Synthesis of Seal Coat Research in Minnesota

LRRB
LOCAL
ROAD RESEARCH
BOARD

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INTRODUCTION

While seal coating has been widely used as a cost-effective strategy in asphalt pavement preservation by the Minnesota Department of Transportation (MnDOT) and local agencies to extend the life of pavements, some cities and counties in Minnesota have reported their concerns about the premature stripping of street pavements that have been seal coated. The Local Road Research Board (LRRB) completed a study on seal coats titled, Is Seal Coating Counterproductive or Not? to address these issues.

The purpose of this document is to provide users with quick access to some of the research and resources available in Minnesota.

Summary of Statewide Seal Coating Survey....................2

Synthesis of LRRB Seal Coating Resources....................3

Is Seal Coating Counterproductive or Not?....................3

Alternatives to Seal Coats....................9

Minnesota Seal Coat Handbook....................13

Information on Compatibility (emulsion and aggregates) and Sealcoating Newer Pavements....................17

Understanding Aggregate-Emulsions Compatibility....................17

Sealcoating Newer Pavements....................18

Ongoing Research on Seal Coating....................20

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Since 1959, the Minnesota Local Road Research Board has completed successful research and implementation products supporting local agencies. The secret of this success is the outstanding knowledge within the city and county communities and the willingness to share that expertise to address shared needs.

A special thank you to this outstanding Technical Advisory Panel!

SUMMARY OF STATEWIDE SEAL COATING SURVEY

A survey was sent to all counties and MSA cities via MnDOT State Aid and found the following results:

Responses as to whether they currently seal coat:

	Total	City	County
Yes	60	24	36
No	27	22	5
		46	41

From those that seal coat:

Emulsion Type	Total	City	County
CRS	21	8	13
CRSP	10	3	7
CRS2P	22	7	15
HFRS	1	0	1
	54	18	36

Emulsion Application Rate (gals/ sq yd)	City	County
Cities: 0.22 - 0.26	Majority	
Cities: > 0.30	5	
Counties: 0.25 - 0.28		10
Counties > 0.30		16

Aggregate Type	Total	City	County
A	33	14	19
B	8	3	5
C	4	0	4
	45	17	28

Aggregate Size	Total	City	County
FA-1	1	1	0
FA-2	35	14	21
FA-2 Mod	1	1	0
FA-2.5	12	2	10
FA-3	8	2	6
	57	20	37

1st Seal Coat	Total	City	County
Paving - 1yr	16	5	11
2-3	19	5	14
>3	19	9	10
	54	19	35

Years in Between	City	County
	7-10	7-10+

Cost/sq yd	City	County
Range	$1.00-$4.50	$0.65-$5.17
Average	S2.19	$1.72
Median	$1.85	$1.50

If unfamiliar with the terms referenced above, please refer to the Seal Coat Handbook.

Is Seal Coating Counterproductive or Not?

LRRB 2020-34

Scope

The study had three stated goals:

- Determine whether the seal coating is useful to extend the service life of the pavement
- Find out why stripping occurs under seal coats and provide some methods to solve it
- Make recommendations for seal coating on asphalt pavements

What was done:

- Comprehensive field data collection was conducted.
- Corresponding laboratory testing was then conducted.
  - Interface bond test (IBT) and shear bond test (SBT) evaluated the interface bond strength and shear bond strength of asphalt pavement under seal coating in different temperatures, moisture conditions, and freeze-thaw cycle conditions for various asphalt-emulsion and aggregate combinations.
  - In addition, the proposed IBT test was used for testing the interface bond strength of pavement cores with different pavement ages, material types of seal coats, and degrees of pre-existing damage to evaluate the seal coated pavements.
- The laboratory concluded the following:
  - The interface and shear bond strength between the laboratory seal coat layer and asphalt pavement layer decreased with the increase of freeze-thaw cycles.
  - The combined performance of **polymer-modified asphalt-emulsion and FA-2.0 granite** was optimal for low-temperature resistance.
  - The **optimal aggregate for freeze-thaw cycle resistance was Trap-Rock 1/8 inch** minus.
  - The weak asphalt-aggregate combination in the seal coat application and the increased freeze-thaw cycles were the main factors for premature stripping of many seal coat asphalt pavements.
  - Based on the test results from the pavement cores, it was determined that when partial damage occurs in the seal coats, further deterioration accelerates in the pavement system.

Conclusion

- Testing results were based on a limited number of asphalt pavement cores. The asphalt pavement structures studied in this project have different historical asphalt mixture designs. It was challenging to confirm the exact reason for premature stripping since the historical asphalt mixture design information is unavailable. **Thus, no definitive conclusion could be made on whether or not seal coating is counterproductive.**

CHAPTER 1: Introduction and Background

- Reviewed several different resources
- Briefly summarized seal coat alternatives (microsurfacing, slurry seal, chips seal, fog/bio seal)
- Discussion on stripping/field performance of seal coats
- Discussion on oil, emulsions and inner layers

CHAPTER 2: Field Data Collection for Stripping Areas on Pavements

- 8” cores representing various conditions (traffic, climate, possibility of stripping, and the age of pavement) were taken from eight areas: Brooklyn Park, Eden Prairie, Inver Grove Heights, Minnetonka, Rochester, Woodbury, McLeod County and Chisago County.
- Additional laboratory materials were provided by MnDOT:
  - » Aggregates: granite, trap rock
  - » Emulsions: CSS-1H, CRS-2P

CHAPTER 3: Evaluation of Interface Bond Test for Asphalt Pavement Under Seal Coating

- Four aggregates were tested: Red-Rock FA-2.5, Granite FA-2.5, Granite FA-2.0, and Trap-Rock 1/8 inch minus.
- Two emulsions using PG 58-28:
  - » AE-1 is a polymer modified cationic water-based emulsified asphalt
  - » AE-2 is an ordinarily cationic water-based asphalt-emulsion
- Interface Bond Test (IBT) was used to investigate the interface bond strength between the seal coat and asphalt pavement; weak interface bond strength may be linked to premature stripping. Tests were performed at different temperatures (25°C, 0°C, and -10°C) and multiple freeze-thaw cycles.
- Vialit tests were used to evaluate the adhesive performance of asphalt-emulsions and aggregates at low temperatures. Tests were performed at different temperatures: -10°C, -22°C, and -26°C.
- Four main conclusions were reported:
  - » Polymer-modified asphalt-emulsion (AE-1) based seal coat has a better adhesive performance than the seal coat with the ordinary asphalt-emulsion (AE-2); the material mineral composition of aggregates played a significant role in influencing the durability of the seal coat application.
  - » The interface bond strength between the laboratory seal coat layer and asphalt pavement layer decreased with the increase of freeze-thaw cycles. The presence of fewer voids in seal coat reduced the microstructural damage due to ice expansion of voids during the freeze-thaw cycles, and thus the larger aggregates produced an increase in microstructural damage.
  - » The combined performance of AE-1 and Granite FA-2.0 is optimal from the viewpoint of low-temperature stability, while the optimal aggregate type is Trap-Rock 1/8 inch minus (within the range of aggregate types selected in this study) for freeze-thaw cycle resistance.
  - » Weak asphalt-aggregate combination in seal coat application and increased freeze-thaw cycles are the main factors for premature stripping of many seal coat asphalt pavements.

CHAPTER 4: Evaluation of Shear Bond Test for Asphalt Pavements Under Seal Coating

- Shear bond strength is an indicator for revealing the bond qualities of seal coat with asphalt pavement.
- Laboratory samples using four kinds of aggregates (Trap-Rock 1/8-inch minus, Granite FA-2.0, Granite FA-2.5, and Red-Rock FA-2.5) and the two emulsions AE-1 and AE-2 using the Minnesota seal coat design method. All of the SBT samples were prepared at an identical asphalt-emulsion application rate of 1.63 L/m2 (0.36 gal/yd2).

- Several freeze-thaw cycles were conducted, with a maximum of five cycles used.
- Conclusions reported from SBT results under environmental conditions:
  - » The shear bond strength of AE-1 seal coats was higher than that of AE-2 seal coats. This result indicates that the polymer-modified asphalt-emulsion (AE-1) performs better in terms of interface bonding with aggregates in the seal coats.
  - » Trap-Rock seal coat obtained the highest shear bond strength with asphalt pavement. This could be encouraged by the higher percentage of fine aggregate particles found in the Trap-Rock as well as the chemical interactions present between the aggregate particles and asphalt.
  - » Generally, larger aggregate size resulted in weaker shear bond strength of seal coat under the same asphalt-emulsion application rate. Although aggregate size is a critical factor in determining the shear bond strength of the seal coat, the mineral composition of aggregate was also found to affect the strength.
  - » At the same embedment percentage of aggregate in a seal coat, larger sized aggregate provided better durability of seal coat for shear loading from vehicles. In addition, under the same aggregate type conditions, the shear bond strength of seal coat with asphalt pavement increased with the increase of the asphalt-emulsion application rate.
  - » In general, the shear bond strength weakened with low temperatures. However, the seal coat with larger sized aggregate was more stable with asphalt pavement than the seal coat with smaller sized aggregate at low temperatures.
  - » The shear bond strength of seal coat with asphalt pavement decreased with the increase of freeze-thaw cycles. Although Trap-Rock produced the highest shear bonding performance, its ability to resist freeze-thaw cycle is the worst of all four aggregate types. The larger sized aggregate in the seal coat could improve the resistance for the multiple freeze-thaw cycles.
  - » Materials and environmental combinations have a significant impact on the shear bond strength of seal coat with asphalt pavement. The material and structural design of the seal coat should consider these factors to improve the durability of the seal coat for the preventive maintenance treatment of asphalt pavements.

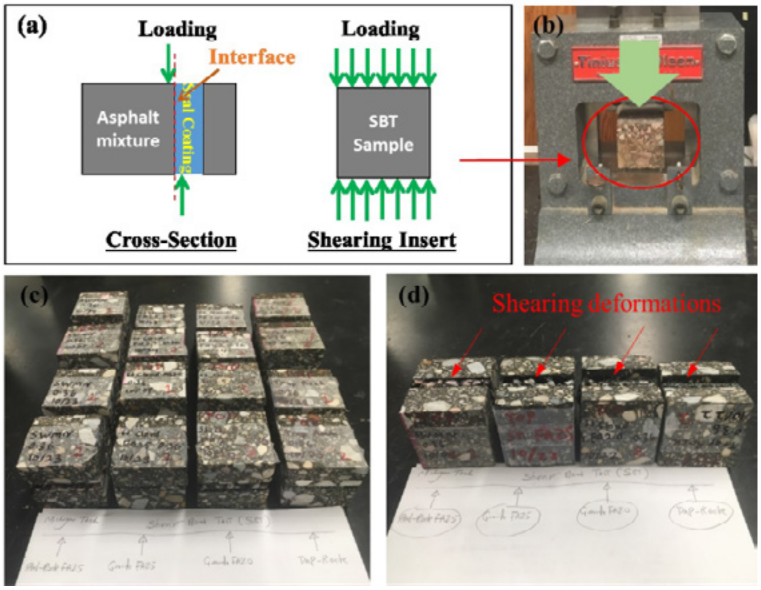
CHAPTER 5: Diagnosis of the Stripping: Laboratory Evaluations

- According to the literature and previous laboratory testing results, the stripping of pavement under seal coating is due to at least the following:
  - » multiple freeze-thaw cycles,
  - » moisture damage, and
  - » asphalt loss from the surface of aggregates
- This task evaluated the impact of these three factors using the Interface Bond Test (IBT). The details of the IBT and the respective seal coat preparations and curing time are the same as those in Chapter 3.
  - » 5.1 Multiple freeze-thaw cycles, same as those in Chapter 3.
  - » 5.2 Moisture damage, used the Moisture-Induced Stress Tester (MIST) which is designed to simulate the stripping within a pressurized chamber that pushes and pulls water through a compacted asphalt sample, simulating the action of an automobile tire on the road
  - » (IBT) was conducted on the collected pavement cores from Brooklyn Park, Eden Prairie, Minnetonka, Rochester, Woodbury, Chisago County, and McLeod County. The cores represent three age categories: 0-1, 6-9, and 10-20 years.
- The main conclusions reported from this phase of the study:
  - » For the premature stripping of asphalt pavement underlying seal coating, the effect of freeze-thaw cycles, moisture damage, and asphalt loss can be considered significant.
  - » If partial damage occurs in seal coats, further deterioration accelerates in the pavement system.
  - » The direct tensile strength of non-seal coating pavement is higher than that of partially damaged seal coating pavement based upon the limited results from the field cores. For future study, a comparison of the direct tensile strength of the non-seal coating pavement and the pavement with good performance seal coats is recommended.

CHAPTER 6: Summary and Conclusions

This project aimed to address the problem of asphalt pavement stripping under seal coating in Minnesota.

- A preliminary comprehensive field data collection was conducted to diagnose premature stripping of asphalt pavement underlying seal coating.
- Interface bond test and shear bond test were conducted on samples prepared with different emulsions and aggregates for seal coat with an existing HMA pavement. The tests were performed under various environmental conditions.
- Based on the laboratory testing results, the research team arrived at the following general conclusions:
  - » The interface and shear bond strength between the laboratory seal coat layer and asphalt pavement layer decreased with the increase of freeze-thaw cycles. The polymer-modified asphalt-emulsion (AE-1) performed better in terms of bonding with aggregates in the seal coats.
  - » Based on the laboratory interface and shear bond test, it was concluded that weak asphalt-aggregate combination in seal coat application and increased freeze-thaw cycles are the main factors for premature stripping of many seal coat asphalt pavements. Due to multiple freeze-thaws and other factors, asphalt may be stripped from the aggregates of the asphalt mixture layers and the seal coat layer.
  - » From the laboratory interface bond test on the pavement cores, further deterioration accelerates in the pavement system when partial damage occurs in the seal coats. However, no definitive conclusion could be made on whether or not seal coating is counterproductive.



CHAPTER 7: Recommendations

- Past research and this study suggest that seal coats installed in the last three decades often lead to premature asphalt surface pavement deterioration. These seal coats create a membrane that is initially impermeable to moisture, but freeze-thaw action and other environmental and operational conditions can weaken the bond and allow water to migrate and saturate the underlying surface pavement. Moisture and additional freeze-thaw cycles may then weaken the pavement surface and strip the asphalt components from the upper surface, leading to the destruction of the upper layer of bituminous.
- It should be noted that the above-mentioned laboratory testing results were based on a limited number of asphalt pavement cores; in future studies, further analysis is needed, including well-controlled test sections.
  - » The freeze-thaw resistance in the seal coat depends on moisture infiltration, temperature, mechanical properties of the seal coat, and the interface between asphalt and aggregates of the seal coat. There are at least two methods to improve freeze-thaw resistance:

» The pre-coated aggregate method may have a positive effect on the resistance to multiple freeze-thaws of the seal coat. Typically, pre-coated aggregates are used to assist in achieving the initial bond between aggregate particles and asphalt in hot sprayed sealing work. It is particularly used to overcome potentially adverse effects arising from dust or moisture on aggregates. There are two pre-coated aggregate methods:

- plant pre-coated aggregates that are stockpiled for later use and
- field pre-coating immediately before use.

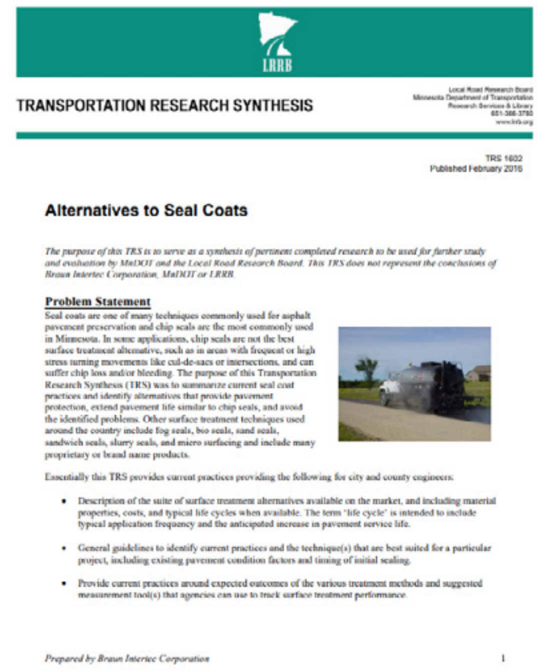
» To better control the pre-coating quality and promote the full bonding of aggregate and asphalt prior to use, the plant pre-coated aggregate method is recommended in the implementation of seal coating on asphalt pavements.

» Improved seal coating design to resist multiple freeze-thaw cycles is a critical approach in seal coating design and construction. One element of seal coating design could be to control technical parameters according to the combination of aggregate and asphalt (such as aggregate size and shape, functional groups, and pH of both the asphalt and aggregate), to improve freeze-thaw resistance. For example, a smaller-sized aggregate in a heavier rate of asphalt emulsion has a deeper embedment depth, and higher silica content in granite may produce stronger hydrogen bonds to the asphalt. Both the higher asphalt film thickness and stronger hydrogen bonds result in stronger adhesion between the aggregate and asphalt in the seal coats, thus preventing seal coat failure. A suitable material combination in the seal coating design is critical to improving freeze-thaw resistance.

Alternatives to Seal Coats

The information presented below is a summary of the LRRB TRS 1602 ***Alternatives to Seal Coats*** report published in 2016; some of this information is outdated. Additionally, there are a few recent or active LRRB projects on:

- NRRA: Spray on Rejuvenator Synthesis (2020) Spray Asphalt Rejuvenators (active)
- NRRA: Analysis of Long-Term Field Performance of Spray-On Rejuvenators (active)
- Underseals (Texas underseal) (active)



TRANSPORTATION RESEARCH SYNTHESIS

Local Road Research Board
Minnesota Department of Transportation
Research Services & Library
651-366-3780
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TRS 1602
Published February 2016

Alternatives to Seal Coats

The purpose of this TRS is to serve as a synthesis of pertinent completed research to be used for further study and evaluation by MnDOT and the Local Road Research Board. This TRS does not represent the conclusions of Braun Intertec Corporation, MnDOT or LRRB.

Problem Statement

Seal coats are one of many techniques commonly used for asphalt pavement preservation and chip seals are the most commonly used in Minnesota. In some applications, chip seals are not the best surface treatment alternative, such as in areas with frequent or high stress turning movements like cul-de-sacs or intersections, and can suffer chip loss and/or bleeding. The purpose of this Transportation Research Synthesis (TRS) was to summarize current seal coat practices and identify alternatives that provide pavement protection, extend pavement life similar to chip seals, and avoid the identified problems. Other surface treatment techniques used around the country include fog seals, bio seals, sand seals, sandwich seals, slurry seals, and micro surfacing and include many proprietary or brand name products.

Essentially this TRS provides current practices providing the following for city and county engineers:

- Description of the suite of surface treatment alternatives available on the market, and including material properties, costs, and typical life cycles when available. The term "life cycle" is intended to include typical application frequency and the anticipated increase in pavement service life.
- General guidelines to identify current practices and the technique(s) that are best suited for a particular project, including existing pavement condition factors and timing of initial sealing.
- Provide current practices around expected outcomes of the various treatment methods and suggested measurement tool(s) that agencies can use to track surface treatment performance.

Prepared by Braun Intertec Corporation 1

Some of the information in the Alternatives to Seal Coats Report is outdated. A few notes from MnDOT:

- Other alternatives include rejuvenators, scrub seal, slurry seal and cape seal
- CQS-1h is newer emulsion used for fog seals
- MnDOT and NRRA have active studies on spray rejuvenators
- ANOVA is an HMA recycling agent additive, not a surface applied sealer
- Micromill is a treatment to smooth roughness or if previous treatment needs removal

Objectives

- Summarize the current state of the practice of alternatives to chip seals used in the Midwest.
- Establish a list of products and techniques for Minnesota cities and counties.

Scope

The report synthesizes information from various Midwest agencies, contractors, material suppliers, and publications to provide information on effectiveness, costs and application techniques for alternative seal coat methods. A successful alternative was defined as a seal that:

- Minimizes impacts to the traveling public and adjacent homeowners in urban areas
- Works well in locations with excessive turning movements, such as cul-de-sacs, parking lots, trails, and other areas where cities and counties historically have had difficulty with chip seals
- Produces similar benefits as a chip seal but does not require cover aggregate
- Is resistant to carbide snowplow blades (particularly at street centerlines)
- Has a fast-curing time
- Can be spray applied

The following factors were included: material costs, application labor costs, application frequency/service life.

The study involved:

- Conducting interviews with Midwest agencies and contractors
- Analyzing responses to identify common practices, preferences, and challenges
- Compiling a literature review on various seal coat alternatives

Section Summaries

Literature Review

- Pavement preservation treatments follow the three 'Rs' – the right treatment on the right pavement at the right time.
- Chip seal is the most common approach. It involves an application of asphalt binder on an existing pavement surface, followed by a placement of a layer of aggregate chips, and finally rolled to embed the aggregate into the binder. It can create waterproof, skid resistant surface, restore weathered surfaces, correct bleeding, provide a temporary base course cover, and define shoulders.
- Chip seal is not an appropriate method when the pavement is structurally deficient, or unsealed cracks are generally wider than 0.25 inches.
- Chip seal is not recommended where medium to high-severity alligator cracking, extensive potholes, and/or excessive rutting are present.
- Chip seals have relatively long curing times for non-polymer modified emulsions, loose aggregate chips which can cause windshield damage, noise due to the rough surface, and need of warm weather to allow for construction.
- Alternatives to chip sealing include:
    - » Coal Tar: Can be effective but banned due to health risks, as it is a potent source of polycyclic aromatic hydrocarbons (PAHs) to air, soils, streams, lakes, and homes.
    - » Fog Seal: Light application of diluted, asphalt emulsion. It is good for small cracks but may reduce skid resistance. It can prevent raveling/popouts of chip seals or marginal aggregates used in hot mix asphalt (HMA), reduce snowplow damage, and darken new chip seals. Products include:
        - CSS-1h, CSS-1 and SS-1h
        - CRS-2, CRS-2P, CRS-2Pd
        - Blacklidge LD-7
        - Gilsonite Sealer Binders (GSB)
        - Grit or Mastic Surface Treatments - Roads: Onyx®, Parking Lots, Trails: Axys®, TMat®, AsPen®
        - Rejuvenator Emulsions - Oils: ETR-1, ARA-1, Reclamite®, AC/Oil: Cyclogen®, ERA®, PMAC/Oil: Pass QB®
    - » Bio Fog Seal: Environmentally friendly but with unproven benefits. Common bio fog seal products include RePlay® and Anova™.
    - » Slurry Seal: Suitable for sound, oxidized pavements; provides skid resistance and restores texture.
    - » MicroSurface: Offers a durable surface and fills minor surface irregularities.
    - » MicroMill

Preservation method comparison

Method	Cost ($/yd²)	Typical Treatment Life (Years) Based on Pavement Condition		
		Good	Fair	Poor
Micro Surfacing	$2.5 – 3.5	12 – 15	7 – 12	5 – 7
Chip Seal	$0.8 – 1.5	6 – 8	4 – 6	3 – 4
Slurry Seal	$1.3 – 2.2	6 – 7	Limited use/performance	Not recommended
Fog Seal	$0.3 – 1.5	1 – 3	Limited use/performance	Not recommended
Bio Fog Seal	$1.0 – 1.6	3 – 5	Limited use/performance	Not recommended

Market products

Company	Product	Area	Website
Valley Slurry Seal Co.	-	Slurry seal	http://www.slurry.com/
Astech	-	Slurry/Micro seal	Asphalt Surface Technologies Corp
Biorestor	Biorestor	Agricultural Based Asphalt Seal and Rejuvenator	http://www.biosealusa.com/
Pavement Technology, Inc	Reclamite	Asphalt rejuvenator	http://pavetechinc.com/
Zydex	ZycoTherm	Asphalt additive	http://www.zydexindustries.com/default.aspx
Seal Master	AsPen	Asphalt rejuvenator	http://sealmaster.net/
Prevent Potholes	FASTSET	Polymer Modified Cationic Asphalt Emulsion Fog Seal	http://www.preventpotholes.com/
Bio Pave Products LLC	RePlay®	Agricultural Oil Seal and Preservation Agent	http://www.valleysealcoat.com/replay.php
Gee Asphalt Systems Inc.	GSB-88	Asphalt Cement Rejuvenator	http://www.geeasphalt.com/
Cargill	Anova™	Bio-based rejuvenators and emulsifiers	http://www.cargill.com/products/industrial/asphalt-solutions/index.jsp
Invia/Ingevity	Onyx Axys	Mastic Seal	https://www.invia-tech.com/

Surveys

Information was gathered from Midwest agencies, contractors, and material suppliers via phone and in person interviews. A brief summary of the results:

- Five main pavement preservation methods used in the Midwest are: fog seal, chip seal (most common method), slurry seal, micro surfacing, and thin lift overlays.
- Cost per square yard: lowest for the fog seal and highest for the thin lift overlays.
- Life cycle has the same trend: 1-3 years for fog seal and more than 10 years for the thin lift overlays.
- The initial pavement condition evaluation, along with a detailed quality control (QC) program and full-time inspection during construction, can ensure a high-quality long-lasting surface treatment.

Summary

- Summarizes the current State of the Practice of surface treatment alternatives to chip seals used in the Midwest and establishes a list of products and techniques for Minnesota cities and counties.
- A summary of the key properties of the available seal coat alternatives are shown in the following table.

Seal coat alternatives summary

Method	Key Notes
Micro surfacing	• Works well in areas with excessive turning movements • Does not require cover aggregate (no loose chips) • Resistant to scraping or abrasion from carbide snowplow blades • Can correct the surface profile to some degree (fills minor ruts and other surface irregularities)
Slurry Seal	• Works okay in areas with excessive turning movements • Does not require cover aggregate (no loose chips) • Resistant to scraping or abrasion from carbide snowplow blades
Chip Seal	• The most common approach • Can restore or improve skid resistance • Vehicle damage from flying stones (loose chips)
Fog Seal (and Bio Fog Seal)	• Can minimize impacts to the traveling public and adjacent homeowners in urban areas • Is spray applied • Reduce scraping or abrasion from carbide snowplow blades • Loss of skid resistance, especially during rain events

Appendix A – Literature Review

Synthesis of various research papers, reports, and specifications related to the performance and preservation of asphalt pavements using different materials and methods.

Appendix B – Surveys

Provides details of each of the interviews.

Appendix C – Certification Program for Pavement Preservation Treatments National Center for Pavement Preservation

Provides details of a certification program developed by the National Center for Pavement Preservation. Key points include:

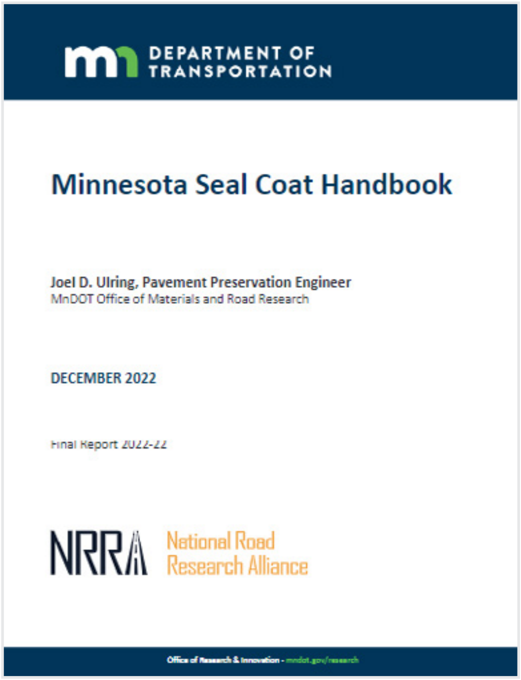
- Pavement preservation is essential for protecting highways from environmental and traffic damage, supporting long-term financial planning.
- Many agencies lack expertise in current treatments. Certification can prevent failures and ensure effective application.
- Certified personnel ensure proper design, construction, and performance of treatments, aiding project oversight and field issue resolution.
- AMRL accredited labs for developing slurry system mix designs ensure quality management and reduce errors.
- Contractors can be decertified for failing to follow plans or fraudulent actions, with appeals process in place.

Minnesota Seal Coat Handbook

Final Report 2022-22

About the Handbook

The [*Minnesota Seal Coat Handbook*](), originally published by the LRRB in 1998 and updated in 2006 and 2022, provides guidelines on the design, application, and maintenance of seal coats for pavement preservation. It covers the selection of materials, design methods, equipment calibration, and troubleshooting of common problems. The handbook also includes specific sections on fog sealing, chip sealing for recreational trails, field inspector responsibilities, adapting procedures for special situations, and ensuring effective and durable pavement maintenance practices.


DEPARTMENT OF TRANSPORTATION

Minnesota Seal Coat Handbook

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MnDOT Office of Materials and Road Research

DECEMBER 2022

Final Report 2022-22

NRRA National Road Research Alliance

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CHAPTER 1: Introduction to Bituminous Surface Treatments

General introduction of surface treatment and their benefits.

CHAPTER 2: Types of BSTs and Surface Seals

Brief overview of the various types of surface treatments used in Minnesota:

- Chip Seal
- Scrub Seal
- Underseal (Interlayer)
- Surface Seal

CHAPTER 3: Chip Seal

This chapter of the handbook provides guidelines on the design and application of seal coats, essential for maintaining and extending the life of pavements. This chapter is divided into several key sections, each addressing a different aspect of the seal coat process.

3.2 Aggregate

- MnDOT Specification 3127, Fine Aggregate for Bituminous Seal Coat, identifies three classes of aggregate: Class A, Class B, and Class C. Selection is based on availability, cost, the type of road being sealed, and traffic volume and movement.
- Class A aggregate consists of crushed quarry or mine trap (basalt, diabase, gabbro or other related igneous rock types); quartzite; or granite. These are primary granites from the St. Cloud and Ortonville areas; quartzite from the New Ulm area; and trap rock (basalt) from Dresser, Wisconsin.
- Class B aggregate consists of all other crushed quarry or mine rock such as limestone, dolomite, rhyolite and schist. Limestone available near the Rochester area has been used.
- Class C aggregate consists of natural or partly crushed gravels obtained from a natural gravel deposit.
- Class A aggregates are the hardest and can withstand the pounding from traffic better. Crushed aggregate, such as Class A and B, lock together better than Class C aggregates due to their shape. Class B and C aggregates generally require more asphalt binder because they are much more absorptive.

Other important takeaways:

- Cover aggregate should be applied so it is only one-layer thick.
- Use high-quality, clean, and durable aggregate.
- Cubical aggregate with a Flatness Index (FI) less than 25 is desired.
- The best chip seal gradations are those that are single size stone.
- Round aggregates are more easily dislodged by snowplows because of their inability to lock together. Using a single-size aggregate will help prevent the plow blade from dislodging the taller or larger stones.

3.3 Asphalt Binders

- Asphalt binder is used in road applications for its waterproof and adhesive properties, requiring viscosity reduction through heating or emulsification.
- Asphalt emulsions are created by mixing asphalt and water, stabilized chemically and by high shear blending, resulting in fine asphalt particles dispersed in water.
- Emulsions are classified by their electrical charge (cationic (positive), anionic (negative)) and setting speed (rapid, medium, slow); **cationic emulsions are preferred in Minnesota for better bonding with negatively charged aggregates**.
- Emulsifiers keep asphalt particles suspended in water.
- **Polymer-modified emulsions enhance properties like chip retention**, softening point, and flexibility, allowing earlier sweeping and better protection of the chip seal.
- Proper storage and handling of emulsions include maintaining appropriate temperatures, using gentle heating, ensuring cleanliness, and following safety practices to prevent emulsion breakdown and maintain quality.

3.4 Design

- The design of chip seals aims to ensure materials are of high quality and proper amounts of cover aggregate and bituminous binder are applied. The procedure recommended have been adapted by the Asphalt Institute and the Asphalt Emulsion Manufacturers Association.
- **Asphalt Binder Considerations:** Key to chip seal design is understanding the residual asphalt content after the emulsion's water evaporates, ensuring 70% of aggregate particle height is embedded in the residual asphalt for durability.
- **Cover Aggregate Considerations:** Factors like gradation, particle shape, bulk specific gravity, and absorption influence the amount of aggregate and binder needed. Single-sized aggregates are preferred for better inspection and binder accommodation.
- **McLeod Design Procedure:** Sets aggregate application rates based on gradation, shape, and specific gravity, and binder rates based on aggregate properties, traffic volume, and pavement condition.
  - » The design calculates aggregate and binder application rates accounting for traffic volume, pavement condition, aggregate absorption, and traffic whip-off to prevent chip loss or bleeding.
  - » Median particle size is determined through gradation charts, and the Flakiness Index measures the percentage of flat particles to ensure proper chip thickness and embedment.
  - » Different aggregates absorb binder differently, requiring adjustments.
  - » Calculations from lab tests guide initial application rates, which may be adjusted in the field.

3.5 Fog Sealing over a Chip Seal

- Applied over a chip seal, fog sealing locks in chips, reduces stone loss, enhances pavement life, and increases impermeability to water and air.
- Common fog seal emulsions include CSS-1hd and CQS-1hD50, selected for their low viscosity to penetrate pavement voids effectively.
- The pavement must be clean and dry. Fog sealing is done immediately after sweeping.
- [MnDOT Specification 2356] calls for fog sealing for all chip seal applications except residential streets, overlapping the centerline to maximize embedment. This helps protect the chip seal from snowplow damage.
- Application rate is typically 0.06 to 0.12 gal/yd² of diluted emulsion, with higher rates for coarser chips.
- Benefits of fog sealing include:
  - » Creates a surface resembling new hot-mix asphalt.
  - » Aids in chip retention
  - » Allows engineers to add binder if embedment is low, with rates up to 0.20 gal/yd².

3.6 Chip Sealing for Recreational Trails

- Recreational trails require smooth surfaces and therefore a FA-1 aggregate gradation is recommended.
- Slightly higher binder and aggregate applications are used for trails (v roadways); typical rates of 0.23-0.26 gal/yd² of binder and 18-20 lb/yd² of FA-1 aggregate.
- For optimal smoothness, use both a double-drum steel roller for compaction and a rubber-tire roller for final smoothing.
- Chip sealing should be done in July and August. Communication with users through signage and notifications is crucial during these peak use times.

3.7 Field Inspector Responsibilities

- Field inspectors are key to the success of a chip seal project; verifying that specifications are adhered to, and quality standards are met.
- Requires full-time attention and hands-on involvement.

3.8 Equipment Calibration

- Calibration of chip sealing equipment ensures uniform application of aggregate and binder. Routine calibration before starting the project reduces delays and ensures the equipment functions correctly, promoting smooth operation and quality results.
- Proper calibration prevents common issues such as streak, inadequate binder coverage, and uneven aggregate application, thereby enhancing the durability and performance of the chip seal.
- Chip spreader calibration involves placing mats, collecting and weighing aggregate, and adjusting spreader gates to ensure consistent application across the width.
- Asphalt Distributor calibration includes aligning spray bar nozzles and adjusting spray bar height to ensure even binder distribution and prevent streaking.
- Calibration tests for both double and triple overlap spray applications verify that emulsion sprays the pavement surface correctly, ensuring optimal binder application.

3.9 Common Problems and Solutions

- A quality chip seal is dependent on factors like aggregate type, asphalt binder properties, pavement condition, construction methods, equipment calibration, operator expertise, and traffic control.
- Common Problems and Solutions:
  - » **Loss of Cover Aggregate:** Can be addressed by increasing asphalt binder application and using clean aggregate free from dust.
  - » **Bleeding or Flushing:** Caused by excessive binder or improper aggregate type; solutions include adjusting binder application rates and using cubical aggregate.
  - » **Streaking:** Due to incorrect spray bar height or nozzle alignment; solutions involve adjusting spray equipment and clearing clogged nozzles.
  - » **Bad Centerline Joint**: Requires fog sealing to prevent binder absorption.
  - » **Inadequate Coverage of Pavement Markings with Possible Cover Aggregate Loss:** Remove or pretreat markings before chip sealing to ensure proper adhesion.
  - » **Utilities in the Pavement:** Cover the utilities with material: roofing paper, kraft paper or sand.

3.10 Frequently Asked Questions

- This section addresses common queries regarding seal coat design, materials, and application processes.

3.11 Special Situations

- **Cul-de-Sacs:** Challenge of excessive aggregate loss due to poor embedment or binder breakage; requires careful distributor operation to prevent overlaps and ensure proper chip orientation.
- **Intersections and Turn Lanes:** Issues include scuffing, chip rollover, and potential bleeding from increased turning and stopping actions; requires careful handling of binder application.
- **Parking Lots:** Similar challenges as cul-de-sacs due to large areas requiring multiple passes; critical to plan and execute operations meticulously to achieve proper chip embedment.
- **High-Volume Roadways:** Concerns about loose aggregate causing windshield damage and bleeding; solutions include choke seals or double seals to secure aggregates and reduce loose rock risks

INFORMATION ON COMPATIBILITY (EMULSION AND AGGREGATES) AND SEALCOATING NEWER PAVEMENTS

Through working with the Technical Advisory Panel, additional concerns arose which warranted further investigation. These centered around the compatibility of aggregates and emulsions and the decision on whether or not to seal coat newer pavements. Evidence on these two topics is summarized below.

Understanding Aggregate-Emulsions Compatibility

This information is summarized from the Minnesota Seal Coat Handbook.

Aggregates

Minnesota has an abundant supply of good quality aggregate. Consequently, there are many choices available when considering which aggregate to use for a chip seal project. MnDOT Specification 3127, Fine Aggregate for Bituminous Seal Coat, identifies the following three classes of aggregate:

- **Class A** aggregate consists of crushed quarry or mine trap (basalt, diabase, gabbro or other related igneous rock types); quartzite; or granite.
- **Class B** aggregate consists of all other crushed quarry or mine rock such as limestone, dolomite, rhyolite and schist.
- **Class C** aggregate consists of natural or partly crushed gravels obtained from a natural gravel deposit.

As with most any type of construction material, chip seal aggregates are chosen based on several factors such as availability, cost, the type of road being sealed, and traffic volume and movement.

Some guidelines include:

- Class A aggregates are the hardest and can withstand the pounding from traffic better than either Class B or Class C aggregates.
- Crushed aggregate, such as Class A and B, lock together better than Class C aggregates due to their shape.
- Class B and C aggregates generally require more asphalt binder because they are much more absorptive than Class A aggregates.

Most aggregates have a negative charge; a electrostatic test of the aggregate source could be conducted to ensure that the emulsion is compatible (NCHRP 342 Chip Seal Best Practices).

Emulsions

Emulsions are classified by their electrical charge:

- Cationic (have an emulsifier with a positive (+) electrical charge surrounding the asphalt particles)
- Anionic (negative (-))
- Nonionic (neutral)

Since opposite electrical charges attract, anionic emulsions should be used with aggregates having a positive (+) charge. Similarly, cationic emulsions should be used with aggregates having a negative (-) charge. Failure to use materials with opposite electrical charges may result in the materials repelling each other, causing failure.

In addition to being classified by their electrical charge, emulsions are further classified according to **how quickly they revert to asphalt cement.** As the emulsifier is drawn toward aggregate surfaces with an opposite electrical charge, the asphalt particles begin to settle to the bottom of the emulsion. The speed at which this occurs is indicated by the RS, MS and SS designation:

- RS - rapid setting
- MS - medium setting
- SS - slow setting

High-float emulsions (HF), designated because they pass the Float Test (AASHTO T-50 or ASTM D-139), have added chemicals that permit a thicker asphalt film on the aggregate particles. This property allows high-float emulsions to be used with somewhat dusty aggregate with good success.

Lastly, emulsions are subdivided by numbers that relate to the viscosity of the emulsion and the hardness of the base asphalt cement. The numbers “1” and “2” are used to designate the viscosity of the emulsion. The lower the number, the lower the viscosity and the more fluid the emulsion. If the number is followed by the letter “h,” the emulsion has a harder base asphalt. The letter “d” refers to diluted.

Because most aggregates have a negative charge, cationic (+) emulsions are mostly used in Minnesota.

Sealcoating Newer Pavements

According to NCHRP 342 Chip Seal Best Practices:

“Chip seals are most frequently used as PM treatments on flexible pavements. The ideal benefits of applying a chip seal are obtained if the chip seal is applied early in a pavement’s life (i.e., before it exhibits a great degree of distress)”

Per the survey that was recently conducted in Minnesota (see above for more details), some agencies have adopted the practice of seal coating one year after the initial paving:

1st Seal Coat	Total	City	County
Paving - 1yr	16	5	11
2-3	19	5	14
>3	19	9	10
	54	19	35

In conducting an internet and literature search, no empirical data was found on the economics of seal coating a new asphalt pavement (i.e. one year after paving). [NCHRP Report 523 – Optimal Timing of Pavement Preventive Maintenance Treatment Applications] describes a methodology for determining the optimal timing for the application of preventive maintenance treatments to flexible and rigid pavement but does not answer this specific question nor is it user-friendly to local agencies.

Without a resource to cite, the decision on whether to seal coat a newer pavement is more hypothetical and can be based on benefits of a good seal coat:

- Extended Pavement Life: Chip sealing protects the underlying pavement from moisture and oxidation, slowing down the aging process.
- Improved Traction: The layer of crushed stone enhances the surface texture, providing better skid resistance.
- Cost-Effective: Compared to full resurfacing, chip sealing is relatively inexpensive and can extend the life of the pavement by several years.

These benefits need to be balanced with:

- Not for Fresh Asphalt: Freshly laid asphalt needs to cure for three to six months before seal coating can be applied. Applying it too soon can interfere with the curing process.
- Requires Maintenance: Seal coating is not a one-time application. It needs to be reapplied every five to seven years, so you should consider this ongoing cost in your maintenance budget.

Regarding the optimal time to seal coat a pavement:

- Too early may trap oils within the asphalt, leading to surface issues.
- Waiting too long can leave the pavement vulnerable to weathering, UV damage, and chemical exposure.

ONGOING RESEARCH ON SEAL COATING

An earlier long-term aging chip seal study, Determination of Optimum Time for the Application of Surface Treatments to Asphalt Concrete Pavements – Phase II, evaluated seal coats on a Trunk Highway.

This Long-Term Field Performance Evaluation of Chip-Seals project started in 2014 and is scheduled to be completed in 2026. Building upon the prior study, the focus of the current project is to conduct a similar research study on newly constructed local road pavements.

This project aims to determine the effect of chip seal treatment timing on asphalt pavement aging while determining the optimal time for treatment application based on laboratory test results and field performance data.

Key elements of the project include:

- Newly constructed pavements consisting of two rural (Cass and Crow Wing Counties) and one urban (St. Cloud) road segments were selected.
- Each of the three study areas consists of a control section and five test cells (each rural cell is 1-mile in length; urban cells are 333-feet).
- In each area one of the test cells was chip sealed each year between 2015 and 2019.
- During the past 10 years core samples were obtained from the test cells in 2015, 2017, and 2019 and tested to measure Fracture Energy (FE) of the pavement. Annual visual inspections have been performed and the conditions will be visually documented along with any maintenance repairs made.
- In 2023, the LRRB, in working with MnDOT, contracted with the National Center for Asphalt Technology (NCAT) to review the project information and data collected, establish a testing program to evaluate the test cells and complete a report concerning what benefits the chip seal treatment provided to the bituminous pavement.
- The work is scheduled to be completed by June of 2026.

Synthesis of Seal Coat Research in Minnesota

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