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Pavement Preservation Catalogue for Canadian Airfields

Final Report

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Abstract

There is an extensive body of information dealing with pavement preservation technology for Canadian airfield pavements. However, the information is dispersed in numerous publications, standards, manuals, field performance reports, and technical briefs, and is not properly assembled or classified. To organize this information within a structured framework and to provide Canadian Airport Authorities with the latest information on pavement preservation technology, a *Pavement Preservation Catalogue for Canadian Airports* has been developed. The objective of the Catalogue is to facilitate the cost-effective provision of safe pavement facilities at Canadian airfields.

The Catalogue includes technical information on pavement maintenance and rehabilitation treatments for all airfield pavement types. It features a modular design that will facilitate ongoing enhancements including future computerized search and retrieval. Emphasis has been placed on innovative pavement preservation treatments for Canadian airfield pavements.

The content of the Catalogue centers on the description of individual pavement preservation treatments and currently contains descriptions for twenty-five (25) treatments.

The Catalogue can be enhanced in future by the inclusion of additional existing/new technical reports as they become available. As new pavement preservation technologies are developed and additional technical information is uncovered, they should be added to the content of the Catalogue.

Notes:

1) The views expressed in this report are those of the consultant and do not necessarily reflect or represent (in whole or in part) the views and/or engineering practices recommended by Transport Canada for the maintenance and rehabilitation of airfield pavements.

2) Some of the repair materials, practices and technologies identified and described in this report may not be suitable for the repair of airport pavement structures. However, such material provided by the consultant has been retained in the report for information purposes.

3) The terminology used in this report is that of the consultant and some terms may not be identical to those normally used by Transport Canada.

4) Where Transport Canada does not agree with statements made by the consultant, a qualifying note contained in [brackets] has been added.

Technical Evaluation Engineering

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Transport Canada's Technical Evaluation Engineering Division provides specialized engineering expertise, products, services and advice in support of the Canadian aerodrome regulatory environment and strives to improve and promote technical excellence respecting safety within the Canadian national airport system.

The Engineering Division's program encompasses a number of on-going activities directed at enhancing aerodrome safety. These activities include: research and development, technical evaluations and assessments, provision of technical documentation, promotion of advances in technology, provision of technical leadership, development of regulations and standards, inspection and auditing support, monitoring, awareness, training and education and the national/international harmonization of regulations, standards and procedures.

Our focus is on:

a) Aerodrome Electrical Systems & Visual Aids for aerodromes and airspace (obstacle lighting) including their associated control and power systems;

b) Airfield Pavement Structures (runways, taxiways, aprons) with primary emphasis on safety requirements for their provision, operation and maintenance; and

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for
Canadian Airfields

1.0 Introduction

The *Pavement Preservation Catalogue for Canadian Airfields* is based on a series of discussions with Transport Canada personnel, a comprehensive literature review, and a review of the pavement preservation practices of Canadian airport operators based on the results of a rehabilitation and maintenance practices survey. Twenty-six Canadian airport operators responded to the survey questionnaire. The questionnaire, and the results of the survey, are summarized in Appendix E.

1.1 The Need for a Pavement Preservation Catalogue

Development of a *Pavement Preservation Catalogue for Canadian Airfields* is needed for the following reasons.

1) There is an extensive body of information dealing with pavement preservation technology for Canadian airfield pavements. However, the information is dispersed in numerous publications, standards, manuals, field performance reports, and technical briefs, and is not properly assembled or classified. The Catalogue assembles this information and provides a framework for the systematic classification and retrieval of engineering information on pavement preservation.

2) Many reports concerning pavement preservation activities carried out at Canadian airfields have been displaced and are often difficult to locate. The Catalogue inventories and references technical reports dealing with pavement preservation for Canadian airfields.

3) The Catalogue provides the necessary background engineering information for the development of pavement maintenance and rehabilitation manuals, and organizes this information into a structured and searchable format.

4) There is a growing awareness in the airport community of the advantages of developing pavement preservation programs within a pavement management system framework. One essential component of a pavement management system is knowledge of alternative pavement preservation treatments. The Catalogue provides a comprehensive knowledge base for both innovative and routine pavement preservation treatments for all pavement types.

5) Canada has a mature network of airfield pavements. Consequently, the major emphasis in recent years has been on the rehabilitation and maintenance of existing airport pavement facilities. If cost-effective and innovative strategies for pavement preservation are employed, these facilities can continue to provide high levels of service for long periods of time and will result in savings to airport operators while providing safe pavement facilities.

1.2 Objectives of the Catalogue

The objective of the Pavement Preservation Catalogue is to provide Canadian Airport Authorities with the latest information on pavement preservation technology, and organize this information within a structured framework. The Catalogue is intended to facilitate the cost-effective provision of safe pavement facilities at Canadian airfields.

The specific objectives of the Catalogue include the following.

1) To inventory and summarize available technical documentation on pavement preservation with emphasis on experience gained at Canadian airfields and innovative pavement preservation treatments.

2) To provide information for the development of a computerized database of available technical literature (manuals, guidelines, technical studies, research reports) dealing with airfield pavement preservation technology in Canada.

3) To provide information that will facilitate the development of manuals of practice, Engineering Reference Documents and other in-depth technical reports for Canadian airfield operators.

4) To provide guidance material for the selection of cost-effective maintenance and rehabilitation treatments, recognizing that the selection should be done within the framework of a pavement management system.

5) To describe the technology of pavement maintenance and rehabilitation treatments using a structured, electronically searchable format. The emphasis has been placed on maintenance and rehabilitation treatments that are applicable to Canadian airfield pavements, are innovative, and that affect aerodrome safety.

1.3 Role of the Catalogue in a Pavement Management System

A pavement management system provides an organizational framework for all the work activities and services necessary to provide, operate and maintain airfield pavements in a safe and cost-effective manner (Transport Canada, 2001). A key component of any pavement management system is a detailed 5-year pavement management plan that identifies for each year during the period:

- the pavement facilities that will receive maintenance or rehabilitation treatment,
- the type of treatment, and
- how much the treatment will cost.

Within the context of a pavement management system, information provided in the Catalogue can be used in two ways. It can be used to facilitate the development of a pavement management plan, and to provide information to Canadian airfield operators regarding feasible alternative treatments, their applicability, and cost. Selection and timing of the treatment should be made within the framework of a pavement management system considering pavement preservation needs and available funding.

The selection of specific treatments for pavement management plans can be facilitated using decision trees and selection matrices (Hicks et al, 2000) that identify feasible alternative treatments. The selection of specific treatments should strive to achieve optimal selection and timing. The optimal selection of pavement preservation treatments should consider the reason for investing in the pavement infrastructure, treatment cost, effectiveness, and the consequences of advancing or deferring treatment timing.

The pavement management plan is a planning tool and the treatment types that are part of the plan may change. Selection of the treatment that is ultimately implemented is typically based on a detailed site-specific engineering and economic analysis.

1.4 The Difference Between Airfield and Highway Pavements

Many specifications, manuals, field performance and other technical reports and documents that are referenced in the *Pavement Preservation Catalogue for Canadian Airfields* concern highway pavements, local roads, and streets. The question can be asked: "Are the reports prepared for highways, local roads and streets applicable to airfield pavements?"

On the one hand, there are obvious differences between airfield and highway pavements. Airfield pavements are subjected to a wider range of wheel loads than highway pavements. The heavier wheel loads are also slower moving. The application of aircraft wheel loads to airfield pavement surfaces is relatively infrequent compared to highway load applications. On the other hand, there are many similarities. Airfield pavements are also used by service vehicles. Both airfield and highway pavements are built and rehabilitated using the same technology (same materials, construction equipment, and construction methods), are built on the same subgrade soils, and are exposed to the same environment. While the pavement design methodologies for airfield and highway pavements differ, the technologies used for the construction and rehabilitation of these two pavement facility types are similar. Consequently, the majority of reports on pavement preservation issued for highway pavements are applicable to airfield pavements and these reports have been included in the Catalogue.

The similarity between airfield and highway pavements has been noted by others. For example, Murphy and Emery (1999) concluded that there is no technical reason why cold in-place recycling of asphalt concrete pavements (a technique that has been used extensively to rehabilitate highway pavements but not at all to rehabilitate airfield pavements) cannot be applied to runways, taxiways and aprons, provided airport operational constraints can be met. MacMillan and Scarlett (1999) concluded that from the perspective of low temperature performance, an airport pavement should not be expected to perform differently than a highway pavement.

1.5 The Importance of Catalogue Structure and Content

The structure and content of the Catalogue are both equally important. Emphasis has been placed on providing clear definitions for Catalogue design parameters and on the development of a logical and detailed Catalogue structure. The content of the Catalogue will need to be enhanced in the future by including technical and engineering reports that could not be located at this time and new reports not yet available. The content of the Catalogue should also be enhanced by including information on new pavement preservation technologies as it becomes available.

As the content of the Catalogue continues to evolve, the structure of the Catalogue will provide stability and guidance for the classification and placement of new information.

2.0 Design Features and Requirements

This section describes the design features and requirements of the *Pavement Preservation Catalogue for Canadian Airfields,* and outlines how they have been incorporated into the structure and content of the Catalogue.

Basic design of the Catalogue requires:

1) a comprehensive approach that includes:

   a) all airfields, small and large
   b) all pavement types and airport pavement facilities
   c) all Canadian environmental regions
   d) all pavement preservation treatments (maintenance as well as rehabilitation)
   e) all technology items

2) a modular design to facilitate ongoing enhancements, computerized search and retrieval

3) a hierarchical structure for inclusion of technology items.

2.1 Comprehensive Approach

The Catalogue needs to be comprehensive and accommodate the following.

2.1.1 All Airfields, Small and Large

The Catalogue should be applicable to pavements at all airfields, small and large, and particularly to small and medium-size airfields that do not have pavement professionals on staff. The Catalogue should provide operators of small and medium-sized airfields with a ready source of technical information on pavement maintenance. For the operators of large airports with specialized engineering staff, the Catalogue should provide a basic reference for new and innovative pavement preservation treatments.

2.1.2 All Pavement Types and Airport Pavement Facilities

Pavement maintenance and restoration practices are highly dependent on pavement type. The Catalogue should address pavement maintenance treatments for all common pavement types, namely:

i) asphalt concrete
ii) Portland cement concrete (PCC) (exposed surface)
iii) composite pavements (asphalt concrete over a PCC slab)
iv) surface-treated pavements
v) gravel surfaces.

Likewise, all airport pavement facilities (runways, taxiways, aprons, and airside roadways) should be included.

2.1.3 All Canadian Environmental Regions

The Catalogue should be applicable to airfields in all Canadian environmental regions (wet-freeze, dry-freeze, and wet coastal regions). Maintenance materials and techniques applicable in one region are not always suitable for use in other environmental regions.

2.1.4 All Pavement Preservation Treatments

The Catalogue should address all pavement preservation treatments, maintenance as well as rehabilitation. The system approach requires that the selection of treatments to enhance the safety and operational capacity of airfield pavements take into account all feasible maintenance and rehabilitation treatment alternatives. For example, while a maintenance treatment (patching) can be used to remove the potential for FOD caused by a ravelled asphalt concrete surface, a rehabilitation treatment (overlay) should be also considered. The treatment selection depends, among other factors, on the severity and extent of ravelling, the causes of ravelling, and the available budget.

There is no generally accepted distinction between maintenance and rehabilitation treatments. For example, ultra-thin, thin, and one-layer asphalt concrete overlays are alternatively referred to as maintenance or rehabilitation treatments. Consequently, the Catalogue should address all pavement preservation treatments without limiting the Catalogue to only one particular type of pavement preservation. Also, by including all pavement preservation treatments, it is not necessary to distinguish between, or define, pavement maintenance treatments and pavement rehabilitation treatments.

The Catalogue should not include information and technical reports dealing with pavement reconstruction technology or the technology for constructing new pavements. This limitation is necessary to keep the focus on innovative pavement preservation treatments and to ensure that the size of the Catalogue remains manageable. In this report, reconstruction is defined as an activity that involves removal of all asphalt or Portland cement bound pavement layers, re-grading of the underlying granular or base materials, and the construction of new bound pavement layers.

However, it is recognized that the line of what constitutes major rehabilitation or reconstruction is sometimes blurred.

There are numerous ongoing developments in the area of pavement material technology (e.g. premium asphalt cements, Superpave mix design, high performance concrete) and construction technology (e.g. new production and placement procedures, end-result specifications, smoothness specifications). The inclusion of information on new construction is considered to be outside the scope of the Catalogue. However, all investigative reports dealing with airfield pavement construction or preservation should be included in the Catalogue.

2.1.5 All Technology Items

The *Pavement Preservation Catalogue for Canadian Airfields* should function as a compendium of information concerning a variety of pavement preservation technology items. Some authorities, such as the Strategic Highway Research Program, refer to technology items as products. Technology items may have a different format and purpose such as:

- Specifications
- Manuals of practice
- Research reports on materials or techniques
- Latest technological advancements in pavement preservation
- Investigative reports dealing with the performance of specific treatments, materials, and construction techniques.

Alternatively, technology items may relate to different implementation stages of pavement preservation treatments:

- Implemented and accepted pavement preservation treatments
- New and experimental treatments
- Initial trials of new products, equipment, and techniques
- Treatments under development
- Theoretical studies.

The Catalogue should include all technology items concerning pavement preservation.

2.2 Modular Design

The knowledge base comprising the Catalogue should be organized using a modular structure to facilitate usage and retrieval of information, future enhancements, and computerized search and retrieval. The Catalogue will need to be updated and enhanced in the future. The modular structure of the manual should accommodate future enhancements, and information organized using this structure should be amendable to computerized search and retrieval of information. If relevant information is not currently available, the Catalogue should provide a place holder so that the information can be added at a future date.

2.3 Hierarchical Structure for Inclusion of Technology Items

The number of technology items that could be considered for potential inclusion in the preservation Catalogue is enormous. For example, the number of technology items (manuals, material specifications, performance reports, field manuals, laboratory and rheological analysis, etc.) dealing with sealing of cracks in asphalt concrete pavements that have been produced in North America during the last 20 years exceeds 100. It is not possible, nor would it be constructive, to review and catalogue all these items. Clearly, a schema must be established to select the relevant technology items to be included in the Catalogue. The schema adopted for the preservation Catalogue utilizes the four parameters and the hierarchical indicators listed in Table 1.

Table 1: Hierarchical Indicators for the Selection of Technology Items

Parameter	Hierarchical Indicators Listed in Descending Order
Applicability to Canadian Airfields	- Application to Canadian airfield pavements - Application to Canadian roadway pavements - Application to North American pavements - Other applications
Degree of Innovation	- Innovative and experimental treatments and products - State-of-the–art treatments and products - Product and treatments in common use - Products and treatments no longer commonly used
Implementation Stage	- Full-scale implementation exists - Limited field implementation - Laboratory evaluation - Theoretical analysis
Environmental Exposure	- Wet-freeze and dry-freeze environment - Coastal wet environment - Other environments

Following this schema, the first priority would be placed on innovative preservation treatments implemented at Canadian airfields. On the other hand, technology items involving theoretical studies of old pavement preservation treatments intended for highway pavements located in a warm environment would likely not be included in the Catalogue.

3.0 Structure and Operation of the Catalogue

This section describes the framework used to organize, classify, store and retrieve technical information on pavement preservation and the operation of the Catalogue.

The Catalogue structure incorporates five classification categories:

1. Pavement preservation treatments
2. Technology items (product types)

3. Pavement type
4. Preservation type
5. Pavement defects.

The content of the catalogue is organized according to treatments. Each of the five classification categories is further subdivided into classification subcategories. The overall classification schema showing the five categories is given in Figure 1 which also shows the tables that provide additional information on the classification subcategories. Such a Catalogue structure is required to ensure that information can be searched and sorted by electronic means and to facilitate the easy non-electronic retrieval of information.

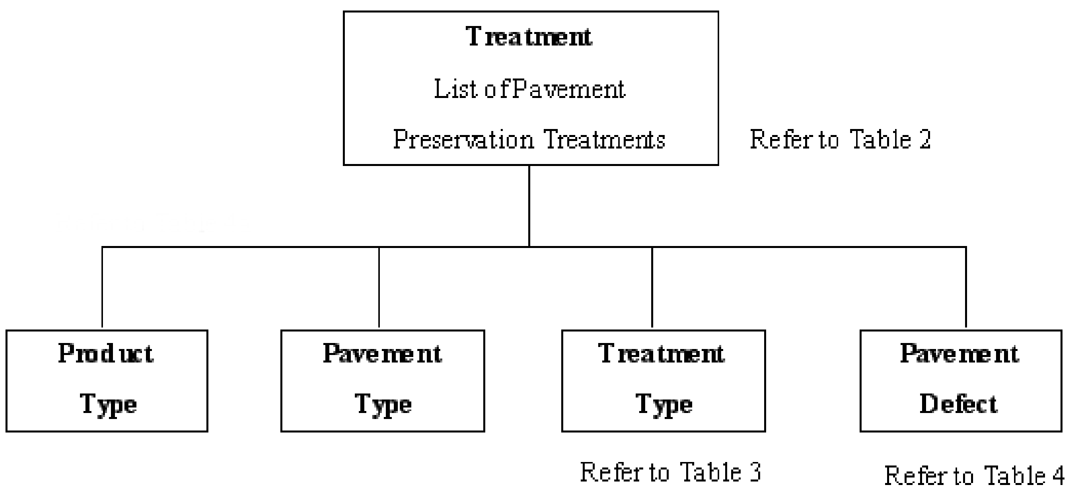

Figure 1: Structure of the Catalogue

3.1 Classification Levels and Sub-Levels

The following definitions and descriptions of classification levels and sub-levels have been established to accommodate existing pavement preservation information.

3.1.1 Pavement Preservation Treatments

The category "pavement preservation treatment" contains the list of pavement preservation treatments included in the Catalogue. The treatments have been classified according to pavement type, treatment type, and pavement defects as shown in Figure 2. The Catalogue provides descriptions for the 25 pavement preservation treatments listed in Table 2.

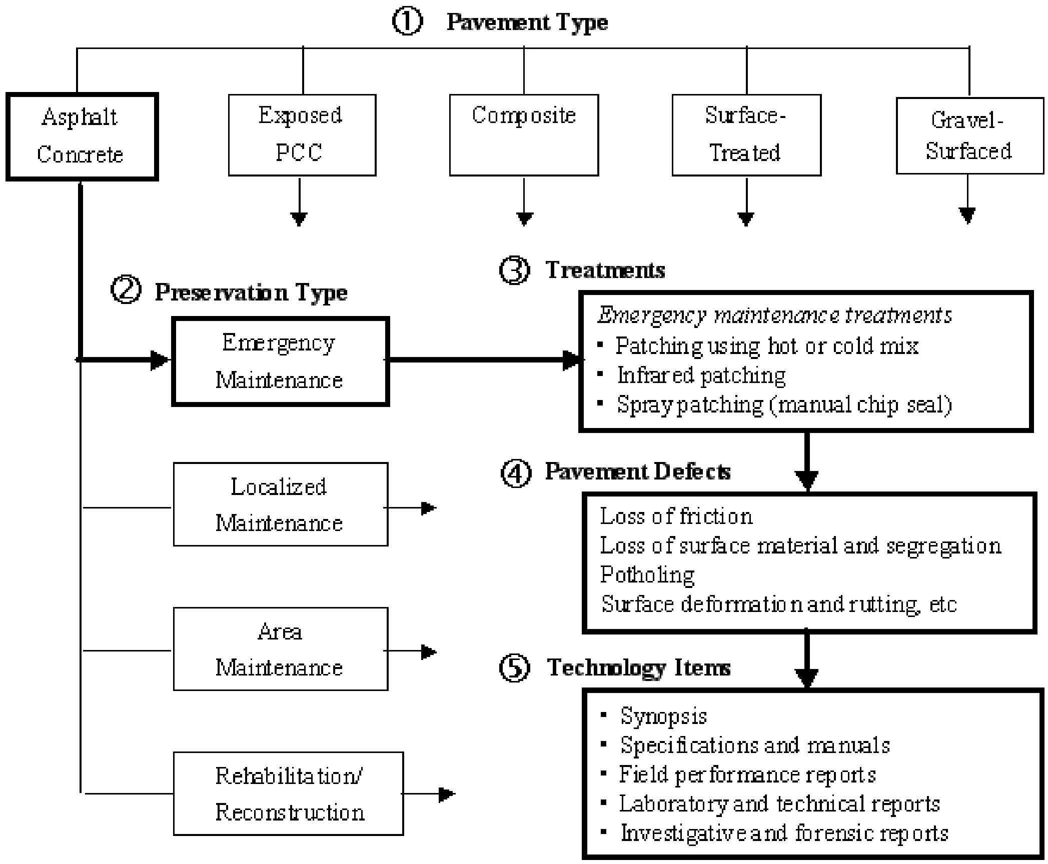

Figure 2: Relationship Between the Five Classification Categories

3.1.2 Technology Items (Product Types)

Technical information on pavement preservation technology is dispersed in a wide variety of reports and documents. All these reports and documents are referred to as technology items. For the purposes of the Catalogue, the technology items were divided into the following five subcategories.

a) Synopsis of practice
b) Specifications and manuals
c) Field performance reports
d) Laboratory and theoretical reports
e) Investigative reports.

A synopsis of practice was developed for each of the 25 treatments included in the Catalogue. Thus, the information available for each treatment always includes a synopsis. The inclusion of products b) to e) in the Catalogue depends on their availability. In accordance with the scope of the Catalogue, technology items that are included in the Catalogue have been selected using the hierarchical approach outlined in Table 1.

Table 2: Listing of Pavement Preservation Treatments

Preservation Treatment Type	Pavement Type				
	Asphalt Concrete	**Composite**	**Exposed PCC**	**Surface-Treated**	**Gravel Surface**
Emergency Maintenance	• Small area patching using hot or cold mix • Infrared patching • Spray patching • Manual chip seal	• Same as for asphalt pavements	• Shallow patch repair with PCC material • Shallow patch repair with asphalt concrete • Spray patching • Full depth asphalt patching	• Patching using hot or cold mix • Manual chip seal	• Grading and gravelling
Localized Maintenance	• Machine patching • Cold milling and machine patching • Machine chip seal	• Same as for asphalt pavements • Load transfer restoration	• Machine patching with asphalt concrete • Full depth asphalt repairs • Full and partial depth repairs using PCC • Load transfer restoration	• Machine chip seal • Machine patching	• Grading and gravelling
Area Maintenance	• Crack sealing • Chip sealing • Slurry seal • Micro-surfacing • Drainage improvements • Surface texturization* • Drainage improvements	• Same as for asphalt pavements • Sub-sealing (under slab grouting)	• Joint/crack sealing with rubberized or silicone sealant • Micro-surfacing • Surface texturization* • Full and partial depth repairs using PCC • Drainage improvements	• Single surface treatment	• Dust control • Grading and gravelling
Rehabilitation/ Reconstruction	• Asphalt concrete overlays using virgin or recycled hot or cold mix materials • Milling and resurfacing • In-place hot or cold recycling • Whitetopping (PCC overlay)	• Same as for asphalt pavements • Sub-sealing (under slab grouting) • Bonded/unbonded PCC overlay	• Hot mix resurfacing • Sub-sealing (under slab grouting) • Bonded/unbonded PCC overlay	• Single or double surface treatment • Asphalt concrete overlays using virgin or recycled material	• Grading and gravelling • Single or double surface treatment

Note: The list of treatments can be expanded as additional information becomes available.
* Includes grinding, grooving, shot-blasting, rubber removal, and similar techniques.

3.1.3 Pavement Type

The Catalogue structure includes the following five pavement types.

a) *Asphalt concrete pavements* consisting of asphalt concrete surface layer(s) and one or more base and subbase layers
b) *Portland Cement Concrete (PCC) pavements* that encompass jointed concrete pavements with and without joint reinforcement, continuously reinforced pavements, and prestressed pavements (surface exposed)
c) *Composite pavements* consisting of an asphalt concrete surface over a PCC slab
d) *Surface-treated pavements* consisting of a thin bituminous surface
e) *Gravel surfaced pavements.*

3.1.4 Treatment (Preservation) Type

The pavement preservation treatments are classified as emergency maintenance, localized maintenance, area maintenance, and rehabilitation/reconstruction. The four types of pavement preservation treatments differ not only in their purpose, but also in the process used for their selection as summarized in Table 3.

a) *Emergency Maintenance*

Emergency maintenance is used to correct localized pavement deficiencies, mainly the loss or deterioration of pavement surface material, that may result in FOD hazards or a rough pavement surface. The decision to apply emergency maintenance treatments is based on frequent inspections of pavement condition. Emergency maintenance cannot be planned in advance and is often carried out on short notice.

b) *Localized Maintenance*

Localized maintenance is used to keep locally deteriorated pavement areas at condition levels compatible with the rest of the facility or the area. For example, if only one end of a runway (for example, the touchdown zone) exhibits a loss of skid resistance while the rest of the runway is in safe operational condition, localized maintenance treatment can be used to increase the skid resistance of the affected area to make the runway safe until the entire runway requires rehabilitation.

c) *Area Maintenance*

Area maintenance refers to treatments that are applied to an entire facility such as a runway. Area maintenance treatments are typically applied for two purposes. The first purpose is to prolong the pavement life by the application of a maintenance treatment (e.g. by routing and sealing cracks in an asphalt concrete surface). Such maintenance is deemed to be the most cost-effective alternative for the given situation. The second purpose is to maintain the pavement in a safe operational condition until adequate resources for pavement rehabilitation are available. In this situation, area maintenance treatment may not be the most cost-effective alternative in terms of treatment selection and timing.

Table 3: Definition of Preservation Treatments

Preservation Type	Purpose	Recommended Process for Treatment Selection in Terms of:			Information/ Decision Support Needed for Cost-Effective Treatment Selection
		Condition Surveys	Type of Treatment	Time of Treatment	
Emergency Maintenance	To correct localized deficiencies, including FOD, that occur unexpectedly	Daily or weekly inspections	Guidelines based on a knowledge of local pavement conditions and maintenance treatments		Practical guidelines describing treatment techniques and materials
Localized Maintenance	To maintain locally deteriorated areas at condition levels compatible with the remaining area	Yearly or biennial inspections or pavement condition surveys	Guidelines that may include decision trees	Guidelines or through pavement maintenance system	Practical guidelines describing treatment techniques and materials
Area Maintenance	To prolong the pavement service life of an entire area (such as a runway)	Yearly or biennial pavement condition surveys	Guidelines that may include decision trees	Preferably selected using pavement management process or using guidelines	Knowledge of available treatments. Pavement management system.
Rehabilitation/ Reconstruction	To substantially improve pavement condition of an entire area by changing surface layer materials	Yearly or biennial pavement condition surveys	Project level pavement design (preliminary selection using decision trees)	Preferably selected using pavement management process	Knowledge of available treatments. Pavement management system. Pavement design methodology.

d) Rehabilitation/Reconstruction

Rehabilitation treatments are applied to the entire area of the facility and involve substantial changes to surface layer materials and possibly to base and subbase layer materials.

3.1.5 Pavement Defects

All pavement preservation treatments have been linked not only to pavement and treatment type, but also to one or more pavement defects the treatments are intended to address. Pavement defects (or distresses) are defined separately for each of the five pavement types as shown in Table 4. The names of the pavement defects reflect the terminology used in Transport Canada Report TP 1949 (Transport Canada, 1985).

Table 4: Classification Categories for Pavement Defects

Classification Sub-Levels for Major Pavement Defects				
Asphalt Concrete Pavements	**PCC Pavements**	**Composite Pavements**	**Surface-Treated Pavements**	**Gravel Surfaced Pavements**
• loss of friction • ravelling and segregation • pot-holing • rutting • transverse and longitudinal cracking • alligator cracking • map cracking • frost heaving and subgrade settlement	• loss of friction • scaling • surface spalling • joint and crack spalling • joint faulting • sagging and slab warping • joint sealant loss • corner and edge cracking • transverse and longitudinal cracking • "D" cracking • joint failures • frost heaving and subgrade settlement	• loss of friction • ravelling and segregation • pot-holing • surface deformation and rutting • stepping (faulting) • transverse and longitudinal cracking • Corner and edge cracking • other cracking • joint failures • frost heaving and subgrade settlement	• loss of friction • loss of cover aggregate • pot-holing • surface deformation and rutting • transverse and longitudinal cracking • alligator cracking • pavement edge breaks and cracking • frost heaving and subgrade settlement	• loose gravel • dust • pot-holing • surface deformation and rutting • washboarding • frost heaving and subgrade settlement

To summarize, there are five classification categories (treatment, product type, pavement type, treatment type, and pavement defect) as illustrated in Figure 1. The list of treatments is given in Table 1. Table 4 provides a list of pavement defects, and Table 5 provides a list of the three remaining classification categories (product type, pavement type, and preservation type).

Table 5: Four of the Five Classification Categories

Classification Category			
Product Type	**Pavement Type**	**Preservation Type**	**Pavement Defect**
Classification Subcategory			
a. synopsis of practice b. specifications and manuals c. field performance reports d. laboratory and theoretical reports e. investigative and forensic reports	A. asphalt concrete E. exposed PCC C. composite pavements S. surface-treatments G. gravel roads	E. emergency maintenance L. localized maintenance A. area maintenance R. rehabilitation treatments	Major pavement defects will be defined separately for each pavement type.

3.2 Organization and Content of the Catalogue

The content of the Catalogue is centered on the description of individual pavement preservation treatments. Currently, the Catalogue contains descriptions for the 25 pavement preservation treatments provided in the Appendices to this report. The treatments are described sequentially following the list given in Table 2 (first by pavement type and then by treatment type). Each treatment has also been classified according to pavement type, treatment type, and the pavement distress types addressed by the treatment.

3.2.1 Description of Treatments

The description for each pavement preservation treatment follows the list of technology items, namely:

a) Synopsis of practice
b) Specifications and manuals
c) Field performance reports
d) Laboratory and theoretical reports
e) Investigative reports.

a) Synopsis of Practice

A unique catalogue feature is the inclusion of a synopsis of practice for all pavement preservation treatments which consists of a short description of the treatment including the following.

i) Purpose - Description of the pavement condition and defects addressed by the treatment.

ii) Benefits and Contribution to Safety - Expected life-span of the treatment and/or expected effect on pavement life. Contribution to operational safety. May include references to specific studies on treatment effectiveness.

iii) Costs - Typical or representative costs. Indicates the relative cost of different pavement preservation treatments.

iv) Extent of Use - Extent of use was based on the survey of Canadian airport operators.

v) Latest Trends and New Developments - An outline of the most recent developments, challenges and issues associated with the treatment.

b) Specifications and Manuals

This technology item includes specifications and manuals for materials and technological processes, field construction guidelines, manuals of practice, recommended contracting procedures, warranties and other similar reports that document successful practices. Relevant reports have been referenced and briefly described.

c) Field Performance Reports

Field performance reports include reports on the performance of treatments, materials, or technological processes observed in the field. The description includes a reference and a brief outline of results.

d) Laboratory and Theoretical Reports

Laboratory and theoretical reports deal with the effectiveness of treatments and materials based on laboratory testing or analytical evaluation. The relevant reports have been referenced and summarized.

e) Investigative Reports

Investigative studies are typically carried out to ascertain reasons for the unexpected performance of treatments or materials. Often, these reports provide valuable insight into the effect of a unique combination of construction events, material properties, traffic loads, and environmental conditions. For this reason, investigative reports, unlike other technology items, are also provided for the technology dealing with the construction of new pavements.

3.2.2 Inclusion of References

Some technology items (such as specifications and manuals, laboratory and theoretical reports) are too numerous for them all to be referenced in the Catalogue. In addition to the hierarchical scheme given in Table 1, the following rule of thumb was used. All reports dealing with pavement preservation on Canadian airfields have been included in the Catalogue. For treatments where suitable Canadian reports were not available, one or two reports from North America were included for each of the technology items. If North American information on a new technology was sparse, reports originating from outside of North America were included.

3.3 Management and Retrieval of Information

The structure of the Catalogue has been designed to facilitate the management of technical information on pavement restoration. The structure enables the user to search and sort the catalogue products utilizing a variety of classification levels and sub-levels. While it is possible to search and retrieve information in many ways, two basic approaches can be used:

- search for information on a specific pavement preservation treatment, or
- search for information on treatments that address a specific pavement defect.

Searching for information on a specific treatment may involve retrieving all products dealing with the treatment - for example, a search for all products (synopsis, specifications and manuals, etc.) on joint and crack sealing of asphalt concrete pavements. Searching for information on a specific pavement defect may involve, for example, retrieving all products that concern: a) asphalt concrete pavements, and b) transverse and longitudinal cracking. Or the user can narrow the search and instead of retrieving "all" products retrieve only specifications and manuals of practice (for asphalt concrete pavements, and transverse and longitudinal cracking).

While computerization of the catalogue is not part of this project, the structure of the Catalogue and the organization of information in it will facilitate future computerization.

3.4 Functionality of the Catalogue

The *Pavement Preservation Catalogue for Canadian Airfields* has been developed both as a paper-based report and an electronic report. Currently, the electronic version of the Catalogue is not searchable using search engines but must rely on search capabilities enabled by word processing software. However, the Catalogue structure and contents are suitable for future electronic sorting and retrieval using relational database technology.

4.0 Sources of Information

Information for the Catalogue was obtained from numerous sources. The principal sources of information are summarized in this section.

4.1 Survey of Canadian Airport Operators

As part of this project, a questionnaire was prepared and distributed to approximately 70 Canadian airport operators. A copy of the survey is given in Appendix E. The purpose of the survey was twofold:

a) To obtain up-to-date information from Canadian airport operators regarding rehabilitation and maintenance practices in terms of the types of pavement preservation treatments used, frequency of use, and the degree of satisfaction with the performance of the treatment.

b) To solicit technical reports or other documentation on the use and performance of pavement preservation treatments.

Of the 70 questionnaires that were distributed, 26 operators responded. In many instances, the mailing out of the survey questionnaire was followed by a telephone follow-up.

The results of the survey are summarized in Appendix E. Following are some general observations regarding the survey.

a) None of the respondents forwarded any documentation on pavement maintenance and rehabilitation treatments other than that already published by Transport Canada.

b) Many operators appeared reluctant to discuss the performance of specific products and treatments because they did not want to be viewed as endorsing or criticizing them.

c) Several operators indicated that they do not have any relevant information and directed us back to Transport Canada regional and national offices.

4.2 In-Depth Discussions with Canadian Airport Operators

The project team met with engineering representatives from several airport authorities and conducted a number of in-depth telephone interviews with Canadian airport operators. In general, the telephone interviews were conducted in conjunction with the survey questionnaire.

4.3 Pavement Rehabilitation Practices of Canadian Provincial & Municipal Highway Agencies

The review of pavement maintenance and rehabilitation practices included published manuals, guidelines and specifications. Comprehensive manuals reviewed included those published by the Transportation Association of Canada (1997), Ontario Ministry of Transportation (1990), Alberta Transportation and Utilities (1997), and Ministère des Transports du Québec (1999).

4.4 US Civil and Military Airport Rehabilitation and Maintenance Practices

Information sources included U.S. Federal Aviation Administration (FAA) Advisory Circulars and FAA Guidance Reports (FAA 99).

4.5 Miscellaneous Information Sources

The project team searched the Internet, databases, libraries, and the publication directories of transportation organizations in order to obtain additional materials for the Catalogue. The organizations targeted in this effort included the following:

- Transport Canada
- Public Works and Government Services Canada
- Department of National Defence
- Airport Management Conference of Ontario
- SWIFT
- Atlantic Canada Airports Association

- British Columbia Airport Managers Association
- Alberta Airport Operators Association
- Manitoba Aviation Airport Operators
- Canadian Airports Council
- International Association of Airport Executives
- Air Transportation Association of Canada
- Canadian Business Aircraft Association
- International Civil Aviation Organization
- Cement Association of Canada
- U.S. Asphalt Institute and National Asphalt Paving Association
- Strategic Highway Research Program
- University of Waterloo, Ottawa-Carleton, Laval, and Alberta.

5.0 Conclusions and Recommendations

5.1 Conclusions

5.1.1 The *Pavement Preservation Catalogue for Canadian Airfields* provides a useful tool for assembling and organizing dispersed and fragmented engineering and technical information on pavement preservation technology. Emphasis has been placed on innovative treatments carried out by Canadian airport authorities.

5.1.2 The Catalogue is intended to provide the operators of small and medium airfields with technical information on pavement maintenance. For the operators of large airport facilities with specialized engineering staff, the Catalogue provides a reference for new and innovative pavement preservation treatments. The Catalogue provides an inventory of technical reports dealing with pavement preservation for Canadian airfields.

5.1.3 The Catalogue knowledge base is organized using a modular structure to facilitate usage and retrieval of information, future enhancements, and computerized search and retrieval. The Catalogue provides place holders so that information can be added in future.

5.1.4 The results of the survey of pavement preservation practices at Canadian airfields show that technical reports documenting past pavement preservation practices are not readily available and can be difficult to obtain.

5.1.5 The content of the Catalogue should evolve in the future, while the structure of the catalogue will provide stability. The structure of the Catalogue will accommodate additional information as it becomes available and provide guidance for its classification and placement within the Catalogue.

5.2 Recommendations

5.2.1 The content of the Catalogue should be enhanced by the inclusion of additional technical and engineering reports that could not be located, and by the inclusion of new reports as they become available. The content of the Catalogue should also be enhanced as new pavement preservation technologies are developed and additional technical information is uncovered.

5.2.2 To obtain additional technical reports and information from Canadian airport operators and from the Canadian engineering consulting industry will require considerable effort.

5.2.3 Only a few copies exist for many of the reports addressing Canadian airport pavements that have been referenced in the Catalogue. It is recommended that these reports be converted into an electronic format for wider availability.

6.0 References

1) Alberta Transportation and Utilities. 1997. *Pavement Design Manual*, Edition 1.

2) FAA 99. *FAA Central Region AIP Regional Guidance for Airport Development Projects*, Report ACE-2110.

3) MacMillan, C., and Scarlet J. R. 1999. *Selection of Performance Graded Binders for Canadian Airport Pavements*, Proceedings, Canadian Technical Asphalt Association.

4) Ministère des Transports du Québec. 1999. *Guide d'entretien et de rehabilitation des chausses en béton de ciment.*

5) Murphy, D. J. and Emery J. J. 1999. Evaluation of Modified Cold In-Place Asphalt Recycling, Proceedings of the Annual Conference of Transportation Association of Canada, St. John, New Brunswick.

6) Ontario Ministry of Transportation. 1990. *Pavement Design and Rehabilitation Manual*, Queen's Printer for Ontario, ISBN 0-7729-6379-7.

7) Transport Canada. 1985. Airport Pavement Evaluation – Condition Surveys, Report TP 1849, AK-68-32-000, Transport Canada, Airport Authority Group.

8) Transport Canada. 2002. Pavement Management Systems. Transport Canada web site at "www.tc.gc.ca".

9) Transportation Association of Canada. 1997. *Pavement Design and Management Guide*, 2323 St. Laurent Blvd, Ottawa, K1G 4J8, ISBN 1-55187-114-9.

Appendix A

Asphalt Concrete, Composite
and
Surface-Treated Pavements

Pavement Preservation Treatments

1.0 Small-Area Patching of Asphalt Concrete Pavements Using Hot or Cold Mix

Pavement type:	Asphalt Concrete
	Composite
Treatment type:	Emergency Maintenance
	Area maintenance
Distresses treated:	Ravelling and segregation
	Pot-holing
	Alligator cracking

a) Synopsis

Small-area patching of AC pavements involves placing and spreading asphalt materials (hot, cold, virgin or recycled mix) [Transport Canada does not recommend use of recycled mix as a patching material] to repair potholes and other pavement distresses without the use of pavers or graders. If pavers or graders are used, the activity is called machine patching. Small-area patching was traditionally called manual patching. However, even relatively small potholes can now be filled using mechanized equipment. Small-area patching also includes preparation of the patching area (excavating, cleaning, applying a tack coat) and compaction with or without mechanized equipment.

Patching is one of the most common pavement maintenance treatments used to repair pavement surfaces that are breaking into pieces thereby posing a FOD hazard. A typical application of small-area patching is the repair of potholes. A pothole may be defined as any localized loss of paving material or depression in the pavement surface that may compromise surface smoothness. The causes of pothole formation include poor quality surface material(s), cracking, poor drainage, loss of subgrade support, freeze-thaw action, and pavement fatigue.

Typically, small-area patching includes the following recommended steps:

- Saw cutting a rectangular/square area around and at least 0.30 metres back from the distressed section and preferably large enough to accommodate compaction equipment.
- Removing broken pavement material from the sawn patch area.
- Cleaning out loose material from the patch area by blowing or brushing.
- Applying a tack coat to provide a bond between the existing pavement and the patching material.
- Placing the bituminous mix into the patch area. If the patch area is deeper than 80 mm, the mix should be placed in lifts of not more than 80 mm. Each lift must be compacted.
- Placing additional layers until the level of the surrounding pavement is reached.
- Compacting the mix with a roller, a vibratory plate compactor, hand tamper or truck wheels.

Small-area patching repairs can be divided into three types based on their expected life-span.

Permanent: Permanent repairs should be used on pavements that are in good condition to bring the life-span of the repaired area in line with that of the surrounding pavement. Permanent repairs require adequate resources and time. The repaired area is usually saw cut and filled with hot mix.

1.0 Small-Area Patching of Asphalt Concrete Pavements Using Hot or Cold Mix

Semi-Permanent: Semi-permanent repairs have a usual life expectancy of more than one or two years. Usually, the area is not saw cut and may be repaired with cold mix.

Temporary: Temporary repairs are used when the pavement condition may pose a hazard to aircraft traffic and repairs must be carried out as soon as possible. Some new patching materials can be applied to potholes containing water.

The cost of small-area patching is highly dependent on the extent of repairs and on the selection of patching material. The cost of one tonne of emulsified cold mix is usually under $100.00.

Selection of Patching Materials

While it is recognized that hot mix AC is the most durable treatment, some suppliers of proprietary cold patching mixes suggest that their products can achieve similar performance. The selection of patching materials depends on a number of factors, including the urgency of the repair, time constraints, local experience with the patching product, extent of repairs, and the required life-span of the repair. The required life-span of the repair typically depends on anticipated future maintenance and rehabilitation plans.

Effective Construction

Until the late 1980's, all small-area patching repairs were done manually. Since then, several mechanized devices have been developed to facilitate patching. These devices dispense either hot mix or aggregate and heated emulsified asphalt (sprayed simultaneously). For durable repairs it is necessary to use appropriate patching materials and techniques and to address the underlying cause of the pavement failure. Unless the original cause of the pavement defect is corrected, the repairs will be susceptible to early deterioration.

b) Specifications and Manuals

There is one applicable airfield pavement maintenance specification available from Transport Canada: PMS-5220 – *Asphalt Pavement Pothole Patching.*

Transport Canada has also published an Engineering Reference Document (ERD 125-01) on *Maintenance and Repair of Airport Hot-Mix Asphalt Concrete (HMAC) Pavements.*

A useful manual of practice was developed by Wilson, T. P. and Romine, A. R. (1993) as part of the SHRP research effort (Report No. SHRP-H-348).

Several highway agencies have developed manuals for patching of AC pavements. One of the most comprehensive has been published by Minnesota Technology Transfer Centre (Johnson, 2000).

1.0 Small-Area Patching of Asphalt Concrete Pavements Using Hot or Cold Mix

c) Field Performance Reports

JEGEL (1992) evaluated the performance of pavement infrared patching completed at Ottawa International Airport during 1990 and 1991. The infrared patching process was used to repair localized longitudinal, transverse, and meandering pavement cracks. Within a year or two, most of the original cracks had reappeared on the surface of the pavement and were as severe or worse than the cracks prior to treatment.

HITEC, Highway Innovative Technology Evaluation Centre, has developed guidelines for the field evaluation of pothole repairs (HITEC, 1995).

Evans et al (1994) reported on the field performance of four different patching procedures for potholes (employing eight different patching materials).

i) A *throw-and-roll* method that used a cold mix with no prior preparation or drying of the repair area.
ii) An *edge seal* method that was identical to the throw-and-roll method but also included an application of bituminous sealing material placed on the joint between the patch and the pavement to prevent the intrusion of additional moisture.
iii) A *semi-permanent* method that included careful preparation of the repair area (by straightening of the edges of the pothole using a pavement saw, jackhammer or milling machine) and filling the pothole with cold mix.
iv) A *spray injection* method that involved use of spray injection devices that shoot aggregate and heated emulsified asphalt simultaneously into the pothole.

Evans at al (1994) concluded that there was no significant improvement in the performance of repairs placed using the semi-permanent versus the throw-and-roll repairs when proprietary materials were used.

d) Laboratory and Other Reports

No field performance studies were found either issued by, or for, Canadian airport operators. Typically, laboratory reports deal with the properties of the patching materials. Some of the proprietary patching materials contain crushed, angular aggregate and polymer-modified bituminous binder. Wilson (1993) reported a lack of correlation between the properties of patching materials (based on laboratory tests) and their field performance.

1.0 Small-Area Patching of Asphalt Concrete Pavements Using Hot or Cold Mix

References

1. Evans et al.1995. *Evaluation of Materials, Procedures, and Equipment for Pavement Maintenance*. Proceedings of the Seventh Maintenance Management Conference, National Academy Press, Washington, D.C. ISBN 0-309-06106-7.

2. HITEC. 1995. *Guidelines for Field Evaluations of Pothole Repairs*, CERF report: HITEC 95-1, Product 01. ISBN0-7844-0090-3.

3. JEGEL. 1992. *Evaluation of Pavement Infrared Patching, Ottawa International Airport*, JEGEL Report 92184, Transport Canada, Professional and Technical Services, Airports Group.

4. Johnson, A. 2000. Best Practices Handbook on Asphalt Pavement Maintenance, Minnesota Technology Transfer Centre, University of Minnesota, 5511 Washington Avenue S.E., Minneapolis, MN 55455-0375.

5. Wilson, T. P. 1993. *Strategic Highway Research Program Pothole Repair Materials and Procedures*, Transportation Research Board Record 1392, Washington, D.C.

2.0 Machine Patching of Asphalt Concrete Pavements

Pavement type:	Asphalt concrete
	Composite
Treatment type:	Localized maintenance
Distresses treated:	Ravelling and segregation
	Pot-holing, Rutting, Alligator cracking
	Frost heaving, Subgrade settlement

a) Synopsis

Machine patching of asphalt concrete pavements involves the placement and spreading of premixed asphaltic materials (hot or cold mix) using a paver or grader.

Typically, machine patching includes the following recommended steps.

- Removal of any loose or broken sections of existing pavement. If the patch is placed on a runway, it is recommended that the pavement be milled to a depth of 40 mm. If the patch is replacing the entire thickness of asphalt concrete layer, the granular base should be restored and compacted.
- Application of a tack coat at the vertical sides of the patch and over the entire patched area if the surface is asphalt concrete.
- Placement of the mix which should be done using a paver. The material should be placed in layers not exceeding 60 mm.
- Smoothing and feathering out the edges of the patch.
- Compaction of the patch area using rollers.
- Application of a sealing compound at the joint between the patch and the existing pavement.

Machine patching repairs can be divided into two types based on their expected life-span.

Permanent Patching

Permanent patching repairs should be used on pavements that are in good condition to bring the life-span of the repaired area in line with that of the surrounding pavement. Permanent repairs require adequate resources and time. Typically, permanent repairs include milling, application of a tack coat, placement and compaction of hot mix, and sealing of joints in the existing pavement with a sealing compound.

Semi-Permanent Patching

Semi-permanent repairs have a limited life expectancy and are used when it is anticipated that the entire pavement will be rehabilitated within a few years. To reduce cost, the area and depth of patching may be restricted, the patched area may not receive a tack coat, and a cold mix may sometimes used.

2.0 Machine Patching of Asphalt Concrete Pavements

Effective patching tips:

- It is recommended that the same type of hot mix be used for patching as was originally used for the pavement surface layer.
- If the patch is to be used over an area exhibiting structural weakness (e.g. alligator cracking, rutting, depression, settlement), it may be necessary to remove some or all of the underlying base/subbase material (to the depth of subgrade), and place a layer of AC material in the patch area that is thicker than the existing pavement.
- The minimum recommended thickness of hot mix patch in a wet-freeze environment is 40 mm (even with the application of a tack coat). In a dry-freeze environment the recommended minimum thickness is 30 mm.

b) Specifications and Manuals

There is one applicable airfield pavement maintenance specification available from Transport Canada: PMS-5210 – *Asphalt Pavement Full Depth Patching.*

Transport Canada has also published an Engineering Reference Document (ERD 125-01) on *Maintenance and Repair of Airport Hot-Mix Asphalt Concrete (HMAC) Pavements.*

The Ontario Ministry of Transportation (Chong et al, 1989) developed a set of pavement maintenance guidelines that contains useful information on patching of AC pavements.

c) Field Performance and Other Reports

No laboratory, theoretical or investigative reports on machine patching were found.

References

1. Chong, G. J., Jewer, F. W., and Macey, K. (1989). Pavement Maintenance Guidelines, Distresses, Maintenance Alternatives, and Performance Standards, Report SP-001, Ministry of Transportation Ontario, 1201 Wilson Avenue, Downsview, Ontario, M3M 1J8, ISBN 0-7729-5834-3.

3.0 Patching of Asphalt Concrete Pavements Using Infrared Heating

Pavement type:	Asphalt concrete
	Composite
Treatment type:	Area maintenance
Distresses treated:	Ravelling and segregation
	Pot-holing
	Alligator cracking
	Transverse and longitudinal cracking

a) Synopsis

The patching of asphalt concrete pavements using infrared heating is similar in purpose to that for small-area patching using hot or cold mix. However, there are differences in the construction method used and in the additional application of infrared heating to repair localized, transverse, and longitudinal cracking.

Infrared patching involves the following steps.

- Removal of loose and damaged pieces of pavement from the patch area by blowing and brushing.
- Heating and softening of the asphalt concrete pavement in the repair area with a portable infrared heating device.
- Scarifying the heated surface, removal of the old and oxidized asphalt material and adding the patch material. Typically, a new hot mix is used.
- Mixing of the existing reclaimed AC material with the added material.
- Compaction of the repair area with a roller, a vibratory plate compactor, or a hand tamper (for small potholes only).

Infrared patching was successfully used in the late 1980's by several agencies including the Ontario Ministry of Transportation and the Municipality of Metropolitan Toronto Transportation Department (JEGEL 1992). Recently, the usage of infrared patching has declined. The 2001 survey of Canadian airport operators indicated that three authorities (who responded to the survey) have used infrared asphalt patching. Two operators reported poor performance and one operator reported good performance.

b) Specifications and Manuals

There is one applicable airfield pavement maintenance specification available from Transport Canada: PMS-5230 – *Asphalt Pavement Patching Using Infra-Red Heating.*

Transport Canada has also published an Engineering Reference Document (ERD 125-01) on *Maintenance and Repair of Airport Hot-Mix Asphalt Concrete (HMAC) Pavements.*

c) Field Performance Reports

JEGEL (1992) evaluated the performance of pavement infrared patching completed at Ottawa International Airport during 1990 and 1991. The infrared patching process was used to repair localized longitudinal, transverse, and meandering pavement cracking. Within one to two years, most of the original cracks reappeared on the surface of the pavement and were as severe or worse than the cracks prior to treatment. JEGEL (1992) recommended that the standard Transport Canada Specifications be supplemented by the following.

i) The heating unit(s) should apply heat in a uniform manner to the surface of the existing pavement to achieve the desired hot-in-place temperature of the AC mix (120 to 150 degrees Celsius) to a depth of at least 50 mm (75 mm preferred).
ii) A suitable rejuvenator should be added and uniformly mixed with the scarified material to obtain an after-the-repair recovered asphalt cement penetration of at least 60. If the voids in the mineral aggregate are insufficient to add the required amount of the rejuvenator, consideration should be given to adding new hot mix incorporating a higher penetration grade of asphalt cement.
iii) Consideration should be given to using new asphalt concrete mix containing finer aggregate to prevent segregation.
iv) All infrared patching work should be done during favourable weather conditions (typically between May 15 and October 15 for southern parts of Canada).

d) Laboratory and Other Reports

No laboratory, theoretical or investigative reports on infrared patching were found. However, the JEGEL (1992) report may be considered an investigative report.

References

1. JEGEL (1992). *Evaluation of Pavement Infrared Patching, Ottawa International Airport*, JEGEL Report 92184, Transport Canada, Professional and Technical Services, Airports Group.

4.0 Sealing of Cracks in Asphalt Concrete Pavements

Pavement type:	Asphalt concrete
	Composite
Treatment type:	Area maintenance
Distresses treated:	Transverse and longitudinal cracking

a) Synopsis

Sealing of cracks in asphalt concrete pavements usually involves routing (creating a reservoir at the top of the crack) and filling the crack (and the reservoir) with a sealant. Consequently, this treatment is also called rout-and-seal treatment.

Crack sealing is a necessary and important maintenance activity that is required to mitigate the infiltration of water into the pavement structure. The benefits of crack sealing for airport pavements have not been fully documented. For AC highway pavements, Ponniah and Kennepohl (1994) estimated that rout-and-seal can extend pavement life by 3 to 5 years. The additional benefit of sealing for airport pavements is the prevention of spalling and ravelling of unsealed crack edges. The typical cost of a rout-and-seal operation is in the range of $2 per linear metre.

Sealing operations should be performed soon after cracks develop, typically when the pavement is 3 to 5 years old. At that time, the crack pattern should be well developed and the crack should reach a width of 3 to 10 mm. Cracks that are sealed are typically less than 20 mm wide. Sealing is usually ineffective for pavements with an AC layer thinner than about 80 mm because the cracking of thin AC layers is closely spaced and often unsuitable for sealing.

The 2001 survey of Canadian airport operators indicated that about half of the respondents with asphalt concrete pavements seal cracks and that this treatment is generally considered to be effective.

The success of sealing operations depends on the following factors.

Effective Sealant Materials

There is a plethora of asphalt concrete sealants on the market, and the performance of sealants can differ significantly. Some agencies are not satisfied with the existing ASTM specifications for sealants (ASTM D-3405, ASTM D-3407, ASTM D-1190, U.S. Federal Specification SS-S-1401C, AASHTO T187-60, and the related Canadian Specification CGSB-37.50-M89) and use agency-specific specifications. Some agencies, such as the Ontario Ministry of Transportation, also require a field evaluation of the sealant over one winter. The adhesive and cohesive properties of the sealant can change depending on the storage (sedimentation), heating in the field, and preparation of the crack surface. An additional sealant requirement for airfield applications is its resistance to jet fuel.

4.0 Sealing of Cracks in Asphalt Concrete Pavements

Effective Rout Configuration

Opinions regarding the most effective rout configuration differ. A typical rout configuration is 15 x 15 mm or as directed. [A rout configuration of 40 mm (wide) x 10 mm (deep) is not recommended by Transport Canada for airport use]. Some jurisdictions even advocate not routing the crack and using an “over-band” or ”band-aid-sealing” method (i.e. just fill the cracks and smooth the excess sealant to create an over-band).

Effective Construction Procedure

All authorities agree that the crack must be cleaned prior to sealing. Some authorities advocate cleaning using high-pressure air-blasting (hot-air lance), other authorities specify hot air-blasting for cleaning a routed crack of dust and debris and for drying, yet others recommend sandblasting. The sealant should be dispersed into the crack via a pipe wand linked to a pumping device which is capable of maintaining the sealant at constant temperature.

The sealant should be heated in double-jacketed kettle to avoid exposure of the sealant to direct heat.

b) Specifications and Manuals

There are three airfield pavement maintenance specifications available from Transport Canada for crack sealing:
- PMS-5110 - *Crack Sealing Using Hot-Poured Bituminous Sealant*
- PMS-5120 - *Crack Sealing Using Jet Fuel Resistant Sealant*
- PMS-5130 - *Crack Sealing Using Cold-Poured Emulsified Sealant*.

Transport Canada has also published an Engineering Reference Document (ERD 125-03) *Joint/Crack Sealing of Hot-Mix asphalt Concrete and Portland Cement Concrete Pavements*.

Two provinces, Ontario and Quebec, have developed specifications: (OPSS, 1998) and Ministère des Transports (1999), respectively.

Ministère des Transports du Québec (1993) has developed a very useful handbook that provides detailed procedures for field supervisors responsible for quality control.

Several northern U.S. states (Michigan and Minnesota) have recently developed crack sealing specifications. In Michigan, crack sealing specifications call for a 2-year warranty against adhesion failures (Michigan DOT, 1999).

US FHWA (2000), in cooperation with the Centre for Pavement Preservation, has recently released a CD containing crack sealing manuals produced by Minnesota and Michigan.

4.0 Sealing of Cracks in Asphalt Concrete Pavements

c) Field Performance Reports

No field performance studies either issued by, or for, Canadian airport operators were found. In the Canadian context, the most relevant study is that carried out by Ponniah and Kennepohl (1996). The authors concluded that rout-and-seal can extend the life of highway pavements by 3 to 5 years. A large study carried out by SHRP (Smith and Romine, 1993) concluded that, when performed properly, crack sealing is cost-effective.

SHRP (1994) published a training supplement containing several recommended improvements for carrying out crack sealing based on lessons learned during the execution of SHRP H-101 project across the United States and Canada.

d) Laboratory and Theoretical Reports

Transport Canada carried out a laboratory study on the benefits of using a compressed hot-air lance as compared to a compressed cold-air lance on the performance of crack sealants (Transport Canada, 1997). The study concluded that use of the hot-air lance in sealing pavement cracks does not enhance the adhesion of good sealants and may, on the contrary, cause premature sealant failure.

Zanzoto (1996) in a study sponsored by the Transportation Association of Canada concluded that new laboratory test methods are required in order to identify sealants that will perform adequately in the field.

Masson and Lacasse (1998) from the National research Council of Canada developed a framework for the development of performance-based specifications for pavement crack sealants.

e) Investigative Reports

No field performance studies either issued by, or for, Canadian airport operators were found.

Chong and Phang (1987) reported that for unsealed transverse cracks, the deterioration of asphalt concrete material also occurred at the bottom of the asphalt concrete layer. The investigation included excavation and examination of the asphalt concrete material at the bottom of the asphalt concrete layer.

References

1. Chong, G. J., and Phang, W. A. 1987. *Improved Preventive Maintenance: Sealing Cracks in Flexible Pavements in Cold Regions*, Ontario Ministry of Transportation, 1201 Wilson Avenue, Downsview, Ontario, M3M 1J8.

4.0 Sealing of Cracks in Asphalt Concrete Pavements

2. Masson, J. F., and Lacasse, M.A. 1998. Considerations for a Performance-Based Specifications for Bituminous Crack Sealants, in *Flexible Pavement Rehabilitation and Maintenance*, Kandhal P. S., and Stroup-Gardiner M.., ed., ASTM STP 1348, ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19438-2959.

3. Michigan Technological University. 1999. *Sealing and Filling of Cracks for Bituminous Concrete Pavements*, Department of Civil and technological Engineering, 1400 Townsend Drive, Houghton, MI 49931.

4. Ministère des Transports du Québec. 1993. *The Supervisor's Handbook for Sealing of Cracks (Asphalt Concrete*), Directorate of Operations Support, Ministère des Transports du Québec.

5. Ministère des Transports du Québec. 1999. *Traitement des Fissures sur Routes en Enrobe*, Revetements souples de chausee.

6. Minnesota DOT (1999). *Special Provision for Bituminous Crack Treatment with Warranty*, C&T:APPR.MLL:MF 08-30-99.

7. Ontario Provincial Standards Specification. 1988. *OPSS 216-101*.

8. Ponniah, J., and Kennepohl, G. 1996. *Crack Sealing in Flexible pavement: A Life-Cycle Cost Analysis*, Transportation Research Board, Washington, D.C.

9. SHRP. 1994. *Making Pavement Maintenance More Effective, Training Supplement*. Report SHRP-H-380, Strategic Highway Research Program, National Research Council, Washington, DC.

10. Smith, K. L., Romine, A. R. 1993. *Asphalt Pavement Repair Manuals of Practice: Materials and Procedures for Sealing and Filling Cracks in Asphalt-Surfaced Pavements*. Strategic Highway Research Program. Report No. SHRP-H-348.

11. Transport Canada. 1997. *Study of the Effect of the Hot-Air Lance on Asphalt Concrete Pavements*, Technical Evaluation Engineering, Report No. OPR:AAR/AARM/AARME.

12. US FHWA (2000). *State Preservation Programs: Pavement Preservation State of Practice*. A CD distributed by US Department of Transportation.

13. Zanzoto, L. (1996). *Laboratory Testing of Crack Sealing Materials for Flexible Pavements*. Transportation Association of Canada, 2323 St. Laurent Blvd., Ottawa, ON K1G 4J8.

5.0 Spray Patching

Pavement type: Asphalt concrete
Surface-treated
Treatment type: Area maintenance
Distresses treated: Loss of surface material, segregation, ravelling
Loss of friction
Cracking

a) Synopsis

Spray patching used to be one of the key maintenance treatments used for asphalt concrete and surface-treated pavements. However, the 2001 survey of airport operators indicated that only one operator (out of the 26 operators who responded to the survey) uses spray patching routinely and another one has tried it. The survey also indicated that four authorities have surfaced-treated pavements. One authority has surface-treated runways, two authorities have surface-treated aprons, and two surface-treated airside roadways.

Spray patching consists of the application of emulsified asphalt (hot or cold) followed by spreading of aggregate (stone chips or sand). Spray patching can be performed using a manual method or using specialized equipment that sprays an emulsion, applies cover aggregate, and provides the initial compaction in one pass. A properly applied chip seal produces an all-weather sealed pavement surface, prevents or retards propagation of surficial distresses, and provides improved skid resistance.

The recommended procedure for manual spray patching consists of the following steps (Chong et al, 1989).

- Removal of all loose material and debris.
- Spraying of an emulsion in a uniform manner.
- Application of aggregate to obtain even coverage.
- Compaction. Wheels of the truck used to supply the cover aggregate can be used for compaction.
- Sweeping of loose aggregate from the area surrounding and over the patch.

One typical spray patching machine available in Canada can apply a spray patch on a width ranging from 300 to 2,400 mm. The machine uses a polymer-modified emulsion and stone chips with a maximum size of about 10 mm.

Spray patching should be carried out only during warm, dry months. Cooler temperatures and wetter conditions can result in long times for the emulsion to set.

5.0 Spray Patching

b) Specifications and Manuals

No manuals or specifications prepared either by, or for, Transport Canada were found.

The Ontario Ministry of Transportation has a maintenance performance standard for manual spray patching (MTO, 1989) and for spray patching using a mechanized spray patching machine (Special Provision No. 339 F18).

c) Field Performance and Other Reports

The Ontario Ministry of Transportation evaluated the performance of spray patching produced by a mechanized device (Lynch and Korgemagi, 1989) and found the results to be satisfactory.

References

1. Lynch, D., and Korgemagi, P. 1989. Evaluation of a Mechanized Spray Patching Machine. Ministry of Transportation and communications, Downsview, Ontario.

2. MTO. 1989. *Maintenance Performance Standard M-1004, Spray Patching (Chip Seal),* in Chong, G. J., Jewer, F. W., and Macey, K. 1989. Pavement Maintenance Guidelines, Distresses, Maintenance Alternatives, and Performance Standards, Report SP-001, Ministry of Transportation Ontario, 1201 Wilson Avenue, Downsview, Ontario, M3M 1J8, ISBN 0-7729-5834-3.

6.0 Slurry Seals

Pavement type:	Asphalt concrete Composite
Treatment type:	Area maintenance
Distresses treated:	Loss of surface material, segregation, ravelling Loss of friction Cracking

a) Synopsis

A slurry seal is a mixture of graded fine aggregate, mineral filler, emulsified asphalt, and water. The mixture is applied cold to a pavement as a surface treatment. A slurry seal is used to correct distresses such as ravelling and coarse aggregate loss. It is also used as a preventive maintenance treatment to seal pavement surfaces against intrusion by water.

The slurry seal mixture is supplied using specialized equipment that carries all of the components of the mixture, accurately measures and mixes them in a pug-mill, and spreads the mixture (by means of a spreader box linked to the mixing unit) in a strip 3 to 4 metres wide as a thin, homogeneous coat of slurry mix.

After the slurry seal application, traffic can use the pavement without restriction in about 45 to 120 minutes, depending on the setting time of the asphalt emulsion, weather and traffic conditions.

The 2001 survey of Canadian airport operators indicated that three operators (out of the 26 operators who responded to the survey) are using slurry seals routinely and that two operators have tried them. Four operators reported good results and one operator reported poor results.

The cost of a slurry seal is less than half the cost of a 50 mm hot mix overlay (about $2 to $3 per square metre).

There are several pavement surface sealing products that may resemble a slurry seal:

Fog Seal - A fog seal is an application of diluted asphalt emulsion without a cover aggregate, used to seal asphalt pavement surfaces, seal minor cracks and prevent ravelling. Several types of rejuvenators and scrub seals (Mamlouk, 2000) have been also applied to pavement surfaces.

Cap Seal – A cap seal is an application that combines a chip seal and slurry surfacing. It is produced by constructing a chip seal (an application of bituminous material on the pavement surface followed by an application of chips of uniform size) followed by an application of slurry seal.

Micro-surfacing - In essence, a micro-surfacing mixture that is similar to a slurry seal mixture but with two significant exceptions: it contains larger and higher quality aggregate and a polymer additive.

6.0 Slurry Seals

Slurry seals should be applied only during the warmer, dryer months. Cooler temperatures and wetter conditions can result in long curing times during which the slurry seal can be damaged by traffic.

b) Specifications and Manuals

There is one applicable airfield pavement maintenance specification available from Transport Canada: PMS-5720 *Coal Tar Slurry Seal.*

Transport Canada has also published an Engineering Reference Document (ERD 125-01) on *Maintenance and Repair of Airport Hot-Mix Asphalt Concrete (HMAC) Pavements* that contains a description of slurry seals.

The Department of National Defence has developed a specification for pavement surface sealers.

A number of slurry sealing standards have been issued by the International Slurry Surfacing Association (ISSA, 1991). Some agencies, such as the Minnesota Department of Transportation have developed slurry seal manuals (Johnson and Snopl, 2000).

c) Field Performance and Other Reports

SHRP (1994) published a training supplement containing several recommended improvements for carrying out slurry seals based on lessons learned during the execution of SHRP H-101 project across the United States and Canada.

References

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3. Mamlouk, M. S. 2000. Preventive Maintenance of Flexible Pavement - Case Studies. Transportation Research Board, paper 00-0308, Washington, D,C.

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7.0 Micro-Surfacing

Pavement type:	Asphalt concrete Composite Exposed PCC
Treatment type:	Area maintenance
Distresses treated:	Ravelling and segregation Loss of friction Pot-holing, rutting Cracking

a) Synopsis

A micro-surfacing material is a bituminous mixture consisting of the following components:

- *Aggregate* - A crushed densely graded aggregate with a maximum size of about 10 mm. The crushed aggregate is necessary to provide the mix with internal stability.

- *Emulsified Asphalt* - Emulsified asphalt enables mixing and placement of the material at ambient temperatures. The amount of asphalt cement in the emulsion is about 7% by weight.

- *Polymer Additive* - A polymer additive, usually latex, that provides the mix with increased stability and flexibility. The amount of polymer additive represents about 3% of the asphalt by weight.

- *Mineral Filler* - Mineral filler is used to control the set times of the micro-surfacing material. It is usually Portland cement and constitutes about 1% of the total dry mix weight.

Micro-surfacing mixtures are similar to slurry seal mixtures but with two significant differences: micro-surfacings contain larger and higher quality aggregate and a polymer additive. A micro-surfacing mixture is applied cold using specialized equipment that carries all of the mixture components, accurately measures and mixes them in a pug mill, and spreads the mixture (by means of a spreader box attached to the mixing unit) in a strip 3 to 4 metres wide as a thin, homogeneous coat of slurry mix. After the micro-surfacing application, traffic can use the pavement without restriction in about 45 to 120 minutes, depending on the setting time of the asphalt emulsion, weather and traffic conditions.

Micro-surfacings have been used for both AC and PCC pavements. For AC pavements, micro-surfacings are applied to correct surface distresses - for example, ravelling, coarse aggregate loss, block cracking and rutting. Because it contains crushed aggregate, it can be used to fill-in ruts of depths up to 40 mm (Hixon and Ooten, 1993). Micro-surfacings are also used as preventive maintenance treatments to seal pavement surfaces from water intrusion. For PCC pavements, micro-surfacings have been used to improve surface friction and smoothness.

7.0 Micro-Surfacing

The 2001 survey of Canadian airport operators indicated that two authorities (out of the 26 that responded to the survey) have used micro-surfacings - one with very good results and one with good results.

The cost of micro-surfacing is about 50 to 70 percent of the cost of a 50 mm hot mix overlay (about $5 per square metre).

Micro-surfacings should be applied only during warm, dry months. Cool temperatures and wet conditions can result in long curing times during which the micro-surfacing can be damaged by traffic.

b) Specifications and Manuals

There are no applicable pavement maintenance specifications for micro-surfacing published by Transport Canada. It should be pointed out that Specification PMS-5720 applies to Coal Tar Slurry Seal and not to micro-surfacing.

A number of micro-surfacing standards have been issued by the International Slurry Surfacing Association (ISSA, 1991). Some agencies, such as the Ontario Ministry of Transportation have developed micro-surfacing specifications (Kazmierowski et al, 1995). The City of Toronto has also developed a specification for urban roadways and the Department of National Defence has a specification for airport pavements.

c) Field Performance Reports

The use of micro-surfacing in Canada started in the early1990's. Micro-surfacings have been applied to airports, urban streets (Hein and Emery, 1994), local highways (Kazmierowski et al, 1993), and freeways (Kazmierowski and Bradbury, 1995). Micro-surfacing was introduced to the USA in 1983 (Hixon and Ooten, 1993). Results of the field studies referenced above indicate that micro-surfacing is a viable alternative rehabilitation technique that can provide a durable, high skid-resistant surface. Weather conditions have a considerable effect on the constructability of micro-surfacings (Kazmierowski and Bradbury, 1995).

Micro-surfacing was used on a trial basis at the Toronto City Centre Airport on the Toronto Island in 1996. A section of the airport apron pavement and a taxiway were repaired using micro-surfacing techniques. Construction of the micro-surfacing trial went without difficulty. To date, performance of the micro-surfacing has been fairly good although there has been some pavement surface damage caused by winter maintenance equipment such as snow ploughs and wire brooms.

7.0 Micro-Surfacing

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3. ISSA, 1991. *Recommended Performance Guidelines for Micro-Surfacing*, Report A 143 (Revised), International Slurry Surfacing Association, 1101 Connecticut Avenue, N.M., Washington, D.C. 20036-4303.

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8.0 Cold Recycling of Asphalt Concrete Pavements

Pavement type: Asphalt concrete
Treatment type: Rehabilitation
Distresses treated: All distresses

a) Synopsis

Cold recycling normally consists of milling an existing asphalt pavement to a specified depth, mixing the reclaimed pavement material with bituminous and/or other additives, spreading and compacting the resulting mixture. This is followed by placement of a new asphalt surface course - a hot mix asphalt overlay, or a surface treatment (AASHTO, 1998).

Unlike hot in-place recycling, cold recycling is not limited to pavements exhibiting only surface defects. The cold mix tends to be self-healing and helps to retard reflection cracking.

Two methods for cold recycling of asphalt pavements are:

Cold In-Place Recycling (CIR): All asphalt pavement material processing is completed in-situ. Cold in-place recycling is faster and environmentally preferable because of the reduced need to transport materials.

Cold Central Plant Recycling (CCPR): Reclaimed asphalt pavement (RAP) is hauled to the plant site and stockpiled, processed (crushed, screened and mixed with additives), transported to the job site, placed and compacted. CCPR is used if surplus reclaimed asphalt pavement is available, the entire AC pavement layer needs to be removed, or there are concerns about the quality and homogeneity of the existing AC material.

Cold recycling consists of the following steps.

- *Milling of the Old Asphalt Pavement* - Milling is usually limited to a maximum depth of 150 mm, and is typically 75 to 100 mm deep.
- *Screening and Crushing* - The maximum particle size ranges from 25 to 37 mm.
- *Adding New Materials and Mixing* - Depending on the properties of the existing asphalt concrete material, the new material added may include a combination of asphalt emulsion, water, and aggregate. The typical emulsion is a polymer-modified asphalt emulsion or a polymer-modified high-float emulsion. The total amount of emulsion and water is about 4%, the emulsion alone being about 1.5 %. Addition of aggregate may be required to achieve the desired material stability. Other common additives include Portland cement and fly ash (AASHTO, 1998).
- *Levelling and Reprofiling of Recycled Mix* - The placement procedure for cold recycled mix is similar to that used for hot mix asphalt concrete paving and uses conventional self-propelled asphalt pavers. For CCPR, the placement may be done in several lifts. For CIR, the placement is done in one lift whereby a slat elevator is used to pick up and transport all the processed recycled material from a windrow in one pass.

- *Compaction* - Compaction commences after the emulsion begins to break, normally ½ to 2 hours after placement. Compaction is achieved using a large rubber-tired roller (28-tonne typically) followed by a vibratory steel drum roller (11-tonne typically).
- *Curing and Compaction by Traffic* - Depending on the additives used, weather, and traffic, a waiting time of about two weeks is recommended before placement of a surface course.
- *Placement of Surface Course* - A typical surface course consists of 40 to 50 mm of hot mix asphalt concrete.

Candidate pavements for cold in-place recycling should be thoroughly evaluated and properties of the existing asphalt concrete determined. Some of the property deficiencies may be improved by adding asphalt emulsion, fine or coarse aggregate, or Portland cement.

Cold in-place recycling should be carried out only during warm, dry months. Cool temperatures and wet conditions can result in long curing times during which the cold mix is susceptible to moisture intrusion and abrasion.

b) Specifications and Manuals

No specifications or manuals on cold in-place recycling published by Transport Canada were found.

Ontario has developed construction specifications (OPSS, 1995) and mix design specifications (MTO, 1996) for CIR.

Comprehensive guides on cold recycling of asphalt pavement were published by AASHTO (1998) and by FHWA (Kandhal and Mallick, 1997).

Wirtgen, a German manufacturer of cold recycling equipment widely available in North America, issued a detailed cold recycling manual containing over 150 pages (Wirtgen, 1998).

c) Field Performance Reports

Murphy and Emery (1994) evaluated the performance of several CIR projects in Ontario and concluded that CIR is a technologically sound, cost-effective, and environmentally friendly method for rehabilitating pavements.

Based on the evaluation of eight CIR projects in Ontario, Murphy and Emery (1999) concluded that there is no technical reason why CIR cannot be applied to runways, taxiways and aprons, provided that airport operational constraints can be met.

Kazmierowski et al (1992) compared the performance of 50 and 100 mm thick CIR test sections. The 50 mm CIR test section exhibited fewer surface defects (segregation) in the CIR mat than the 100 mm section. Berthelot et al (2000) reported good results achieved by combining CIR of asphalt pavement with subgrade strengthening using stabilization materials in Saskatchewan.

Based on field experience in New Mexico, McKeen at al (1997) felt that a structural layer coefficient for cold in-place recycled AC material ranging from 0.25 to 0.30 is warranted for some projects, as compared to the normally used hot mix AC value of 0.44.

O'Leary and Williams (1992) reviewed several studies dealing with structural layer coefficients for recycled emulsion mixes. They quoted a Purdue study that found SLC's in the range of 0.17 to 0.44, with a median value of 0.29. An Oregon study found an SLC equivalent to that of a conventional hot mix (0.44).

d) Laboratory and Theoretical Reports

Murphy, D. J. and Emery J. J. (1999, 1994) used laboratory-determined resilient modulus and subsequent elastic layer analysis of vertical strain at the top of the subgrade to determine granular base equivalency factors for CIR material. Schmidt et al (1973) reported the results of a laboratory study on cement-modified asphalt emulsion mixes.

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9.0 Hot In-Place Recycling of Asphalt Concrete Pavements

Pavement type:	Asphalt concrete Composite
Treatment type:	Rehabilitation
Distresses treated:	Ravelling and segregation Pot-holing Rutting Cracking

a) Synopsis

Hot in-place recycling is a paving process that involves reprocessing of the existing asphalt concrete material in-place at temperatures normally associated with hot mix AC paving. Hot in-place recycling is a suitable rehabilitation treatment for asphalt concrete pavements that exhibit a variety of distresses that mainly affect the top pavement layer. It consists of the following steps.

- Heating of the existing asphalt concrete surface. Several methods are available including infrared heating panels, flame burners, and microwave heating.
- Scarification. The depth of scarification is usually limited to the top 50 mm of the asphalt concrete surface.
- Adding new materials and mixing. Depending on the properties of the existing asphalt concrete material, the new material added may include a combination of rejuvenating agents and aggregate, or the addition of new hot mix. The objective is to compensate for deficiencies in the existing asphalt material to obtain a hot mix of comparable quality to a plant recycled mix.
- Levelling and reprofiling of the recycled mix.
- Placement of a thin hot mix layer (optional step). Some hot in-place recycling equipment can add new hot mix material on top of the hot-in place recycled mix as an integral overlay. The thickness of the integral overlay is typically less than 30 mm.
- Levelling and profiling of the integral overlay (if an integral overlay is used)
- Compaction. Standard compaction procedures utilizing steel and rubber tired rollers are employed.

Hot mix in-place recycling with an integral overlay is left as the finished surface layer. When an integral overlay is not used, a hot mix surface course may be placed on top of the recycled mix.

Candidate pavements for hot in-place recycling should be thoroughly evaluated and the properties of the existing asphalt concrete determined. Some of the deficiencies in the properties of the existing asphalt concrete can be improved by adding rejuvenators, fine or coarse aggregate, or new hot mix. Rejuvenators and aggregate should be preheated to assist in meeting the recycled mix temperature requirements.

Hot in-place recycling should be carried out only during the warm, dry months. Cool temperatures and wet conditions can result in long heating times leading to overheating and burning of the pavement surface, and the creation of smoke and vapours. Cooler ambient temperatures can also result in lower mix temperatures leading to an insufficient depth of scarification, fracturing of aggregate during milling, and poor compaction.

Experience indicates that hot-in-place pavements perform comparably to conventionally rehabilitated pavements (Marks and Kazmierowski, 1992). Centreline cracks that develop along the construction joints of conventional hot mix overlays do not tend to develop. The hot in-place process ensures the construction of a hot longitudinal centreline joint.

b) Specifications and Manuals

No specifications or manuals published by Transport Canada were found. Hot in-place recycling at Canadian airports has been done using local specifications developed for the provinces of British Columbia and Ontario. These specifications are provided in Appendix B of Transport Canada's 1995 report referenced below.

Transport Canada (1995) provides a description of six hot in-place recycling projects carried out before 1994. Three projects were in B.C. and three in Ontario. The reference provides a description of the construction process and construction specifications but does not contain pavement performance data.

A comprehensive guide for hot in-place recycling was issued by the US FHWA (Kandhal and Mallick, 1997).

c) Field Performance Reports

Marks and Kazmierowski (1992) evaluated the performance of two hot in-place recycling projects in Ontario constructed between 1987 and 1991. They concluded that hot in-place recycling is an acceptable rehabilitation technique for pavements exhibiting moderate surface pavement distresses that are not associated with structural deficiencies.

Dunn at al (2000) evaluated the performance of four hot in-place highway rehabilitation projects in Alberta. They concluded that hot in-place rehabilitation in Alberta has an average service life of 9 to 11 years.

References

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9.0 Hot In-Place Recycling of Asphalt Concrete Pavements

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10.0 Hot Mix Resurfacing of Bituminous Surfaced Pavements

Pavement type:	Asphalt concrete Composite pavements Surface-treated
Treatment type:	Rehabilitation Area maintenance
Distresses treated:	All distresses

a) Synopsis

Resurfacing with hot mix is the most common rehabilitation treatment for asphalt concrete pavements. The typical cost of an asphalt concrete overlay operation is estimated to be in the range of $35 to $55 per tonne. The Transportation Association of Canada (TAC) estimates that asphalt concrete overlays can have an expected service life of 12 to 15 years.

There are many variations on the use of hot mix asphalt concrete for resurfacing purposes. Some of the common variations are outlined below.

Using Virgin or Recycled Mixes - The use of recycled material in hot mix pavements is common, particularly for the binder course. For surface courses on high performance pavements, the use of virgin materials is usually specified. A comprehensive guide for hot recycling was issued by the US FHWA (Kandhal and Mallick, 1997).

Partial Depth Removal Prior to Resurfacing - The existence of surface distresses such as ravelling, segregation, and hardening of asphalt cement may dictate partial-depth removal of the asphalt concrete prior to resurfacing. Also, partial-depth removal and replacement may be necessary where conditions will not permit elevation of the pavement surface. Partial depth removal is normally accomplished using cold milling equipment. The reclaimed asphalt pavement material may be reused as a hot or cold mix or mixed with granular material.

Full Depth Removal - Full depth removal of the existing asphalt concrete is considered when it is too damaged to overlay or too thin to be recycled in-place. The minimum thickness of asphalt concrete layer for in-place recycling is about 80 mm (MTO, 1990). The existing asphalt pavement can be removed by a variety of methods including milling, front-end loading, ripping, etc. The reclaimed asphalt pavement material may be reused as hot or cold mix or mixed with granular material. After removal of the asphalt concrete, the exposed granular base should be restored, strengthened with additional granular material if necessary, and recompacted.

SuperPave - Unveiled in 1992, the Superpave system represents a fundamentally new system for designing asphalt concrete mixtures. Currently, the SuperPave system addresses mainly the properties of asphalt cement binders (Scarlett and McMillan, 1997; and MacMillan and Scarlett, 1999).

10.0 Hot Mix Resurfacing of Bituminous Surfaced Pavements

Thin Asphalt Concrete Overlays - Conventional asphalt concrete overlays using virgin or recycled hot mix are usually constructed with a minimum thickness of 40 mm. Thinner overlays can be constructed using specialized mixes such as Novachip. The Novachip process is also known as an ultra-thin friction course (Kandhal and Lockett, 1998).

Incorporation of Recycled and Other Materials into the Aggregate Skeleton - Over the years, a number of materials have been incorporated into hot mix asphalt pavement aggregates in order to improve properties of the mix or to reuse recycled material. Additional materials have included crumb rubber (Emery 1994), steel slag, sulphur, asbestos fibers, glass, and asphalt shingles.

Incorporation of Recycled and Other Materials into the Asphalt Cement - Over the years, a number of materials have been incorporated into the asphalt cement in order to improve properties of the mix or to reuse recycled materials. Additional materials have included liquid rubber (Emery 1994), shingle asphalt, and polymers including plastics and latex.

Use of Reinforcing Geotextile Materials - Over the years, geotextile products have been tried to enhance the structural capacity of HMAC (Halim,1983) and its resistance to forming reflection cracks (Buttlar at al, 2000). The products tried have included glass fibres (Glassgrid) plastic mesh or geogrid material (Tensar, Stratagrid), fabrics and steel mesh. The cost-effectiveness of these products has been the subject of debate.

b) Specifications and Manuals

A useful manual on the construction of asphalt overlays is The Asphalt Institute Manual (The Asphalt Institute, 1998). There are many specifications governing the selection of materials and the construction of hot mix asphalt concrete overlays. The current trend in specifications is the move from method-based specifications to End Result Specifications (ERS).

AASHTO defines ERS (AASHTO, 1992) as "*a specification that places the entire responsibility on the contractor or producer for supplying an item of construction or material of specified quality*." ERS relies heavily on statistical analysis for the control and acceptance of a product and is therefore considered to be unbiased. Most ERS systems, while assessing penalties for the production and placement of substandard materials, also provide a bonus for higher levels of quality. The provision of bonus clauses would provide the incentive for contractors to construct a higher quality end product in order to receive the maximum allowable bonus. For example, in the 1998 construction season, the Ontario Ministry of Transportation paid over $ 5,000,000 in bonus money (OPSC, 1999) based on a construction program that included 3.5 million tonnes of hot mix asphalt (HMA). The majority of the construction program included overlays (rather than new pavement construction).

In Canada, agencies that have or are implementing ERS specifications for pavement construction include the transportation departments of Alberta, British Columbia, New Brunswick, Nova Scotia, Ontario, Québec, Public Works and Government Services Canada and the DND.

10.0 Hot Mix Resurfacing of Bituminous Surfaced Pavements

Typical ERS for HMAC overlays include asphalt cement content, aggregate gradation, air voids content, compaction, and smoothness. The general consensus is that the implementation of ERS has reduced the variability in pavement construction with the likely result of increased pavement life and reduced maintenance costs.

c) Field Performance Reports

JEGEL (1995) carried out an evaluation of the probable causes of localized depressions, scuffing and tearing of a new hot mix asphalt overlay on the Muskoka Airport runway. The probable causes were identified as an event of hot weather in the Muskokas, critical aircraft tire shear loadings, and helicopter pad punching loadings.

There is a considerable number of reports dealing with the performance of HMAC overlays on Canadian highways. The most notable study is the C-LTPP study (Canadian Long-Term Pavement Performance study) that is part of Canadian SHRP (Strategic Highway Research Program) effort. C-LTPP involves the systematic observation of 24 test sites located on the major highway system in all ten provinces, each with two to four adjacent test sections having different overlay thicknesses or types. The use of adjacent test sections in C-LTPP allows a comparison of the performance of different rehabilitation strategies under identical traffic and climatic conditions and the same underlying pavement structure (EBA, 1996).

d) Laboratory and Theoretical Reports

Scarlett and McMillan (1997) and MacMillan and Scarlett (1999) carried out a review study to develop guidelines for the selection of performance graded binders for Canadian airport pavements. They concluded that from the perspective of low temperature performance, an airport pavement should not be expected to perform differently than a highway pavement. Therefore, the SHRP performance graded binder specification for low temperatures was felt to be equally applicable to airport pavements and highway pavements.

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11.0 Surface Treatment

Pavement type:	Asphalt Concrete Surface-treated
Treatment type:	Area maintenance
Distresses treated:	Loss of surface material, segregation, ravelling Loss of friction Cracking

a) Synopsis

A surface treatment consists of a spray application of a bituminous binder followed by the distribution of aggregates that are subsequently rolled into the binder. The 2001 survey indicated that 4 out of 26 airport authorities that responded to the survey use surfaced-treated pavements on either runways (one authority), aprons (two authorities), or airside roadways (2 authorities).

In Canada, the application of surface treatment on HMAC material as a maintenance treatment is infrequent. Typically, single surface treatments are used as a maintenance treatment for surface-treated pavements.

Recommended procedure for the construction of surface treatments consists of the following steps.

- Major distresses such as potholes and surface distortion should be fixed before applying a surface treatment.
- Removal of all loose material and debris. This is typically accomplished using mechanical sweepers.
- Spraying of an emulsion in a uniform manner using a distributor. The application rate must take into account the porosity of the surface, and the type and size of the cover aggregate. For high-performance surfaced-treated pavements it may be specified that the emulsion be polymer modified and applied hot.
- Application of aggregate to obtain even coverage. Aggregate gradation can be either dense or open. For high-performance surfaced-treated pavements, the specified aggregate is stone chips of relatively uniform size.
- Compaction. Compaction should be done by rubber-tired rollers and should start soon after application of the cover aggregate. Steel rollers have a tendency to crush the aggregate particles.
- Sweeping loose aggregate from the surface using mechanical sweepers.

Surface-treatment should be carried out only during warm, dry months. Cool temperatures and wet conditions can result in long times for the emulsion to set. Hot emulsion should be applied only to dry surfaces.

11.0 Surface Treatment

b) Specifications and Manuals

No manuals or specifications prepared by, or for, Transport Canada were located.

The Asphalt Institute (1989) has developed a manual for surface treatments.

Several highway agencies have developed specifications for surface treatments including Ontario Ministry of Transportation (Chong at al, 1989) and Michigan (MDOT, 2000).

c) Field Performance and Other Reports

No laboratory, theoretical, investigative or forensic reports on surface treatments were located.

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3. The Asphalt Institute. 1989. *Asphalt Surface Treatment*, Manual Series No. 13 (MS-13).

Appendix B

PCC Pavements
(Exposed Surface)

Pavement Preservation Treatments

1.0 Partial Depth Repair of PCC Pavements Using Asphalt Concrete

Pavement type:	Exposed PCC
Treatment type:	Emergency maintenance Localized maintenance
Distresses treated:	Joint/crack spalling and scaling Surface spalling and scaling Corner and edge cracking, joint failures

a) Synopsis

Partial depth repair of PCC pavements (exposed surface) with asphalt concrete is considered a temporary repair and involves removing all unsound PCC and loose material, cleaning, and placement of the patching material.

Partial depth repair using asphaltic concrete is a common emergency maintenance activity used to replace unsound/deteriorating concrete in areas exhibiting joint/crack chipping, cracking, and breaking (collectively known as spalling), pot-holing, and other surface defects. The benefits of partial depth repairs include improved ride quality and serviceability along with mitigating FOD hazards. A SHRP (1993) study found that asphalt concrete patches of PCC pavements are used in most locations on US highways and are considered temporary, but may be left in place for many years if performing well. The typical cost of a partial depth repair operation using asphalt concrete is in the range of \$125 to \$195 per m^2.

Partial depth repairs should only be used for surface distresses in the upper third of the slab. Partial depth repairs are not recommended for transverse and longitudinal crack repairs, slabs with poor load transfer, and for areas where reinforcing steel/load transfer devices are exposed. For many pavements requiring partial depth repairs with AC, additional maintenance treatments, such as crack/joint sealing, may also be required.

The 2001 survey of Canadian airport operators indicated that all authorities with exposed PCC pavements (who responded to the survey) have used partial depth repairs with asphalt concrete. Over 80 percent of operators were satisfied with the performance of asphaltic concrete patches.

The success of partial depth repair operations depends on the following factors.

Repair Material Selection

The selection of repair material depends on a number of factors including time constraints, climate, repair size and configuration, experience with local materials, and future maintenance/rehabilitation plans. The most effective asphalt concrete for partial depth repairs is hot mix asphalt (HMA). Cold mixes and proprietary asphaltic concrete products have also been successfully used.

1.0 Partial Depth Repair of PCC Pavements Using Asphalt Concrete

Effective Construction Procedure

The first step is to ensure that the repair area is of sufficient extent to remove all deteriorated and/or delaminated concrete. This will include sounding and over-sizing the repair area. All authorities agree that the perimeter of the repair should have a vertical face and should not be feather-edged. This can be accomplished by pavement saw cutting or milling. A typical installation operation involves:

- removal of damaged and delaminated PCC material
- cleaning by sand blasting or high pressure air blast
- installation of a joint bond breaker
- application of a tack coat
- application of the repair material
- compaction.

b) Specifications and Manuals

There is an airfield pavement maintenance specification available from Transport Canada for partial depth repairs of exposed concrete pavement with asphaltic concrete: PMS-5330 - *PC Concrete Pavement Patching with Asphalt*.

Transport Canada also published an Engineering Reference Document (ERD 125-02) entitled *Maintenance and Repair of Airport Portland Cement Concrete (PCC) Pavements*.

A useful manual of practice was developed by Patel et al (1993) as part of the SHRP research effort (Report No. SHRP-H-349).

The Ministère des Transports du Québec (1999) has issued a useful guide for repair of PCC pavement using AC.

The ACPA (1998) has issued a useful publication entitled *Guidelines for Partial-Depth Spall Repair (TB003.02P).*

c) Field Performance Reports

No field performance studies issued by, or for, Canadian airport operators were located.

A recently completed LTPP study by Wilson at al (1999) monitored the field performance of partial depth spall repairs on highways with PCC pavements and found that asphalt concrete patches had a lower survival rate compared to PCC patches.

d) Laboratory and Theoretical Reports

No laboratory studies issued by, or for, Canadian airport operators were found.

References

1. American Concrete Pavement Association. 1998. *Guidelines for Partial-Depth Spall Repair*. TB003.02P

2. Ministère des Transports du Québec. 1999. *Guide d'entretien et de rehabilitation des chausses en béton de ciment.*

3. Patel, A. J., Good Mojab, C. A., Romine, A. R. 1993. *Concrete Pavement Repair Manuals of Practice: Materials and Procedures Rapid Repair of Partial-Depth Spalls in Concrete Pavements*. Strategic Highway Research Program. Report No. SHRP-H-349.

4. Wilson, T. P., Smith, K. L., Romine, A. R. 1999. *LTPP Pavement Maintenance Materials: PCC Partial-Depth Spall Repair Experiment*, Final Report. FHWA-RD-99-153.

2.0 Partial Depth Repair of PCC Pavements Using PCC Material

Pavement type:	Exposed PCC
Treatment type:	Emergency maintenance Localized maintenance Area maintenance
Distresses treated:	Joint/crack spalling and scaling Surface spalling and scaling Corner and edge cracking, joint failures

a) Synopsis

Partial depth repair of exposed PCC pavements with PCC material involves removing all unsound concrete, thorough cleaning, area preparation typically with a bonding agent, followed by placement of the patching material.

Partial depth repair using PCC material is a maintenance activity used to replace unsound, deteriorating concrete in areas exhibiting joint/crack chipping, cracking, and breaking (collectively known as spalling) and other defects. The benefits of partial depth repairs include improved ride quality and serviceability along with mitigating FOD hazards. A SHRP study (Patel et al, 1993) reported that 80 to 100 percent of partial depth repairs perform well after 3 to 10 years. The typical cost of a partial depth repair operation is in the range of $185 to $225 per m^2.

Partial depth repairs should only be instituted for surface distresses in the upper third of the slab. Partial depth repairs are not recommended for transverse and longitudinal crack repairs, slabs with poor load transfer, and areas where reinforcing steel/load transfer devices are exposed. For many pavements requiring partial depth repairs with PCC, additional maintenance treatments, such as crack/joint sealing, may also be required.

The 2001 survey of Canadian airport operators indicated that roughly 60 percent of all authorities with exposed PCC pavements (who responded to the survey) have tried partial depth repairs with PCC materials. The opinions regarding the treatment's effectiveness vary. Two operators who had used proprietary repair materials were not satisfied with their performance.

The success of partial depth repair operations depends on the following factors.

Repair Material Selection

Selection of the repair material depends on a number of factors including time constraints, climate, repair size and configuration, experience with local materials, and future maintenance and rehabilitation plans. Ideal repair materials should have physical properties, such as elastic modulus, ultimate strength, thermal expansion similar to the parent concrete. PCC repair materials include Type 10 normal Portland cement, Type 30 high early strength cement, modified cement mixtures that can include addition of accelerating admixtures, polymers, or specialty cements such as, magnesium phosphate, calcium sulfate (gypsum), high-alumina, and proprietary repair materials.

2.0 Partial Depth Repair of PCC Pavements Using PCC Material

After selection of the repair material, an appropriate bonding agent that is compatible with the repair material may be required. Bonding agents can range from sand-cement slurries to specialty epoxy bonding agents.

Effective Construction Procedure

The first step is to ensure that the repair area is of sufficient extent to remove all deteriorated and/or delaminated concrete. This will include sounding and over-sizing the repair area. All authorities agree that the perimeter of the repair should have a vertical face and should not be feather-edged. This can be accomplished by saw cutting (preferable method) or milling. As the majority of spalls are associated with joint/crack edges, joint preparation including an appropriate bond breaker is required. A typical installation operation will involve:

- removal of delaminated concrete
- cleaning of the PCC surface by sand blasting or high pressure air blast
- installation of a joint bond breaker
- application of a bonding agent (avoid puddling)
- application of the repair material
- consolidation
- finishing
- curing.

Partial depth repairs at joints must include sealing joints on completion.

b) Specifications and Manuals

There are two airfield pavement maintenance specifications available from Transport Canada for partial depth repairs of exposed PCC pavements: PMS-5310 – *PC Concrete Pavement Patching with PC Concrete* and PMS-5320 - *PC Concrete Pavement Patching with Proprietary Products.*

Transport Canada also published an Engineering Reference Document (ERD 125-02) entitled *Maintenance and Repair of Airport Portland Cement Concrete (PCC) Pavements*.

Ontario has developed specifications for partial depth repairs of exposed PCC pavements (OPSS, 1998) .

The Ministère des Transports du Québec (1999) has issued a useful guide for repair PCC pavement.

A useful manual of practice was developed by Patel at al (1993) as part of the SHRP research effort (Report No. SHRP-H-349).

2.0 Partial Depth Repair of PCC Pavements Using PCC Material

The ACPA has issued a useful publication entitled *Guidelines for Partial-Depth Spall Repair (TB003.02P).*

c) Field Performance Reports

No field performance studies issued by, or for, Canadian airport operators were located.

A recently completed LTPP (1999) study monitoring the field performance of partial depth spall repairs found that repairs on 3 of 4 test sites had a 90% survival rate while repairs on the fourth test site had a 60% survival rate. The monitoring period ranged from 4 to 7 years and the study included more than 1,600 individual spalls.

d) Laboratory and Theoretical Reports

We have not encountered any laboratory studies issued by, or for, Canadian airport operators.

Laboratory testing conducted as part of the LTPP study (Patel et al, 1993) revealed that substrate (pavement surface) preparation is critical for bonding of the repair material. The study found that the bond strength of materials installed onto a wet substrate decreased if the substrate was dry, and materials that were installed dry lost strength when tested on a wet substrate.

References

1. American Concrete Pavement Association. 1998. *Guidelines for Partial-Depth Spall Repair*. TB003.02P

2. Ministère des Transports du Québec. 1999. *Guide d'entretien et de rehabilitation des chausses en béton de ciment.*

3. Ontario Provincial Standard Drawings. 1996. *Partial Depth Repairs in Concrete Pavement OPSD 560.040*.

4. Ontario Provincial Standards Specification. 1996. *Construction Specification for Partial-Depth Repairs in Concrete Pavement OPSS 364*.

5. Patel, A. J., Good Mojab, C. A., Romine, A. R. 1993. *Concrete Pavement Repair Manuals of Practice: Materials and Procedures Rapid Repair of Partial-Depth Spalls in Concrete Pavements*. Strategic Highway Research Program. Report No. SHRP-H-349.

6. Wilson, T. P., Smith, K. L., Romine, A. R. 1999. *LTPP Pavement Maintenance Materials: PCC Partial-Depth Spall Repair Experiment*, Final Report. FHWA-RD-99-153.

3.0 Joint/Crack Sealing of PCC Pavements

Pavement type: Exposed PCC
Treatment type: Area maintenance
Distresses treated: Joint sealant loss
Transverse and longitudinal cracking

a) Synopsis

Sealing of joints/cracks in exposed PCC pavements usually involves creating a reservoir at the top of the joint/crack (typically by saw cutting), installing backer rod (for joints only, depends on the sealant type and manufacturer's recommendations), and filling the reservoir with a sealant.

Joint/crack sealing and resealing is a necessary and important maintenance activity that is required to mitigate the infiltration of water, de-icing chemicals and incompressible materials into the pavement joints/structure. The additional benefit of sealing joints in PCC pavements is the prevention of spalling and ravelling of joint edges.

The benefits of joint/crack sealing for PCC pavements have been well documented. A recent study questioned the cost-effectiveness of sealing PCC pavements (Hawkins et al, 2001) but only evaluated pavements with an open-graded drainage bases. The effectiveness of different sealant materials has also lead to considerable discussion.

The typical cost of a rout and seal operation is in the range of $3 to $5 per linear metre for hot poured rubberized sealant and $10 to $17 per linear metre for silicone sealant based on a Transport Canada *Summary Report of Silicone Sealants Performance at Canadian Airports.* The American Concrete Pavement Association (ACPA) reports that hot pour sealants have a service life of 3-5 years, silicone sealants 8-10 years, and preformed neoprene seals can last up to 15 years.

Sealing operations should be performed on all joints, on 'working' cracks less than 7 mm wide, and when existing sealants begin to deteriorate. Many pavements requiring crack sealing and joint resealing may also require other maintenance treatments, such as spall repairs.

The 2001 survey of Canadian airport operators indicated that all authorities with exposed PCC pavements seal joints/cracks and that this treatment is generally considered to be effective.

The success of sealing operations depends on the following factors.

Effective Sealant Materials

There are four main categories of concrete sealants on the market: hot-poured, cold-poured, silicone, and preformed. The performance of sealants can differ significantly depending on their adhesive and cohesive properties which can change depending on how the sealant is stored and heated, and how well the surface of the crack or joint has been prepared. Sealants intended for some airfield specific locations require resistance to jet fuel. Existing specifications for sealants include

3.0 Joint/Crack Sealing of PCC Pavements

CAN/CGSB 19.20-M87, ASTM D-3405, ASTM D-3569 and ASTM D-2628.

Effective Reservoir Configuration

The shape factor for effective reservoir configuration differs based on sealant material type, the length of slab, and joint type (transverse or longitudinal). The consensus would indicate that the sealant should be slightly recessed in the reservoir. Manufacturer recommendations should be taken into account when determining a shape factor.

Effective Construction Procedure

All authorities agree that joints/cracks must be cleaned prior to sealing. A typical installation operation involves:

- saw cut
- water wash
- air blast
- sand blast
- backer rod insertion (if required)
- sealant application.

b) Specifications and Manuals

There are five airfield pavement maintenance specifications available from Transport Canada for crack sealing:

PMS-5110 - *Crack Sealing Using Hot-Poured Bituminous Sealant*
PMS-5120 - *Crack Sealing Using Jet Fuel Resistant Sealant*
PMS-5130 - *Crack Sealing Using Cold-Poured Emulsified Sealant*
PMS-5150 - *PC Concrete Joint Sealing and Resealing.*
M100-2 - *Cold-Pour Rubber Bituminous Emulsified Pavement Crack Sealer*.

Transport Canada also published an Engineering Reference Document (ERD 125-02) entitled *Maintenance and Repair of Airport Portland Cement Concrete (PCC) Pavements*.

Ontario has developed specifications for sealing cracks and joints in exposed PCC pavements (OPSS, 1998).

The Ministère des Transports du Québec (1999) has issued a useful guide for repair of PCC pavement.

The ACPA (1995) has issued a useful publication entitled *Joint and Crack Sealing and Repair for Concrete Pavements.*

3.0 Joint/Crack Sealing of PCC Pavements

c) Field Performance Reports

A 1982 Transport Canada report (AK-67-09-233) undertook to study sealant performance by establishing and monitoring test sections at various airports and investigating specification compliance through laboratory testing. The study concluded that: construction practice is critical to the performance of a joint sealant, continual laboratory monitoring is required to ensure that material specifications are achieved, and unification of test standards is required to simplify comparison.

An undated Transport Canada study *Silicone Sealants Performance at Canadian Airports* identified that joint failures were predominantly adhesion failures or 'joint chipping', and concluded that adhesion failures can be attributed to construction deficiencies. The study noted a dramatic increase in joint chipping associated with silicone sealants but could not reach a conclusion as to the cause. The study recommended that the use of silicone sealants be avoided until the cause was determined. The Ontario Ministry of Transportation switched from pre-formed neoprene filler to hot-poured rubberized asphalt sealants in 1972.

d) Laboratory and Theoretical Reports

Laboratory testing conducted by Razaqpur Engineering (1996), in a study sponsored by Transport Canada, found that hot-poured sealants became rigid and brittle or easily lost their bond with concrete at extreme cold temperatures. The performance of cold-poured sealants at low temperatures was better than that of hot-poured sealants. The results of the study indicated that the mechanical properties of silicone sealants were not responsible for the observed joint chipping.

References

1. American Concrete Pavement Association. 1995. *Joint and Crack Sealing and Repair for Concrete Pavements*. TB012P

2. Evans, L. D., Romine, A. R. 1993. *Concrete Pavement Repair Manuals of Practice: Materials and Procedures for the repair of Joint Seals in Concrete Pavements*, Strategic Highway Research Program, Report No. SHRP-H-349.

3. Hawkins, B. K., Ioannides, A., and Minkarah, I. A. 2001. *To Seal or Not to Seal: Construction of a Field Experiment to Resolve an Age-Old Dilemma*, paper presented at the 80th Annual Meeting of the Transportation Research Board, Washington, D.C.

4. Ministère des Transports du Québec. 1999. Guide d'entretien et de rehabilitation des chausses en béton de ciment.

5. Ontario Provincial Standard Drawings. 1998. *Sealing or Resealing of Joints and Cracks in Concrete Pavement OPSD 508.020*.

3.0 Joint/Crack Sealing of PCC Pavements

6. Ontario Provincial Standards Specification. 1998. *Sealing and Resealing of Joints and Cracks in Concrete Pavement OPSS 369*.

7. Razaqpur Engineering. 1996. *Concrete Pavement Joint Sealants: Plastic Flow Characteristics*, Transport Canada, Civil Engineering Services.

8. Transport Canada. 1982. *Concrete Pavement Joint Sealant Studies Report.* AK-67-09-233.

9. Transport Canada. No date. *Silicone Sealants Performance at Canadian Airports, Summary Report.*

4.0 Sub-Sealing

Pavement type:	Exposed PCC Composite
Treatment type:	Localized maintenance Area maintenance Rehabilitation
Distresses treated:	Joint faulting Sagging and slab warping

a) Synopsis

Sub-sealing of PCC and composite pavements (also referred to as slab stabilization, joint stabilization, mud-jacking) involves sub-sealing of voids in the base beneath joints and cracks, and raising sunken slabs to grade by pumping a grout underneath. Sub-sealing typically involves identifying void size, drilling grout holes, injecting grout, and sealing grout holes.

Sub-sealing is a maintenance activity used to restore support beneath slabs, typically at joint and crack locations, as a result of slab pumping. The benefits of sub-sealing include improved ride quality and serviceability along with mitigating FOD hazards from resulting corner breaks if the slabs are left untreated. The Transportation Association of Canada (1997) estimates the expected service life of sub-sealing to be 5 to 10 years. The typical cost of a sub-sealing operation is in the range of \$1.50 to \$2.50 per m^2.

Sub-sealing should only be undertaken for joints and cracks subjected to traffic that exhibit loss of support. Sub-sealing should be instituted prior to the onset of pavement damage. Sub-sealing is not recommended for the correction of slab faulting. Pavements requiring sub-sealing may also require other maintenance treatments, such as crack/joint sealing and diamond grinding. Sub-sealing has also been used as part of rehabilitation programs using overlays.

The 2001 survey of Canadian airport operators indicates that two out of thirteen authorities with exposed PCC or composite pavements have used sub-sealing. Both operators were satisfied with the performance.

The success of sub-sealing operations depends on the following factors.

Determining Loss of Support

Sub-sealing should only be considered when loss of support exists which can be determined by visual inspection, ground penetrating radar (GPR) and deflection testing. Visual inspection will reveal tell-tale signs such as faulting, pumping, and corner breaks, but cannot accurately determine extent. GPR uses electromagnetic pulses to determine boundary interfaces by determining pulse rebound responses but sensitivity of the equipment may not always identify shallow voids. Deflection testing (Falling Weight Deflectometer, etc.) measures deflections at both the approach and departure sides of joints. Analysis methods such as *Void Detection Procedures For Jointed PCC Pavements* (Crovetti and Darter, 1985) can be used to estimate the depth and area of voids.

4.0 Sub-Sealing

Grout Material Selection

Numerous materials have been successfully used as grouts for sub-sealing operations, including Portland cement and bituminous mixtures, fly ash-cement, polyurethane, and proprietary products. Regardless of the material used, all grouts should be able to flow into the smallest of voids, should have sufficient strength gain to support the slab and the load, and should not erode or deteriorate beneath the slab.

Effective Construction Procedure

A typical installation operation will involve:

- determining the location of grout injection and inspection holes
- drilling holes
- injecting grout until lift is observed or the grout material is observed flowing from hole to hole
- sealing holes and cleaning
- waiting until grout sets before opening to traffic
- verification testing.

b) Specifications and Manuals

Transport Canada has published an Engineering Reference Document (ERD 125-02) entitled *Maintenance and Repair of Airport Portland Cement Concrete (PCC) Pavements*.

The Ministère des Transports du Québec (1999) has issued a useful guide for repair of PCC pavement.

The ACPA (1994) has issued a useful publication entitled *Slab Stabilization Guidelines for Concrete Pavements.*

c) Field Performance Reports

No field performance studies issued by, or for, Canadian airport operators were located.

Kazmierowski and Wrong (1986) described sub-sealing operations carried out on highway pavement slabs exhibiting severe joint faulting. They concluded that on stepped/faulted pavements where measured joint load transfer efficiencies are less than 70%, sub-sealing provides an efficient cost-effective technique for stabilizing vertical joint movements and reducing slab deflections.

A survey of undersealing practices in the USA was carried out by Taha et al (1994). Undersealing is performed by 16 US state highway agencies. The preferred material used in undersealing is fly ash-cement grout. The maximum vertical slab movement allowed during pumping varies from 0.4 mm to 6.4 mm. The long-term effectiveness of undersealing is generally good.

4.0 Sub-Sealing

d) Laboratory and Theoretical Reports

No laboratory studies issued by, or for, Canadian airport operators were found.

References

1. American Concrete Pavement Association. 1994. *Slab Stabilization Guidelines for Concrete Pavements*, Report TB-018 P.

2. Crovetti, J. A., Darter, M. I. 1985. *Void Detection Procedures for Jointed PCC Pavements*. NCHRP 1-21.

3. Ministère des Transports du Québec. 1999. *Guide d'entretien et de rehabilitation des chausses en béton de ciment.*

4. Kazmierowski, T. J., and Wrong, G. A. 1986. *Experimental Cement Grout Subsealing of a Concrete Pavement in Ontario,* Proceedings of the 1986 Annual Conference of Road and Transportation Association of Canada.

5. Taha, R., Selim, A., Hasan, S., and Lunde B. 1994. Evaluation of Highway Undersealing Practices of Portland Cement Concrete Pavements, Transportation Research Board Record 1449, Transportation Research Board, Washington, D.C.

6. Transportation Association of Canada. 1997. *Pavement Design and Management Guide*, 2323 St. Laurent Blvd, Ottawa, K1G 4J8, ISBN 1-55187-114-9.

5.0 Full-Depth Repairs of Composite or Exposed PCC Pavements Using PCC Material

Pavement type:	Exposed PCC Composite
Treatment type:	Localized maintenance Area maintenance Rehabilitation
Distresses treated:	Joint failures Transverse and longitudinal cracking Corner and edge cracking "D" cracking Frost heaving and subgrade settlement

a) Synopsis

Full-depth repair of exposed PCC pavements with PCC material involves removing the deteriorated portion of the slab full depth, installation of load transfer devices, and placement of concrete. In the case of composite pavements, the asphalt concrete surface is also removed and replaced.

Full-depth repair is a maintenance activity used to replace unsound/deteriorating concrete in areas of joint failures, cracking, frost heaving, subgrade settlement, areas with poor load transfer, and areas where reinforcing steel/load transfer devices are exposed. Full-depth repairs may also be appropriate for repair of crack chipping, cracking, and breaking (collectively known as spalling) that extend through the slab or extend deeper than would be considered suitable for partial depth repair (about 1/3 of the slab thickness). The benefits of full-depth repairs include improved ride quality and serviceability along with mitigation of FOD hazards. The typical cost of a full depth repair operation is in the range of \$125 to \$200 per m^2.

Pavements requiring full-depth repair may also require other maintenance treatments, such as crack/joint sealing and slab stabilization. Full depth repairs using PCC are also a prerequisite for rehabilitation using overlays.

The success of full-depth repair operations depends on the following factors.

Size of the Repair Area

Sizing a full-depth repair is an important consideration to ensure that all deteriorated concrete is removed and that the area is sufficiently wide to allow for base repairs, if required. Full-depth repair boundaries should be parallel to existing joints. It is preferable to have full depth repairs extend full width of the slab to eliminate re-entrant corners. A final review of repair boundaries should be undertaken with consideration given to combining adjacent repair areas if in close proximity.

5.0 Full-Depth Repairs of Composite or Exposed PCC Pavements Using PCC Material

Load Transfer

The perimeter of full-depth repair areas may require the provision of load transfer devices. Typically, load transfer devices consisting of 35 mm (minimum) dowels are considered appropriate. The dowels should be adequately grouted/epoxied into the parent concrete.

Repair Materials

Depending on the requirement to open the area to traffic, PCC repair materials can include Type 10 normal Portland cement if time is not critical or the "fast-track" rapid setting mixes if time is critical. Fast track materials include Type 30 high early strength cement, modified cement mixtures with the addition of accelerating admixtures, polymers, or specialty cements such as magnesium phosphate, calcium sulphate (gypsum), high-alumina, and proprietary repair materials. If timing is critical, consideration can also be given to the use of pre-cast slabs.

Effective Construction Procedure

A typical full-depth repair operation includes the following steps:

- isolate (saw-cut) the deteriorated area
- remove the old concrete
- repair the subbase if necessary
- provide load transfer at the joint faces
- place and finish the new concrete
- cure and insulate the concrete
- seal the joints.

b) Specifications and Manuals

There are two airfield pavement maintenance specifications available from Transport Canada for full depth repairs of exposed PCC pavements: PMS-5350 – *PC Concrete Pavement Full Depth Repairs*, and PMS-5360 - *Concrete Slab Replacement with Precast Slabs.*

Transport Canada has published an Engineering Reference Document (ERD 125-02) entitled *Maintenance and Repair of Airport Portland Cement Concrete (PCC) Pavements*.

Ontario has developed construction specifications (OPSS, 1995, 1998) for full depth repair of concrete pavement or concrete base.

The Ministère des Transports du Québec (1999) has issued a useful guide for repair of PCC pavement.

5.0 Full-Depth Repairs of Composite or Exposed PCC Pavements Using PCC Material

The ACPA (1995) has issued a useful publication entitled *Guidelines for Full Depth Repair (TB002.02P).*

c) Field Performance Reports

Field performance studies issued by, or for, Canadian airport operators have largely been limited to two products/methods - precast slabs and the proprietary product Pyrament cement.

A 1993 Transport Canada study of *Concrete Pavement Repair Using Precast Slabs* concluded that the technique met all design and operational requirements. A trial application at Calgary Airport resulted in the repaired facility being operational within 24 hours. An earlier study (McCormick Rankin) also reported positive time saving benefits. The authors noted that productivity was in part dependent on determining a precast slab size that could be readily picked up by conventional construction equipment. The study reported that precast slabs with load transfer devices can be as much as 4 times more expensive than conventional cast-in-place concrete.

Two studies were conducted at Toronto's Lester B. Pearson International Airport on the use of Pyrament - PBC - XT Cement (Acres, 1989 and McCormick Rankin, 1991). Pyrament was reported by the manufacturer to be a high strength, quick-setting concrete that is resistant to abrasion, sulphates, scaling, etc. Transport Canada studies concluded that, although this product has potential, it should not be used in critical areas until further expertise with the product can be developed.

References

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2. American Concrete Pavement Association. 1995. *Guidelines for Full Depth Repair*, Report TB002.02P.

3. McCormick Rankin. 1988. *Final Report to Investigate Methods of Using Precast Slabs for Portland Cement Concrete Restoration,* Transport Canada.

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8. Ontario Provincial Standards Specification. 1995. *Construction Specification for Full Depth Repair of Concrete Pavement or Concrete Base OPSS 360.*

9. Ontario Provincial Standards Specification. 1998. *Construction Specification for Fast Track Full Depth Repairs to Concrete Pavement OPSS 362.*

10. Schmitt, R. J. 1993. *Concrete Pavements Repair Using Precast Slabs,* Transport Canada Meeting 23.

6.0 Load Transfer Restoration

Pavement type:	Exposed PCC Composite
Treatment type:	Area maintenance Local maintenance Rehabilitation
Distresses treated:	Transverse and longitudinal cracking Faulting

a) Synopsis

Load transfer restoration of exposed PCC and composite pavements usually involves cutting a slot, placing a dowel bar in the slot, and backfilling/grouting the slot.

Load transfer restoration is a maintenance activity used to reduce tensile stresses in the concrete slab near the joints. Load transfer restoration reduces the potential for pumping and faulting as well as reducing deflections at both transverse joints and corners. The benefits of load transfer restoration for pavements have been well documented. The typical cost of a load transfer restoration operation is in the order of $40 per dowel bar.

Load transfer restoration operations are suitable for pavements that exhibit poor load transfer but are considered structurally adequate. To ensure structural adequacy, evaluation of the concrete condition at the joint should be carried out. Rigid pavements with little remaining structural capacity are not suitable candidates for load transfer restoration. The FHWA (1997) suggests that joints/cracks with deflection load transfer of 60 percent or less, faulting greater than 2.5 mm, or differential deflections of 250 µm or more would benefit from load transfer restoration. Evaluation of load transfer efficiency should be based on high-load falling weight deflectometer (HWD) testing.

The most common type of load transfer device is the smooth round dowel bar. The size of the dowel bars depends on the slab thickness and anticipated loads. Typically, dowel bars have a diameter of 30 to 40 mm and a length of 400 to 600 mm. Other types of load transfer devices include deformed reinforcing steel, small beams and shear devices. Smooth dowels are preferable because they can withstand shear loads while allowing for expansion and contraction of the slab. Corrosion protection such as epoxy coating is recommended. Prior to placement, dowels should be oiled (full length), fitted with expansion caps, and placed on chairs within the slot.

The success of load transfer operations depends on the following factors.

Effective Slot Cutting

A diamond tipped slot cutting saw has become the most common equipment used for slot cutting although modified milling machines have also been used. Slots should be parallel to the direction of travel which typically means that they are perpendicular to the joint. The slots must be long enough to accommodate the dowel and of sufficient size (diameter and length) to allow for the backfill to flow around the dowel. The dowels should be placed mid-slab. The sawing operation must minimize the amount of spalling at the slot edges.

Effective Slot Preparation

Care must be taken when removing concrete from the slots. Breakage of the parent concrete may necessitate full depth repairs. The base of the slot should be relatively level to allow for proper dowel alignment. The slot must be properly cleaned by first sand blasting followed by high pressure air blasting. Prior to placement of the dowel, the sides and base of the slot must be caulked to ensure that the backfill does not enter the joint.

Backfill Selection

Backfill materials should develop adequate early strength gain to facilitate opening of the area to traffic and should exhibit little to no shrinkage. Cementicious materials suitable for partial depth repairs are considered appropriate load transfer retrofit backfills. Refer to Patel et al (1993) for the selection of backfill materials.

Effective Construction Procedure

A typical installation operation will involve:

- cutting the slots
- preparing the slots
- placing the dowels
- backfilling.

b) Specifications and Manuals

Transport Canada has published an Engineering Reference Document (ERD 125-02) entitled *Maintenance and Repair of Airport Portland Cement Concrete (PCC) Pavements*.

The Ministère des Transports du Québec (1999) has issued a useful guide for repair of PCC pavement.

The FHWA in conjunction with the ACPA has issued a useful publication entitled *Guide for Load Transfer Restoration.*

c) Field Performance Reports

No field performance studies issued by, or for, Canadian airport operators were located.

While formal reports on the performance of dowel bar retrofitting for load transfer restoration were not found, a trial involving load transfer restoration was completed during the 1990's on Runway 06R-24L at Lester B. Pearson International Airport. The trial section appeared to be performing well prior to the overlay of the runway in the late 1990's.

Mamlouk et al (2000) evaluated the performance of dowel retrofitting of transverse cracks in Michigan. Some dowels were placed at a depth shallower than the mid-depth of the concrete slab for the purpose of reducing construction costs. Initial results indicated that dowel retrofitting of transverse cracks is a viable method for preventive maintenance of PCC pavement.

Washington State Department of Transportation has been using dowel retrofitting since 1992 with good results (Pierce, 1994).

d) Laboratory and Theoretical Reports

No laboratory studies issued by, or for, Canadian airport operators were found.

References

1. Federal Highway Administration. 1997. *Concrete Pavement Rehabilitation, Guide for Load Transfer Restoration*, FHWA-SA-97-103. ACPA JP001P.

2. Mamlouk M. S., Eacker, M., and Owusu-Antiwi, E. 2000. *Dowel Retrofitting – A Viable Method for Preventive Maintenance*, Transportation Research Board Paper 00-1145, Transportation Research Board, Washington, D.C.

3. Ministère des Transports du Québec. 1999. *Guide d'entretien et de rehabilitation des chausses en béton de ciment.*

4. Patel, A. J., Good Mojab, C. A., Romine, A. R. 1993. *Concrete Pavement Repair Manuals of Practice: Materials and Procedures Rapid Repair of Partial-Depth Spalls in Concrete Pavements*, Strategic Highway Research Program, Report No. SHRP-H-349.

5. Pierce, L. M. 1994. *Portland Cement Concrete Pavement Rehabilitation in Washington State: Case Study*, Transportation Research Board Record 1449, Transportation Research Board, Washington, D.C.

7.0 Asphalt Concrete Overlays of Exposed PCC Pavements

Pavement type:	Exposed PCC
Treatment type:	Rehabilitation
	Area Maintenance
Distresses treated:	All distresses

a) Synopsis

Asphalt concrete overlays of exposed PCC pavements usually involve repair of structural deficiencies in the existing slab, application of a bonding agent (tack coat), followed by the paving operations.

An asphalt concrete overlay is a rehabilitation technique used to increase the structural capacity of an existing pavement as well as improve surface characteristics such as smoothness and skid resistance. The typical cost of an asphalt concrete overlay is estimated to be in the range of $35 to $55 per tonne. The Transportation Association of Canada (TAC) estimates that asphalt concrete overlays can have an expected service life of 12 to 15 years. Some of the technological variations described for *Hot Mix Resurfacing of Bituminous Surfaced Pavements* are also applicable to *Asphalt Concrete Overlays of Exposed PCC Pavements*.

The 2001 survey of Canadian airport operators indicated that 7 of 13 authorities (who responded to the survey) have resurfaced PCC pavements with asphalt concrete. Roughly 70 percent were satisfied with the performance.

The success of an asphalt concrete overlay operation depends on the factors described below.

Assessing Existing Conditions

Asphalt concrete overlays are intended for sound/stable pavements. They are not an appropriate rehabilitation technique for structurally deficient pavements such as those with working cracks or those with sub-slab voids. Structurally deficient pavements will be susceptible to premature deterioration as a result of reflection cracking.

A field evaluation should consider the existing pavement surface condition, strength evaluation by non-destructive methods such as deflection testing, and cores/boreholes to evaluate the condition of the pavement component materials.

Pre-Overlay Repairs

For an asphalt concrete overlay to be successful, existing distresses must be repaired. This may include partial and full-depth repairs, slab replacement, slab stabilization, and fault grinding. Depending on the condition of the existing pavement, separation layers (typically utilizing open graded large aggregate mixes) may be required to mitigate reflection cracking.

7.0 Asphalt Concrete Overlays of Exposed PCC Pavements

Effective Construction Procedure

A typical asphaltic concrete overlay operation involves:

- distress repair
- surface cleaning
- application of tack coat
- overlay placement
- compaction.

b) Specifications and Manuals

Transport Canada has published an Engineering Reference Document (ERD 125-02) entitled *Maintenance and Repair of Airport Portland Cement Concrete (PCC) Pavements*.

The Ministère des Transports du Québec (1999) has issued a useful guide for repair of PCC pavement.

The Asphalt Institute has issued a useful publication entitled *Asphalt Overlays for Highway and Street Rehabilitation.*

c) Field Performance Reports

No field performance studies issued by, or for, Canadian airport operators were located.

d) Laboratory and Theoretical Reports

No laboratory studies issued by, or for, Canadian airport operators were found.

References

1. The Asphalt Institute. *Asphalt Overlays for Highway and Street Rehabilitation.* MS-17.

2. Ministère des Transports du Québec (1999). *Guide d'entretien et de rehabilitation des chausses en béton de ciment.*

3. Transportation Association of Canada (1997). *Pavement Design and Management Guide.*

8.0 Bonded Overlays of Exposed PCC Pavements

Pavement type: Exposed PCC
Treatment type: Rehabilitation
Distresses treated: All distresses

a) Synopsis

Bonded overlays of exposed PCC pavements usually involve the placement of a relatively thin PCC layer over an existing PCC pavement to form a new monolithic section.

A bonded overlay is a rehabilitation technique designed to increase the structural capacity of an existing sound pavement as well as improve surface characteristics such as smoothness and skid resistance. The time required to open the facility to traffic can be shortened by using 'fast track' construction techniques. The typical cost of a bonded overlay is estimated to be in the range of $20 to $30 per m^2. The Transportation Association of Canada (TAC) estimates that bonded overlays can have an expected service life of 15 to 20 years.

The 2001 survey of Canadian airport operators indicated that none of the authorities with exposed concrete pavements (who responded to the survey) had used bonded overlays.

The success of a bonded overlay operation depends on the factors described below.

Assessing Existing Conditions

Bonded overlays are intended for sound pavements and are not appropriate for pavements in poor condition. Bonded overlays should not be used on pavements exhibiting durability problems, such as alkali aggregate reactivity (AAR) (also known as alkali silica reactivity (ASR) or "D" cracking).

Pre-Overlay Repairs

For a bonded overlay to be successful, existing defects must be repaired. This may include partial and full depth repairs, slab replacement, slab stabilization, and fault grinding. Because of the relative thinness of bonded overlays, defects that are left untreated may reflect through the overlay.

Surface Preparation

A clean sound surface is essential for achievement of a monolithic section using a bonded overlay. Unsound surface concrete should be removed by milling or shot blasting. The pavement surface should then be cleaned by sand blasting or high pressure water blasting followed by an air blast to remove surface dust. The surface should then be primed with an appropriate bonding agent to achieve a good bond between the parent concrete and the overlay. It is typically required that joints in the overlay match joints in the underlying pavement which necessitates that the existing joints be surveyed and their location marked.

8.0 Bonded Overlays of Exposed PCC Pavements

Effective Construction Procedure

A typical bonded overlay operation involves:

- distress repair
- surface cleaning
- application of a bonding agent
- overlay placement
- finishing
- curing
- jointing and sealing.

b) Specifications and Manuals

No manuals or specifications issued by Transport Canada dealing explicitly with the construction of bonded overlays are available.

Transport Canada has published an Engineering Reference Document (ERD 125-02) entitled *Maintenance and Repair of Airport Portland Cement Concrete (PCC) Pavements*.

The Ministère des Transports du Québec (1999) has issued a useful guide for repair of PCC pavement.

The ACPA (1990) has issued a useful publication entitled *Guidelines for Bonded Concrete Overlays (TB007 P).*

c) Field Performance and Other Reports

No field performance studies issued by, or for, Canadian airport operators were located.

Volle (2000) evaluated the performance of two bonded PCC overlays constructed in Illinois. While one of the overlays was performing well, the second overlay was in need of rehabilitation only a few years after construction.

d) Laboratory and Theoretical Reports

No laboratory studies issued by, or for, Canadian airport operators were found.

References

1. American Concrete Pavement Association. 1990. *Guidelines for Bonded Concrete Overlay*, TB-007 P.

8.0 Bonded Overlays of Exposed PCC Pavements

2. Ministère des Transports du Québec. 1999. *Guide d'entretien et de rehabilitation des chausses en béton de ciment.*

3. Vole, T. H. 2000. *Thin Concrete Overlays in Illinois: Preliminary Report on the Performance,* Transportation Research Board Paper No. 01-2147, Transportation Research Board, Washington, D.C.

4. Transportation Association of Canada.1997. Pavement Design and Management Guide.

9.0 Unbonded PCC Overlays

Pavement type:	Exposed PCC
	Composite
Treatment type:	Rehabilitation
Distresses treated:	All distresses

a) Synopsis

An unbonded overlay of a PCC or composite pavement usually involves placement of a relatively thick concrete layer over the existing pavement with a separation layer between the two. The overlay receives support from the underlying layer while the separation layer mitigates reflection cracking. Usually, joints in the overlay need not match joints in the underlying pavement.

An unbonded overlay is an effective rehabilitation technique when the existing pavement is in poor condition. Unbonded overlays are designed to increase the structural capacity of the pavement and improve surface characteristics such as smoothness and skid resistance. The typical cost of an unbonded overlay is in the range of $30 to $40 per m^2. The Transportation Association of Canada (TAC) estimates that unbonded overlays can have an expected service life of 25 to 30 years.

The 2001 survey of Canadian airport operators indicated that none had used unbonded PCC overlays.

The success of unbonded overlays depends on the factors described below.

Effective Separation Layer

Most highway authorities agree that sand-asphalt mixtures work well as separation layers (ACPA, 1990). Sheet type separation layers, such as thin rubber membranes, do not perform well.

Pre-Overlay Repairs

Only severely distressed areas need to be repaired before placement of unbonded overlays. Repairs may include full depth repairs and slab stabilization.

Effective Construction Procedure

A typical bonded overlay operation will involve:

- minimal distress repair
- placement of the separation layer
- concrete placement
- finishing
- curing
- jointing and sealing.

9.0 Unbonded PCC Overlays

b) Specifications and Manuals

No manuals or specifications issued by Transport Canada dealing explicitly with the construction of unbonded PCC overlays are available.

Transport Canada has published an Engineering Reference Document (ERD 125-02) entitled *Maintenance and Repair of Airport Portland Cement Concrete (PCC) Pavements*.

The Ministère des Transports du Québec (1999) has issued a useful guide for repair of PCC pavement.

The ACPA (1990) has issued a useful publication entitled *Guidelines for Unbonded Concrete Overlays.*

Owusu-Antwi and Khazanovich (1999) published useful guidelines for the design and construction of unbonded PCC overlays.

c) Field Performance Reports

No field performance studies issued by, or for, Canadian airport operators were located.

Kazmierowski and Strum (1993) evaluated the performance of an unbonded PCC overlay on a four-lane highway. This appears to be the only published report on the performance of an unbonded PCC overlay constructed in Canada. Kazmierowski and Strum concluded that unbonded overlays are a viable rehabilitation technique for distressed PCC pavements.

d) Laboratory and Theoretical Reports

No laboratory studies issued by, or for, Canadian airport operators were found.

References

1. American Concrete Pavement Association. 1990. *Guidelines for Unbonded Concrete Overlays.* TB-005 P

2. Owusu-Antwi, E. B., and Khazanovich, L. 1999. Design and Construction Guidelines for Unbonded PCC Overlays. Paper presented at 78th Annual Meeting of the Transportation Research Board, Washington, D.C.

3. Kazmierowski, T. J., and Sturm, H. 1993. Performance of Ontario's First Major Rehabilitation and Overlay Project, Fifth International Conference on Concrete Pavement Design and Rehabilitation, Purdue University, West Lafayette, Indiana.

9.0 Unbonded PCC Overlays

4. Ministère des Transports du Québec. 1999. *Guide d'entretien et de rehabilitation des chausses en béton de ciment.*

5. Transportation Association of Canada. 1997. *Pavement Design and Management Guide.*

10.0 Whitetopping of Asphalt Concrete Pavements

Pavement type:	Asphalt concrete
Treatment type:	Rehabilitation
Distresses treated:	All distresses

a) Synopsis

Whitetopping of an asphalt concrete pavement involves placement of a PCC layer over the existing asphalt to form a new surface. Thickness of the PCC overlay is usually greater than 100 mm. Only severe distresses (such as frost heaving and subgrade settlement) require repair prior to whitetopping.

Whitetopping is a rehabilitation technique that can improve the surface characteristics of asphalt concrete such as smoothness and skid resistance while mitigating the occurrence of reflection cracking which is common with AC overlays. The typical cost of a whitetopping operation is in the range of \$20 to \$30 per m^2.

The 2001 survey of Canadian airport operators indicated that none had used whitetopping.

The success of whitetopping operations depends on the factors described below.

Design

The design procedure for whitetopping is similar to the design used for conventional PCC pavements and must consider both thickness and joint spacing/configuration. Design considerations include design life, future traffic, the structural capacity of the existing pavement, subgrade support characteristics, drainage, design details, load transfer devices and joint spacing.

Preparation

Whitetopping requires very little preparation prior to placement of the concrete. Rutting can be addressed by a milling or levelling course. The concrete should not be placed on overly hot asphaltic concrete that would adversely affect curing. Further, the asphalt surface should be moistened to minimize absorption of water from the concrete mix.

Effective Construction Procedure

A typical whitetopping operation involves:

- minimal distress repair of the existing AC pavement
- surface wetting
- concrete placement
- compaction and finishing
- curing
- jointing and sealing.

10.0 Whitetopping of Asphalt Concrete Pavements

b) Specifications and Manuals

No manuals or specifications issued by Transport Canada dealing explicitly with the construction of whitetopping overlays are available. However, Transport Canada has published an Engineering Reference Document (ERD 125-02) entitled *Maintenance and Repair of Airport Portland Cement Concrete (PCC) Pavements*.

Ministère des Transports du Québec (1999) has issued a useful guide for repair of PCC pavement.

The ACPA has issued a useful publication entitled *Whitetopping-State of the Practice (EB210 P)* and published similar guidelines such as a Transportation Research Board paper (Mack et al, 1998).

c) Field Performance Reports

No field performance studies issued by, or for, Canadian airport operators were located.

A recent review of the performance of whitetopping overlays was carried out by Webb and Delatte (2000). The authors concluded that for asphalt pavements plagued by rutting, whitetopping offers an economical and durable solution. They also discuss recent developments in the use of ultra-thin whitetopping overlays (less than 100 mm) that are designed to bond to the AC surface.

d) Laboratory and Theoretical Reports

No laboratory studies issued by, or for, Canadian airport operators were found.

References

1. American Concrete Pavement Association. *Whitetopping-State of the Practice*. EB210P.

2. Mack, J. W., Hawbaker, L. D., and Cole, L. W. 1998. *Ultra-Thin Whitetopping (UTW): The State-of-Practice for Thin Concrete Overlays of Asphalt*, Transportation Research Board Paper No. 98-0445, Transportation Research Board, Washington, DC.

3. Ministère des Transports du Québec. 1999. *Guide d'entretien et de rehabilitation des chausses en béton de ciment.*

4. Webb, R. D., and Delatte. 2000. *Performance of Whitetopping Overlays.* Transportation Research Board Paper No. 00-1068, Transportation Research Board, Washington, DC.

Appendix C

Gravel Surfaced Pavements

Pavement Preservation Treatments

1.0 Grading and Gravelling

Pavement type: Gravel surfaced pavements
Treatment type: Area maintenance
Distresses treated: Loose gravel, dust
Pot-holing, surface deformation and rutting
Washboarding, frost heaving and subgrade settlement

a) Synopsis

Grading with and without the addition of gravel is the most common maintenance treatment for gravel-surfaced pavements.

The recommended procedure for grading consists of the following steps.

- Grading of the pavement to achieve an appropriate crown and transverse slope. If the pavement crust is hard, the surface may need to be scarified. Some graders have scarifying tools attached to their frame.
- Addition of granular material. Watering may be required to facilitate compaction. For some applications, a dust palliative may also be added (Farha, 1992).
- Compaction. Steel vibratory rollers are preferred. Rubber tire rollers are an acceptable alternative.

The 2001 survey of the Canadian airport operators indicated that 14 out of 26 airport authorities have gravel pavements on either runways (one authority), aprons (three authorities) or airside roadways (ten authorities).

b) Specifications and Manuals

No manuals or specifications on the maintenance of gravel surfaced roads were located.

Transport Canada has published an Engineering Reference Document (ERD 125-06) entitled *Maintenance and Repair of Airport Gravel & Turf Landing Strips.*

Eaton and Beaucham (1992) and Visser et al (1994) developed useful guides for the management of gravel roads.

c) Field Performance and Other Reports

Transport Canada (1986) issued a report on shoulder erosion. While this report does not address grading of gravel surface pavements, it is concerned with maintenance of unpaved shoulders that are typically turf shoulders.

1.0 Grading and Gravelling

References

1. Farha, M. H. 1992. Trials of Dust Control Products at Campbell River Airport, B.C., Technical Evaluation Engineering, Aerodrome Safety, Transport Canada, Ottawa.

2. Transport Canada. 1986. Airfield Pavement Shoulder Erosion at Transport Canada Airports, Report AK-67-09-345, Airports Authority Group, Airport Facilities Branch, Surface Structures Division, Ottawa..

3. Visser, A. T., De Villiers, E. M., and van Fheerden, M. J. J. 1994. Operational Unpaved Road Management System in the Cape Province of South Africa, Transportation Research Board Record 1434, Transportation Research Board, Washington, D.C.

2.0 Dust Control

Pavement type: Gravel surfaced pavements
Treatment type: Area maintenance
Distresses treated: Dust
Loose gravel

a) Synopsis

Control of dust in the atmosphere generated by traffic and wind from the exposed aggregate surface is important for several reasons. Dust pollutes the atmosphere, creates health and driving hazards, increases building maintenance and aircraft and vehicle operating costs, and results in the loss of material from the surface and subsequent increase in pavement maintenance costs (Epps and Ehsan, 1999).

The basic maintenance practices available to reduce dust emissions include:

- Sprayed bituminous sealing
- Chemical palliative application
- Regular watering of the surface
- Reduction of aircraft and vehicle speed.

The 2001 survey indicated that 14 out of 26 airport authorities have gravel pavements on either runways (one authority), aprons (three authorities) or airside roadways (ten authorities).

b) Specifications and Manuals

No manuals or specifications on dust control were located.

c) Field Performance and Other Reports

Farha (1992) evaluated the performance of three dust palliative products at Campbell River Airport, B.C. The products evaluated were: i) Curasol AH, ii) Lignosite Road Binder, CAS 68131-32-8, and iii) EMC Squared "Earth Material Catalyst". Farha (1992) concluded that "Lignosite Road Binder" is the preferred product for dust control based on effectiveness, low cost and simplicity of application.

Epps and Ehsan, 1999, carried out a laboratory evaluation of three commercially available dust palliatives applied to three different aggregate types. Results obtained confirm that the use of dust palliatives can significantly reduce erosion of low-volume unpaved roads and show that the effectiveness of a particular palliative depends on aggregate type, traffic loads, and environmental conditions.

2.0 Dust Control

References

1. Epps, A., and Ehsan, M. 1999. A Laboratory Study Comparing the Effectiveness of Three Dust Palliatives on Unpaved Roads. Paper presented at the 79th Annual Meeting of the Transportation Research Board, Washington, D.C.

2. Farha, M. H. 1992. Trials of Dust Control Products at Campbell River Airport, B.C., Technical Evaluation Engineering, Aerodrome Safety, Transport Canada, Ottawa.

Appendix D

All Pavement Types

Pavement Preservation Treatments

1.0 Drainage Improvements

Pavement type:	Asphalt concrete, exposed PCC Composite, surface-treated, gravel surface
Treatment type:	Localized maintenance Area maintenance Rehabilitation
Distresses treated:	Pot-holing Rutting Cracking Frost heaving and subgrade settlement Faulting

a) Synopsis

Good drainage is an essential component of a well performing airport pavement. Pavement related drainage can be divided into pavement surface drainage, internal pavement drainage, and groundwater and slope drainage.

Surface Drainage

Surface drainage characteristics are influenced by the combination of the longitudinal and transverse slopes and surface layer permeability. Pavement rehabilitation and maintenance treatments should maintain the recommended crown and transverse slope. Surface infiltration is minimized by use of low permeability surface course materials. Normal asphalt concrete and PCC generally fulfil this function provided that cracks and joints in the pavement are properly sealed. Crack sealing, slurry sealing, and micro-surfacing treatments may be effective in reducing the infiltration of water through the pavement surface. Shoulder grading and turf surfaces should be maintained to ensure proper drainage.

Internal Drainage

The function of internal pavement drainage is to collect and discharge water that may enter the pavement structure through the pavement surface, shoulders, or from the subgrade. Internal drainage is facilitated by sloping the subgrade towards sub-drains (typically at a 3% slope), using drainable granular materials and protecting them from contamination with fines by using separator layers, and by discharging water from sub-drains. The maintenance and rehabilitation improvements of internal drainage are usually limited to cleaning outlets and installing or re-installing sub-drains. It is typically recommended that sub-drains (consisting of perforated plastic pipes, wrapped with a filter sock), should be installed in narrow trenches filled with clear stone or concrete sand.

Groundwater and Slope Drainage

The function of groundwater control and slope drainage is to intercept and drain groundwater in order to eliminate weakening of the subgrade by excessive moisture. A typical application is the use of drainage blankets under the pavement structure. Maintenance activities are typically limited to installing or re-installing interceptor drains and cleaning inlets and outlets.

b) Specifications and Manuals

No specifications or manuals prepared issued by, or for, Transport Canada are available.

A good review of the design of drainage systems for pavement structures is contained in MTO (1990).

c) Field Performance Reports

No reports dealing explicitly with the drainage of airport pavement structures were located.

There are a considerable number of reports on the design and performance of permeable granular bases - for example, a report from British Columbia (Haughton and Davidson, 1987) and from Ontario (Hajek et al, 1991). In the US, an NCHRP 1-34 study (Yu et al., 1998) included the performance evaluation of several pavement projects where side-by-side comparisons of pavement sections (both rigid and flexible) with and without open-graded drainage layers were possible.

d) Other Reports

No reports dealing explicitly with the drainage of airport pavement structures were found.

Raymond et al (1998, 1995) carried out a series of forensic evaluations of highway sub-drains in Ontario.

References

1. Haughton, D. R., and Davidson, A. 1987. *Subgrade Permeability and Pavement Performance*, Paper No. 870717, presented at the 67th Annual Meeting of the Transportation Research Board, Washington, D.C.

2. Kazmierowski, T. J., A. Bradbury, and J. Hajek. 1991. *Field Evaluation of Various Types of Open-Graded Drainage Layers*. Transportation Research Record 1434. Transportation Research Board, Washington, D.C.

3. MTO. 1990. *Pavement Design and rehabilitation Manual*, Ontario Ministry of Transportation, ISBN: 0-7729-6379-7.

1.0 Drainage Improvements

4. Raymond, G. P., Bathurst, R. J., and Hajek, J. J. 1988. *A Geotextile-Wrapped Aggregate Highway Drain Evaluation*, Proceedings, 6th International Conference on Geosynthetics, Atlanta, Georgia.

5. Raymond, G. P., Bathurst, R. J., and Hajek, J. J. 1995. *Evaluation of Highway Edge Drains Incorporating Geosynthetics*, in "Unbound Aggregates in Roads", Dawson, A., and Jones, R. editors, the University of Nottingham, Nottingham, United Kingdom, NG7 2RD.

6. Yu, H. T., Khazanovich L., Rao, S., Darter M. I., and Von Quintus, H. 1998. *Guidelines for Subsurface Drainage Based on Performance*, Final Report Prepared for National Cooperative Highway Research Program Project 1-34, National Research Council, Washington, DC.

2.0 Retexturing

Pavement type:	Exposed PCC Composite Asphalt Concrete
Treatment type:	Area maintenance Rehabilitation
Distresses treated:	Loss of friction Faulting

a) Synopsis

The retexturing of pavement surfaces usually involves the removal of a shallow depth of pavement surface material by using either chemical methods (etching) or impact methods (high pressure water or shot-blast). Transport Canada considers shot-blasting to be the most effective and economical method.

Retexturing is a maintenance activity used to improve pavement surface texture and thereby the skid resistance of the pavement surface. Retexturing (grinding) can also be used to make minor grade adjustments that will improve surface ride quality. The additional benefit of retexturing airport pavements is the removal of rubber from aircraft touchdown zones. The typical cost of retexturing is in the range of \$3 to \$4 per m^2.

Because a small amount of material is removed from the pavement surface, retexturing should only be used on pavements that are structurally adequate.

b) Specifications and Manuals

Transport Canada has published an airfield pavement maintenance specification entitled *Runway Rubber Removal & Surface Retexturing By Shot-Blasting (PMS 5540).*

Transport Canada has also published several Engineering Reference Documents on airfield pavement maintenance: a) *Maintenance and Repair of Airport Hot-Mix Asphalt Concrete (HMAC) Pavements (ERD 125-01),* and b) *Maintenance and Repair of Airport Portland Cement Concrete (PCC) Pavements (ERD 125-02).*

Ministère des Transports du Québec (1999) has issued a useful guide for repair of PCC pavement.

The ACPA (1990) has issued a useful publication entitled *Diamond Grinding.*

US. Federal Aviation Administration has published an Advisory Circular (Federal Aviation Administration, 1986) that contains guidance on determining runway surface friction characteristics, specifications for friction measuring equipment, and procedures for the construction and maintenance of skid resistant airport pavement surfaces.

2.0 Retexturing

c) Field Performance Reports

Hein et al (1992) evaluated the effectiveness of using pavement grinding on PCC surfaces located in the takeoff areas of Runway 06R/24L and taxiways Bravo and Echo at Toronto International Airport. Pavement grinding resulted in a relatively smooth pavement surface. The authors cautioned that grinding of structurally inadequate pavements will result in a further reduction in structural capacity and accelerated pavement deterioration.

A 1993 Transport Canada summary report (Transport Canada, 1993) reviewed trials of rubber removal techniques undertaken at Canadian Airports. The study reviewed chemical methods, ultra-high pressure water, and shot-blasting (satisfactory for rubber removal and improvement of pavement surface texture). The study also noted that the diamond grinding used at Toronto International Airport to correct slab stepping problems produced an excellent surface texture. Another Transport Canada report on rubber removal (Transport Canada, 1990) concluded that the use of ultra-high pressure water to remove rubber is effective and recommended the method for acceptance in project bids for removal of runway rubber deposits.

d) Laboratory and Theoretical Reports

Comfort and Gong (1998) analyzed pavement friction data collected by ground vehicles during the 1998 North Bay Joint Winter Runway Friction Measurement Program. The objective of the program was to assess pavement frictional properties during winter conditions (pavement covered with wet ice, slush, and packed and loose snow) and to obtain correlation among pavement friction measuring devices.

References

1. American Concrete Pavement Association. 1990. *Diamond Grinding and Concrete Pavement Restoration*. TB008P

2. Comfort, G., and Gong, Y. 1998. *Analysis of the Friction Factors Measured by the Ground Vehicles at the 1998 North Bay Trials*, Transport Canada, Transportation Development Centre, Report TP 13366E.

3. Federal Aviation Administration. 1986. *Advisory Circular No. 150/5320-12A.*

4. Ministère des Transports du Québec 1999. *Guide d'entretien et de rehabilitation des chausses en béton de ciment.*

5. Hein, D. K., MacKay, M. H., and Emery, J. J. 1992. *Evaluation and Treatment of Slab Stepping on a Major Runway*, Transportation Research Board Paper No. 1334, Transportation Research Board, Washington, D.C.

2.0 Retexturing

6. Transport Canada. 1990. *Runway Rubber Removal by Ultra High Pressure Water,* Report AK-97-09-376, Civil Engineering Services, Airports Group.

7. Transport Canada (1993). *Runway Surface Re-Texturing by Shotblast.*

Appendix E

Canadian Airport Operators Survey/Questionnaire

on

Pavement Preservation Treatments

Canadian Airport Operators Survey on Pavement Preservation Treatments

In conducting the review of airport pavement rehabilitation and preservation practices in Canada, input was sought from Canadian airport operators. A questionnaire was prepared and distributed to approximately 70 Canadian airport operators. The purpose of the survey was twofold:

- To obtain up-to-date information from individual Canadian airport operators regarding rehabilitation and maintenance practices in terms of the type of pavement preservation treatments used, frequency of their use, and the degree of satisfaction with subsequent performance of the treatment.

- To solicit technical reports and other documentation on the use and performance of pavement preservation treatments.

The survey was sent to all major airport operators in Canada. Responses were obtained from 26 operators. A copy of the survey questionnaire is given in this appendix. Questions covered the type of pavements used, the type of pavement maintenance and rehabilitation treatments used in the past, and ongoing pavement rehabilitation activities. For the most part, survey responses were complete and informative.

Table E1 provides the names of operators who responded to the survey, and a summary of their pavement facilities. All five pavement types (asphalt concrete, composite, exposed PCC, surface-treated, and gravel surfaced) are used for airside pavements.

Table E2 provides a summary of the pavement maintenance treatments used in the past and their performance. The results indicate that all pavement maintenance treatments included on the survey questionnaire have been used in the past, including micro-surfacing and slurry seals. However, micro-surfacing and surface treatments have not been used on PCC pavements.

Table E3 provides a summary of pavement rehabilitation treatments used in the past and their performance. The results indicate that the majority of all pavement rehabilitation treatments included on the survey questionnaire have been used in the past. The rehabilitation treatments that have not been used include whitetopping, cold in-place recycling, crack-and-seat and resurface with hot mix, and bonded/un-bonded overlays.

Canadian Airport Operators Survey on Pavement Preservation Treatments

Table E1: General Airport Pavement Facility Information

Airport		Types of Pavement Surfaces			
		Runways	Taxiways	Aprons	Airside Roads
1	Halifax International	Composite	H/CMAC	Composite/PCC	H/CMAC/Gravel
2	Penticton	HMAC	HMAC	H/CMAC	H/CMAC/Gravel
3	Medicine Hat	HMAC	HMAC	HMAC	N/A
4	Saskatoon	HMAC	H/CMAC/PCC	HMAC/PCC	H/CMAC
5	Campbell River	HMAC	HMAC	H/CMAC/ Surfaced Treated	Gravel
6	Sarnia Chris Hadfield	HMAC	HMAC	H/CMAC	H/CMAC
7	Kelowna	HMAC	HMAC	H/CMAC/PCC	H/CMAC
8	Whitehorse	HMAC	HMAC	H/CMAC/PCC	H/CMAC/ Surface Treated
9	Ottawa International	H/CMAC/ Composite	HMAC	HMAC/PCC	H/CMAC
10	Calgary International	H/CMAC/ Composite/PCC	H/CMAC/ Composite/PCC	PCC	H/CMAC/Gravel/ Surface Treated
11	Prince Albert	HMAC/ Composite/PCC	HMAC	HMAC/PCC/ Composite	Gravel
12	Muskoka	H/CMAC	H/CMAC	H/CMAC	H/CMAC
13	Regina	HMAC	HMAC	HMAC	HMAC
14	MTO - Remote Northern	HMAC/Gravel	HMAC/Gravel	HMAC/Gravel	
15	Toronto City Centre	HMAC /Surface Treated	HMAC	HMAC/ Surface Treated	HMAC
16	Charlottetown	HMAC	HMAC	PCC/HMAC	HMAC/Gravel
17	Saint John	HMAC	HMAC	HMAC	HMAC
18	Thompson	HMAC	HMAC/Gravel	PCC/Gravel	HMAC
19	Abbotsford	H/CMAC/PCC/ Composite	H/CMAC/ Composite	Composite	HMAC
20	Vancouver International	PCC/Composite	PCC/HMAC	PCC/HMAC	HMAC/Gravel
21	Flin Flon	HMAC	HMAC	HMAC	HMAC
22	Manitoba DOT - Northern	Gravel	Gravel	Gravel	Gravel
23	Dryden	HMAC/Gravel	HMAC	HMAC	HMAC/Gravel
24	Yorkton	HMAC/Gravel	HMAC/PCC/Gravel	HMAC/PCC	HMAC/Gravel
25	Windsor	HMAC	HMAC	PCC/HMAC	HMAC
26	Moncton	PCC/HMAC	HMAC	PCC/HMAC	HMAC/Gravel

Canadian Airport Operators Survey on Pavement Preservation Treatments

Table E2: Summary of Pavement Maintenance Treatments

Bituminous Pavements	Current Practice		Performance			
	Routine	Have Tried	Very Good	Good	Poor	Unknown
Joint Sealing with Rubberized Sealant	25	1	7	18	1	0
Shallow Patch Repair with Hot or Cold Mix	17	3	3	17	0	0
Spray Patching	1	1	0	1	1	0
Infrared/Heat Asphalt Patching	0	3	0	1	2	0
Slurry Sealing	3	2	0	4	1	0
Micro-Surfacing	0	2	1	1	0	0
Surface Treatment / Chip Sealing	0	1	0	1	0	0
Patching with Brand-Name (Proprietary) Cold Mix	2	2	0	2	2	0
Exposed Concrete (PCC) Pavements						
Joint/Crack Sealing with Rubberized Sealant	8	5	2	9	1	1
Joint/Crack Sealing with Silicone Sealant	2	4	1	4	1	0
Joint/Crack Sealing with Pre-Formed Sealant	0	2	0	0	1	0
Shallow Patch Repair with Concrete Material	1	7	1	3	3	1
Shallow Patch Repair with Hot or Cold Mix	8	3	0	9	0	2
Shallow Patch Repair with Brand Name Materials	0	2	0	0	2	0
Spray Patching	0	0	0	0	0	0
Full-Depth Asphalt Patching	2	2	1	2	1	0
Slurry Sealing	0	3	0	1	1	1
Micro-Surfacing	0	0	0	0	0	0
Surface Treatment/Chip Sealing	0	0	0	0	0	0

Table E3: Summary of Pavement Rehabilitation Treatments

Bituminous Pavements	Current Practice		Performance			
	Routine	Have Tried	Very Good	Good	Poor	Unknown
Hot Mix Resurfacing	12	6	1	17	0	0
Milling and Resurfacing with Hot or Cold Mix	10	6	2	13	0	0
Hot In-Place Recycling	0	3	0	3	0	0
Cold In-Place Recycling	0	0	0	0	0	0
Full Depth Reclamation	1	3	0	4	0	0
Full Depth Reclamation and Stabilization	1	2	0	3	0	0
Concrete In-Lay (White Topping)	0	0	0	0	0	0
Drainage Improvements	0	4	0	3	0	0
Exposed Concrete (PCC) Pavements						
Hot Mix Resurfacing	2	5	0	5	2	0
Joint Stabilization (Under Slab Grouting)	1	1	0	2	0	0
Diamond Grinding	0	1	0	1	0	0
Crack & Seat and Resurface with Hot Mix	0	0	0	0	0	0
Bonded / Unbonded Concrete Overlay	0	0	0	0	0	0
Spray Patching	0	0	0	0	0	0
Drainage Improvements	0	3	0	3	0	0
Full Slab Replacement	1	1	1	1	0	0
Mill and Replace with Fibre Reinforced Concrete	1	0	0	1	0	0

Canadian Airport Operators Survey on Pavement Preservation Treatments

Transport Canada
Pavement Restoration Information Engineering Study

1. Respondent Information

Name: ______________________________ Title: ________________________

Agency: ____

Phone: __ __________________________ Fax: _________________________

Email: ___________________________

2. General Facility Information

What is the largest aircraft using your facility?____________________________________
What is the predominant aircraft? ____________________________________
What is the typical daily traffic movement? ____________________________________

What pavement surface types do you have at your facility? (check all appropriate boxes)

	Concrete	Composite	Hot or Cold Mix Asphalt	Surface Treated	Gravel
Runways					
Taxiways					
Aprons					
Airside Roads					

3. Pavement Management

Do you have a pavement management system?

Yes ___ Under Development ___ Planning to Develop ___ No ___

What system to you have/plan to use?

___ Developed by others, name ____
___ Developed in-house ___ Not applicable

Canadian Airport Operators Survey on Pavement Preservation Treatments

How do rate the condition of your pavements?

Pavement Condition Index (PCI)? ___
Other? ____

4. Pavement Preventative/Routine Maintenance

Does your agency complete preventative/routine maintenance? Yes ___ No ___

Is maintenance initiated only when a perceived hazard exists? Yes ___ No ___

How do you develop and prioritize your pavement maintenance and rehabilitation program?

___ Using PMS ___ Engineering Judgement ___ Worst Condition First

Which of the following routine maintenance treatments do you use or have tried during the past 10 years:

Maintenance for Bituminous Pavements							
Treatment	**Current Practice**		**Performance**				**Would You Use This Treatment Again? Why or Why Not?**
	Routine	**Have Tried**	**Very Good**	**Good**	**Poor**	**Unknown**	
Joint/Crack Sealing with Rubberized Sealant							
Shallow Patch Repair with Hot or Cold Mix							
Spray Patching							
Infrared/Heat Asphalt Patching							
Slurry Sealing							
Micro-Surfacing							
Surface Treatment / Chip Sealing							
Patching with Brand-Name (Proprietary) Cold Mix							
Other Techniques/Materials (Please Add)							

Canadian Airport Operators Survey on Pavement Preservation Treatments

Maintenance for PCC (Exposed Concrete) Pavements							
Treatment	**Current Practice**		**Performance**				**Would You Use This Treatment Again? Why or Why Not?**
	Routine	**Have Tried**	**Very Good**	**Good**	**Poor**	**Unknown**	
Joint/Crack Sealing with Rubberized Sealant							
Joint/Crack Sealing with Silicone Sealant							
Joint Sealing with Pre-Formed Sealants							
Shallow Patch Repair with Concrete Materials							
Shallow Patch Repair with Hot or Cold Mix							
Shallow Patch Repair with Brand-Name Materials							
Spray Patching							
Full-Depth Asphalt Patching							
Slurry Sealing							
Micro-Surfacing							
Surface Treatment / Chip Sealing							
Other Techniques/Materials (Please Add)							

5. Rehabilitation Techniques

Which of the following rehabilitation treatments are in use or have been tried?

Rehabilitation Treatments for Bituminous Pavements							
Treatment	**Current Practice**		**Performance**				**Would You Use This Treatment Again? Why or Why Not?**
	Routine	**Have Tried**	**Very Good**	**Good**	**Poor**	**Unknown**	
Hot Mix Resurfacing							
Milling and Resurfacing with Hot or Cold Mix							
Hot In-Place Recycling							
Cold In-Place Recycling							
Full-Depth Reclamation							
Full-Depth Reclamation and Stabilization							
Concrete In-Lay (Whitetopping)							
Drainage Improvements (Specify)							
Other Techniques/Materials (Please Add)							

Canadian Airport Operators Survey on Pavement Preservation Treatments

Rehabilitation Treatments for PCC Pavements (Exposed Surface)							
Treatment	Current Practice		Performance				Would You Use This Treatment Again? Why or Why Not?
	Routine	Have Tried	Very Good	Good	Poor	Unknown	
Hot Mix Resurfacing							
Joint Stabilization (Under Slab Grouting)							
Diamond Grinding							
Rubblizing and Resurfacing with Hot Mix							
Crack & Seat and Resurface with Hot Mix							
Bonded/Unbonded Concrete Overlay							
Spray Patching							
Drainage Improvements (Specify)							
Other Techniques/Materials (Please Add)							

6. Ongoing Research and Development Activities

Is your agency currently evaluating the performance of new pavement maintenance/rehabilitation techniques? Yes ___ No ___ If yes, please elaborate:

____

____

Has your agency previously evaluated the performance of pavement of maintenance/rehabilitation techniques? Yes ___ No ___ If yes, please elaborate:

____

____

If yes, do you have any reports or documentation? Yes ___ No ___

Canadian Airport Operators Survey on Pavement Preservation Treatments

Would it be possible for the ERES research team to obtain any relevant documentation or data, if available? If yes, please indicate from whom or send us relevant documentation.

____

____

Please provide any other comments/insights on your agency experience with pavement maintenance/rehabilitation techniques.

____

____

Would you like to receive a copy of the results of this survey? Yes ___ No ___

Thank you for your participation in this survey. Please submit the completed form to David Hein by email (dhein@ara.com) or Chris Olidis by email (colidis@eresnet.com), or by fax (905) 846-3473 on or before January 26, 2001.

If you have any questions or concerns, please contact Dave Hein (905-846-9088) or Chris Olidis (905-422-5599).