Recent Developments with Seal Coating in Alberta

Jim Gavin, P. Eng.
Roadway Construction Standards Specialist

Marta Juhasz, P. Eng.
Surfacing Standards Specialist

Alberta Transportation
Edmonton, Alberta

Jean-Martin Croteau, P. Eng.
Manager, Quality Systems and Technical Development
Works Alberta Ltd.
Edmonton, Alberta

Ted Harrison, P.Eng.
Manager, Materials Engineering

Joseph Luca, P.Eng.
Design Engineering

GENIVAR
Red Deer, Alberta

ABSTRACT

Seal coating, using either single sized (chips) or graded aggregate, has been used as a surface treatment on Alberta rural roadways for many years. There is a general consensus within Alberta Transportation and many rural road agencies that seal coating is a highly effective and inexpensive treatment for preserving pavements. However, this type of construction often generates complaints from the travelling public, especially on higher volume roadways. These complaints are broadly related to vehicle damage associated with "loose chips", increased tire noise, and to a lesser extent travel delays and questionable workmanship.

In recent years Alberta Transportation has used, on a trial basis, alternative materials, application techniques and seal coating systems as a means to alleviate the public complaints and/or to improve the overall robustness of the seal coat product. This paper presents an overview and the findings related to the seal coating work carried out recently in Alberta using polymer-modified emulsions, fog sealing, pre-spraying outside of the wheel paths; racked-in chip sealing system and fibre-reinforced chip sealing system.

RÉSUMÉ

L'enduit de scellement avec un granulat d'une seule grosseur ou un granulat calibré a été employé depuis plusieurs années comme traitement de surface sur les routes rurales de l'Alberta. Il y a un consensus général chez Transports Alberta et chez plusieurs agences de routes rurales que le traitement de surface est un enduit très efficace et peu coûteux pour préserver les chaussées. Cependant ce type de construction génère souvent des plaintes du public voyageur surtout sur les routes à trafic plus élevé. Ces plaintes sont largement reliées aux dommages associés aux gravillons libres, au bruit accru des pneus et en moindre étendue aux retards et à une main d'oeuvre douteuse.

Dernièrement, Transports Alberta a employé sur une base d'essai des matériaux, des techniques d'application et des systems d'enduits de scellement autres comme un moyen de réduction des plaintes du public ou pour améliorer la robustesse en général du produit d'enduit de scellement. Cet exposé présente une vue d'ensemble et les résultats reliés au travail d'enduits de scellement réalisés récemment en Alberta utilisant les émulsions polymères, le scellement en bruine, la pré-pulvérisation en dehors des pistes des roues, les systèmes d'enduits de scellement s'emboitant et ceux renforcés de fibres.

1.0 INTRODUCTION

Seal coats have been applied to pavements in Alberta since 1941 [1-3]. They are primarily used by Alberta Transportation as a preservation tool to protect the pavement surface against deterioration due to traffic and environmental elements. Other benefits include improved all-season skid resistance, protection against water ingress into the pavement structure, improved lane demarcation, and reduced pavement temperatures during the summer due to the reflective nature of the light coloured surface.

Up until the mid 1980s, the Department's practice was to seal coat all highways within three to five years of being paved. This practice was discontinued due to budgetary restrictions. Currently, seal coating treatments are selected based upon needs and the yearly amount budgeted for this type of work. This selection process is further described in Section 2.

Prior to 1992, seal coat construction was completed by a combination of private sector contractors and departmental seal coat camps. Since 1992, the Department has only used private sector forces to undertake this work.

The approximate length of pavements treated each year has varied from a peak in the 1980's of 1,700 lane-kilometres (lane-km) to a low in the 1990's of 500 lane-km. In more recent years this number has risen to approximately 800 to 1,000 lane-km. Highways with an Average Annual Daily Traffic (AADT) of less than 800 vehicles per day (vpd) are treated using a graded aggregate while single sized aggregate (chips) are used on the remainder.

Double seal coats involving two applications of binder and graded aggregate were placed on low volume granular base course surfaces up until the early 1990's. This practice is not frequently used now by the Department.

While considered to be an effective tool for pavement preservation, the Department is at times reluctant to use seal coats due to public complaints. The complaints are usually related to vehicle damage associated with "flying" chips. Concerns about travel delays, increased tire noise and instances of questionable workmanship have also been expressed.

This report describes how seal coats are used by Alberta Transportation and recent initiatives undertaken to help alleviate the public complaints and to improve the overall robustness of the seal coat product.

2.0 PROCESS FOR PROJECT SELECTION

A planned seal coat program was first used by Alberta Transportation in 1959. Up until the mid 1980's this process involved a scheduled seal coat application for all primary highways (single and double digit numbered), typically done three to five years following paving. Since then the process has been changed due to reduced budgets and now projects are selected based upon their relative need and the overall budget allocation.

In 1996, Alberta Transportation outsourced all of its design and contract administration functions to engineering consultants. Currently each of the four regions has a surfacing design consultant in order to undertake all pavement surfacing designs. Each year department staff prepare a list of projects that they feel are in need of seal coating and provide that list to their regional surfacing consultant. The consultant then inspects each roadway and assesses the condition of the pavement based upon nine distress attributes along with traffic volume and pavement age. The seal coat rating system, known as Seal Coat Advisor (SECOA), has been used by the Department since 1992. Prior to that time department staff (lead by an in-house surfacing expert) inspected each candidate project throughout the province and ranked each project based upon judgement and experience. The SECOA expert rating system was developed by capturing the thought process used by this internal expert. Between 1992 and 1997, modifications were made to SECOA resulting in the system currently used today [1].

The assessments for all candidate projects throughout the province are assembled together and ranked based upon their relative score (i.e. from highest to lowest need). The number of projects programmed depends upon the annual seal coat budget but the actual projects selected are based upon this ranked rating. There may however be minor adjustments in project selection if there are large discrepancies in the number of projects between regions. Each region then tenders all of their seal coat work through a single contract. The tender preparation and contract administration is handled through a single consultant for each region.

An example Seal Coat Rating sheet is shown in Figure 1 and the corresponding Seal Coat Scoring sheet is shown in Figure 2.

SEAL COAT RATING - SHEET "A"
(Judgements of the Attributes of Pavements as Candidates for Seal Coat Application)

PROJECT NUMBER: Hwy 1 (EBL) **PAVING CONTRACT NUMBER:**

PROJECT DESCRIPTION

From: E. of Jct. Hwy 561
To: E. of Hwy 56
Control Section: :14 **From Km:** 13.520 **To Km:** 61.773 2002 - 2006
Control Section: **From Km:** **To Km:**
Control Section: **From Km:** **To Km:**

RATING CATEGORY **N.B.: Circle the appropriate "Rating" for each attribute observed.**

1.	Segregated Areas Segregated Areas	A) Ravelling		None	Slight	Moderate	Severe
		B) Frequency		Negligible	Few	Many	Very many
2.	Aggregate Loss (Exclusive of Segregation)	A) General Ravelling		Negligible	Slight	Moderate	Severe
		B) Coarse Rock Loss		Negligible	Slight	Moderate	Severe
3.	Hairline Cracking Hairline Cracking	A) Severity		None	Slight	Moderate	Severe
		B) Extent		Negligible	Slight	Moderate	Severe
4.	Presence of Foreign Material	A) Severity		Negligible	Slight	Moderate	Severe
5.	Pavement Surface Texture			High	Normal	Low	Very Low
6.	Traffic Volume	6270 - 6980	Weighted AADT = 6636	Low	Moderate	High	Very High
7.	Age of Pavement Surface	2002 - 2006	2 - 6 years	1 to 3	4 to 6	7 to 9	> 9

N.B.: Pavement with excessive bleeding, rutting or longitudinal / alligator cracking should not be considered as candidates for a Seal Coat application.

Remarks:
km 14.9: Segregation in middle of outside lane
km 17.7 to km 18.1: Rest Area
km 33.85 to km 34.1: Seal coat (1990)
km 40.5: Coarse agg. Loss in outside lane, OWP
km 52.4: Bridge
km 56.9 to km 57.5: Roadside turn-out

Figure 1. Example Seal Coat Rating Sheet

SEAL COAT SCORING - SHEET "B"

PROJECT NUMBER: Hwy 1 (EBL) **PAVING CONTRACT NUMBER:**

PROJECT DESCRIPTION

From: E. of Jct. Hwy 561

To: E. of Hwy 56

Control Section: :14	**From Km:** 13.520	**To Km:** 61.773	2002 - 2006
Control Section:	**From Km:**	**To Km:**	
Control Section:	**From Km:**	**To Km:**	
Control Section:	**From Km:**	**To Km:**	

RATING CATEGORY		Rating (Sheet A)	Weighting Factor (Table 1)	Score	
1. Segregated Areas	A) Ravelling	slight	5	AxB	15
	B) Frequency	very many	3		
2. Aggregate Loss (Exclusive of Segregation)	A) General Ravelling	slight	5	A+B	10
	B) Coarse Rock Loss	moderate	5		
3. Hairline Cracking	A) Severity	slight	2	AxB	6
	B) Extent	severe	3		
4. Presence of Foreign Material		slight	1		1
5. Pavement Surface Texture		normal	0		0
6. Traffic Volume: 6270 - 6980	Weighted AADT = 6636	high	7		7
7. Age of Pavement Surface	Years = 2 - 6	4 to 6	3		3
				Total Score	**42**

Inspected By: SB/WM **Consultant:** AMEC Earth and Environmental **Date:** 7 October 2008 **Region:** South

Figure 2. Example Seal Coat Scoring Sheet

3.0 SPECIFICATIONS

In the mid 1990's, Alberta Transportation switched from a method type specification to more of a warranty type specification for seal coat construction. Prior to this time the Department specified the grade of asphalt emulsion to be used and a range in application rates for both the binder and aggregate. Separate payment was provided for the supply of asphalt emulsion.

In 1994 the specifications were revised to remove separate payment for the supply of emulsion and requirements for specified emulsion grade, application rates and seasonal restrictions. Criteria were added for the performance of the seal coat during a one-year warranty period. The philosophy was to concentrate more on how well the product performs and less on how to build it. In subsequent years there have been a few project failures that were partially attributed to late season placement and accordingly, the specifications were again revised to require the placement of chip seals between May 1st and August 15th (May 1st to September 15th for graded aggregates). On a number of occasions, the Contractor has been held to undertaking repairs during the warranty period.

4.0 MATERIALS

In recent years, approximately 70 percent of the seal coating done by Alberta Transportation involves chip seals using a single-sized aggregate and cationic emulsion, with the remaining 30 percent using a graded aggregate and a high float emulsion. Micro-surfacing using a Type III aggregate [4] and a quick setting cationic emulsion (polymer modified) is used less frequently within urban or semi-urban areas.

4.1 Aggregate

Gradation requirements for graded and chip aggregates are shown in Table 1. The AW chip designation is used on high volume highways and consists of aggregates with a slightly larger mean diameter yet still retaining the same 12.5 mm top size.

Table 1. Alberta Transportation Specifications for Designation 3 - Seal Coat Aggregates

Percent Passing Metric Sieve Size (μm)	Aggregate Class[1] (mm)			
	12.5 AW	12.5 BW	12.5C	16
16,000				100
12,500	100	100	100	72 – 95
10,000	35 – 65	55 - 75	70 - 93	53 – 82
5,000	0 – 15	0 - 15	30 - 60	27 – 54
1,250	0 – 3	0 - 3	9 - 28	9 – 28
315	N/A	N/A	0 - 15	0 – 15
160	N/A	N/A	0 - 11	0 – 11
80	0 – 0.3	0 – 0.3	0 - 8	0 – 8
Percent Fracture (2 faces)	75+ (100% 1 face)	75+ (100% 1 face)	60+	60 +
Flakiness Index	15	15	N/A	N/A

Note 1: Des 3 – Cl. 12.5 AW used with Average Annual Daily Traffic (AADT) > 10,000
Des 3 – Cl. 12.5 BW used with AADT of 800 – 10,000
Des 3 – Cl. 12.5 C used with AADT < 800
Des 3 – Cl. 16 used for double seal coats.

4.2 Asphalt Binders

Current specifications call for the Contractor to use a cationic emulsion for chip seals and a high float emulsion for graded seals. The grades most commonly selected by the contractor are CRS-2 for chip seal and a HF-150S for graded seals.

5.0 RECENT INITITIATIVES

In recent years, a number of different construction techniques, materials and specification changes have been trialed. These changes were undertaken in an attempt to reduce the incidence of loose flying chips, improve traffic accommodation and/or improve the overall robustness of the seal coat product.

5.1 Specification Changes

Several specification changes had been made in recent years to improve traffic accommodation and reduce the overall travel delay. A persistent problem on seal coat projects, particularly on divided highways, occurs when speeders ignore posted speed limits and kick up loose chips as they pass motorists who are observing the posted limit. Pilot vehicles are now required on all projects to better control the overall traffic flow and maintain a more consistent speed between vehicles. To further reduce motorist frustration, the maximum length of roadway selected for seal coating is now limited to 30 km and the maximum length of roadway that the contractor can have under a 50 km per hour speed restriction is 20 km.

In order to forewarn motorists, contractors are now required to install advertisement signage outside the project limits a minimum of seven days prior to construction activities. The signs are to indicate “Seal Coat Construction”, the length of project and expected dates of construction.

5.2 Polymer Modified Emulsion

Like other agencies [5-7] Alberta Transportation has increased its use of polymer modified emulsions primarily to promote early aggregate adhesion. As of 2009, a CRS-2P emulsion will be used on all multi-lane divided highways, i.e. projects traditionally prone to receiving complaints of loose chips. Polymer modified emulsions are also reported to be more durable and less susceptible to snowplough damage [5]. Using a polymer modified emulsion is considered to be a low risk, low cost enhancement with a premium cost of approximately $0.20/m^2.

5.3 Two-Stage Binder Application

Selecting the proper binder application rate is one of the most important considerations towards constructing a successful seal coat. This can be a tricky matter on high volume highways or on pavements where the surface condition varies significantly across the lane. A lower application rate is required if the existing surface is tightly closed or slightly flushed and for wheel path locations of high volume highways. Conversely, a non-wheel path surface or an open porous surface would require a higher application rate.

Two seal coat performance problems commonly seen on high volume highways within Alberta are related to not achieving two different application rates within the same travel lane - that being flushing within the wheel paths (application too high) and chip loss or snowplough damage along the centre-line joint or outer edge of application (application too low). To address those problems Alberta Transportation has used, on a trial basis, a two-stage application process where two asphalt distributors work in close tandem. This procedure has been successfully used in New Zealand and Australia [6]. The first distributor applies a light application of approximately 0.3 l/m^2 to the non-wheel path surfaces (i.e. two strips on the outside and one strip between the wheel paths). A second distributor sprays the entire lane at a target application rate which is appropriate for a high volume highway (Photos 1 and 2).

Photo 1. Pre-Spray Binder Application

Photo 2. Regular Application with a Second Distributor

The light application (pre-spray) rate is meant to represent the difference in design rates due to different traffic volumes (i.e. non-wheel path surfaces have a lower traffic factor). This procedure was successfully used in 2008 on the outer travel lane of the Queen Elizabeth II highway (Hwy 2) near Red Deer. The performance to-date has been good as little to no wheel path flushing has been observed along with no aggregate loss or snowplough damage. It is possible that this procedure could help, albeit marginally, in reducing the instances of loose chips during construction.

An additional section of Hwy 2 near Red Deer will be treated in 2009 using this pre-spray technique. The premium cost associated with this work is approximately \$0.09/m^2 (across the total lane surface).

5.4 Fog Sealing

Fog sealing (or top shooting) of a newly placed seal coat is used by other agencies as a means to reduce aggregate loss and towards further decreasing the permeability of the pavement [7]. Alberta Transportation has used fog sealing on a limited basis as a planned means to reduce loose flying chips and on a remediation basis where excessive chip loss was believed to be caused by an under application of binder.

In 2008, a six kilometre length of Hwy 613 immediately east of Westaskiwin was chip sealed. On that project a fog seal using an SS-1 emulsion (50 percent dilution) was applied at a rate of 0.5 to 0.6 l/m^2 to the chip seal on the same day of placement but after receiving "second brooming" (i.e. the final brooming before removing the pilot vehicles and the 50 km per hour speed restriction). A 500 m section of seal coat was left un-fogged so that a comparison could be made on the relative occurrence of loose chips.

For each section, areas of the paved shoulder were swept clean right after the final brooming. The same shoulder areas were swept 24 hours later to collect loose chips that had become dislodged from the chip sealed lane. The weight of loose chips (> 5.0 mm) on the section without the fog seal was 136.1 g/m^2 versus 9.9 g/m^2 within the fog coated section indicating that fewer chips were dislodged from the fog coated surface (thus less chance for vehicle damage). Project staff also felt that after driving on both surfaces the instance of loose chips was lower within the fogged section.

While there appears to be a benefit in using this technique there are also a few disadvantages. The fog sealing procedure requires extra lane closure time (2 to 3 hours) while the fog seal cures resulting in extra travel delays. The procedure also reduces the amount of chip sealing that can be done per day as the curing of the fog seal must be complete prior to dusk and the opening of all lanes to traffic. There is also the risk of motorists inadvertently driving on the fresh fog seal and thus generating further complaints (Photo 3.) For those reasons, the Department and contractors are reluctant to include fog sealing as a normal procedure. The use of blotting sand on top of the fog seal has not been used by the Department but may be worth pursuing in the future to lessen some of these risks.

Photo 3. Tire Tracking on Insufficiently Cured Fog Seal

5.5 Racked-In Seal Coat

A racked-in or choke seal is similar to a regular chip seal except that a second layer of smaller size chips are also applied [5-7]. The smaller chips are intended to wedge or rack themselves within the larger chips that are first applied. In this process, as with a regular chip seal, only a single application of binder is used. The same type of chip aggregate is applied for the first layer but at a much lower rate than used in a regular chip seal. In a regular chip seal the aggregate application is normally 5 to 10 percent higher than the full coverage design rate; however, with the racked-in system the aggregate is placed at roughly 75 to 85 percent of the full coverage design rate. Note that the full coverage design application rate is defined as the minimum amount needed to achieve kneaded one-stone coverage of the complete surface. A second chip spreader follows closely behind the first and spreads the smaller chips. An excess of smaller chips are applied to guarantee complete coverage and ensure that any loose chips would consist of only the smaller chips resulting in less vehicle damage. Accordingly, the racked-in process is well-suited for use on roadways with high or fast moving traffic.

In 2008, Alberta Transportation completed trial applications using a racked-in seal, both with and without a propriety fibre-reinforced membrane, on Hwy 39 southwest of Edmonton. The details of that project are discussed in Section 6.0. Costs for using a racked-in seal coat are estimated to be \$0.35 per m^2 higher than a regular chip seal; however, the department has limited experience using this product. The provincial average cost for chip seal (BW aggregate) in 2008 was \$3.40 per m^2.

5.6 Fibre-Reinforced Membrane System

Fibre-reinforced membrane systems are proprietary treatments that have been categorized as either a Stress Absorbing Membrane (SAM) when used as a surface treatment, or as a Stress Absorbing Membrane Interlayer (SAMI) when covered with a subsequent wearing course [8]. In each case the process is used to inhibit pavement cracking and/or to mitigate reflective cracking.

The fibre-reinforced membrane is installed using specialized equipment. The trailer mounted unit is hooked to a distributor nurse truck and includes storage for the columns of fibreglass spools (Figure 3). The trailer unit applies the first layer of binder. Strands from the fibreglass spools are feed into a chopping unit. An air blowing system then uniformly shoots the chopped strands in random orientation onto the first binder layer. The same trailer unit finishes by spraying a second layer of binder to encapsulate the fibres.

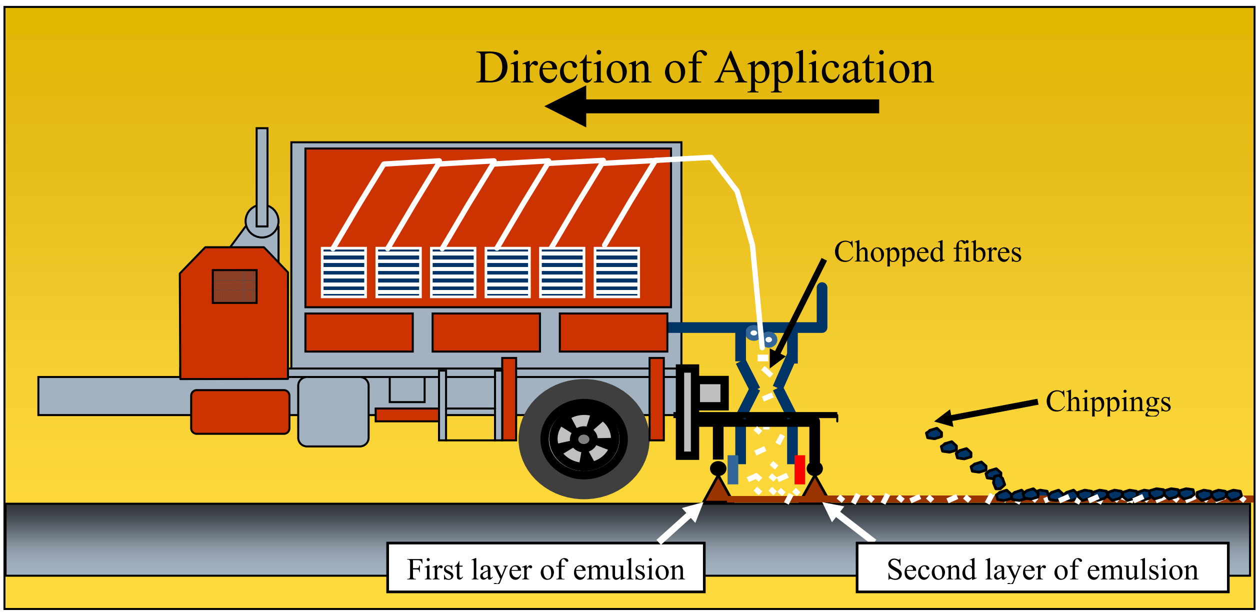

Figure 3. Fibre-Reinforced Membrane Placement Process

A single layer of chips is then spread, rolled and broomed as in a conventional chip sealing operation. However, for the Hwy 39 trial project the two stage racked-in process, as previously described, was used.

In addition to mitigating reflective cracking, the fibre-reinforced membrane is reported [8] to be a more robust sealing system that provides greater resistance to deterioration due to traffic and snowplough damage.

6.0 TRIAL APPLICATION USING RACKED-IN AND FIBRE-REINFORCED MEMBRANE SYSTEMS

6.1 Overview

In 2008, Alberta Transportation used the services of Works Alberta Ltd. to design and place a seal coat on Hwy 39:10, west of Leduc, using two different seal coat systems: a racked-in system without fibre-reinforcement and a racked-in system with fibre-reinforcement. This two-lane highway has for years ranked high for seal coating however, regional staff were reluctant to include it within their program because of high traffic volumes (AADT of 8000 to 8500) and thus the potential for generating complaints related to travel delay and vehicle damage (loose chips).

In discussions with representatives from Works Alberta Ltd., the advantage of using a racked-in system was identified with regard to reduced vehicle damage. Works Alberta Ltd. was also able to offer in-house technical advice on utilizing seal coat design methods not familiar to practitioners within Alberta but used elsewhere in North America and Europe. The Department decided to trial the racked-in procedure primarily to investigate the potential for reducing the incidence of loose chips. Works Alberta Ltd. was also the maintenance contractor for the Contract Maintenance Area (CMA) in which this highway is situated and thus this work was handled as an Extra Work item under that CMA contract.

This pavement was last paved in 1999 and the factors that contributed to its high ranking were high frequency of pavement segregation areas, extensive areas of hairline distress cracking within the wheel paths (Photo 4), and high traffic volumes. Transverse cracking of slight to moderate severity was present at a spacing of 10 to 20 m. Because of the extensive wheel path cracking this project was considered a good candidate to trial the fibre-reinforced membrane system and its ability to mitigate this form of cracking. Regular chip seals are considered to be only moderately successful in that regard. The racked-in process for aggregate application was also used with the fibre-reinforced membrane. Accordingly, the two different products will be described in this report as racked-in (with fibres) and racked-in (without fibres).

GENIVAR was hired by the department to complete a pavement distress mapping of the highway, provide project management duties during construction and report documentation of all activities associated with the trial placement [9]. The pavement distress maps will be used in future years to help monitor performance.

6.2 Seal Coat Designs

The determination of the optimized systems was carried out in two steps:

- selection of the type of seal coat system based on environment, roadway condition and local experience, and
- selection of materials and determination of binder spray rate and chippings spread rate.

Photo 4. Hwy 39:10 - Extensive Wheel Path Cracking of Slight Severity

6.2.1 Selection of Type of Seal Coat System

The selection of the type of seal coating system depends on a number factors related to the environment, roadway condition, and local experience. The environmental factors includes local climatic conditions, the shade conditions, and the timing of placement of the seal coating system, while the roadway condition factors include the location, the existing surface conditions, the traffic counts, the traffic speed, the roadway layout, the substrate hardness, and trafficked pathways within the roadway. The local experience is also required to select a seal coat system that accounts for specific conditions. For example, potential snowplough damage is a very important in Canada, while in other counties factors such as reduction of aggregate loss, the pressure to open the road to traffic or rolling noise may influence the selection of an optimized system.

The selection of a suitable seal coating system is often carried out with the help of flow diagram, catalogues of systems or decision trees. Computer programs have been developed in France and in the UK to help with selection of optimized systems [10, 11]. In the case of Hwy 39:01, the approach from both the UK and France were used and compared. The UK Road Note 39 as well as the French technical guidelines suggested the application of a multi-layer system to account for the type and speed of traffic, as well as to reduce the risk of having large chips come loose. The surface conditions and more particularly the extensive presence of cracking was the leading factor for the selection of the fibre-reinforcement. Accordingly, the multi-layer racked-in system was better suited for the amount of binder necessary to encapsulate the fibres in the fibre-reinforced section of the project. And, as a result, it was decided to use the same system throughout the project.

6.2.2 Selection of Materials and Determination of Binder Spray Rate and Chippings Spread Rate

Binder: Bitumen emulsions are the preferred binders for seal coating in many industrial countries and the usage cationic rapid setting emulsions are prevalent for chip seals. The setting of cationic emulsion is strongly affected by the chemical nature of the aggregate, which destabilizes cationic emulsions causing them to break and set rapidly. Thus, gain in strength of cationic seal coat systems is rapid, which is preferable where and when the success of the treatment is highly dependent on the rapid gain of strength of the system, which was the case for Hwy 39:01. Bitumen emulsions modified by the addition of polymers to enhance their adhesion and cohesion properties are particularly suitable for high volume roads and/or where snowploughing may be considered aggressive, which again was the case on Hwy 39:01. The selected binder for the seal coating work on Hwy 39:01 was a polymer modified cationic rapid setting emulsion, CRS-2P.

Chippings: Racked-in seal coating systems are built using hard and well calibrated chippings. Chippings are commonly defined as one-size aggregate and the sizes used to build the racked-in systems on Hwy 39:01 were a 7/11 mm bottom chip that satisfied the Alberta Transportation *Des 3 – Cl. 12.5 BW* and a 4/6 mm top chip. The cleanliness of the chipping is of the utmost importance for the performance of any chip sealing systems and in both cases: bottom and top chips had less than 0.3 percent particles passing the 80 µm sieve. The flakiness of the chippings is also another important factor for the bottom chip as it provides structure to the system. The flakiness of the bottom chip was 8.9 percent, which again satisfied Alberta Transportation for the *Des 3 – Cl. 12.5 BW* aggregate. The flakiness of the top chip was not measured as it is not considered critical for a racked-in system.

Binder/Chippings Adhesion Properties: The initial test for determining the adhesion properties of a binder/aggregate system consists of making sure that the emulsion has the ability to coat the aggregate. A simple coating test was performed to verify the compatibility of the emulsion with the aggregate. The Vialit Pendulum test (NF T 66-037) was also performed to assess the long term adhesion property of chip sealing system selected for Hwy 39:01. The tests replicate the ability of the binder of a chip sealing system to retain chips under different environmental conditioning.

Binder Spray Rate: Binder spray rate is established using the information specific to both, the site and the selected chip sealing system. The information specific to the site includes the existing surface conditions, the traffic count, the traffic speed, the roadway layout, the substrate hardness and trafficked pathways within the roadway, local climatic conditions, the shade conditions, and the timing of placement of the seal coating system. The information specific to the selected seal coating system includes size, gradation, and flakiness of the aggregate. The UK and French approaches for establishing binder spray are quite similar. Comprehensive tables are used and even computer software has been developed to determine binder spray rates. The North American approach still relies on the experience of the localized agency, however, the McLeod/Minnesota method is often used as a reference. The selection of the binder spray rate for Hwy 39:01 was determined using the information provided by the UK, French and the McLeod/Minnesota methods and local experience. The selected binder rate was 2.00 l/m^2 for the racked-in (without fibres) system and 2.15 l/m^2 for the racked-in (with fibres) system. The rates were slightly higher than what the UK and French methods proposed to account for snowplough aggression. The increase in binder rate between the fibre and no fibre system relates to the necessity to ensure full encapsulation of the fibres.

Chippings spread rates: The spread rate of the chippings may be determined using empirical methods based on field trials or by methods based on the aggregate properties such as the ***average least dimension,***

the *voids in the loose aggregate* and the *bulk specific gravity* of the aggregate. The selected coverage varies from one system to another and from one layer to another. Some cover aggregate gets thrown to the side of the roadway by the traffic. The amount of traffic whip-off varies from one type of system to another and also from one layer to another, plus traffic speed. The lower layer chips of multi-layer systems are usually applied at a rate that is less than 100 percent of the full surface coverage design rate to provide space to place the smaller upper chips within the chips of the lower layer. The typical coverage is also associated with the number of binder applications. In the case of the racked-in system selected for Hwy 39:01 there was only one layer of binder and two layers of chips; the first layer was set at 25 percent below the design coverage rate and the second layer was set at 20 percent below the design coverage rate. The spread rate was established using the French Standard NF P98-276-1 [11] and the spread rates were 10.0 to 10.5 kg/m^2 for the bottom chip and 5.2 to 5.6 kg/m^2 for the top chip.

6.3 Placement Details

6.3.1 Overview

The 12.83 kilometre length of highway was split, with the western half (km 14.30 to 20.715) containing the racked-in (with fibres) treatment and the eastern half (km 20.715 to 27.130) containing the racked-in (no fibres) treatment. A one kilometre section from km 15.03 to 16.03 was selected as a test site where both products were to be used and a detailed distress map of the existing pavement was completed. The layout of the test site, as shown in Figure 4, consists of a lane-by-lane comparison of the two products.

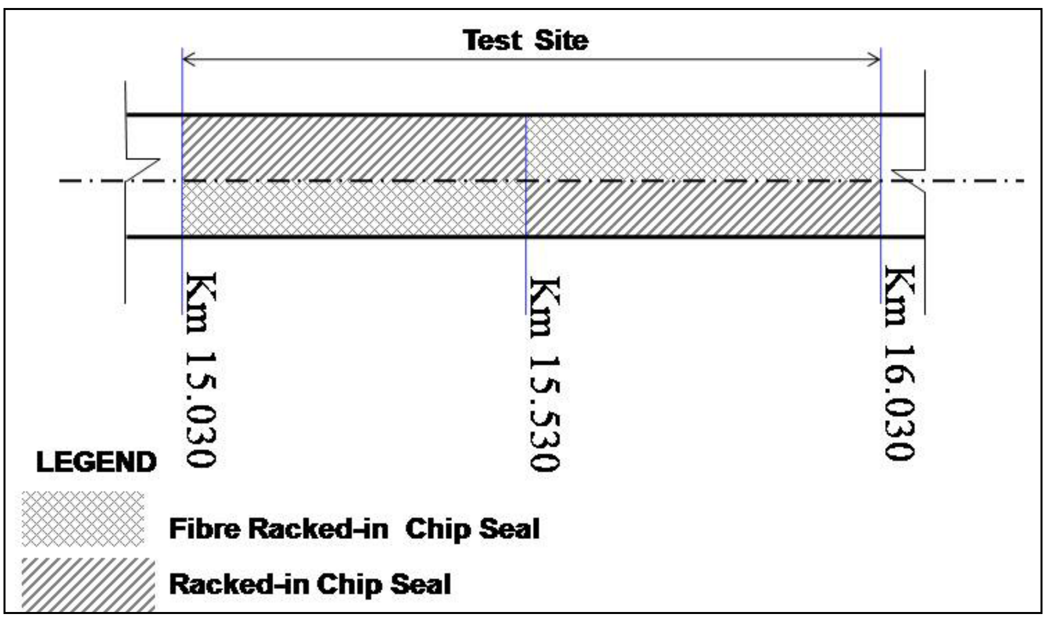

Figure 4. Hwy 39 Test Section Layout

Both products were placed over a four day period from July 10th to 13th inclusive. Weather conditions were generally favourable with a mix of sun and cloud, daily highs between 17 and 24°C and daily lows between 4 and 9°C. Brief showers occurred in the afternoon of the July 11th, however this did not affect operations, as work was already suspended that afternoon due to electrical problems with the on-board computer system of the asphalt distributor used for the fibre-reinforced system.

The same equipment was used for each product except for the asphalt distributor. The reinforced-fibre asphalt distributor as described earlier was used to spray the fibres/binder for the racked-in (with fibres) product, while a regular asphalt distributor was used to spray the binder for the racked-in seal (without fibres). The chip spreading, rolling and brooming operations were the same for both products. Two chip spreaders were used for chip placement. Rolling was completed using two self-propelled pneumatic rollers and one single-drum steel roller.

Other construction procedures were similar to that used on regular seal coat projects except for the sweeping operations. On regular seal coat projects, the surface is broomed a minimum of two times on the day of placement prior to removing the pilot vehicles and increasing the posted speed. On Hwy 39 the Contractor wished to do only one brooming on the day of placement and delay the second and final brooming until the next day. The objective was to leave an excess of the small chips as cover aggregate to be further wedged within the large aggregate with the overnight traffic. The one concern with this practice was the extra availability of chips and potential for flying chips. As it turned out, this problem did not materialize as the smaller chips, while still loose, were not large enough to cause any actual damage.

6.3.2 Racked-In Seal Coat (Without Fibres)

Production rates using both types of racked-in products were similar to that of regular seal coat projects taking into account weather and equipment breakdown.

Daily production and average spread rates for the racked-in seal coat (without fibres) are shown in Table 2.

Table 2. Daily Placement Summary for Racked-In Seal Coat (Without Fibres)

Material	Application Details	Units	July 10th	July 11th
Racked-In Seal Coat	Area Treated	m^2	38,890	9,636
CRS-2P Polymer Modified	Actual spray rate	l/m^2	1.98	2.07
	Target spray rate	l/m^2	2.0	2.0
12.5 BW Chips (1st application)	Actual spread rate	kg/m^2	12.6	10.9
	Target spread rate	kg/m^2	10.5	10.5
5 mm Chips (2nd application)	Actual spread rate	kg/m^2	7.5	5.4
	Target spread rate	kg/m^2	5.6	5.6

The bulk binder spray rates matched quite closely to the target value of 2.0 l/m^2. The aggregate bulk spread rates matched reasonably well to the target values on July 11th, however the spread rates for both the 12.5 BW chips and the 5 mm chips were 20 to 30 percent higher than target values on July 10th.

6.3.3 Fibre-Reinforced Membrane Seal Coat

The specialized trailer used to apply the emulsion and fibres is shown in Photo 5. The fibre-reinforced membrane, before chip placement, is shown in Photo 6. The application of the two aggregate layers is shown in Photos 7 and 8.

Photo 5. Fibre-Reinforced Membrane Placement Trailer Unit

Photo 6. Fibre-Reinforced Membrane Prior to Chip Application

Photo 7. Fibre-Reinforced Membrane with 1st Layer of Racked-In Aggregate

Photo 8. Application of Smaller Chips

Daily production and average spread rates for the racked-in (with fibres) seal coat are shown in Table 3.

Table 3. Daily Placement Summary for Racked-In Seal Coat (With Fibres)

Material	Application Details	Units	July 12th	July 13th
Racked-In Seal Coat (with fibres)	Area Treated	m^2	33,196	20,379
CRS-2P Polymer Modified	Actual spray rate	l/m^2	2.14	2.10
	Target spray rate	l/m^2	2.15	2.15
12.5 BW Chips (1st application)	Actual spread rate	kg/m^2	10.1	10.8
	Target spread rate	kg/m^2	10.5	10.5
5 mm Chips (2nd application)	Actual spread rate	kg/m^2	5.1	7.0
	Target spread rate	kg/m^2	5.6	5.6

The actual application rates for both chip applications and binder application were reasonably close to the target values except for the 5 mm chips applied on July 13th which was in excess by 25 percent.

6.4 Success in Mitigating Loose Chips

There was widespread agreement amongst all those involved with the project that the racked-in system (both with and without fibres) was successful in mitigating the occurrence of loose chips. When driving over both of the racked-in seal coats, the general observation was fewer instances of the larger chips being kicked up into the wheel wells or under body of the vehicle in comparison to that experienced on a regular chip seal. As described earlier, the racked-in seal coats were only broomed once on the day of placement meaning that there were significantly more excess chips present during the first over-night period than that normally seen on a regular seal coat project. For that period, project staff indicated that they could notice a higher instance of loose chips but only involving the minus 5 mm size chips (i.e. less offensive and damaging than the larger chips).

No public complaints were received with regard to vehicle damage or loose chips. Project staff did however, report that there were at least two complaints associated with long waiting times (up to 45 minutes) within the stopped traffic queue. Both complaints were reported on a busy Friday afternoon. As expected, using a racked-in seal coat does not improve, or worsen, problems associated with travel delay or traffic accommodation on high volume roadways.

In an attempt to better quantify whether the racked-in process resulted in fewer loose chips, portions of the shoulders on this project were sweep at different times to measure how much of the larger chips were being dislodged from the adjacent seal coat. These numbers were compared to similar testing done on two other projects using a conventional chip seal. The results did confirm fewer errant chips on the Hwy 39 project; however, because the brooming intervals used for the Hwy 39 project were different than that used on the other two projects there are questions as to whether the numbers are comparable and hence they are not reported here.

6.5 Early Performance Monitoring

The typical appearance of the completed racked-in seal coat is shown in Photos 9 and 10. As expected, it was difficult to discern between the two products (with and without fibres) based upon surface appearance. The appearance somewhat resembles a chip seal surface, however the smaller choke chips were clearly wedged within the matrix of the larger chips. The quality of the final product was considered to be very good. Some of the transverse joints, where either of the asphalt distributors stopped and started, did display localized areas of unequal binder application (minor flushing).

Located within the limits of the racked-in seal (with fibres) section was a busy un-signalized T-intersection with Hwy 60. Placing the seal coat through this area proved problematic from a traffic accommodation viewpoint. The final surface through here also had a non-uniform appearance due to aggregate roll-over and tracking of the emulsion due to the various turning movements. This is a common problem observed with all types of seal coat construction involving busy intersections. In this case it appears to be more of a cosmetic problem than a potential performance problem.

Photo 9. Close Up Appearance of Racked-In Seal (With Fibres)

Photo 10. Racked-In Seal Coats – Without Fibres in Near Lane, With Fibres in Far Lane

The most recent observations of this highway (May 2009) indicate similar and acceptable performance of both products. Detailed pavement distress mapping of the test sections has not yet been completed, however a few observations can be provided. Thermal cracking has reflected through both, the fibre-reinforced and the non fibre-reinforced systems. The fibre-reinforced system is labelled as a mitigation system not a system that stops reflective cracking. The prairie climate is well known to be particularly harsh and the control of thermal reflective cracking is nearly impossible. Consequently, the appearance of thermal reflective cracking in the short term was rather anticipated.

In each of the seal coats, none (or very little) of the wheel path distress cracking has reflected through. In some cases minor web-like shadows can be seen to outline this type of cracking; however, the seal coat itself remains intact. A few instances of reflective longitudinal cracks (both within and outside of the wheel paths) were observed but were not considered significant. A few small areas of aggregate loss, associated with snow plough damage, were also seen in both products. Again, this is not seen as a significant performance problem.

Each of the seal coats had portions with increased chip embedment within the wheel paths, however not to the extent to cause any flushing. This may be a sign of a slight over application of binder, which indicates that the increase in binder spray rate, discussed in Section 6.2, to compensate for potential snowplough damage may in fact not be warranted.

Finally, with regard to noise due to tire-pavement interaction, the use of the smaller chip in the racked-in process and corresponding surface texture does seem to result in a quieter ride. The Department has in the past not put much effort toward improving the sound characteristics of seal coat treatments. However, if this does hold up as a second advantage, then the racked-in process could indeed be perceived as being more “public friendly” and thus the future question may not be “why is the Department switching to this new process” but rather “why is the Department not switching”.

7.0 CONCLUDING REMARKS

This report has described several new materials or seal coating techniques that Alberta Transportation has trialed over the last several years. For 2009, the Department is:

- Increasing it usage of polymer modified emulsion;
- Using the emulsion pre-spray technique on another 44 lane-km of Hwy 2;
- Using the racked-in process on 36.2 lane-km of Hwy 2A south of Leduc, and
- Will treat 8.4 lane-km of Hwy 16 near Edson with micro-surfacing.

The Department will also consider using a fibre-reinforced membrane system for pavements with extensive wheel path cracking, which are normally excluded from seal coating.

The Department will continue to evaluate the constructability and longer term performance for each of these treatments and, where appropriate, refine the project/treatment selection criteria.

DISCLAIMER

The opinions and findings presented are those of the authors and not necessarily those of Alberta Transportation.

REFERENCES

[1] "Alberta Infrastructure Guidelines for the Assessment, Rating and Prioritization of Pavements for Seal Coat", Alberta Transportation internal report (2000)

[2] Ehly LJ. "Seal Coat Surfacing by Alberta Department of Highways", Proceedings, Canadian Technical Asphalt Association, 4, 37-42 (1959)

[3] Ehly LJ. "Alberta Highways Seal Coating Practice", Proceedings, Canadian Technical Asphalt Association, 10, 285-289, (1965)

[4] International Slurry Surfacing Association (ISSA). "Recommended Performance Guidelines for Micro-Surfacing", ISSA, Annapolis, Maryland (Revised May 2003).

[5] Davidson JK, Houston G, Linton P, Croteau J-M. "An Overview of the Design of Emulsion Based Seal Coating Systems Available in Canada and Abroad", Proceedings, Canadian Technical Asphalt Association, 50, 364-377 (2005)

[6] National Cooperative Highway Research Program (NCHRP). Chip Seal Best Practices. NCHRP Synthesis 342, Transportation Research Board, National Research Council, Washington, D.C (2005).

[7] Wood JW, Janisch DW, Gaillard FS. "Minnesota Seal Coat Handbook 2006", Report MN/RC – 2006-34, Minnesota Department of Transportation, St. Paul, Minnesota (2006).

[8] Croteau JM, Chaignon F, Thompson M, "A Four-Year Performance Review of North American and International Fibre-Reinforces Membrane Systems", Proceedings, Canadian Technical Asphalt Association, 52, 400 – 415 (2007).

[9] "Highway 39:10 – Trial Seal Coating Investigation – Racked-In Process", GENIVAR, Alberta Transportation internal report (2008).

[10] Nicholls JC et al. "Design Guide for Road Surface Dressing", Road Note 39, Fifth Edition, Transportation Research Laboratory Limited, Crowthorne, United Kingdom (2002).

[11] "Enduits superficiels d'usure: Guide technique", Ministère de l'Aménagement du territoire, de l'Équipement et des Transports, Paris, France (1995).