PRESERVATION OF BITUMINOUS PAVEMENT USING THIN SURFACE RESTORATION TECHNIQUES

A BEST PRACTICE BY THE NATIONAL GUIDE TO SUSTAINABLE MUNICIPAL INFRASTRUCTURE (INFRAGUIDE)

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INFRAGUIDE – INNOVATIONS AND BEST PRACTICES

Why Canada Needs InfraGuide

Canadian municipalities spend $12 to $15 billion annually on infrastructure but it never seems to be enough. Existing infrastructure is aging while demand grows for more and better roads, and improved water and sewer systems. Municipalities must provide these services to satisfy higher standards for safety, health and environmental protection as well as population growth. The solution is to change the way we plan, design and manage infrastructure. Only by doing so can municipalities meet new demands within a fiscally responsible and environmentally sustainable framework, while preserving our quality of life.

This is what the National Guide to Sustainable Municipal Infrastructure: Innovations and Best Practices (InfraGuide) seeks to accomplish.

In 2001, the federal government, through its Infrastructure Canada Program (IC) and the National Research Council (NRC), joined forces with the Federation of Canadian Municipalities (FCM) to create the *National Guide to Sustainable Municipal Infrastructure (InfraGuide)*. InfraGuide is both a new, national network of people and a growing collection of published best practice documents for use by decision makers and technical personnel in the public and private sectors. Based on Canadian experience and research, the reports set out the best practices to support sustainable municipal infrastructure decisions and actions in six key areas: municipal roads and sidewalks, potable water, storm and wastewater, decision making and investment planning, environmental protocols, and transit. The best practices are available on-line and in hard copy.

A Knowledge Network of Excellence

InfraGuide's creation is made possible through $12.5 million from Infrastructure Canada, in-kind contributions from various facets of the industry, technical resources, the collaborative effort of municipal practitioners, researchers and other experts, and a host of volunteers throughout the country. By gathering and synthesizing the best Canadian experience and knowledge, InfraGuide helps municipalities get the maximum return on every dollar they spend on infrastructure—while being mindful of the social and environmental implications of their decisions.

Volunteer technical committees and working groups—with the assistance of consultants and other stakeholders—are responsible for the research and publication of the best practices. This is a system of shared knowledge, shared responsibility and shared benefits. We urge you to become a part of the

InfraGuide Network of Excellence. Whether you are a municipal engineer, a planner or a municipal councillor, your input is critical to the quality of our work.

Please join us.

Contact InfraGuide toll-free at **1-866-330-3350** or visit our Web site at ***www.infraguide.ca*** for more information. We look forward to working with you.

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Mike Sheflin	Former CAO Regional Municipality of Ottawa-Carleton, Ottawa, Ontario
Brian Anderson	Ontario Good Roads Association, Chatham, Ontario
Vince Aurilio	Ontario Hot Mix Producers Association, Mississauga, Ontario
Don Brennan	Province of Newfoundland
Don Brynildsen	City of Vancouver, British Columbia
Al Cepas	City of Edmonton, Alberta
Brian Crist	City of Whitehorse, Yukon
Bill Larkin	City of Winnipeg, Manitoba
Tim Smith	Cement Association of Canada, Ottawa
Sylvain Boudreau	Technical Manager, National Research Council Canada, Ottawa, Ontario
Shelley McDonald	Technical Advisor, National Research Council Canada, Ottawa, Ontario

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Al Cepas, Chair	Pavement Management Engineer, Transportation Department, City of Edmonton, Alberta
Vince Aurilio	Technical Director, Ontario Hot Mix Producers Association, Mississauga, Ontario
Bruce Armstrong	LaFarge Asphalt Engineering, Mississauga, Ontario
Bill Biensch	Maintenance Project Engineer, City of Calgary, Alberta
Don P. Brennan	Department of Works Services and Transportation, Government of Newfoundland and Labrador, St.John's, Newfoundland and Labrador
Jean Martin Croteau	Manager, Specialty Products and Processes, Miller Paving Limited, Gormley, Ontario

Colin Prang	Project Engineer for Roadway Preservation, City of Saskatoon, Saskatchewan
Graham Zeisner	RoadLogic Inc., Ottawa, Ontario
Jerry J. Hajek	Consultant, ERES Division of Applied Research Associates Inc.

David Hein Consultant, Principal Engineer,
ERES Division of Applied Research Associates Inc.

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Steve Goodman	City of Ottawa, Ontario
Colin Sizer	City of Brampton, Ontario

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Governing Council:

Joe Augé	Government of the Northwest Territories, Yellowknife, Northwest Territories
Mike Badham	City of Regina, Saskatchewan
Sherif Barakat	National Research Council Canada, Ottawa, Ontario
Brock Carlton	Federation of Canadian Municipalities, Ottawa, Ontario
Jim D'Orazio	Greater Toronto Sewer and Watermain Contractors Association, Toronto, Ontario
Douglas P. Floyd	Delcan Corporation, Toronto, Ontario
Derm Flynn	Town of Appleton, Newfoundland and Labrador
John Hodgson	City of Edmonton, Alberta
Joan Lougheed	Councillor, City of Burlington, Ontario
Saeed Mirza	McGill University, Montréal, Quebec
Umendra Mital	City of Surrey, British Columbia
René Morency	Régie des installations olympiques, Montréal, Quebec
Vaughn Paul	First Nations (Alberta) Technical Services Advisory Group, Edmonton, Alberta
Ric Robertshaw	Public Works, Region of Peel, Brampton, Ontario
Dave Rudberg	City of Vancouver, British Columbia
Van Simonson	City of Saskatoon, Saskatchewan
Basil Stewart, Mayor	City of Summerside, Prince Edward Island

Serge Thériault	Government of New Brunswick, Fredericton, New Brunswick
Tony Varriano	Infrastructure Canada, Ottawa, Ontario
Alec Waters	Alberta Infrastructure Department, Edmonton, Alberta
Wally Wells	The Wells Infrastructure Group Inc., Toronto, Ontario

Municipal Infrastructure Committee:

Al Cepas	City of Edmonton, Alberta
Wayne Green	Green Management Inc., Mississauga, Ontario
Haseen Khan	Government of Newfoundland and Labrador St. John’s, Newfoundland and Labrador
Ed S. Kovacs	City of Cambridge, Ontario
Saeed Mirza	McGill University, Montréal, Quebec
Umendra Mital	City of Surrey, British Columbia
Carl Yates	Halifax Regional Water Commission, Nova Scotia

Relationship Infrastructure Committee:

Geoff Greenough	City of Moncton, New Brunswick
Joan Lougheed	City Councillor, Burlington, Ontario
Osama Moselhi	Concordia University, Montréal, Quebec
Anne-Marie Parent	Parent Latreille and Associates, Montréal, Quebec
Konrad Siu	City of Edmonton, Alberta
Wally Wells	The Wells Infrastructure Group Inc., Toronto, Ontario

Founding Member:

Canadian Public Works Association (CPWA)

EXECUTIVE SUMMARY

This document outlines best practice for the use of thin surface restoration techniques for the preservation of bituminous pavements. Thin surface restoration techniques are treatments applied to the pavement surface that increase pavement thickness by less than 40 mm. This distinction is made because overlays that are 40 mm thick or more are usually associated with routine paving operations.

The following treatments are described in this best practice:

1. thin hot mix overlay (less than 40 mm);
2. hot-in-place recycling (with the total depth of re-processed and new material of less than 40 mm);
3. micro-surfacing;
4. slurry seal;
5. surface treatment;
6. restorative seal; and
7. texturization.

Thin surface restoration techniques do not significantly increase the strength of the pavement, but benefit pavements by protecting the pavement structure from premature deterioration and/or by improving or restoring the pavement surface. Thin pavement surface restoration techniques are also well-suited as temporary treatments until a permanent treatment can be implemented. In addition, for low traffic volume roads, thin pavement surface restoration techniques provide a cost-effective dust-free wearing surface.

This best practice should be of interest to managers and technical personnel responsible for developing pavement preservation programs and for the selection of pavement preservation treatments. The benefits of this best practice can be realized in several ways:

The best practice describes the technology of thin surface restoration techniques for bituminous pavements, including materials and construction techniques, expected service life and costs, surface preparation requirements, detailed procedures for choosing between alternative treatments, examples of use by Canadian municipalities, potential challenges, and new developments.
The practice promotes the use of preventive maintenance for pavement preservation. It describes how to use thin surface restoration techniques as preventive maintenance treatments, and provides guidelines on how to incorporate the use of these treatments into existing pavement management procedures.

It provides guidelines for the systematic evaluation of the performance of new treatments.

It also provides references for key reports, manuals, and performance reports where the user can obtain additional information.

Finally, it promotes the use of common terms for describing different types of thin surface restoration techniques to improve inter- and intra-agency communication. The use of thin surface restoration techniques should be part of the pavement preservation toolbox of all municipal agencies.

1. GENERAL

1.1. INTRODUCTION

The key to cost-effective preservation of pavements is to have a toolbox that includes thin surface restoration techniques for bituminous pavements. Thin surface restoration techniques are treatments applied to the pavement surface that increase pavement thickness by less than 40 mm. Most common types of thin surface restoration techniques for bituminous pavements are thin asphalt concrete overlay, surface treatment, slurry seal, and micro-surfacing. These treatments do not significantly increase the strength of the pavement, but benefit pavements by protecting the pavement structure from premature deterioration and by improving or restoring pavement surface. In addition, for low traffic volume roads, thin pavement surface restoration techniques can provide a cost-effective dust-free wearing surface.

1.2. PURPOSE AND SCOPE

The purpose of this best practice is to provide guidelines for the use of thin restoration techniques for the preservation of bituminous pavements. The report describes the following seven types of thin pavement restoration techniques:

1. thin hot mix overlay (less than 40 mm in thickness);
2. hot-in-place recycling (with total depth of re-processed and new material of less than 40 mm);
3. micro-surfacing;
4. slurry seal;
5. surface treatment;
6. restorative seal; and
7. texturization.

Specific topics include:

- The use of thin surface restoration techniques in pavement preservation, particularly their role in preventive maintenance.
- Technology of thin surface restoration techniques, including materials and construction, selection criteria, design, surface preparation, and municipal use.
- The selection of thin surface restoration techniques both on a network level, as part of pavement management system, and on a project level as detailed evaluation of alternatives for specific projects.
- Guidelines for establishing ongoing monitoring and performance evaluation of pavement preservation treatments.

The 40 mm thickness limitation was chosen to group together treatments that serve a similar purpose and are often applied as preventive maintenance treatments. Nevertheless, the grouping is arbitrary and the user should not be restricted by the 40 mm limitation when choosing overlay thickness. Also, the thin surface restoration techniques described in this best practice do not include all preventive maintenance treatments for asphalt concrete pavements. Notably missing are treatments involving sealing of cracks (described in the best practice *Guidelines for Sealing and Filling Cracks in Asphalt Concrete Pavement* (InfraGuide, 2003a) and patching (e.g., spray patching or hot mix patching) described in *Reference Manual of Pavement Preservation Treatments* (InfraGuide, 2005).

The description of thin surface restoration techniques is illustrated by examples of practice obtained by interviewing representatives of 22 Canadian municipalities known for their innovative approaches to pavement preservation, and by surveying over 40 other Canadian municipalities. Both small and large municipalities from all regions of the country were included in the surveys. The results indicate a large variation in the use of thin surface restoration techniques between municipalities. About 30 percent of municipalities do not use any of the seven thin surface restoration techniques, whereas about 20 percent of municipalities routinely use three or more treatments (Figure 1–1).

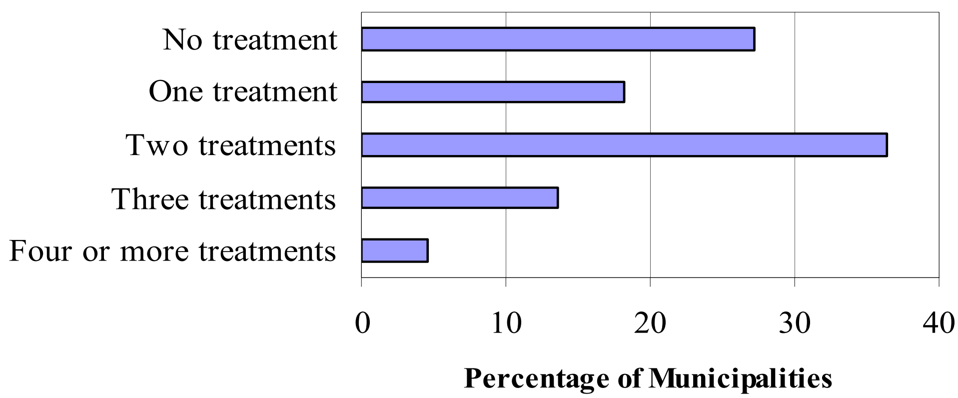


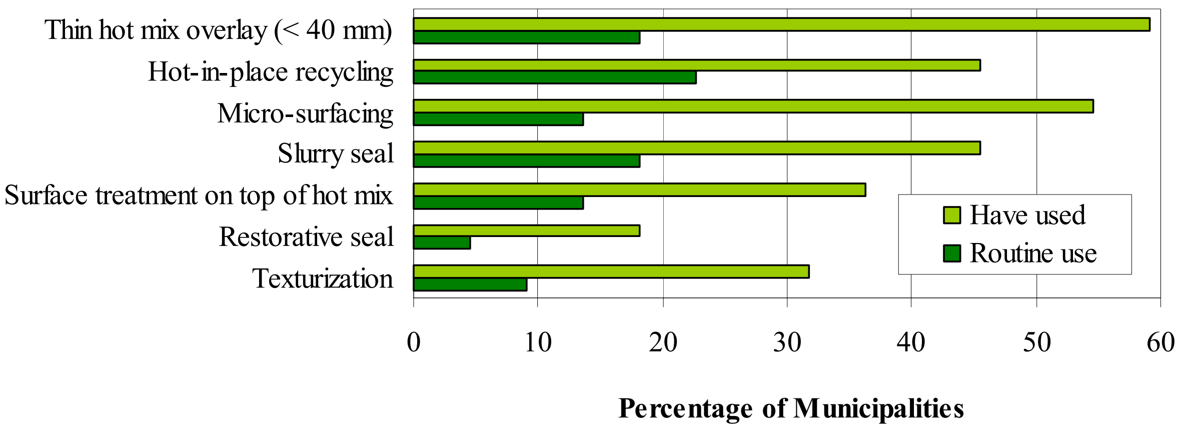
Figure 1–1: Frequency of use of thin surface restoration techniques by Canadian municipalities[1]

To reflect the uneven usage of thin surface restoration techniques, this best practice provides both basic information for those who have never used thin surface restoration techniques as well as additional information on recent developments and technological advancements for those who already use them. More detailed information can be obtained from key publications and manuals referenced in this report.

[1] Based on 2003/04 survey interviews with 22 municipalities

According to Figure 1–2, even though a relatively high percentage of municipalities used several thin surface restoration techniques in the past, a relatively small percentage of municipalities routinely use them. For example, about 55 percent of municipalities used, micro-surfacing in the past, whereas only about 15 percent of municipalities used it routinely. This report should contribute to more frequent and cost-effective use of thin surface restoration techniques by Canadian municipalities.

Figure 1–2: Types of thin surface restoration techniques used by municipalities[2]



1.3. HOW TO USE THIS DOCUMENT

This document should be used together with other pavement management procedures and best practices dealing with pavement preservation. Additional information on the technology of thin surface restoration techniques, as well as on other pavement preservation treatments, is provided in *Reference Manual of Pavement Preservation Treatments* (InfraGuide, 2005).

The selection of projects involving thin surface restoration techniques should be integrated with the selection of all other pavement preservation treatments as outlined in the best practice *Priority Planning and Budgeting Process for Pavement Maintenance and Rehabilitation* (InfraGuide, 2003b). The use of thin surface restoration techniques as part of a preventive maintenance program should include the principles outlined in the best practice *Timely Preventive Maintenance for Municipal Roads — A Primer* (InfraGuide, 2002).

[2] Based on 2003/04 survey interviews with 22 municipalities

1.4 GLOSSARY

The objective of the glossary is to promote common terminology for thin surface restoration techniques. This is necessary because many terms describing types of thin surface restoration techniques, and even the term *thin surface restoration techniques*, do not have generally accepted definitions.[3] To facilitate the introduction of a common terminology, the glossary includes description of commonly used terms concerning thin surface restoration techniques even if these terms are not used in this best practice.

Asphalt binder — Asphalt material (such as asphalt cement, asphalt emulsion, or liquid asphalt) used to bind together aggregate particles or to bind them to the pavement surface.

Asphalt emulsion or emulsion — A homogeneous mixture of asphalt cement, water and emulsifier where microscopic droplets of asphalt are dispersed and suspended in water. Typically, asphalt cement makes up to 70 percent of the emulsion. Emulsions are used for many thin pavement surfacings such as surface treatment, micro-surfacing, slurry seal, and restorative seal. Different types of asphalt emulsions are defined in Table 1–1.

Cape seal — Application of *slurry seal* to a newly constructed *surface treatment*, typically after one or two months when the surface treatment is cured.

Chip seal — *See seal coat*.

Dense-graded — Dense-graded (also called *graded or well-graded*) refers to the property of aggregate or to the property of materials utilizing such aggregate, e.g., dense-graded asphalt concrete. Dense graded aggregate particles are fairly uniformly distributed throughout a full range of applicable sieve sizes. Refer also to the definition for open-graded.

[3] Canadian General Standards Board no longer supports standards dealing with pavement technology such as Standard Can 2-16.6-M81 (*Principal Uses and terminology for Asphalt Materials for Road Purposes*) that may contain definitions applicable to this best practice.

Table 1–1: **Types of asphalt emulsion**

Type of asphalt emulsion			
Characteristic		**Type**	**Abbreviation**
Electrical charge of the emulsion		*Cationic* (C, or positive charge); *Anionic* (or negative charge); *Nonionic* (or neutral charge)	C[1]
Setting time in terms of the time required for the emulsion to revert to asphalt cement		*Rapid Setting* (RS); *Medium Setting* (MS), *Slow Setting* (SS)	RS, MS, SS
Setting time in terms of hardening of a micro-surfacing or a slurry seal mix		*Quick set, Quick-traffic,* or *Quick-Set Mixing Grade*[2]	QS
Viscosity of emulsion[3]		*Low viscosity, High viscosity*	1, 2
Hardness of AC in emulsion[4]		*Hard*	h
Passing the Float Test[5]		*High Float*	HF
Penetration of AC in a high float emulsion		*Low, Medium, or High Penetration*	100, 150, 250
Addition to AC or the emulsion	Polymers	*Polymer modified*	P
	Rubber (ground rubber tires)	*Rubberized*	No commonly used abbreviation

1) For anionic emulsions the C designation is simply omitted. Nonionic emulsions are seldom used.
2) The three terms are used interchangeably.
3) Viscosity is a measure of the fluidity of an emulsion at specified temperatures. Applies only to emulsions that are not High Float. Performance-grading of the asphalt cement used for emulsions is not yet available.
4) Applies only to emulsions that are not High Float. As measured by penetration test.
5) AASHTO T-50 or ASTM D-139. Unless otherwise specified (by the HF designation), the emulsion is not high float.

Example: CRS-2P means cationic rapid setting high viscosity polymerized asphalt emulsion.

Diamond grinding — Removing the surface of an asphalt pavement (or Portland concrete pavement) using a machine equipped with closely-spaced parallel diamond-tipped saw blades. The ridges left between the blades break off readily resulting in the *surface texture depth* that is similar to that of new dense-graded asphalt concrete. Some agencies accept the use of diamond grinding as a finished surface if it is used to improve smoothness of newly constructed asphalt concrete pavements.

Fog seal — See *restorative seal*.

Hot-in-place recycling — A paving process that involves softening of the existing asphalt surface with heat, mechanically removing the surface material and mixing it on the road (in-place) with a recycling agent and, if required, with aggregate or beneficiating hot mix, at temperatures normally associated with hot-mix paving. Hot-in-place recycling qualifies as a thin pavement surfacing if the total depth of the recycled layer, and the additional layer used to protect the recycled layer, is less than 40 mm.

Hot-in-place recycling with an integral overlay — Hot-in-place recycling with the addition of a thin layer of hot mix (on the top of the recycled layer) during the recycling operation.

Liquid asphalt — Asphalt cement which has been modified by blending it with petroleum solvents (kerosene, diesel fuel) to be liquid at room temperature. Liquid asphalt is also called cut-back.

Micro-milling — Removal of the surface of an asphalt concrete pavement (or Portland cement concrete pavement) by a self-propelled guided unit equipped with a helical cutting drum with carbide-tipped tools. Typically, the depth of micro-milling is up to 15 mm and results in a *surface texture depth* of about 1 mm and groove-to-groove spacing of 5 mm.

Micro-surfacing — An unheated mixture of polymer-modified asphalt emulsion, high-quality frictional aggregate, mineral filler, water, and other additives, mixed and spread over the pavement surface as a slurry. The fundamental difference between micro-surfacing and a *slurry seal* is related to the tightness and strength of the mineral skeleton (Croteau et al, 2002). The mineral skeleton used for micro-surfacing consists of high-quality interlocking crushed aggregate particles. Consequently, it is possible to place micro-surfacing in layers thicker than the largest aggregate size, or in multiple layers, without the risk of permanent deformation. In contrast, a typical slurry seal thickness does not exceed the thickness of the largest aggregate particle in the mix.

Milling — Removal of asphalt or Portland cement materials from pavements by a self-propelled unit having a cutting drum equipped with carbide-tipped tools. *Micro-milling* and *precision-milling* are types of milling.

Open-graded — Refers to the property of aggregate or to the property of materials utilizing such aggregate, e.g., open-graded asphalt concrete. An open-graded aggregate contains a predominant amount of aggregate particles of similar size, creating a large amount of voids between the particles. Open-graded is also called uniformly graded or gap-graded. Refer also to the definition for *dense-graded*.

Preventive maintenance — A planned strategy of cost-effective treatments. There is a difference between preventive maintenance (a strategy) and preventive maintenance treatment (an action). – ensure consistent definition with other published BP's

Preventive maintenance treatment — A treatment performed to prevent premature deterioration of the pavement, or to retard the progress of pavement defects. The objective is to slow down the rate of pavement deterioration and cost-effectively increase the useful life of the pavement. – use MR-1 definition

Precision milling — Removal of the surface of an asphalt concrete (or Portland cement concrete) pavement by a self-propelled unit having a cutting drum equipped with closely spaced carbide-tipped tools. Typically, the depth of precision milling is up to 25 mm and results in a *surface texture depth* of about 5 mm.

Primer — See definition provided in Table 1–2.

Recycling agent — Organic material added to reclaimed asphalt concrete material to improve binder deficiencies and to restore aged binder to desired specifications. Also called rejuvenating agent or rejuvenator.

Restorative seal — An application of a bituminous material to the surface of asphalt concrete pavement. Restorative seals are also referred to as rejuvenators or *fog seals*. Some agencies or suppliers recommend light sanding after the application of restorative seals (about one kg of sand per square meter).

Scrub seal — Application of asphalt binder to the pavement surface followed by the broom scrubbing of the binder into cracks and voids, and sanding. Scrub seal is a type of *surface treatment*.

Seal coat, **Seal, Surface seal, Chip seal, —** Any thin pavement surfacing that adds bituminous material to the pavement surface and is not a hot mix. There is no common definition of a seal coat. Some agencies, such as the British Columbia Ministry of Transportation and Highways, use this term to mean surface treatment only, other agencies call all thin surface restoration techniques that do not use hot mix (surface treatment, slurry seal, micro-surfacing, restorative seals) seal coats, others (Smith, 1990) use the terms *surface treatment* and *seal coat* interchangeably. Alberta Transportation uses the term asphalt seal coat to mean in-place mixing and spreading a cold asphalt mix. It is recommended to distinguish between *surface treatment* and *seal coat*. Surface treatment is a specific type of seal coat.

Slurry seal — An unheated mixture of emulsion, graded fine aggregate, mineral filler, water, and other additives, mixed and uniformly spread over the pavement surface as a slurry. Slurry seal is also referred to as quickset slurry seal (Croteau et al, 2002), emulsified asphalt slurry seal (ISSA, 2003), or thin cold-mix seal. Slurry seals are formulated with the objective of creating a bitumen rich mortar. The mineral skeleton is typically not very strong with limited interlocking of the aggregate particles. Consequently, slurry seals are applied in thin lifts to avoid permanent deformation by traffic.

Surface texture depth — Texture depth of the pavement surface measured by the sand patch test (ASTM E965). The test involves taking a known volume of artificial sand (glass beads) and spreading it over the pavement surface until all depressions are filled to the peaks. The ratio of volume of sand to the area covered by the sand is the surface texture depth. Typical *dense-graded* hot mix has a texture depth of about 0.4 mm or less.

Surface treatment — An application of asphalt binder, immediately followed by an application of cover aggregate, to any type of pavement surface.[4] Surface treatment is also *called bituminous surface treatment* (e.g., in New Brunswick) or

[4] Canadian General Standards Board (CGSB) Can 2-16.6-M81 (Principal Uses and Terminology for Asphalt Materials for Road Purposes) gives the definition of surface treatment as: “an application of asphalt material, usually followed by a cover coat of aggregate, to any type of road or pavement surface, which

asphalt surface treatment (e.g., in Manitoba, and Northwest and Yukon Territories*)* or a *seal coat* (Alberta Transportation). There are different types of surface treatments depending on the type of cover aggregate and the number of applications as summarized in Table 1–2.

Tack coat — Application of bituminous material, typically asphalt emulsion diluted by water, to the surface of asphalt concrete (or Portland concrete) layer. It is used to improve the bond between the existing surface and the overlying course. A tack coat applied on a granular surface is called *primer or prime coat* (Table 1–2).

Texturization — A process of abrading pavement surface to reduce roughness or improve pavement friction, resulting in the surface that can be used as a driving surface. Texturization techniques include diamond grinding, fine milling, micro-milling, precision milling, and other techniques.

Table 1–2: **Terms used to describe different types of surface treatments.**

	Aggregate Type		
Type of application	**Open-graded** (chips)	**Dense-graded** (graded aggregate)	**Sand**
One application of binder and one application of cover aggregate	*Chip seal*[1] *or* *Single chip seal*	*Surface treatment or Single surface treatment*	*Sand seal*[3] *Primer*[4] *Scrub seal*[5]
Two[2] applications of binder and two application of cover aggregate	*Double chip seal*	*Double surface treatment*	Not used
One application of binder followed by two applications of cover aggregate	*Choke seal*[6,7]	Not used	Not used
Application of aggregate followed by one application of binder and a second application of aggregate[6]	*Sandwich seal*	Not used	Not used

1) Chip seal is also called surface treatment. Chip seal is a surface treatment using open-graded aggregate.
2) Three applications are also used. Two or more applications of binder and cover aggregate are also called double or multiple chip seals or double or multiple surface treatments.
3) If left as a finished surface.
4) If applied on a granular surface and followed by another surface treatment application. *Primer* is also called a *prime coat*.
5) If brooms are used to scrub the binder into cracks and voids.
6) Also called racked in chip seal (FHWA 2003).
7) The aggregate used on top is smaller than that used on the bottom. Typically used on the surface with excess asphalt binder.

Notes:

Names of surface treatments may include adjectives describing material properties of the binder and cover aggregate, e.g., rubberized asphalt chip seal.

Surface treatments that are applied on only a portion of the roadway are called, depending on the type of aggregate used and on the application method, spray patching, manual chip seal, and mechanized spray patching.

Thin (pavement) surfacing — A treatment applied to the pavement surface that increases pavement thickness by less than 40 mm.

Thin (hot mix) overlays — Asphalt concrete overlays less than 40 mm thick.[5] Overlays that are 20 mm thick or less are commonly called *ultra-thin (hot mix) overlays*.

Ultra-thin hot mix overlay — Overlay that is less than 20 mm thick.

[5] The National Asphalt Pavement Association (NAPA) uses the term "thin hot-mix asphalt surfacings" defined as asphalt concrete overlays that are 1½ inch (38 mm) thick or less.

2. THE FUNCTION OF THIN SURFACE RESTORATION TECHNIQUES

2.1. REASONS

The interest in thin surface restoration techniques has increased with the ongoing improvements in their technology and cost-effectiveness, the need for less expensive pavement preservation treatments and the growing importance of preventive maintenance. In addition, these treatments have other benefits compared to traditional hot-mix overlays because they use less material and less energy (e.g., slurry seals and micro-surfacing produce thin asphalt concrete surfaces without heating the material), and their impact on other features of the roadway is minimal (e.g., reduction in curb height, and the need to increase thickness of shoulders and adjust the height of guide rails).

Thin surface restoration techniques can improve the pavement profile (by reducing roughness and rutting), improve pavement friction and, with the exception of texturization techniques, seal the pavement surface. Thin surface restoration techniques do not substantially change pavement structural strength and cannot effectively correct large surface distortions. There are four basic reasons for using thin surface restoration techniques:

a) Protecting pavement structure
Thin surface restoration techniques can be used as preventive maintenance treatments to prevent premature deterioration of the pavement or to retard the progress of pavement defects. The objective is to slow down the rate of pavement deterioration and cost-effectively increase the useful life of the pavement. As a preventive maintenance treatment, thin surface restoration techniques are applied when the pavements are mostly in good condition. Preventive maintenance concepts are described in the best practice *Timely Preventive Maintenance for Municipal Roads — A Primer* (InfraGuide, 2002).

b) Restoring or improving pavement surface
Thin surface restoration techniques are used as inexpensive treatments to restore or improve pavement condition to an acceptable level. The restoration includes correction of roughness and rutting, improvement of pavement friction, sealing a porous pavement surface, and reducing pavement-tire noise. For example, micro-milling can be used to reduce or eliminate wheel track rutting or to restore pavement friction.

c) Providing wearing surface
Thin surface restoration techniques can be used as a wearing surface for new or rehabilitated pavements. For example, surface treatments are often used to provide a wearing surface on a granular base, a slurry seal can be used to provide a wearing surface on a recycled asphalt concrete layer.

d) Extending pavement life until a permanent treatment is applied
Thin surface restoration techniques are well-suited as temporary treatments, keeping the pavement at or above an acceptable condition, until a permanent treatment can be implemented. This situation may arise, for example, because of lack of funding, unexpected rapid deterioration of the pavement surface, or the need to extend pavement life by only a few years for instance to enable coordination of works with other planned works in the right-of-way.

2.2 BENEFITS

This best practice should be of interest to managers and technical personnel responsible for developing pavement preservation programs and for the selection of pavement preservation treatments. The benefits of this best practice can be realized in several ways:

- The best practice describes the technology of thin surface restoration techniques, including materials and construction techniques, expected service life and costs, surface preparation requirements, detailed procedures for choosing between alternative treatments, examples of use by Canadian municipalities, potential challenges, and new developments.
- It promotes the use of preventive maintenance for pavement preservation. This is accomplished by describing the use of thin surface restoration techniques as preventive maintenance treatments, and by providing guidelines on how to incorporate the use of these treatments as part of existing pavement management procedures.
- It provides guidelines for systematic monitoring and performance evaluation of new treatments.
- It provides references for key reports, manuals, and performance reports where the user can obtain additional information.
- It promotes the use of common terms for describing different types of thin surface restoration techniques to improve inter- and intra-agency communication.

2.3 LIMITATIONS

The subject of thin surface restoration techniques is extensive and this best practice can only provide a basic description of the subject. The focus is on the use, performance, and selection of thin surface restoration techniques with limited information on material specifications and construction procedures. Also, the best practice concentrates on the most common and current techniques used by Canadian municipalities with only limited amounts of information on experimental techniques used elsewhere. Technical information provided in this best practice is for general use and its applicability should always be verified for specific site conditions.

3. WORK DESCRIPTION

3.1 COSTS AND BENEFITS

Typical costs and benefits of thin surface restoration techniques are summarized in Table 3–1. The costs in Table 3–1 are relative costs that are related to the assumed cost of $5.00 for one square meter of thin hot mix overlay. Actual costs depend on layer thickness; quality of materials; size, location, and time of the project; and on market forces.

Table 3–1: Expected benefits and typical cost of thin surface restoration techniques.

	Expected benefit (life-span) when applied to asphalt concrete pavement, years		Typical unit cost, $	
Treatment	Used to protect pavement structure	Used to restore or improve pavement surface	Per m^2	Per 1 km of 2-lane road
1. Thin hot mix overlay (<40 mm)	5 to 10	6 to 12	5.00	47,500
2. Hot-in-place recycling (< 40 mm)	5 to 10	6 to 14	5.50	41,000
3. Micro-surfacing	4 to 6	5 to 8	3.50	26,500
4. Slurry seal	3 to 6	3 to 7	2.50	18,500
5. Surface treatment[1)]	4 to 6	5 to 8	2.00	15,000
6. Restorative seal	1 to 2	1 to 3	1.00	7,500
7. Texturization	0	1 to 5	2.00	15,000

1) If applied on granular base: 7-10 years for single surface treatment
9 to 13 years for double surface treatment

Treatment benefits given in Table 3–1 are shown separately for the two main reasons the thin surface restoration techniques are used: (a) protecting pavement structure and (b) restoring or improving pavement surface (Section 2.1).

If a treatment is *used to protect pavement structure* of the existing pavement as a preventive maintenance treatment, the benefit of the treatment is expressed in terms of the additional life-span of the pavement. For example, if a slurry seal is used to improve the durability of an asphalt concrete pavement (slurry seal is applied when pavement is in good condition), its benefit is expressed as the additional life-span of the original pavement (3-6 years).

If a treatment is *used to restore or improve pavement surface*, and is initiated as a remedy for a specific distress, its benefit is expressed in terms of the life-span of the treatment itself. For example, if slurry seal is used to restore pavement friction, its benefit is expressed as the time-span of the slurry seal (3-7 years).

The difference between the two reasons for using the treatment is not always clear cut. However, it is important to realize that benefits of preventive maintenance treatments are typically expressed as the extension of the life-span of the pavement receiving the preventive maintenance treatment rather than as the life-span of the treatment itself.[6]

Expected benefits of thin surface restoration techniques are provided as a range of life-spans in years. Longer life-spans are typically associated with thicker or multiple treatments, higher-quality materials, improved construction quality, lower traffic volumes, and the application of treatments to pavements in better condition.

3.2 Types of Thin Pavement Surfacings

This section contains a brief description of the seven main types of thin surface restoration techniques listed in Section 2.1. The description includes materials and construction, selection criteria and surface preparation, examples of municipal use, and resources to obtain more information.

Additional information on these and other pavement preservation treatments is summarized in *Reference Manual of Pavement Preservation Treatments* (InfraGuide, 2005).

3.2.1 Thin Hot Mix Overlays

To be considered a thin surfacing, the thickness of a hot mix overlay must be less than 40 mm. This requirement was made as overlays that are 40 mm thick or more are used by many agencies and are usually associated with routine paving operations. On the other hand, overlays that are less than 40 mm thick are typically singled out by agencies as thin overlays that may require special construction provisions. Also, overlays thinner than 40 mm do not contribute substantially to the structural strength of the pavement and tend to provide a similar function, as do other thin surface restoration techniques. Overlays that are less than 20 mm thick are typically called ultra-thin (hot mix) overlays.

Materials and Construction

The two main types of hot mix used for thin overlays are polymer-modified dense-graded and open-graded mixes. Dense-graded mixes typically use sandy mixes with the largest aggregate particle passing the 13.2 mm sieve, and seal the pavement surface from the intrusion of water. Open graded mixes contain a large percentage of one-size coarse aggregate resulting in a mix with interconnected voids and high permeability. Open graded mixes provide good pavement friction, reduce the potential for hydroplaning, and reduce pavement-tire noise.

[6] Refer to NGSMI, 2002, Page 4, Figure 1.

The construction sequence for thin hot mix overlays, shown in Figure 3–1, incorporates the use of a material transfer vehicle (MTV). The use of an MTV is recommended, particularly for large projects, to reduce the possibility of segregation and to improve pavement smoothness.

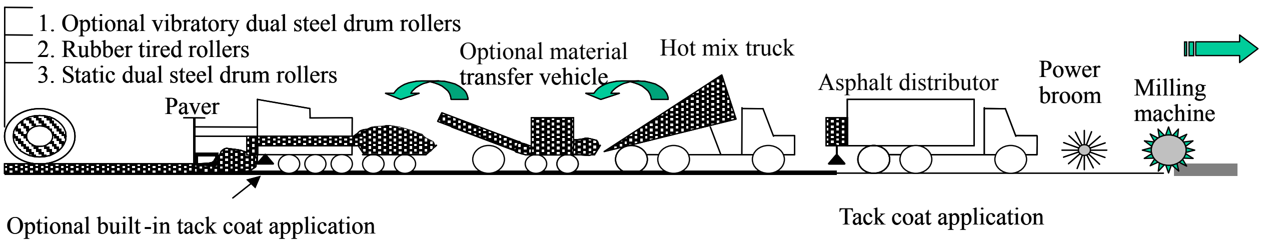


Figure 3–1: Construction sequence for thin hot mix overlays with prior milling.

Selection Criteria and Surface Preparation

Thin overlays are typically used for structurally sound pavements to provide a new protective surface, improve ride quality and pavement friction, and to provide a quiet pavement surface. They can also be used as a preventive maintenance treatment to slow surface raveling, seal small cracks, and seal the pavement.

Thin pavement overlays should be constructed on a uniform platform that bonds well with the overlay. The improvements to the existing surface may include precision milling to improve ride quality and cross-section, an application of a leveling course or a scratch course, patching, full-depth repairs, and an application of a tack coat. The existence of distresses such as segregation, raveling and block cracking, or conditions that do not permit raising of the pavement surface, may dictate a partial removal of the asphalt concrete by milling or precision milling prior to overlay. Routing and sealing of cracks prior to paving is not recommended because hot mix paving may dislodge crack sealant and the sealant, in the form of strips may interfere with the placement of the thin overlay.

The majority of agencies use a tack coat prior to placing a thin overlay. The tack coat strengthens the bond between asphalt concrete layers. The bond increases the strength of the pavement structure (by limiting slippage between layers) and the durability of the overlay (by reducing the possibility of delamination). Tack coat is also required to seal the underlying pavement layers when an open-graded overlay is used. Some agencies use a tack coat on previously milled surfaces only, arguing that these surfaces lack asphalt binder; other agencies use a tack coat only when the surface is not milled, arguing that a milled surface already provides a good aggregate interlock. Considering the relatively low cost of a tack coat (usually less than $ 0.50 per square meter), its routine use is recommended.

Municipal Use

The County of Leeds and Grenville in Ontario has been successfully using ultra-thin overlays since 1996. The County is currently using 12 mm thick overlays on about 30 km of roads annually. The ultra-thin overlay is constructed in two steps—as a scratch coat and a surface coat. Both coats use the same material consisting of high quality crushed aggregate passing 9.5 mm sieve size and containing 6.5 percent of asphalt cement. The product can be constructed by typical paving contractors using the following steps:

A scratch (leveling) coat is "tight-bladed" by a grader using a box-like attachment shown in Figure 3–2. The scratch coat is used to fill in depressions and ruts, and is typically applied on 15 to 20 percent of the pavement surface. The scratch coat is compacted by steel rollers. A 12 mm thick surface coat is applied by a paver and compacted by steel rollers operating in a static mode.

Figure 3–2: Application of a scratch coat of a densely-graded hot mix by a grader with box-like attachment. **(Courtesy of Ontario Ministry of Transportation)**

The County does not use a tack coat considering the relatively high asphalt cement content of the mix and the typical hot weather construction.

The City of Ottawa has successfully used a proprietary ultra-thin hot mix overlay product. The ultra-thin overlay is typically 15 to 20 mm thick and contains an open-graded high quality aggregate passing the 13.2 mm sieve size. The mix is applied by a specialized paver with built-in application of a tack coat. In urban environments, special attention must be paid to handling the open-graded mix around pavement utility openings. Thin hot mix overlays such as this can improve pavement friction and provide a quiet pavement surface because of its porosity (Figures 3–2 and 3–3). The impermeability of the pavement underneath the thin hot mix overlay is achieved by a thick tack coat.

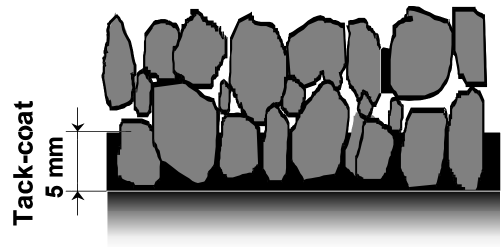


Figure 3–3: Typical aggregate skeleton.

Figure 3–4: Thin open graded hot mix overlay surface on the left; sand mix surface on the right. The diameter of the coins is 18 mm.

The City of Montréal experimented with several types of ultra-thin and thin hot mix overlays in 1992 and 1993 ranging in thickness from 13 to 30 mm. Some of these overlays are still in service.

Resources

The US Federal Highway Administration produced a useful booklet on the construction of thin hot-mix overlays (FHWA, 2000). Publication *Thin Hot-Mix Asphalt Surfacings* by the National Asphalt Pavement Association (NAPA 2001) contains descriptions of several thin hot mix overlay products. The Ohio Department of Transportation (2002) issued a technical bulletin describing Smoothseal, a 15 to 25 mm thin overlay using dense-graded polymer-modified asphalt concrete.

3.2.2 HOT-IN-PLACE RECYCLING

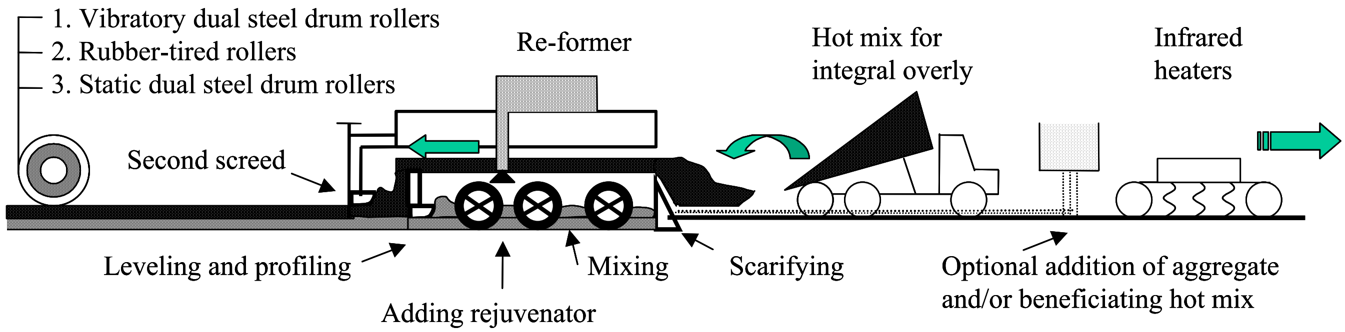


Figure 3–5: Construction sequence for hot-in-place recycling with an integral overlay.

Hot-in-place recycling (HIR) is included in this best practice for completeness because it is sometimes done to the depth of only 20 mm, and even after sealing the thin recycled layer (with a slurry seal, surface treatment, or with an integral hot mix overlay), the resulting thickness of the new and re-processed layers can be less than 40 mm.

Materials and Construction
The construction of HIR with an integral overlay using a reformer is schematically illustrated in Figure 3–5. There are other types of HIR processes and equipment that can be used to heat, remove, mix, and lay down the recycled surface layer. The recycled asphalt concrete is typically mixed with a recycling agent, and can be further supplemented with pre-heated aggregate and/or (beneficiating) hot mix. The resulting recycled layer can be used as a wearing surface or can be protected by a slurry seal, surface treatment or a hot-mix overlay. If an integral overlay is used, the overlay serves as the wearing surface.

Selection Criteria and Surface Preparation
HIR is suitable for structurally sound pavements with surface defects, such as raveling and segregation, cracking, and rutting, that affect mainly the top pavement surface layer. An additional requirement is that the asphalt concrete surface layer should be suitable for recycling. The layer should have a uniform composition (aggregate gradation, asphalt content, and thickness), and materials of good quality (aggregate and asphalt binder). Material properties of pavements considered for HIR should be thoroughly evaluated. Because of the size of a recycling train, HIR is suitable for large projects with room to maneuver (e.g., on rural highways or on multilane arterial roads or streets).

Municipal Use
About 35 percent of the 22 municipalities surveyed use HIR. The depth of the recycling layer ranges from 25 mm to 50 mm. For example, City of Montréal is using 30 mm recycling depth on minor roads and 50 mm depth on major roads. Representatives of several municipalities noted that the target recycling depth is not always achieved. The thickness of the internal overlay ranges from 10 to 40 mm. Some agencies leave the recycled surface as is (e.g., City of Ottawa), other agencies use an integral overlay (e.g., City of Montréal), slurry seal (e.g., City of Calgary), or an additional hot mix overlay.

Resources
The FHWA (1997) publication *Pavement Recycling Guidelines for State and Local Governments* describes all aspects of recycling of asphalt pavement materials to produce new pavement materials.

3.2.3 MICRO-SURFACING

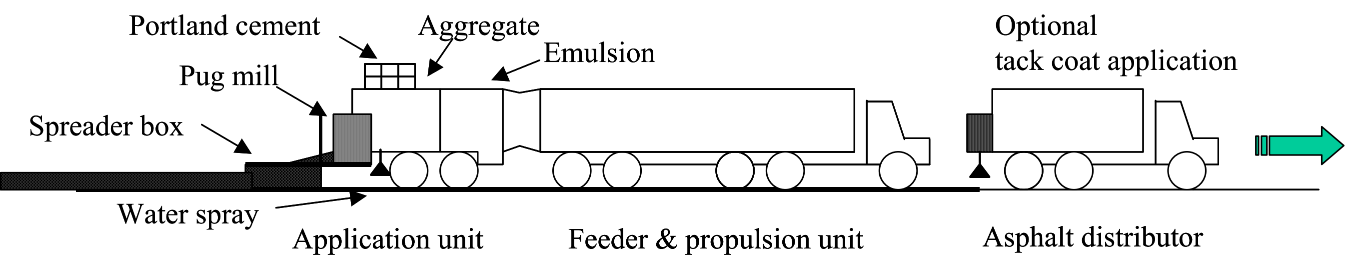


Figure 3–6: Construction sequence for micro-surfacing using a continuous feed machine.

Micro-surfacing is an unheated mixture of polymer-modified asphalt emulsion, high-quality frictional aggregate, mineral filler, water, and other additives, mixed and spread over the pavement surface as a slurry.

Materials and Construction
The construction of micro-surfacing using a self-propelled continuous feed mixing machine is schematically illustrated in Figure 3–6 and shown on a photograph in Figure 3–7a. Figure 3–7b also shows a finished product a year after construction. Micro-surfacing mix is always designed by a contractor or an emulsion supplier, and consists of the following three main ingredients:

Polymer-modified asphalt emulsion contains 60 to 65 percent of asphalt cement. Polymers, typically latex, represent about 3 to 5 percent of the weight of the asphalt cement. Altogether, micro-surfacing contains about 8 to 9 percent of residual asphalt binder. The addition of polymers improves bonding properties of asphalt cement and reduces its temperature susceptibility.

(a) (b)

Figure 3–7: Truck-mounted self-propelled continuous feed micro-surfacing machine (a); surface texture (b).

Finished surface using Type II aggregate is on the right. The diameter of the coin is 26 mm. (Courtesy of Miller Paving Ltd.)

Aggregate used for micro-surfacing is manufactured high-quality crushed stone, typically dense graded.[7] The International Slurry Surfacing Association (ISSA, 2003a) recommends two types of gradations, Type II and Type III. The Type II gradation is finer, with 90 to 100 percent passing 4.75 mm sieve, and is typically used on residential streets. The appearance of Type II micro-surfacing texture is shown in Figure 3–7b. The surface shows the stony character of the texture typical for micro-surfacing. The Type III gradation is coarser with 70 to 90 percent of aggregate passing 4.75 mm sieve, and is typically used on high traffic volume facilities. A minimum thickness of micro-surfacing mix using Type III gradation is 10 mm for a single course.

Mineral filler, typically Portland cement or hydrated lime, is used to control curing time of the mix. The amount of mineral filler is typically less than 1 percent of the total dry mix weight.

Selection Criteria and Surface Preparation

Micro-surfacing is used to correct surficial distresses such as slight block cracking, raveling and segregation, flushing, and loss of pavement friction. Because micro-surfacing contains high-quality crushed aggregate, it is also used to fill-in ruts and surface deformation to the depth of up to 40 mm. Micro-

[7] Open-graded aggregate is not commonly used in North America. Typically, open-graded micro-surfacing mix contains cellulose or mineral fibers to increase consistency of the mix and prevent draining of the emulsion. An experimental application under the trade name Gripfibre® was used by the City of Montréal in the early 90's.

surfacing has excellent frictional properties and is used on high speed roads including expressways. As a preventive maintenance treatment, it can be used to seal the surface of the pavement protecting the pavement from water infiltration and greatly reducing the rate at which the existing bituminous surface oxidizes. Oxidization of the bituminous surface material leads to raveling and cracking.

The surface on which micro-surfacing is applied should have uniform pavement condition. Areas that exhibit significantly more severe defects (for example raveling, cracking, or rutting) than the remainder of the section should be repaired. The repairs can by made using an additional course of micro-surfacing (Figure 3–8) or by other means depending on the type, extent, and severity of the defects. On high traffic volume facilities, and/or when the surface of the pavement has minor distortions and/or has ruts exceeding about 6 mm, two courses of micro-surfacing are recommended. The first (scratch) course is intended to improve the profile of the pavement and the second course provides the wearing surface. Ruts exceeding 13 mm should be filled with micro-surfacing material using a rut-filling spreader box (ISAA, 2003a).

Figure 3–8: Pre-treating of moderate alligator cracking at the centerline with a strip of micro-surfacing prior to applying a regular course of micro-surfacing on the entire surface. (Courtesy of Ontario Ministry of Transportation.)

Some agencies rout and seal active cracks (e.g., transverse cracks) shortly before micro-surfacing is applied. However, micro-surfacing may not bond well to the new crack sealant resulting in the loss of material. Some agencies require that routing and sealing of cracks is done a year before micro-surfacing.[8] Other agencies carry out routing and sealing several months after micro-surfacing. This

[8] The City of Edmonton. After a year, the sealant surface is expected to oxidize and bond well with micro-surfacing. Some agencies specify that sealant is finished flush with the pavement surface (no overbanding).

sequence is often preferable because it eliminates the possibility of de-bonding and ensures that only cracks that are not sealed by micro-surfacing are routed and sealed.

Some agencies[9] specify tack coat before micro-surfacing to ensure good adhesion between the existing pavement surface and the micro-surfacing mix.

Municipal Use
Only about 12 percent of municipalities surveyed use micro-surfacing routinely. About 60 percent of municipalities and 40 percent of provincial agencies have never used it. Those who have used it reported very good or good performance (Figure 3–9).

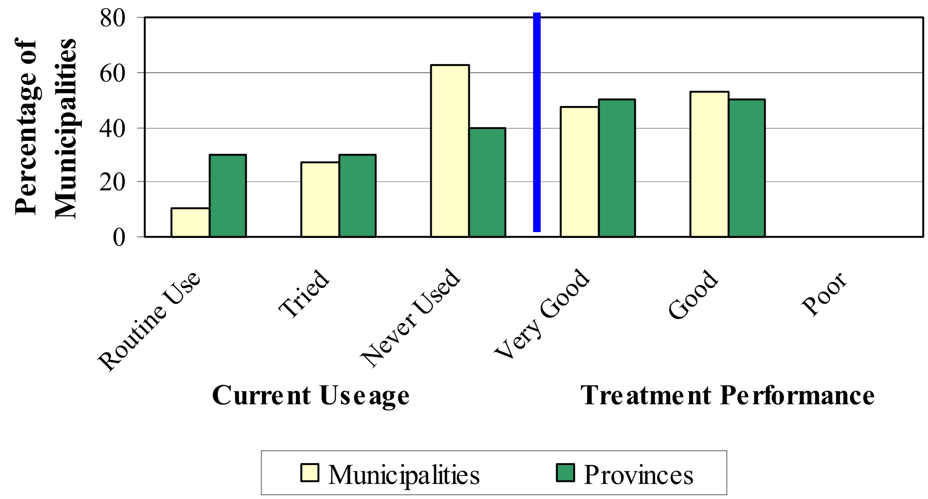


Figure 3–9: Usage and performance of micro-surfacing.[10]

The City of Halifax has used micro-surfacing also on top of surface treatment (chip seal). It performs well and can be used to correct bleeding problems caused by the loss of cover aggregate. The City of Saskatoon has replaced its previous slurry sealing program with a micro-surfacing program because of better cost-effectiveness of micro-surfacing. According to a recent report (City of Saskatoon, 2001), 95 percent of micro-surfacing treatments placed on residential streets in 1996 were still in good condition five years later.

Resources
The International Slurry Surfacing Association maintains a website www.slurry.org that contains recommended specifications and useful guidance (ISSA, 2003a). Croteau et al (2002) summarized developments in the usage of

[9] Ontario Ministry of Transportation.
[10] Based on a survey of 56 municipalities carried out in 2001/2002.

micro-surfacing in Canada. Several agencies, such as Ontario Ministry of Transportation, have developed micro-surfacing specifications that include a 2-year warranty (Kazmierowski and Bradbury, 1995).

3.2.4 SLURRY SEAL

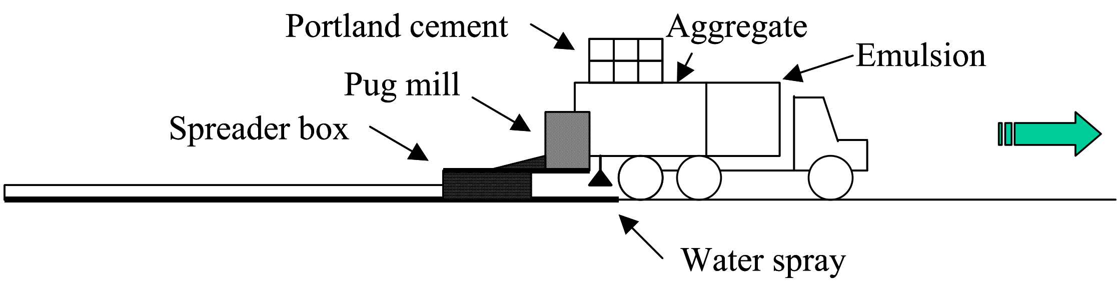


Figure 3–10: Construction sequence for slurry seal.

Slurry seal is a mixture of asphalt emulsion, graded fine aggregate, mineral filler, water, and other additives, mixed and uniformly spread over the pavement surface as a slurry. Slurry seal systems are formulated with the objective of creating a bitumen rich mortar. They are similar to micro-surfacing, but the mineral skeleton is typically not very strong and has limited interlocking of the aggregate particles. Consequently, slurry seals are applied in thin lifts to avoid permanent deformation by traffic.

Materials and Construction
The construction of slurry seal using a self-propelled truck-mounted mixing machine is schematically illustrated in Figure 3–10.

Asphalt emulsion is typically cationic (positive charge) and contains about 60 to 65 percent of residual asphalt cement. The slurry mix contains 9 to 10 percent of asphalt cement.

Aggregate used for slurry seals should be crushed high quality dense graded aggregate. Its gradation generally follows one of the three gradation types, Type I, II and III, recommended by the International Slurry Surfacing Association (ISSA, 2003b). Types II and III have the same gradation as Types II and III used for micro-surfacing. Type I has aggregate particles passing 4.75 mm sieve size. The Type I is typically used for residential streets; Type II for residential streets and urban roads, and Type III for highways and expressways. The thickness of a single application of Type I slurry seal is typically about 4 mm corresponding to the size of the largest aggregate particles.

Mineral filler, typically Portland cement or hydrated lime, is used to control curing time of the mix (break time of the emulsion). The amount of mineral filler is typically less than 1 percent of the total dry mix weight.

Some proprietary slurry seal mixes contain crushed aggregate particles and polymer-modified emulsion, and may have strength and durability characteristics that are closer to a micro-surfacing than to a traditional slurry seal.

Selection Criteria and Surface Preparation

Slurry seals are used to correct surficial distresses such as raveling and coarse aggregate loss, seal slight cracks, and improve pavement friction. They are also used as a preventive maintenance treatment to seal pavement surfaces from intrusion of water and slow surface oxidation and raveling. Slurry seals are best placed on structurally sound pavements that are in good condition with little or no cracking. Slurry seals should not be placed on pavements exhibiting moderate or severe cracks, or progressive rutting.

The surface on which a slurry seal is applied should have uniform characteristics. If defects such as moderate or severe raveling, cracking, or rutting occur intermittently or frequently, the section is probably not a good candidate for slurry sealing. Working cracks, such as transverse cracks should be sealed, preferably after the slurry seal.

Municipal Use

The usage of slurry seals by municipalities, shown in Figure 3–11, is similar to the usage of micro-surfacing shown in Figure 3–9. However, the performance of slurry seals is noticeably lower than that reported for micro-surfacing. For example, for micro-surfacing, about 50 percent of the municipalities reported very good performance and no poor performance; for slurry seals only 6 percent of municipalities reported very good performance and 20 percent of municipalities reported poor performance.

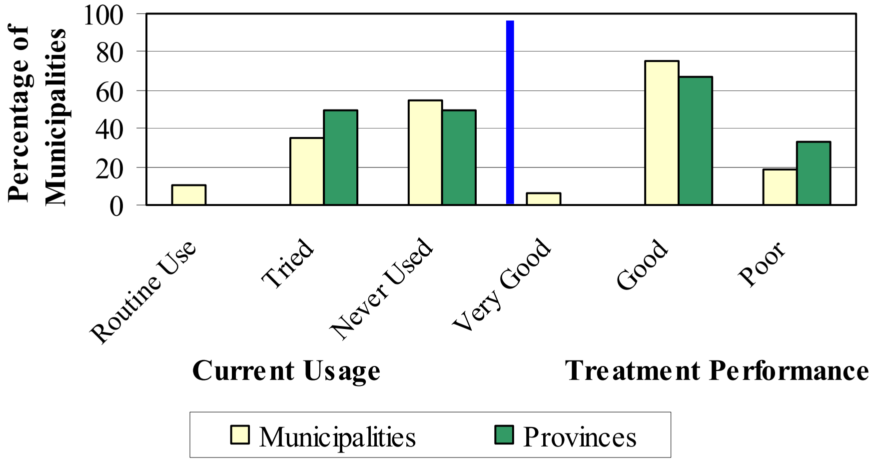


Figure 3–11: Usage and performance of slurry seal.[11]

Grey County in Ontario and the City of Calgary have used slurry seals over surface-treated pavements. The City of Calgary also used a slurry seal to provide wearing surface on HIR asphalt concrete layers.

Resources

The International Slurry Surfacing Association maintains a website www.slurry.org that contains recommended specification for slurry seal and useful technology tips (ISSA, 2003b). Croteau et al (2002) summarized developments in the usage of slurry seals in Canada. Alberta Transportation (1999) developed specifications for slurry seal.

3.2.5 SEAL COATS

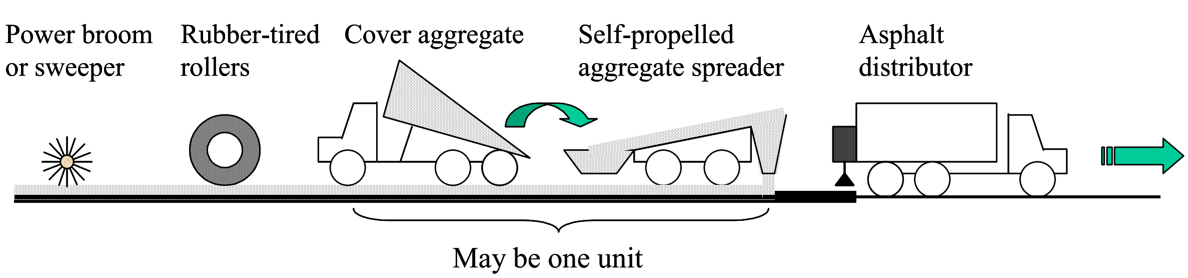


Figure 3–12: Construction sequence for surface treatment.

[11] Based on a survey of 56 municipalities carried out in 2001/2002

Seal coating (also known as surface seal, seal, and chip seal) is the application of asphalt binder, immediately followed by an application of cover aggregate, to any type of pavement surface as shown in Figure 3-12. Typically, seal coats are applied on top of a granular base producing surface-treated pavement, one of the most common pavement types in Canada. Seal coats can be also applied to asphalt concrete pavements as a preventive or corrective maintenance treatment. This type of application is the focus of this section.

Materials

Typically, the asphalt binder used for seal coats is asphalt emulsion applied at an elevated temperature[12] using an asphalt distributor (Figure 3–13). The selection of the type of asphalt emulsion depends, in addition to the availability of the emulsion, on several factors:

- **Aggregate electrical charge** — Cationic emulsions work best with sandstones and granites (negatively charged aggregates); anionic emulsions are most suited for limestones and dolomites.
- **Type of surface —** Polymer-modified emulsions are typically specified for applications on asphalt concrete surfaces.
- **Weather conditions —** Rapid setting emulsions are generally recommended because of their less stringent weather restrictions.
- **Aggregate gradation —** High float emulsions work best with dense-graded aggregate.

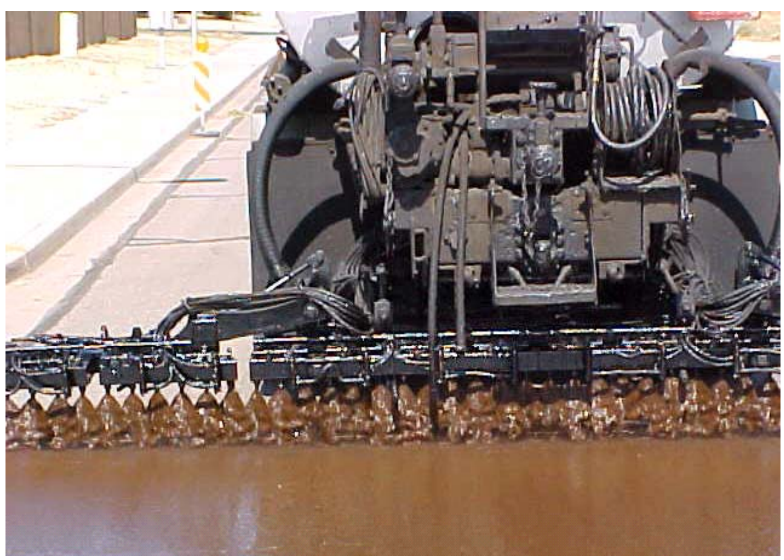


Figure 3–13: Asphalt distributor applying emulsion; view from the back. The emulsion has a typical brown colour which changes into black colour as the emulsion cures. Nozzles on the spray bar provide good coverage of the surface.

The cover aggregate can be either chips (open-graded aggregate) as shown in Figure 3–14, or dense-graded as shown in Figure 3.15. Seal coats using open-graded aggregate is called chip seal (Table 1–2). The selection of aggregates depends on several factors:

- **Aggregate availability** — Open-graded aggregate should be of high quality and washed (dust-free). Such aggregate is typically available only from large commercial producers.
- **Cost of materials** — Dense-graded aggregate is less expensive and requires less emulsion.
- **Rural or urban setting —** Initial traffic on dense-graded aggregate may produce excessive dust. For this reason, chip seals are often specified in urban areas.
- **Local experience and preference —** The construction of surface treatments with graded aggregate is usually more forgiving than the construction with chips.
- **Facility type —** The use of one-size aggregate reduces the amount of excess aggregate and is preferred for high traffic volume roads.

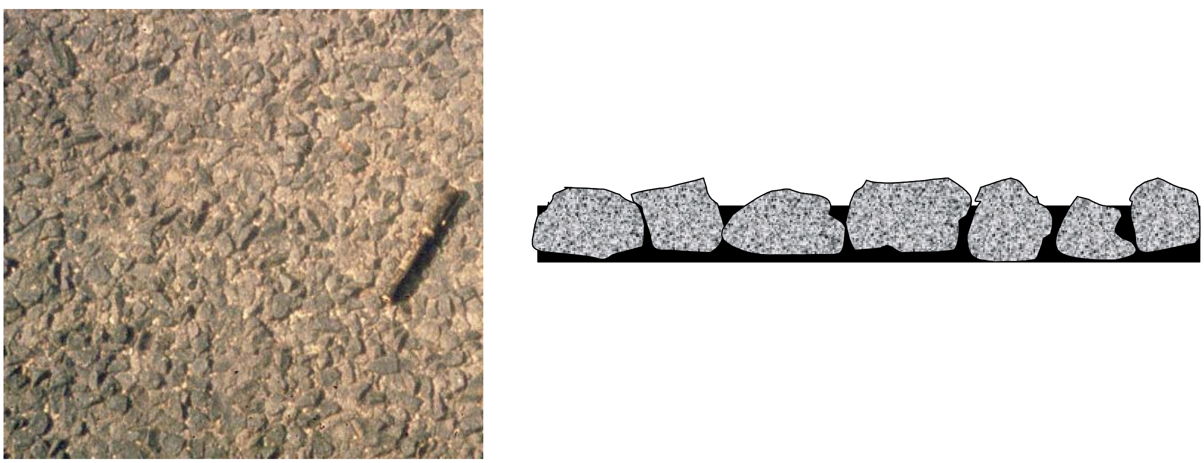


Figure 3–14: Surface of a newly constructed seal coat using 13.2 mm chips and CRS-2P emulsion

[12] Temperatures in the range of 50 to 70 °C are common. Emulsions should not be heated above 85 °C.

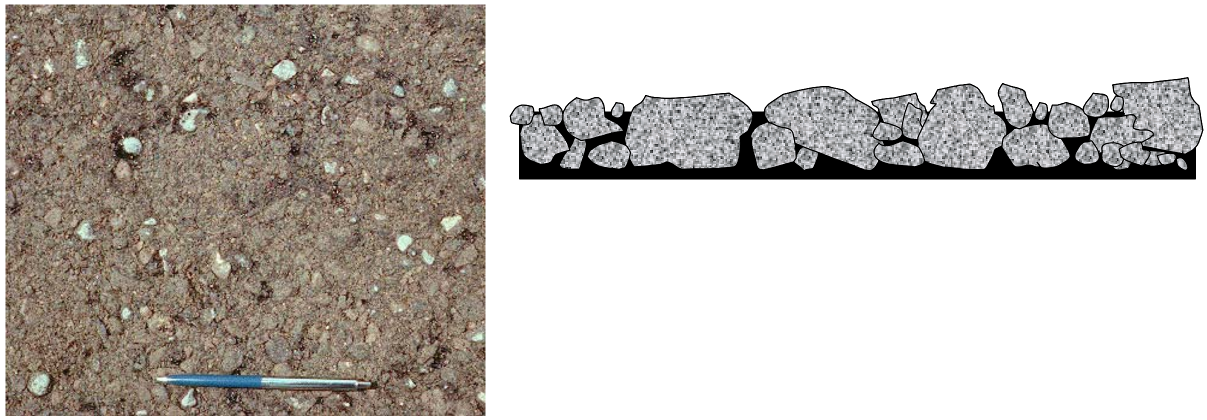


Figure 3–15: Surface of a newly constructed seal coat using 16.0 mm dense graded aggregate and high float emulsion

Design of Seal Coats and Application Rates

Ideally, about 70 percent of the aggregate should be imbedded or surrounded by the binder after exposure to traffic. This requires a proper balance between the amount of emulsion applied to the surface and the amount and type of cover aggregate. Several agencies have developed design procedures, or established recommended application rates, to achieve this balance. The procedures take into account the type and porosity of the surface, the size, type and shape of the cover aggregate, and traffic volumes.

Emulsion application rates for seal coats typically range from 0.9 to 1.7 l/m^2 depend on the existing surface (granular, seal coat or asphalt concrete), traffic volume and composition, etc. and are further adjusted during construction depending on weather conditions and other factors. For example, the application rate of the emulsion generally decreases with the increasing traffic volumes. Traffic pushes chips into the emulsion (and also into the original surface), causes them to rotate and lay down on their flattest side, and propels the binder to the surface (Figure 3–16). There are several references that provide design and construction guidance such as the Minnesota Seal Coat Handbook (Janish and Gaillard, 1998).

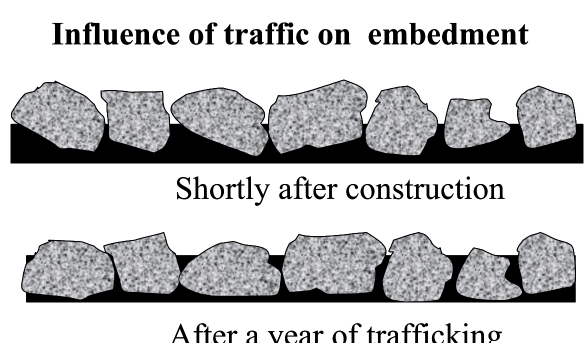


Figure 3–16: Higher traffic volumes typically require lower application rates.

Construction

The need for accurate application of the binder and aggregate cover is facilitated by modern asphalt distributors (Figure 3–13) which can automatically maintain selected application rates regardless of the distributor speed. Newly constructed surface treatments need to be protected from high speed traffic for several hours after construction[13], and the public needs to be protected from loose chips and dust.

Some agencies remove excess aggregate aggressively, other agencies prefer to leave excess aggregate on the road and "live with it", waiting until the excess aggregate is dispersed by traffic. On high traffic volume roads the removal of excess aggregate is required for safety reasons. For the surface treatment itself, it is preferable to leave some "excess" aggregate on because it can be imbedded by traffic as aggregate particles rotate and create additional openings in the mat.

Selection Criteria and Surface Preparation

Surface treatments applied on top of asphalt concrete pavements can be used as preventive or corrective treatments. As preventive treatments, surface treatment is primarily used to seal the surface with non-traffic-load associated cracks and raveling. As a corrective measure, surface treatments are used to restore skid resistance and to maintain wearing surface on thin asphalt concrete pavements.

The surface on which surface treatment is applied should have uniform capacity to absorb emulsion. If the pavement has, for example, raveling near the centerline or the evidence of end-load segregation, the raveled and segregated areas should be pre-treated (e.g., by spray patching). If left untreated, these areas will absorb emulsion and will fail to have enough emulsion to seal the surface and retain cover aggregate—precisely in the areas where the pavement needs the protection most. On the other hand, an increase in the emulsion application rate to match raveled and segregated areas may result in flushing elsewhere. Active cracks, such as transverse cracks, should be sealed, preferably after the surface treatment application.

Municipal Use

Only about 13 percent of municipalities surveyed routinely use surface treatments on top of asphalt concrete pavements (Figure 1–2), while about 36 percent of all provinces use them. One of the reasons for low usage of surface treatments by municipalities are concerns about loose aggregate, dust, and rougher surface texture, concerns that are more pronounced in an urban environment. The City of Halifax has switched from using surface treatments to micro-surfacing and slurry seals. On the other hand, some provincial agencies successfully use surface treatments on highways. For example, Alberta Transportation has applied a chip seal on a 41 km long section of Highway 2 between Calgary and Edmonton in 2000, and Ontario Ministry of Transportation

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[13] For example, vehicles must travel in convoys following pilot vehicles for two hours after construction.

considers surface treatment as a viable pavement preservation strategy for asphalt concrete pavements.

Resources
An overview of the use of surface treatments in Canada was published by the Transportation Association of Canada and its Canadian Strategic Highway Research Program (Scott, 1990). Several agencies have published recommendations for the design and construction of surface treatments including Ontario Ministry of Transportation (Cooper and Aquin, 1983) and Minnesota Department of Transportation (Janish and Gaillard, 1998). Practical handbooks were also published by The Asphalt Institute (1969) and by Asphalt Emulsion Manufacturers Association (no date).

3.2.6 RESTORATIVE SEALS

Figure 3–17: Construction sequence for restorative seal

Restorative seals consist of an application of a bituminous material, typically diluted asphalt emulsion, to the surface of asphalt concrete pavement (Figure 3–17). Restorative seals are also called rejuvenators or fog seals. Some agencies or suppliers recommend light sanding of restorative seals (about one kg of sand per square meter).

Selection Criteria and Surface Preparation
Restorative seals are used to reduce oxidation and hardening of asphalt binder and to seal minor cracks. Some municipalities use restorative seals on all their new pavements. Restorative seals can also slow the progression of raveling and coarse aggregate loss, and are used as remedial measures. Restorative seals have also been used shortly after paving to seal areas with low to moderate segregation. The pavement should be in good condition and should be broomed before the emulsion is applied.

Municipal Use
Even though several municipal representatives noted that properly designed and constructed asphalt concrete pavements benefit from restorative seals, only one municipality of the 22 municipalities surveyed, the City of Brampton, Ontario, is routinely using restorative seals on new pavements. The City of Moncton is using restorative seals only on driveways and parking lots.

Resources
A handbook by Asphalt Emulsion Manufacturers Association (no date) provides guidelines for the use of restorative seals using asphalt emulsions.

3.2.7 TEXTURIZATION

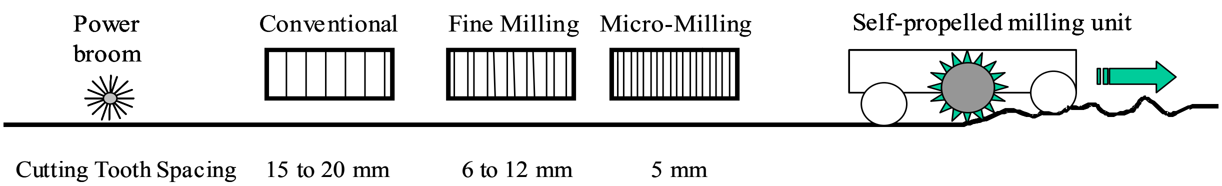

Figure 3–18: Construction sequence for micro-milling or precision milling.

Texturization techniques include conventional milling, fine milling, micro-milling, diamond grinding, precision milling and other techniques that remove unevenness from the pavement surface, or improve its texture, and leave an abraded surface that is used as a driving surface (Figure 3–18).

Selection Criteria
Texturization techniques can smooth out stepping at transverse cracks, wheel track rutting and improve pavement friction. The pavement should have sufficient structural capacity so that the reduction in thickness is not of concern. Figure 3–19 shows an example of pavement surface where micro-milling was used to reduce rutting and roughness.

Municipal Use
Although many municipalities mill asphalt concrete pavements to correct pavement profile and cross-section, they do it as part of overlay placement and do not leave the milled surface exposed. The City of Ottawa used precision milling to reduce roughness caused by stepped transverse cracks on approximately 12 km of arterial road, and left the milled surface exposed to traffic.

Resources
The Basic Asphalt Recycling Manual (ARRA, 2001) handbook by Asphalt Recycling and Reclaiming Association provides guidelines for texturization techniques.

(a) (b)

Figure 3–19: Micro-milling application to reduce rutting and roughness. The milled surface has darker colour (a). The milled surface on the right (b) has groves with the peak to peak distance of about 15 mm.

4. APPLICATION

This section explains how to incorporate thin surface restoration techniques into the pavement preservation planning and budgeting process, and provides guidelines for the selection of surface restoration techniques.

4.1 THIN PAVEMENT SURFACINGS AND PAVEMENT MANAGEMENT

The use of surface restoration techniques should follow the principle of applying the Right Treatment on the Right Road at the Right Time. Consequently, the selection of the Right Treatment is not the task of choosing between different types of surface restoration techniques, it is the task of choosing between all feasible pavement preservation treatments (including regular overlays, sealing of cracks, cold-in-place recycling, etc). Similarly, the selection of the Right Road should consider not just one section of the network that may be suitable for a thin surfacing, but the needs of the entire network. The Right Road involves balancing limited resources among the entire system and facilitates coordination of other work carried out within the right-of-way. Finally, the application at the Right Time means the time when the treatment is most effective. For surface restoration techniques it is typically when the pavement is still in good condition. Thus, the selection of thin pavement surfacings should be part of a pavement management process.

The process of preparing prioritized pavement preservation budgets is described in the best practice *Priority Planning and Budgeting Process for Pavement Maintenance and Rehabilitation* (InfraGuide, 2003b). Briefly, the process consists of a yearly pavement management cycle of eight basic planning, budgeting, engineering and implementation activities that are summarized on the left side of Figure 4–1. To maximize the benefits of using surface restoration techniques as preventive maintenance treatments, the existing management process should be reviewed and, if necessary, changed. The objective is to integrate the technology of surface restoration techniques with the existing pavement preservation process. For example, existing pavement condition surveys may be geared to capture distresses at later stages. However, to be effective as preventive maintenance treatments, surface restoration techniques should be applied during early stages of distress development. Thus, condition surveys may need to be more detailed and more frequent.

The right side of Figure 4–1 provides a summary of changes in the existing pavement management process that may be required for the successful use of surface restoration techniques as preventive maintenance treatments. For details about preventive maintenance, refer to the best practice *Timely Preventive Maintenance for Municipal Roads — A Primer* (InfraGuide, 2002).

4.2 Treatment Selection

Thin surface restoration techniques can play an important role in pavement preservation, particularly in the area of preventive maintenance. However, thin surfacings constitute only one set of pavement preservation treatments. Other types of treatments are also needed as part of a cost-effective pavement preservation program.

Selection criteria and surface preparation requirements for the seven types of thin surfacings were outlined as part of the description of individual treatments in Section 3. This section provides a summary of selection guidelines and an outline of main factors used in the treatment selection process.

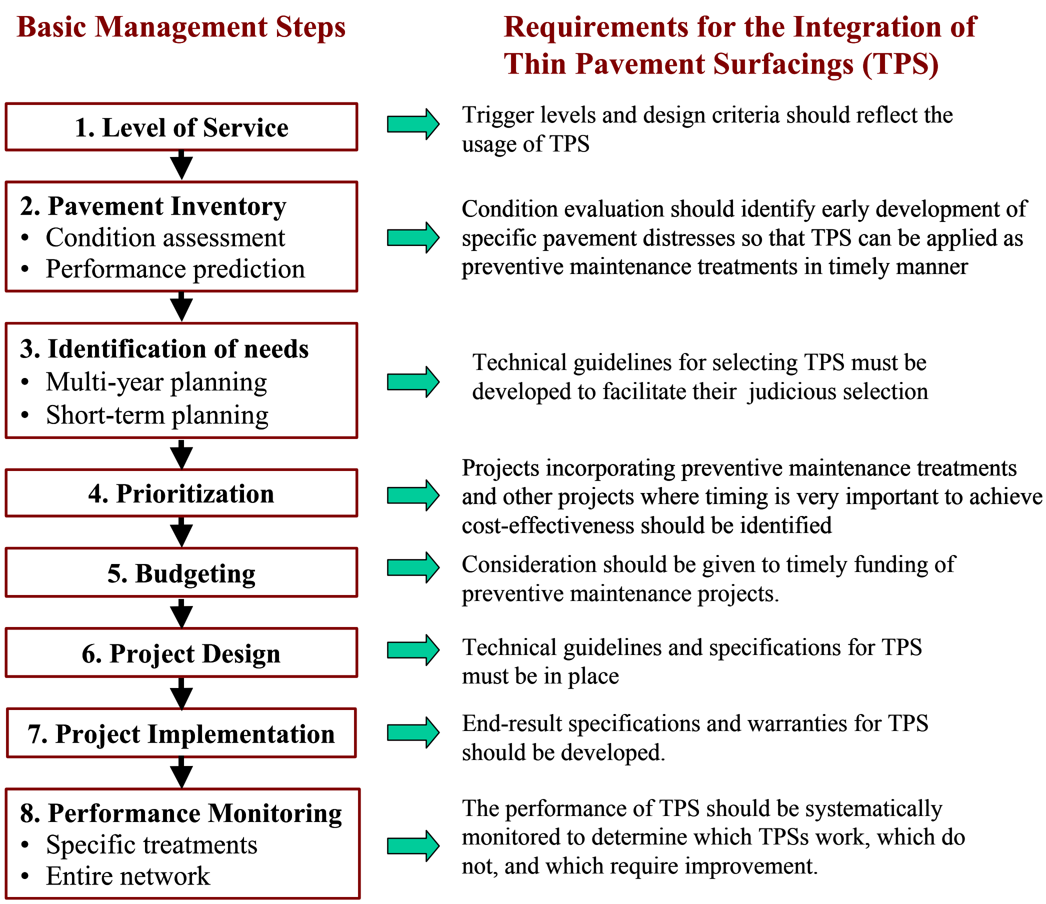

Figure 4–1: Requirements for integrating the use of thin pavement surfacings (TPS) into the pavement management process.

Guidance for the selection of surface restoration techniques is summarized in the following three tables. Each table addresses one of the three typical roles of thin pavement surfacings:

- Protecting the pavement structure, Table 4–1;
- Restoring or improving the pavement surface, Table 4–2; and
- Providing a wearing surface, Table 4–3.

Information on treatment selection given in Tables 4–1 to 4–3 is general and is provided for orientation only. For example, according to Table 4–2, pavement friction on arterial streets can be restored or improved by using a thin overlay, surface treatment, micro-surfacing, slurry seal, or texturization. The selection of a specific treatment should be done by experienced personnel familiar with local conditions. Typically, the selection of the preferred treatment is a two-step process.

- Step 1: Selection of alternatives; and
- Step 2: Evaluation of alternatives.

The first step can be viewed as network-level selection and the second step as a project-level selection.

Table 4–1: Selection of surface restoration techniques to protect the pavement structure.

Thin Pavement Surfacing	Protecting Pavement Structure Against:							
	Penetration of water		Loss of aggregate and ravelling		Hardening of bituminous binder and oxidization		Environment and traffic Exposure	
	Type of facility							
	Local	Arterial	Local	Arterial	Local	Arterial	Local	Arterial
Thin overlay	○	●	○	●	○	○	●	✶
HIP recycling			○	○			●	○
Surface treatment	○	○	○	○	○	○		●
Micro-surfacing	●	✶	●	✶	●	✶	●	●
Slurry seal	✶	○	✶		✶	○	●	●
Restorative seal	○		○	○	●	○	○	○
Texturization								

○ A possibility ● Should be considered ✶ Typical application

Table 4–2: Selection of surface restoration techniques to restore or improve the pavement surface.

Thin Pavement Surfacing	Restoring or Improving Pavement Surface in Terms of:									
	Reduction in roughness and rutting		Increased Pavement friction		Sealing of porous surface		Excessive Pavement-tire noise		Improved aesthetics/ delineation	
	Type of facility									
	Local	Arterial	Local	Arterial	Local	Arterial	Local	Arterial	Local	Arterial
Thin overlay	●	●	○	●	●	●		✶ [1)]		○
HIP recycling		●		○		●				
Surface treatment			○	○	○					
Micro-surfacing	○	○	○	●	●	○			●	●
Slurry seal			●	○	○				●	○
Restorative seal									○	○
Texturization	○	●	○	○					○	○

[1)] E.g., open-graded friction course

○ A possibility ● Should be considered ✶ Typical application

Table 4–3: Selection of surface restoration techniques to provide a wearing surface.

Thin Pavement Surfacing	Providing Surface on:							
	Granular base		Surface treatment		Cold-in-place recycled mix		Hot-in-place recycled mix; Bituminous base	
	Type of facility							
	Local	Arterial	Local	Arterial	Local	Arterial	Local	Arterial
Thin overlay	●	○			●	●	●	●
HIP recycling								
Surface treatment	✶	✶	✶	✶	●	●	●	○
Micro-surfacing			○	●	○	○	●	●
Slurry seal			●	○	○		○	○
Restorative seal								
Texturization								

○ A possibility ● Should be considered ✶ Typical application

Step 1: Selection of alternatives

The first step is the selection of candidate treatments or alternatives, or the selection of generic treatments. The selection of candidate treatments can be facilitated by using decision trees or tables. Generic treatments can also be generated by a pavement management process. Considerations used to select alternatives include:

- Pavement type and pavement structure;
- Roadway classification;
- The type, extent, and severity of distresses;
- Traffic volume, composition, and speed; and
- Policy of the agency regarding pavement preservation (e.g., preventive maintenance, and type and timing of pavement preservation treatments).

Step 2: Evaluation of alternatives

The second step is detailed evaluation of alternatives in terms of costs and benefits. The evaluation of alternatives includes factors such as:

- Economic analysis of alternatives. Life-cycle cost analysis procedure is recommended. The use of this procedure for the economic evaluation of pavement preservation treatments is described in the best practice *Timely Preventive Maintenance for Municipal Roads — A Primer* (InfraGuide, 2002).
- Initial construction costs.
- Minimum desirable life-span of the treatment.
- Future maintenance requirements; impact on future rehabilitation options.
- Experience of the agency with long-term performance of the treatment; risk that the treatment will not perform as expected.
- Preferences of users and local residents.
- Specific pavement surface properties such as pavement friction and pavement-tire noise.
- Traffic restrictions during construction; duration of construction; potential delays during construction.
- Weather requirements during construction.
- Conservation of materials and energy.
- Stimulation of competition.
- Availability of local materials; availability of experienced contractors.
- The use of innovative treatments with future potential.
- Environmental and social impacts.
- Integration of works in the right-of-way.

Appendix A provides an example of treatment selection process that can be used to systematically evaluate and rank candidate pavement preservation treatments.

5. EVALUATION

One of the main barriers to more frequent use of surface restoration techniques is the lack of reliable local information on their long-term performance. To overcome this barrier and gain confidence for using thin treatments, it is necessary for agencies to have a systematic monitoring and evaluation program to document the performance of pavement preservation treatments (e.g., treatment life-span or the extended life-span of the pavement receiving the treatment) and evaluate their cost-effectiveness. Such a program should be part of the overall pavement management system and should include monitoring and evaluation of all pavement preservation treatments. This is particularly important for treatments for which the long-term pavement performance data are lacking.

A routine monitoring and evaluation program (carried out as part of the agency's routine pavement condition monitoring and inspection of the pavement network) may not be sufficiently detailed to enable the evaluation of new treatments or specific treatment improvements. In order for the agency to determine which treatments work well and which do not and why, the monitoring and evaluation program should have the following components:

Program design — Develop a plan for monitoring and evaluation of the pavement preservation treatment. The plan should include objectives, treatment design, and plans for construction quality control and assurance, long-term monitoring, and evaluation. It is preferable to include, on the same site, a control section with a comparable treatment based on a standard or usual practice of the agency.

Site selection — Select an appropriate site for the evaluation. The site should have uniform pavement and traffic conditions, and should be long enough to accommodate a control section. Site conditions should be investigated and documented prior to construction.

Design of treatments — Develop treatment designs and specifications.

Construction — Monitor and document construction procedures. Obtain appropriate samples according to construction quality control and assurance plan.

Long-term monitoring — Follow a long term monitoring plan that is part of the program design. Typically, the first monitoring is done shortly after construction and then on an annual basis for the period prescribed in the program design.

Evaluation and reporting — Prepare and disseminate information on the cost-effectiveness of treatments in a timely manner.

APPENDIX A: EVALUATION OF ALTERNATIVE PAVEMENT MAINTENANCE TREATMENTS

Frequently, different types of surface restoration techniques and other pavement preservation treatments can provide quite similar service. For example, a porous pavement surface (showing segregation and ravelling) can be sealed using a slurry seal, surface treatment, micro-surfacing, or an overlay. The decision in choosing one treatment over another should consider all relevant costs and benefits. This means not only costs and benefits that can be readily expressed in dollars and cents, but also those that depend on subjective judgment.

Section 4.2 of this best practice describes a number of considerations for the judicious selection of pavement preservation treatments. This appendix describes a systematic procedure that can be used to evaluate candidate treatments using all relevant considerations. The procedure, described using an example, consists of the following five steps:

Step 1: Selection of candidate treatments and estimation of their costs and expected performance
The selection of candidate treatments can be facilitated by using decision trees or decision tables such as Tables 4–1 to 4–3. The cost should reflect site-specific conditions and the expected performance should be based on local experience.

Step 2: Life-cycle cost analysis
Life-cycle cost analysis can effectively combine and quantify costs and monetary benefits that are expected to occur over time (over analysis period). The use of life-cycle cost analysis for the selection of pavement preservation treatments is described in Appendix A of best practice *Timely Preventive Maintenance for Municipal Roads — A Primer* (InfraGuide, 2002). Briefly, the procedure uses present value of alternative pavement preservation strategies. Thus, all future construction, maintenance and rehabilitation costs are discounted using an appropriate interest rate. The alternative with the lowest net present value has the lowest life cycle costs.

The basic formula for life-cycle economic analysis is:

$$PW = \text{Initial Cost} + \sum_{1}^{k} \text{Upkeep Cost} \frac{1}{(1 + i_{dis})^n}$$

Initial Cost = initial construction cost, $
Upkeep Costs = MR treatments, $
i_{dis} = Discount rate (%/100)
n = Number of years to present
k = number of upkeep treatments

Step 3: Establishment of evaluation criteria and their relative importance
Evaluation criteria are considerations that influence the selection of candidate treatments, for example, life-cycle cost, local experience with the performance of treatments, and expected initial service life of treatments.

Because some considerations may be more important than others, their importance needs to be considered as well. Typically, this can be done by assigning a relative importance to each consideration. For example, assuming that the total importance is 100 percent and the three considerations listed in the preceding paragraph (life-cycle cost, local experience with the performance of treatments, and expected initial service life of treatments), the assignment of relative importance may be as follows: 50 percent to life-cycle cost, 30 percent to the local experience with the performance of the treatment, and 20 percent to the expected service life.

Step 4: Evaluation of candidate treatments
Each candidate treatment is evaluated using the evaluation criteria established in Step 3. The evaluation is based on a relative scale from 0 to 100. For example, if one of the evaluation criteria is the initial expected service life, the alternative with the longest expected service life (e.g., 20 years) may be assigned the score of 100, whereas an alternative with a 15-year service life the score of 75.

Step 5: Calculation of scores and treatment selection
The scores assigned to the candidate treatments in Step 4 are multiplied (weighted) by the relative importance of the evaluation criteria and summarized. The alternative with the highest weighted score is considered to be the best alternative.

A similar treatment selection procedure was developed by Hicks et al (2000). This procedure is illustrated in the following example.

Example of treatment selection procedure
A two-lane road in a semi-urban setting with gravel shoulders has a pavement exhibiting extensive slight to moderate ravelling and coarse aggregate loss, minor cracking, and slight rutting. The pavement is a seven-year old conventional asphalt concrete pavement. It is estimated that, without any treatment, the pavement will require rehabilitation in 4 years. Further, it is expected that the rehabilitation will consist of milling 40 mm of the existing asphalt concrete and placing a 50 mm overlay.

Rather than waiting until the pavement requires rehabilitation, it is proposed to treat the pavement the next year using a thin surfacing and thus postpone the need for rehabilitation. The question is which thin pavement surfacing should be used, if any.

Step 1: Selection of candidate treatments and estimation of their costs and expected performance

The following three surface restoration techniques are considered to be feasible:

- 25 mm (thin) hot mix overlay. It is estimated that the overlay will postpone the need for rehabilitation for 10 years, from year 4 to year 14 (Figure A–1).
- Micro-surfacing. It is estimated that the performance of micro-surfacing will be similar as that of the thin overlay.
- Surface treatment. It is estimated that the application of surface treatment will postpone the need for rehabilitation for 4 years, from year 4 to year 9 (Figure A–1).

The following unit costs were assumed for illustrative purposes:

Hot mix for 50 mm overlay	\$50.00 per tonne
Milling	\$12.00 per tonne
Hot mix for 25mm overlay	\$55.00 per tonne
Shoulder gravel	\$10.00 per tonne
Micro-surfacing	\$3.50 per m^2
Tack coat	\$0.40 per m^2
Surface treatment	\$2.00 per m^2

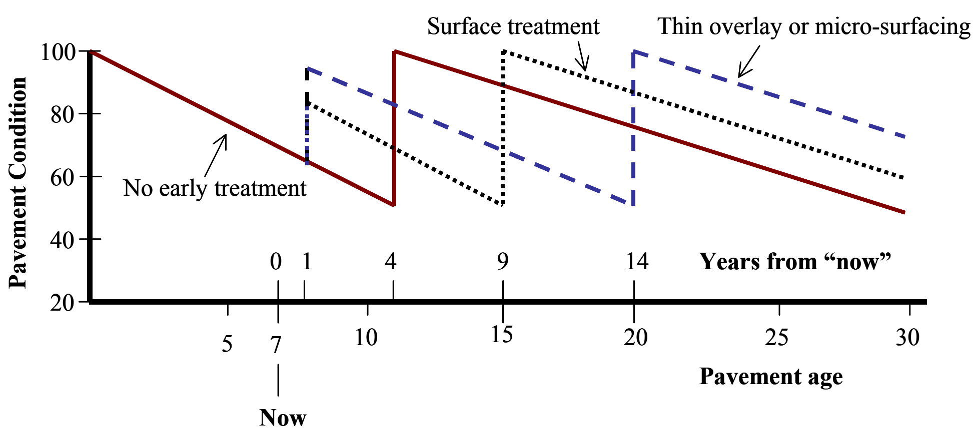

Figure A–1: Expected performance of alternative treatments.

Step 2: Life-cycle cost analysis

The life-cycle analysis used a 50-year analysis period and four and six percent discount rates. For simplicity, it was assumed that all subsequent rehabilitation treatments (in year 11 if no early treatment is applied, or in the subsequent years after the surface restoration techniques require rehabilitation) will be the same, and will consist of milling 40 mm of the existing asphalt concrete and placing a 50 mm overlay. It was further assumed that all these subsequent treatment will last 20 years.

The results of life-cycle cost analysis are summarized in Table A–1.

Table A–1: Life-cycle pavement costs for one km of 2-lane road.

Alternative	Present worth of life-cycle cost for discount rate of:		Initial cost (*discounted at 4%)*	Years from now when the initial cost occurs
	4%	**6%**		
1. No early treatment	74,700	59,100	40,000	4
2. 25 mm overlay	73,400	59,400	25,600	1
3. Micro-surfacing	**72,400**	**54,800**	24,600	1
4. Surface treatment	76,900	62,700	13,900	1

Cost data in Table A–1 indicate that micro-surfacing has the lowest life-cycle cost using both the four percent six percent discount rates.

Step 3: Establishment of evaluation criteria and their relative importance

The following evaluation criteria were selected:

- **Life cycle cost** — The total present value of all costs (initial and subsequent maintenance and rehabilitation costs) calculated using the four percent discount rate.
- **Initial cost** — Even though the lifecycle cost accounts for the time when the initial costs occur, the funds for the thin surfacing alternatives are required the next year and not 4 years from now.
- **Experience with treatment** — Local experience with the performance of alternatives, and risk that the treatment will not perform as expected.
- **Weather restrictions** — The potential for construction delays and problems due to inclement weather.

The selected evaluation criteria and their relative scores are shown in Table A–2, Step 3. The criteria and their relative scores are given for illustrative purposes only. The life-cycle cost was considered to be the most important evaluation criterion and was assigned the relative score of 50 out of 100. The least important evaluation criterion was weather restrictions with a relative score of 5 of 100.

Table A–2: Situation of alternatives.

	Evaluation Criteria								Total score	
	Life-cycle cost at *4% discount rate*		**Initial cost**		**Experience with treatment**		**Weather restrictions**			
STEP 3 — Relative score	**50%**		**15%**		**30%**		**5%**		**100%**	
STEP 4 — Evaluation of candidate treatments									**STEP 5**	
Alternatives	Original	Weighted	Original	Weighted	Original	Weighted	Original	Weighted	**Total Weighted score**	**Rank**
	Score									
1. No early treatment	80	**40**	60	**9**	100	**30**	100	**5**	**84**	3
2. 25-mm overlay	90	**45**	80	**12**	90	**27**	95	**5**	**89**	1
3. Micro-surfacing	100	**50**	80	**12**	70	**21**	65	**3**	**86**	2
4. Surface treatment	65	**32.5**	100	**15**	70	**21**	70	**3.5**	**72**	4

Steps 4: Evaluation of candidate treatments

Each alternative was evaluated in terms of the evaluation criteria established in Step 3 (Table A–2, Step 4). The evaluation in terms of life-cycle costs and initial costs was done using the economic analysis results presented in Table A–1. For example, the alternative with the lowest life-cycle cost (micro-surfacing) was assigned the (original) score of 100, and the alternative with the highest life-cycle cost, surface treatment, 65. The assignment of scores for the evaluation criterion *experience with treatment* indicates that the agency has the most experience with the no early treatment alternative (mill and pave) and the least experience with the surface treatment alternative (and that this alternative has the highest risk that it will not perform as expected).

Step 5: Calculation of scores and treatment selection

Calculation results are summarized in Table A–2, Step 5. The highest (weighted) score was assigned to the 25-mm overlay alternative.

REFERENCES

Alberta Transportation and Utilities, 1999. *Surfacing Specifications, Specification 3.20, Slurry Seal*, web site: http://www.trans.gov.ab.ca/content/doctype245/production/mns220-01.htm

Asphalt Emulsion Manufacturers Association, no date. *Recommended Performance Guidelines*, Second Edition, 3 Church Circle, Suite 250, Annapolis, Maryland 21401. Available at www.aema.org.

Asphalt Recycling and Reclaiming Association (ARRA), 2001. *Basic Asphalt Recycling Manual*, Annapolis, Maryland.

City of Saskatoon, 2001. *Performance Evaluation; Treatment: Micro-Surfacing Cursory Evaluation*, City of Saskatoon, Infrastructure Services Department, Public Works Branch.

Cooper, J. and R. Aquin, 1983. *How to Achieve a Good Surface Treatment*, Ministry of Transportation, Bituminous Section, 1201 Wilson Ave., Downsview, Ontario, M3M 1J8.

Croteau, J-M., J.K. Davidson, and P. Perrone, 2002. *Surface Slurry Sealing Systems in Canada: Performance and Practice*. Proceedings, Canadian Technical Asphalt Association.

FHWA (Federal Highway Administration), 2003, *Pavement Preservation Compendium*, Publication No. FHWA-IF-03-21.

FHWA (Federal Highway Administration), 2002, *Thin Hot-Mix Overlays*, Publication No. FHWA-IF-02-49.

FHWA (Federal Highway Administration), 1997. *Pavement Recycling Guidelines for State and Local Governments,* Report FHWA-SA-98-042, National Technical Information Service, Springfield, Virginia 22161.

Hicks, R.G., S.B. Seeds, and D.G. Peshkin, 2000. *Selecting a Preventive Maintenance Treatment for Flexible Pavements*, Foundation for Pavement Preservation. http:fp2.org.

International Slurry Surfacing Association (ISSA), 2003a. *Recommended Performance Guidelines for Emulsified Asphalt Slurry*, A105. Available at www.slurry.org

International Slurry Surfacing Association (ISSA), 2003b. *Recommended Performance Guidelines for Micro-surfacing*, A143. Available at www.slurry.org

Janish, D.W. and F.S. Gaillard,1998, *Minnesota Seal Coat Handbook*, Minnesota Department of Transportation, Office of Research Services, Mail Stop 330, 395 John Ireland Boulevard, St. Paul, MN 55155.

Kazmierowski, T.J., and A. Bradbury, 1995. *Microsurfacing: Solution for Deteriorated Freeway Surfaces*, Transportation Research Board Record 1473, Washington, D.C.

NAPA, 2001. National Asphalt Pavement Association, *Thin Hot-Mix Asphalt Surfacings*, Publication IS-110. Available at www.hotmix.org.

InfraGuide, 2002, *Timely Preventive Maintenance for Municipal Roads — A Primer,* National Guide to Sustainable Municipal Infrastructure: Innovations and Best Practices, www.infraguide.ca.

InfraGuide, 2003a. *Guidelines for Sealing and Filling Cracks in Asphalt Concrete Pavement,* National Guide to Sustainable Municipal Infrastructure: Innovations and Best Practices, www.infraguide.ca

InfraGuide, 2003b, *Priority Planning and Budgeting Process for Pavement Maintenance and Rehabilitation,* National Guide to Sustainable Municipal Infrastructure: Innovations ands Best Practices, www.infraguide.ca

InfraGuide, 2005. *Reference Manual of Pavement Preservation Treatments*, National Guide to Sustainable Municipal Infrastructure: Innovations ands Best Practices, (in preparation), www.infraguide.ca

Ohio Department of Transportation, 2002. Technical Bulletin: *Smoothseal, Overlays for Use as Preventive Maintenance Surface Treatments*. Website: http://www.flexiblepavements.org/techdocs.html.

Scott, J.L.M, 1990. Canadian Practice in the Design, Use and Application of Bituminous Surface Treatments, Canadian Strategic Highway Research Program, TAC, Ottawa, ON, ISBN 1-895102-93-6.

The Asphalt Institute, 1969. Asphalt Surface Treatments and Asphalt Penetration Macadam, Manual Series No. 13, The Asphalt Institute, College Park, Maryland 20740.