire runway pavement should have consistent asphalt pavement. However, significant improvements to the asphalt technology was necessary to ensure that the new pavement would be able to support the anticipated increased aircraft traffic loading. Also, the objective was to improve the frictional characteristics of the pavement surface.

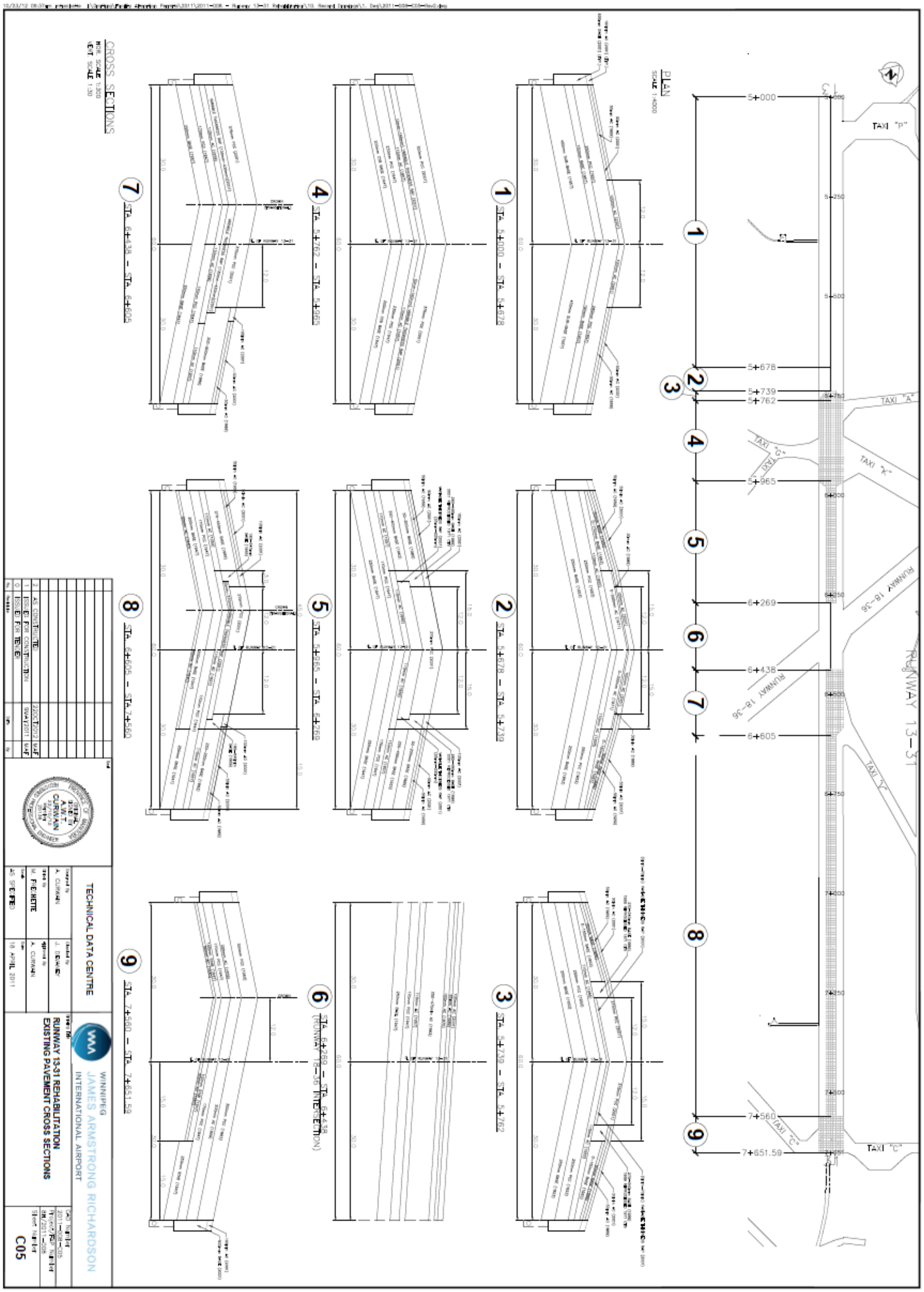

Figure 1: Pavement structures on Runway 13-31 at WIA.

Photograph 11: Localized severe raveling on Runway 13-31.

Photograph 12: Severe longitudinal crack along the concrete/asphalt interface.

Photograph 13: Ravelling, cracking and polished aggregate.

Traditionally, 150/200 A asphalt cement is used in the Winnipeg area and was used at WIA in the past. It was decided to take advantage of the improvements in asphalt cement technology and use Performance Graded (PG) asphalt cement during the pavement rehabilitation. The selected grade was PG 64-37 P (polymer modified).

There were a number of changes introduced in the asphalt paving specification. The number of blows in the Marshall mix design was increased from 50 to 75 blows and the target air voids were required to be 3.5 percent for the surface course and 4.0 percent for the lower course mixes. Minimum required Marshall stability was increased to 14 kN for the surface course and 12 kN for the lower course. Minimum asphalt cement content was 5.3 percent for the surface course and 5.0 percent for the lower course. The Tensile Strength Ratio (TSR) was included to limit the potential for moisture damage, and the minimum TSR for both lifts was specified as 80 percent. The gradation of both mixes was adjusted and brought in alignment with the gradation of these respective mixes at airports that have heavy to very heavy aircraft traffic. Minimum 85 percent of aggregate particles were required to have two faces crushed. The specified aggregate properties included tighter limits for Los Angeles abrasion, sand equivalent, soundness, absorption and flat and elongated particles.

Typically, limestone aggregates were used in WIA pavements. To improve frictional characteristics of the pavement, the Polished Stone Value (PSV) requirement was included in the specification. The limit was minimum 50. Extensive PSV testing was carried out of locally available aggregates. Generally, limestone aggregates had PSV values lower than granitic aggregates. None of the tested aggregates met the specified minimum of 50. The selected granitic aggregates had PSV of 45. Although it is better than those for limestone aggregates, monitoring of frictional characteristics will be needed and surface friction improvements through skid abrading or similar processes may be needed in the future.

Compaction requirement was increased to minimum 98 percent for the mat and 97 percent for longitudinal joints (as a percentage of the mix Bulk Relative Density). The paving was required to be carried out with a minimum of two pavers in echelon.

Photograph 14 shows echelon paving or the lower course mat and Photograph 15 shows the edge of the mat. Since both pavers used for lower course and surface course paving had excellent side confinement, as shown in Photograph 16, the edge of the paved mats was very good as can be seen in Photograph 15. The mat did not have to be cut or trimmed for cold joint construction. Photograph 17 shows the GlasGrid® application beneath the asphalt lower course to mitigate the potential for reflective cracking.

Photograph 14: Echelon paving of the lower course.

Photograph 15: Paved mat of the lower course. The edge is of very good quality.

Photograph 16: Excellent side confinement provided by the paver.

Photograph 17: GlasGrid® placed on existing pavement below the lower course.

Photographs 14 and 18 show echelon paving of the base course and the surface course mat, respectively. The quality of the surface course mat is excellent, and the longitudinal joints are very tight, as shown in Photograph 19.

Photograph 18: Echelon paving of surface course.

Photograph 19: Excellent quality of surface course mat. Longitudinal joint is very tight.

4.0 CONCLUSIONS

Continuous increase in aircraft traffic loading in Canada in terms of both the number of aircraft movements and the load levels applied by individual aircrafts requires changes to conventional paving technology. Temperature increases may cause premature pavement deformations and shear failures. Conventional road pavement technology is often not sufficient to meet the always increasing quality demands for airfield pavements.

The focus of developing new specifications for airfield pavements is mainly on HMA, including advanced asphalt cement types including polymer modification, very good quality aggregates, including their frictional characteristics, and advanced mix designs.

This paper presented the application of advanced pavement technology at two airports. The introduction of advanced HMA technology Edmonton International Airport included:

- Improved hot-mix asphalt technology – addressing asphalt stripping, better resistance to cracking and rutting;

- Construction improvements including paving in echelon, using MTVs, tightening compaction requirements;

- Better preparation of existing concrete surface including some slab replacement and cross-stitching, slightly scarifying the concrete surface for better grip; and

- New, stricter smoothness specification.

The above changes significantly improved pavement performance, reduced the amount of cracking, and eliminated the potential to moisture damage. The quality of paved mats of surface and lower course on runways and taxiways is much better than in the past.

The asphalt technology improvements at Winnipeg International Airport included

- Better quality asphalt cement - using PG 64-37 polymer modified instead of conventional penetration graded 150-200;

- Better quality aggregates including PSV testing

- Improved mix designs;

- Improved construction operation to include echelon paving and MTVs;

Similar to Edmonton Airport, the quality of the pavement asphalt mat at Winnipeg Airport is very good and better performance is anticipated.

5.0 REFERENCES

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