Development of Updated Specifications for Roadway Rehabilitation Techniques

Final Report
May 2011

IOWA STATE UNIVERSITY
Institute for Transportation

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16. Abstract

As our nation's highway system continues to age, asphalt maintenance and rehabilitation techniques have become increasingly important. The deterioration of pavement over time is inevitable. Preventive maintenance is a strategy to extend the serviceable life of a pavement by applying cost-effective treatments that slow the deterioration of pavement and extend its usable life.

Thin maintenance surfaces (TMSs) are preventive maintenance techniques that can effectively prolong the life of pavement when applied at an opportune time. Common TMSs include bituminous fog seal, bituminous seal coat, slurry seal, cold in-place recycling (CIR), and micro-surfacing.

This research project investigated ways to improve Iowa Statewide Urban Design and Specifications (SUDAS) and Iowa Department of Transportation (DOT) documents regarding asphalt roadway maintenance and rehabilitation. Researchers led an effort to review and help ensure that the documents supporting proper selection, design, and construction for asphalt maintenance and rehabilitation techniques reflect the latest research findings on these processes: seal coating, slurry sealing, micro-surfacing, and fog sealing.

Full results of this investigation are included in this report and its appendices. This report also presents a summary of the recommendations based on the study results.

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DEVELOPMENT OF UPDATED SPECIFICATIONS FOR ROADWAY REHABILITATION TECHNIQUES

Final Report
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- John Hinrichsen, formerly Iowa Department of Transportation (DOT), now retired and consulting
- Scott Schram, Iowa DOT
- Steve Salvo, Snyder and Associates
- Greg Parker, Johnson County, Iowa
- Bruce Braun, City of Des Moines, Iowa

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EXECUTIVE SUMMARY

Objectives

This research project investigated ways to improve Iowa Statewide Urban Design and Specifications (SUDAS) and Iowa Department of Transportation (DOT) documents regarding asphalt roadway maintenance and rehabilitation. Researchers led an effort to review and help ensure that the documents supporting proper selection, design, and construction for asphalt maintenance and rehabilitation techniques reflect the latest research findings on these processes: seal coating, slurry sealing, micro-surfacing, and fog sealing.

Problem Statement

As our nation's highway system continues to age, roadway maintenance and rehabilitation techniques have become increasingly important. The deterioration of pavement over time is inevitable. Preventive maintenance is a strategy to extend the serviceable life of a pavement by applying cost-effective treatments that slow the deterioration of pavement and extend its usable life.

Thin maintenance surfaces (TMSs) are preventive maintenance techniques that can effectively prolong the life of pavement when applied at an opportune time. Common TMSs include bituminous fog seal, bituminous seal coat, slurry seal, cold in-place recycling (CIR), and micro-surfacing.

Research Description

Literature Review

Resources from state agencies, local jurisdictions, trade associations, and academia were reviewed to identify relevant information that would improve the current state of SUDAS and Iowa DOT standard specifications. The primary resources from recently-completed research were for projects conducted at Iowa State University (ISU) and the Institute for Transportation (InTrans), which was formerly the Center for Transportation Research and Education (CTRE).

In addition to recent research conducted at ISU, specifications and other documents were obtained from neighboring state highway authorities, local jurisdictions, and professional associations. Specifications for each of the states surrounding Iowa were reviewed to identify differences in comparison to the Iowa DOT and SUDAS specifications.

Practitioner Surveys

In addition to performing a literature review, input from practicing individuals was also obtained and reviewed. A TMS questionnaire was given to attendees at the following conferences:

- County Engineers Conference, December 2008
- Greater Iowa Asphalt Conference, March 2009
- American Public Works Association (APWA) Conference, Spring 2009

The results of these interviews helped researchers to focus in areas where the need for improvement and the interest in the maintenance techniques were the greatest. General information regarding treatment options and project selection and then specific information regarding seal coats were identified as areas where focus would be most beneficial.

Questions regarding proper TMS application and construction were also asked to members of the technical advisory committee (TAC) for the project, as well as contractors who perform asphalt pavement maintenance and rehabilitation, to obtain perspective on TMSs from practicing professionals. Phone interviews were conducted to obtain the opinions of surveyed individuals.

Summary of Recommendations

Following is a summary of the specification updates that were recommended.

Fog Seal

- Harmonize temperature requirements with neighboring jurisdictions by allowing a lower minimum application temperature. At the high end of the range would be 50°F and 40°F would be in the middle of the range.
- Make the specification more robust for municipal use by including a requirement to protect manhole covers, valve covers, and other appurtenances.
- Also consider striking the word “Shoulder” from the title.

Seal Coating

- Include additional fine aggregate (1/4 inch and No. 4) gradations.
- Include high float emulsions in material specifications.
- Harmonize emulsion temperature requirements with recommendations of the American Emulsion Manufacturers Association (AEMA).
- Reduce suggested aggregate end emulsion application rates to match the experience with application rates developed in previous Iowa research projects.
- Specify earlier end of season limits with flexibility to make exceptions under specific circumstances.
- Update equipment requirements.

Slurry Seal

- Require a higher proportion of fine material in the Type III (coarse) slurry seal gradation.
- Harmonize requirements for component materials in mix designs and application rates with guidance from the International Slurry Surfacing Association (ISSA).

Micro-Surfacing

- Require a higher proportion of fine material in the Type III (coarse) micro-surfacing gradation.
- Adjust material requirements to allow limestone aggregate with low clay content and good wear characteristics.

Implementation Benefits

Several benefits will result from this research. Maintenance and rehabilitation projects can be selected, designed, and constructed more efficiently, because the targeted documents will reflect improvements recommended by recent research.

Incorporation of research results in the targeted documents is an efficient method for affecting improvement, because changes in these documents usually result in a change in the standard operating procedure for TMSs. The targeted documents are concise and widely read; therefore, they are accessible to a wide audience.

Since Iowa's road network is mostly established, maintenance and rehabilitation efforts will be an increasingly large proportion of future investments. Therefore, an investment that improves maintenance and rehabilitation projects is effective in providing benefits to road users and other transportation stakeholders.

Implementation Readiness

The Iowa DOT is starting an effort to increase the investment in pavement maintenance. This will likely involve increased use of the maintenance treatments addressed in this study. Appropriate training and insightful project selection will enhance the success of this effort. It is recommended that treatment selection guidelines developed in previous research and the revised specifications be used and evaluated as this program ramps up.

INTRODUCTION

As our nation's highway system continues to age, maintenance and rehabilitation techniques have become increasingly important. The deterioration of pavement over time is inevitable. Preventive maintenance is a strategy to extend the serviceable life of a pavement by applying cost-effective treatments that slow the deterioration of pavement and extend its usable life.

Thin maintenance surfaces (TMSs) are preventive maintenance techniques that can effectively prolong the life of pavement when applied at an opportune time. Common TMSs include bituminous fog seal, bituminous seal coat, slurry seal, cold in-place recycling (CIR), and micro-surfacing. Many of these preventive maintenance techniques have been used successfully in Iowa.

The Iowa Department of Transportation (Iowa DOT) currently has standard specifications and or supplemental specifications for all of the previously mentioned TMSs. The Iowa Statewide Urban Design and Specifications (SUDAS) program currently has specifications for only two TMSs: bituminous seal coat and slurry seal.

Several research projects have recently been conducted to address issues concerning the selection, design, and construction of preventive maintenance techniques. It is in the best interest of designers and users of public infrastructure that documents supporting the proper selection, design, and construction of thin maintenance surfaces reflect the latest research findings. It is the intent of this report to provide suggestions for improving current SUDAS and Iowa DOT documents regarding asphalt roadway maintenance and rehabilitation.

METHODOLOGY

The primary objective of this report is to make recommendations to improve the SUDAS and Iowa DOT standard specifications so they incorporate the results of recent research on TMSs. Existing specifications were reviewed to make recommendations for SUDAS and Iowa DOT standard specifications. The TMSs of interest include bituminous fog seal, bituminous seal coat, slurry seal, and micro-surfacing.

Additional preventive maintenance techniques are macro-surfacing and thin hot mix asphalt (HMA) overlays. These TMSs are outside the scope of this research and will not be included in this report, because the technical advisory committee requested that researchers focus on the other techniques that are more often used in Iowa, or because there was relatively less information on the other techniques that was accessible to the target audience.

Literature Review

Resources from state agencies, local jurisdictions, trade associations, and academia were reviewed to identify relevant information that would improve the current state of SUDAS and Iowa DOT standard specifications. The primary resources from recently-completed research were for projects conducted at Iowa State University (ISU) and the Institute for Transportation (InTrans), which was formerly the Center for Transportation Research and Education (CTRE). The projects included the following:

- Thin Maintenance Surfaces Phase I report (Jahren et al. 1999)
- Thin Maintenance Surfaces Phase II report (Jahren et al. 2003)
- Thin Maintenance Surfaces for Municipalities (Jahren et al. 2007)

Phase I of TMS research focused primarily on providing qualitative guidelines. Conclusions from indicated that TMSs are not effective when applied on pavements that are in poor condition and should not be applied to such pavements. Treatments applied to these surfaces will likely have a limited life. Road surfaces should be considered probable candidates for receiving TMS treatment 7 to 12 years after construction.

TMS Phase II research provides a recommended seal coat design process and guidance on seal coat aggregates and binders. Chapter 3 of the report has considerations for selecting appropriate aggregates and binders for use in seal coat applications. Chapter 5 has information on local aggregates for micro-surfacing. TMSs for Municipalities has recommendations for seal coat construction, as well as case studies of seal coat and micro-surfacing test sections in Iowa.

In addition to recent research conducted at ISU, documents reviewed throughout the literature review process were obtained from neighboring state highway authorities, local jurisdictions, and professional associations. Departments of transportation (DOTs) for each of the states surrounding Iowa were reviewed to identify deviations from the Iowa DOT and SUDAS specifications.

These deviations have been documented and can be found in table form in Appendix A of this report. Deviations have been evaluated and some will be included in the recommendations for SUDAS and Iowa DOT standard specifications. Review of the obtained documents resulted in finding that bituminous seal coats, slurry seals, and polymer-modified micro-surfacing were most commonly used among neighboring state authorities, local jurisdictions, and professional associations. Table 1 shows the sources of documents that were reviewed throughout the literature review process.

Table 1. Literature review resources

State highway authorities	Local jurisdictions	Trade associations, professional societies and manufacturers
Iowa Department of Transportation (Iowa DOT)	Iowa Statewide Urban Design and Specifications (SUDAS) program	American Emulsion Manufacturers Association (AEMA)
Kansas Department of Transportation (KDOT)	Kansas City, Missouri Department of Public Works	International Slurry Surfacing Association (ISSA)
Missouri Department of Transportation (MoDOT)	City of Omaha, Nebraska Department of Public Works	Valley Slurry Seal Co.
Nebraska Department of Roads (NDOR)	City of Chesterfield, Missouri	American Association of State Highway and Transportation Officials (AASHTO)
Minnesota Department of Transportation (Mn/DOT)		Asphalt Institute
South Dakota Department of Transportation (SDDOT)		
Wisconsin Department of Transportation (WisDOT)		
Illinois Department of Transportation (IDOT)		

Common deviations from the Iowa DOT standard specifications for all of the TMSs of interest were in the areas of materials, surface preparation, and limitations. Materials deviations related primarily to bituminous binders and aggregates for the specified TMS. Various aggregate gradations and emulsion types were specified.

Surface preparation requirements also varied in scope and level of detail specified, depending on the source of the specification. Clearing of debris and removal of vegetation from the pavement surface was required by all documents that were reviewed. Additional treatments not required by the Iowa DOT, but recommended by other agencies included crack sealing, repairing damaged pavement sections, and removing pavement markings.

The most common limitation found in each of the reviewed documents related to the timeframe and acceptable temperature ranges specified for constructing TMSs. The duration of a defined construction season varied throughout the reviewed documents but rarely was any discrepancy observed that was in excess of one month. These deviations are most likely due to the geographic location of the source of the reviewed specification.

Minimum allowable temperatures for placement also varied among the reviewed specifications in comparison to those allowed by the Iowa DOT and were commonly ±10°F. Detailed discussions of the deviations to the Iowa DOT standard specifications can be found in subsequent sections of this document for each individual TMS.

In addition to the previously-mentioned specifications and reports, three manuals were found to be useful for developing a basic understanding regarding the use of TMSs:

Best Practices Handbook on Asphalt Maintenance (Johnson 2000) discusses various maintenance strategies and tactics (preventive, reactive, and emergency), the development of a pavement management system, and the use of crack maintenance techniques, TMSs, thin overlays, and pothole repairs. It concisely provides context to the use of TMSs.

Minnesota Seal Coat Manual (Janisch and Gaillard 1998) gives an in-depth review of the design and construction of seal coats or chip seals. A straightforward explanation of emulsion technology is provided and the best design, construction, and inspection practices are examined. In particular, examples of designs for binder and aggregate application rates are provided.

*Basic Asphalt Emulsion Manual, MS-19 (*AEMA 2004), provides an in-depth review of asphalt emulsion technology, including classification, manufacturing, applications, use in construction, and quality control.

Practitioner Surveys

In addition to performing a literature review to identify potential areas of improvement for SUDAS and Iowa DOT standard specifications, input from practicing individuals was also obtained and reviewed. A TMS questionnaire was given to attendees at the following conferences:

- County Engineers Conference, December 2008
- Greater Iowa Asphalt Conference, March 2009
- American Public Works Association (APWA) Conference, Spring 2009

Practitioners were asked to rank issues such as overall guidelines, aggregate selection, asphalt binder selection, and application rates for each individual TMS, as well as overall guidance on when it is appropriate to use TMSs. The results of the survey indicated that overall guidance for selecting an appropriate TMS would be most beneficial to them. After overall guidance for selecting an appropriate TMS, guidance for each individual TMS was the most requested information, based on the survey results. The results also suggest that there is not adequate reference material available for selecting the proper TMS for a specific application. Results of the TMS questionnaire are included in Appendix B.

Questions regarding proper TMS application and construction were also asked to members of the technical advisory committee (TAC) for the project, as well as contractors who perform asphalt pavement maintenance and rehabilitation, to obtain perspective on TMSs from practicing professionals. Phone interviews were conducted to obtain the opinions of surveyed individuals.

Two sets of questions were developed, one for contractors and one for technical advisory committee members. Contractors that were interviewed were Bob Wagner of Blacktop Services Co. of Humboldt, Iowa and Rick Burchett of STA-BILT Construction Co. in Harlan, Iowa. Contractors were asked questions that intended to gather information to see if they were satisfied with current specifications and if they had any suggestions for improvements or concerns about TMSs. They were also asked about construction practices and pavement conditions that were favorable and unfavorable for TMS application. The results of the phone interviews suggest that pavements experiencing stability issues should be avoided and cannot be effectively treated by TMS applications. Both contractors also felt that application of TMSs does not have to be limited to pavements with low traffic volumes. TMS concerns include the cost effectiveness of micro-surfacing due to the limited availability of aggregate that is required for the treatment.

TAC members that were interviewed were Bruce Braun of the City of Des Moines, Iowa, Steve Salvo of Snyder and Associates, and Greg Parker of Johnson County, Iowa. Questions asked to TAC members also sought to obtain information on favorable and unfavorable pavement conditions for TMS application, materials, surface preparation, comments, and concerns regarding TMS. Results of the phone interviews suggest that traffic volume, future maintenance and reconstruction schedule, pavement condition, and age, all, play a role in determining an appropriate TMS.

TMSs are often used in low-volume residential areas where pavement is in good structural condition. There was also a consensus among TAC members on the use of pre-coated aggregate for bituminous seal coats. TAC members felt that pre-coated aggregates minimized dust produced during construction, as well as created better adhesion to the pavement surface. Micro-surfacing was also a concern for TAC members because of the limited availability of required aggregates and the low number of experienced contractors in Iowa.

All of the comments received throughout the phone interview process with TAC members and contractors are in Appendix C.

BITUMINOUS FOG SEAL

Description and Appropriate Applications

A fog seal is a light application of binder to a pavement surface without cover aggregate. Several types of binders can be used, such as diluted emulsion (usually 50:50 emulsion:water dilution), gilsonite sealer binder (gilsonite is a naturally occurring asphalt ore with a high resin content), and proprietary products such as Reclamite® and PASS®.

The application of binder often reduces pavement friction, so a light application of sand usually follows that application of the binder to increase road friction. After application, the fog seal acts as a membrane that protects the underlying asphalt from environmental degradation and binds fine aggregate particles to the pavement. Some fog seal products reportedly penetrate the pavement surface and soften oxidized binder and/or reduce permeability. Advantages and disadvantages for Fog Seals are summarized in Table 2.

Table 2. Fog seal advantages and disadvantages

Advantages	Disadvantages
Reduces surface permeability and seals light severity cracks	Skid resistance is reduced shortly after application; however, this effect can be mitigated with sand applications and it lessens as the binder is worn off the top of aggregate pieces on the surface.
Improves appearance and can provide a good background for pavement markings	Not effective for pavements with higher levels of distress
Prevents oxidation of binder and mitigates fine aggregate raveling	Requires road closure while binder hardens.
If rejuvenating binder is used, softens hardened binder	
Inexpensive	

Design Considerations

Pavements selected for fog seal application should have very little surficial distress and no distress that indicates structural deficiencies. It is best to apply a fog seal before fine aggregate begins to ravel from the surface. The fog seal will bind the small aggregate, so it is not lost and so it can help to maintain the stability of the coarse aggregate.

Compared to asphalt emulsion, gilsonite binders are more expensive; however, this extra expense may be justified for pavements that are likely to have a long life if they are protected against environmental degradation. Proprietary products such as Reclamite® and PASS® may be useful for softening hard-oxidized binders. The application rate should be sufficient to provide the necessary protection, but not so high that pavement friction problem develops. The proper application rate is influenced by the condition of the pavement that is being treated.

If contracting agency personnel have concerns about selecting the correct application rate, it would be advisable to place a test strip, observe the results, and modify the application rate accordingly. Particular care should be taken when fog seal is being applied to dense graded pavements to ensure that the application rate is not too high (to prevent low friction characteristics).

Construction Guidance

Pavements should be cleaned before a fog seal is applied. The binder is sprayed from a distributor truck. The Nebraska Department of Roads (NDOR) Specification (513.03.3.b) specifies a range for the subsequent sand application to be from 4 to 13 pounds per square yard. The sand may be swept from the road after the binder has hardened and been worn off the top of the coarse aggregate by tires.

Literature Review Documentation

The organizations that were included in the literature review for bituminous fog sealing included the following:

- Missouri Department of Transportation (MoDOT)
- Nebraska Department of Roads (NDOR)
- Minnesota Department of Transportation (Mn/DOT)
- South Dakota Department of Transportation (SDDOT)
- Omaha, Nebraska Department of Public Works

The Iowa DOT Standard Specifications for bituminous fog seal (section 2306) was compared to the documents obtained from the above sources. At the conclusion of the literature review it was found that deviations from the Iowa DOT standard specification occurred most frequently in sections 2306.02 Materials, 2306.06 Application, and 2306.07 Limitations. The following are the sections where deviations were found:

- 2306.02 Materials
- 2306.04 Cleaning
- 2306.06 Application
- 2306.07 Limitations

Primary deviations from the Iowa DOT specifications included the types of asphalt emulsions that were specified by various organizations. The Iowa DOT specifies cationic emulsion CSS-1 and anionic emulsion SS-1 for use in bituminous fog seal applications. As of February 15, 2011, the Iowa DOT had also added Supplemental Specifications for Asphalt Emulsions Containing Gilsonite (Iowa DOT 2011). NDOR specifies the use of high float emulsion HFE-150, 300, 1,000, and CRS-1h.

Surface preparation recommended by SDDOT and the Omaha Public Works include protecting manhole covers, water shutoff valves, and adjacent appurtenances from the asphalt emulsion, as well as sealing cracks greater than 1/4 inch before applying a bituminous fog seal. It was also found that the Iowa DOT has the highest temperature (60°F) required for applying a fog seal. SDDOT only requires an ambient air temperature of 35°F, which can be found in section 330.3 of its fog seal specification. A complete table indicating the primary deviations from the Iowa DOT specification for bituminous fog seal can be found in Appendix D.

Possible Specification Changes

SUDAS currently does not have a fog seal specification. The consensus of SUDAS staff, board of directors, and committee members is that SUDAS does not need to develop its own fog seal specification, because this maintenance technique is not used often by SUDAS participants. If such a specification is needed, agencies can reference the following:

- Iowa DOT Specification 2308 for Bituminous Fog Seal
- Iowa DOT SS-09013 – Asphalt Emulsions Containing Gilsonite

The following changes could be considered for Iowa DOT Specification 2308:

- Harmonize temperature requirements with neighboring jurisdictions by allowing a lower minimum application temperature. At the high end of the range would be 50°F and 40°F would be in the middle of the range.
- Make the specification more robust for municipal use by including a requirement to protect manhole covers, valve covers, and other appurtenances.
- Also consider striking the word “Shoulder” from the title.

BITUMINOUS SEAL COAT

Description and Appropriate Applications

A seal coat is a surface treatment that is applicable for asphalt or seal coat pavement. The process includes spraying an emulsion or cutback asphalt binder onto the surface of the pavement and covering it with aggregate. A seal coat is also commonly referred to as a chip seal, surface seal, or tar and rock.

Seal coats are commonly recommended as an effective surface treatment for roads that have average daily traffic (ADT) volumes of less than 2,000. However, seal coats have been used successfully on roads with traffic volumes greater than 2,000 ADT, although not commonly used in Iowa. Seal coats are generally applied to pavements that experience low to medium levels of raveling and cracking, as well as low levels of rutting and alligator cracking. Table 3 lists common advantages and disadvantages of seal coat applications.

Table 3. Seal coat advantages and disadvantages

Advantages	Disadvantages
Seals the surface of pavement	Unbound aggregate can lead to vehicle damage
Seals cracks	Concern for dust produced by aggregate
Aggregate provides new wearing surface	Not capable of filling ruts or depressions
Little or no reflective cracking	Aggregate can provide poor background for pavement marking
Inexpensive surface treatment	Multiple lifts can create a high crown

Design Considerations

Selection of an aggregate for bituminous seal coats is an important design decision. Aggregate type, quality, construction speed, cost, and expected life should be considered when selecting an aggregate for a bituminous seal coat. When using emulsions in bituminous seal coats, clean aggregate must be selected to allow the emulsion to bond to the aggregate. In situations where dust produced by the aggregate is a concern, pre-coated aggregate can be used for bituminous seal coat applications. Aggregate is coated with a thin film of asphalt binder prior to placement. Pre-coating of aggregate reduces dust, facilitates a strong bond between the aggregate and emulsion, and gives the seal coat a darker appearance.

Asphalt emulsions and cutbacks are commonly used in bituminous seal coats. Emulsions can be selected from one of two categories: anionic or cationic. Given that nearly all surfaces have a net negative charge, the two types of emulsions break differently. Anionic emulsions tend to break slower than cationic ones because the negatively-charged surface and emulsion repel each other. Evaporation is the only mechanism by which anionic emulsions break. Cationic emulsions typically break faster than anionic emulsions because of the positively-charged emulsion being attracted to the negatively-charged surface. This additional catalyst works with evaporation to expedite the breaking process (TxDOT 2006). Table 2 illustrates hypothetical situations and responses for selecting an anionic or cationic asphalt emulsion. The emulsified asphalt preferred for bituminous seal coats is a CRS-2P emulsion. CRS-2P is a polymer-modified, cationic, water-based, emulsified asphalt designed for use in bituminous seal coats (Martin Asphalt Company 2006).

High float emulsions (designated HFxx-n or HFEnn) are considered anionic emulsions and have characteristics that are very desirable in certain circumstances. These emulsions coalesce into a gel-like structure that resists draining from the aggregate and flushing. In addition, many high float emulsions include some distillate (such as fuel oil) included in their formulation. The distillate can be effective in wetting clay particles that would otherwise quickly react with the emulsion before the residue could attach to the aggregate. High float emulsions are useful when dusty aggregates must be used or when a slower break time is helpful.

Asphalt cutbacks are mixtures of asphalt and various solvents such as kerosene and fuel oil. The viscosity of the cutback mixture is low enough to be sprayed from a distributor truck. Once on the road, the solvent evaporates, and the asphalt residue stiffens. Cutbacks are more forgiving to apply because the solvent "cuts through" dust and clay on the road surface and aggregate, resulting in better binding under such conditions when compared to emulsion. A longer time lapse is also possible between application of the binder and the aggregate with cutbacks. For several days after application, it is possible to blot locations that have too much binder with sand or cover aggregate. On the other hand, the cutback binder tends to stay soft and susceptible to tracking for longer after application when compared to emulsions. In addition, the solvent evaporation constitutes an atmospheric hydrocarbon release that would likely contribute to greenhouse gas issues.

Table 4. Asphalt emulsion considerations (after TxDOT)

Condition	Preferred emulsion	Recommended emulsion
Low humidity	Anionic	HFRS-2, HFRS-2P
High humidity	Cationic	CRS-2, CRS-2P, CHFRS-2P
Dry dusty aggregate (absorptive)	Anionic	HFRS-2, HFRS-2P
Dusty limestone	Anionic	HFRS-2, HFRS-2P
Hard non-absorptive rock	Anionic or Cationic	Shorter cure time with cationic emulsion (CRS)
Accelerate reopening to traffic	Cationic	CRS-2, CRS-2P, CHFRS-2P

Construction Guidance

The application rate for asphalt binder for bituminous seal coats is recommended to fall into the range of 0.20 to 0.35 gallon per square yard. The amount of binder applied to the surface can vary depending on the condition of the pavement. If the pavement is smooth with few voids or small macro-texture (area between individual aggregates), reduce the application rate. However, if the pavement is rough with many voids and a deep macro texture, increase the application rate.

According to the Asphalt Institute and the Asphalt Emulsion Manufacturers Association (AEMA 2004), emulsions with the -1 suffix should be stored at between 70 and 140°F (20 to 60°C) and emulsions with the suffix -2 should be kept at between 125 and 185°F (50 to 85°C).

Aggregate for bituminous seal coats should be applied with an application rate of 15 to 30 pounds per square yard. If the aggregate is spread more than one stone thick, decrease the application rate. The application of too much aggregate leads to excessive fly rock, dust, and waste. Extra aggregate requires additional cleanup and haul costs. If large areas of binder are exposed between individual aggregates, apply more aggregate.

Jahren et al (1999) describe construction of test sections using designed binder and aggregate application rates. Considerable savings were realized. Aggregate spread rates ranged from 13 to 21 pounds per square yard and emulsion application rates ranged from 0.17 to 0.32 gallon per square yard. The spread and application rate designs were developed following the guidance of the *Minnesota Seal Coat Handbook* (Janisch and Gaillard 1998)

The following are recommendations for construction of bituminous seal coats:

- Clean and sweep pavement to remove any debris and vegetation.
- Cover manhole covers, water shutoff valves, and all other utility accesses to ensure that seal coat is not applied on them.
- Approaches or radii at intersections should be sprayed with binder first if using a slow setting emulsion.
- Keep chip spreader following distance to a minimum for cationic rapid-set emulsions. For slower-setting emulsions, it may be desirable to start the chip spreader after the emulsion skims over slightly on its surface.
- Pneumatic tire roller should follow chip spreader closely.

Literature Review Documentation

The organizations that were included in the literature review for bituminous seal coats included the following:

- Kansas Department of Transportation (KDOT)
- Missouri Department of Transportation (MoDOT)
- Nebraska Department of Roads (NDOR)
- Minnesota Department of Transportation (Mn/DOT)
- South Dakota Department of Transportation (SDDOT)
- Wisconsin Department of Transportation (WisDOT)
- Illinois Department of Transportation (IDOT)
- Iowa Statewide Urban Design and Specification (SUDAS) program

- Kansas City, Missouri Department of Public Works
- Omaha, Nebraska Department of Public Works
- Asphalt Emulsion Manufacturers Association (AEMA)

The Iowa DOT standard specification for bituminous seal coat (Section 2307) was compared to the documents obtained from the above sources. At the conclusion of the literature review, it was found that deviations from the Iowa DOT standard specification occurred most frequently in sections 2307.02 Materials and 2307.04 Construction. The following are the articles where deviations were found:

- 2307.02, A Aggregates
- 2307.02, B Bituminous Material
- 2307.04, A Preparation of Surface
- 2307.04, B Heating Bituminous Materials
- 2307.04, C Spreading Bituminous Material
- 2307.04, D Spreading Cover Aggregate
- 2307.04, E Rolling
- 2307.04, F One Coat Seal Coats
- 2307.04, K Limitations

The three articles that had the most deviations were 2307.04, K Limitations, 2307.04, E Rolling, and 2307.04, A Preparation of Surface. The primary differences in the limitations section of the specification comes from suitable weather requirements, as well as the definition of the construction season. The Iowa DOT specification currently only states that seal coats should not be applied after September 1 on primary projects or after September 15 on other projects. SUDAS specifications indicate that seal coats should not be applied after September 30. IDOT has conditions for conducting seal coat operations until October 30, which can be found in section 403.04 Weather Limitations of the specification for bituminous surface treatment.

MoDOT was the only state agency to specify requirements for seal coats based on ADT. Various grades of seal coats were recommended for ADT scenarios of roads having up to 14,000 ADT. MoDOT traffic volume guidance for seal coats can be found in section 409.1 Design of the standard specification. Guidance for surface preparation prior to seal coat application in the Iowa DOT specification requires that the pavement be cleaned. Other state agencies take further measures to ensure that the pavement surface is acceptable for seal coat applications.

A common practice among public agencies is to have cracks sealed and damaged areas replaced before seal coat operations commence. This can be done by the contracting authority with its own employees, with a separate prime contract, as a separate bid item in the seal coat contract, or as incidental to the seal coating bid item. If crack sealing is incidental to the bid item, it may substantially increase the cost of the seal coating bid item, especially if it not clear how much effort and how much material will be required to seal the cracks.

The Omaha Department of Public Works specifies that all cracks1/4 inch and greater be sealed and damaged areas repaired before a seal coat is applied. The SDDOT specification for seal coats also requires manhole covers, water shutoff valves, and other appurtenances to be covered before seal coat application so that bituminous material does not adhere to these surfaces. Currently, there is no mention of this practice in the Iowa DOT specification. A complete table indicating the primary deviations from the Iowa DOT specification for bituminous seal coats is included in Appendix E.

Possible Specification Changes

Based on discussions with the TAC, changes should be considered for the following:

- Add specifications for smaller gradations of cover aggregate. Such gradations produce a smoother surface with less tire noise. Also, material requirements are reduced. However, decision makers should be cautious when selecting such smaller gradations because, when compared to larger aggregates, they might not wear as long and application rates must be more carefully controlled. Also, contracting authorities should check to ensure that a particular size of cover aggregate is available in their area. Large sizes such as 1/2 inch is more commonly available, while smaller sizes are less available, except for sand, which is usually abundant in most locations. See Table 5 for proposed gradation limits.

Table 5. Proposed gradation limits

Percent Passing										
Sieve	**1/2 in.**		**3/8 in.**		**1/4 in.**		**No. 4**		**Sand**	
Size	**Min. (%)**	**Max. (%)**	**Min. (%)**	**Max. (%)**	**Min. (%)**	**Max. (%)**	**Min. (%)**	**Max. (%)**	**Min. (%)**	**Max. (%)**
3/4 in.	100									
1/2 in.	97	100	100							
3/8 in.	40	90	90	100	100				100	
1/4 in.							100			
No. 4	5	30	10	55	55	85	85	100		
No. 8	0	15	0	20	0	10	10	40	60	90
No. 30			0	7			0	8		40
No. 200	0	2	0	1.5	0	1.5	0	1.5	0	1.5

- Include the following emulsions to the specification (refer to Iowa DOT 4140 for material requirements rather than the American Society for Testing and Materials International/ASTM to harmonize with the Iowa DOT):
  - CRS-2
  - CRS-2P
  - HFRS-2

CRS-2P provides better aggregate retention, less bleeding, and quicker return to traffic, compared to CRS-2; however, the cost is higher. HFRS-2 is compatible with some aggregates that CRS-2 and CRS-2P are not. In addition, it tends to coat more thickly the CRS-2 and CRS-2P. However, cure time is longer. HFRS-2P is also sometimes available; however, apparently no American Association of State Highway and Transportation Officials (AASHTO) or American Society for Testing and Materials International (ASTM) specification currently exists for this grade. It has benefits and costs similar to CRS-2P. Based on conversations with suppliers, the researchers found that most contracting authorities order HFRS-2P on a case-by-case basis and negotiate a specification for polymer modification that is similar to the one for CRS-2P. Regarding 1.07 B Restrictions on Operations in the SUDAS specifications, the requirement that the aggregate spreader keep within 200 feet of the distributor truck should only be required for CRS-2 emulsions. HFRS-2 emulsions do not set as quickly as CRS-2 emulsions and, if the spreader follows too closely, the emulsion will not be viscous enough to hold the aggregate and prevent it from rolling. The result is considerable streaking and bleeding because the top surfaces of the aggregate become coated. It is better to wait to start the spreader after a slight skim has formed on top of the emulsion, which may take as much as 5 minutes.

- For cutbacks, specify MC 3000 and MC 800 for use with seal coating and MC 70 for prime coat, because those grades are commonly available in Iowa. Refer to AASHTO M081-92 for material specifications.

- For CRS-2, CRS-2P, and HFRS-2 emulsions, set the temperatures for heating before spraying in a range from 125 to 185°F to harmonize with AEMA (2004). If the temperature is too low, the binder will be too viscous and will not spray evenly or coat the pavement and aggregate well. If the binder is too hot, it might start to boil locally in the distributor truck or heated tank. In the locations where the boiling takes place, the microscopic asphalt globules in the emulsion are likely to coalesce, thus causing the emulsion to break prematurely. High heat can cause too much general evaporation of the water phase of the emulsion with a result that is similar to that of the local boiling concern. The resulting pieces of the coalesced binder will likely plug the distributor nozzles.

- For aggregates, an initial spread rate of 24 pounds per square yard for 1/2 inch, 21 pounds per square yard for 3/8 inch, and 18 pounds per square yard for 1/4 inch would match the experience from Jahren et al. (2003) for designed seal coats. For binder 0.27 gallon per square yard, 0.24 gallon per square yard, and 0.21 gallon per square yard, respectively, would match the experience from the same reference. Contracting authorities could design application rates for seal coats according to the procedures described in Janisch and Gaillard 1998 and use those results to set the initial application rates, which could be modified after constructing a test strip. If such an approach is taken, it would likely be desirable to let contractors have access to a bid item where they could safely bid their fixed costs per unit length of construction, in case material amounts are sharply reduced, so they are unable to recover their fixed cost from the unit material prices.

- Agencies have different requirements regarding the length of the seal coating season. The Iowa DOT specifies that seal coats cannot be applied after September 1 on primary projects and September 15 on other projects (2307.04 K). SUDAS requires that seal coats be placed before September 30. The question has come up regarding to what extent these provisions should be harmonized between the Iowa DOT specification and the SUDAS specification. The range of dates previously mentioned matches the range of dates specified by neighboring jurisdictions. Mn/DOT specifies no later than August 31, while KDOT specifies no later than September 15. IDOT specifies no later than October 1, with exceptions made under certain circumstances between October 1 and October 30. One approach that SUDAS might consider is to select a conservative date, such as September 1 or September 15, and allow the contacting authority to make exceptions when justified. By using premium materials, it may be possible to extend the season successfully with satisfactory results.

- Based on observations made during test section construction, the following equipment requirements in the Iowa DOT Standard Specifications may be outdated because, apparently, modern construction equipment is no longer manufactured to meet these requirements:
    - 2001.12, C, 2: A tachometer operated by a wheel independent of the truck wheels.
    - 2307.03, A, 1, b: Equip aggregate spreaders described in Article 2001.13, B, with a scalper or segregator screen (provided by the manufacturer) mounted below the feeder roll. Use scalper screen opening sizes recommended by the spreader manufacturer. When adjusted to the proper angle, the coarse fraction of the aggregate is placed first. Afterwards, the fine fraction is dropped through the screen on top of the larger particles. Adjust the screen angle as necessary on the project. Use of this screen is required.

SLURRY SEAL

Description and Appropriate Applications

A slurry seal consists of asphalt emulsion, aggregate, water, and mineral filler that is pre-mixed and placed as slurry on the surface of a pavement. The application thickness of a slurry seal is only as thick as the largest-sized aggregate. The slurry has the consistency of mud and can be easily worked with hand tools. Slurry seals are commonly recommended as an effective surface treatment for roads that have traffic volumes of less than 2,000 ADT. However, slurry seals have been used successfully on roads with traffic volumes greater than 2,000 ADT, although not commonly used in Iowa.

Slurry seals are commonly recommended for use in treating low to medium levels of raveling, cracking, and rutting. Slurry seals are also capable of addressing low levels of alligator cracking on very low-volume roads. Applying slurry seals enhances pavement properties, such as skid resistance, and mitigates the effects of oxidation. Table 6 lists the advantages and disadvantages of slurry seal as a surface treatment.

Table 6. Slurry seal advantages and disadvantages

Advantages	Disadvantages
Seals pavement surface	Not recommended for pavements with severe cracking
Enhances appearance of pavement	Brittle nature reflects cracks
Provides new wearing course	Road must be closed for 6 to 8 hours before opening to traffic
Reduces raveling and further oxidation of underlying asphalt binder	Material may ravel due to snow plow damage
Fills in shallow ruts	
Levels rolled down cracks	
Fills longitudinal cracks	

Design Considerations

Aggregates commonly used for slurry seal applications consist of a combination of crushed stone and mineral filler such as Portland cement. High quality aggregates are necessary for high-quality slurry seals. The Iowa DOT specifies two gradation types for slurry seals: fine and coarse. Coarse mixtures have more stability when compared to fine mixtures and are preferred for rut filling or scratch (bottom) courses. Fine slurry mixtures provide a smoother surface with less macro-texture and, for that reason, may be specified as a surface course. However, in Iowa, it is rarely specified, possibly because of difficulty in obtaining the aggregate.

The asphalt binder used in slurry seal applications is an asphalt emulsion. Grade CSS-1h or SS-1h are specified by the Iowa DOT. CSS-1h and SS-1h are cationic and anionic slow-setting emulsions, respectively. Each emulsion is also formulated with relatively stiff (the suffix h = hard) base asphalt and, thus, can be used in relatively warm climates. The *Basic Asphalt*

Emulsion Manual (AEMA 2004) also recommends DQS-1h and QS-1h, which are quick-setting emulsions. They set faster than slow-set emulsions but slower than rapid-set (RS) emulsions. RS emulsions are not intended for mixing with finely-graded materials and are usually used for seal coats.

Construction Guidance

Due to the high cost and specialized nature of the equipment, slurry seal construction is often performed by a contractor. When using an International Slurry Surfacing Association (ISSA) Type III gradation, an application rate of 20 to 30 pounds per square foot is recommended. Application rates vary depending on the gradation of the aggregate. If a smaller aggregate gradation is used, a lower application rate can be used. The mix design should be performed by the contractor. Agencies typically specify the aggregate type and gradation, as well as the asphalt binder to be used. The following are recommendations for the construction of slurry seals.

- The thickness of the slurry seal is approximately the same as the largest aggregate size.
- Use of RS emulsions can reduce road closure time.
- Hotter and dryer weather conditions accelerate slurry seal curing time.
- Fill shallow ruts with a scratch (base) course to level the pavement; then, return with a surface course.
- Fill deep ruts with multiple lifts using a rut box.
- Wide cracks can be filled with slurry to reduce the width of the crack.

Literature Review Documentation

The organizations that were included in the literature review for bituminous seal coats included the following:

- Missouri Department of Transportation (MoDOT)
- Illinois Department of Transportation (IDOT)
- Iowa Statewide Urban Design and Specification (SUDAS) program
- Valley Slurry Seal Co.
- Kansas City, Missouri Department of Public Works
- Omaha, Nebraska Department of Public Works
- International Slurry Surfacing Association (ISSA)
- Asphalt Emulsion Manufacturers Association (AEMA)

The Iowa DOT Standard Specifications for slurry seal (section 2319) were compared to the documents obtained from the above sources. At the conclusion of the literature review, it was found that deviations from the Iowa DOT specifications occurred most frequently in sections 2319.02 Materials, 2319.04 Preparation of Surface, and 2319.07 Limitations. The following are the articles (or sections) of the specification where deviations were found:

- 2319.02, A Asphalt Emulsions
- 2319.02, B Aggregate
- 2319.02, H Asphalt Binder Content
- 2319.04 Preparation of Surface
- 2319.05 Tack Coat
- 2319.06 Composition and Rate of Application
- 2319.07 Limitations
- 2319.09 Application of Slurry Material

Article 2319.02, B Aggregate had the greatest number of deviations between the Iowa DOT specification and the reviewed specifications. The most common deviations related to aggregate gradations that were specified, as well as the materials that were considered acceptable mineral fillers. The ISSA, Kansas City Department of Public Works, IDOT, and SUDAS all had aggregate gradations other than that specified by the Iowa DOT. Valley Slurry Seal Co. specified three types of aggregate gradations and had recommendations for the application of each. These recommendations for aggregate gradation can be found in section 2.01c of their slurry seal specifications. The Iowa DOT specification for slurry seal currently only recognizes one mineral filler: Type I Portland cement. The Kansas City Department of Public Works and ISSA allow the use of hydrated lime, limestone dust, and fly ash, in addition to Portland cement, as mineral fillers.

Common deviations from the Iowa DOT specification for slurry seal regarding surface preparation include crack sealing, pavement marking removal, covering of utility covers, and repairing damaged areas. The City of Omaha Department of Public Works specifies that cracks greater than 1/4 inch be sealed prior to the application of a slurry seal. IDOT was the only state agency that mentioned pavement marking removal. Pavement marking removal is suggested to improve the slurry seal adherence to the pavement surface.

MoDOT recommends slurry seal applications for roads with less than 3,500 ADT, which was also the only specification that had a traffic volume limitation specified. In the Mn/DOT *Asphalt Maintenance Handbook*, slurry seals should not be applied to an existing pavement surface if it is unstable with moderate or severe cracking. A complete table indicating the primary deviations from the Iowa DOT specification for slurry seals is included in Appendix F.

Possible Specification Changes

Based on discussions with the TAC, changes should be considered for the following:

- Consider increasing the lower limit for fine material in the Type III Aggregate Gradation. Jahren et al. documented a circumstance on a micro-surfacing project where an aggregate that marginally met the Type III gradation on the coarse side did not spread out of the spreader box with sufficient thickness to provide a long-lasting maintenance treatment. Slurry seal and micro-surfacing are sufficiently similar so that it is likely that a similar unfavorable result could occur on a micro-surfacing project that uses similarly-graded aggregate. A specification was successfully pilot tested on a City of West Des Moines, Iowa micro-surfacing project with the gradation limits shown in Table 7 (Jahren et al. 2007). For comparison, the current gradation limits from the SUDAS specification are shown in Table 8.

Table 7. Type III micro-surfacing gradation limits (West Des Moines specifications)

Sieve Size	% Passing
3/8"	100
#4	70–100
#8	45–70
#16	28–50
#30	19–34
#50	13–25
#100	10–18
#200	8–15

Table 8. Type III slurry seal aggregate gradation limits for SUDAS

Percent Passing		
Sieve Size	**Min. (%)**	**Max. (%)**
3/8 in.	100	
No. 4	70	90
No. 8	45	70
No. 16	28	50
No. 30	19	34
No. 50	12	25
No. 100	7	18
No. 200	5	15

- It is recommended that limits for component materials in the slurry seal mixture and the application rates be harmonized with ISSA A105 (2005) as shown in Tables 9 and 10, respectively.

Table 9. Slurry seal component materials (ISSA 2005)

COMPONENT MATERIALS	LIMITS
Residual Asphalt	Type I: 10 - 16% Type II: 7.5 - 13.5% Type III: 6.5 - 12% (Based on dry weight of aggregate)
Mineral Filler	0.5 - 2.0% (Based on dry weight of aggregate)
Additives	As needed
Water	As needed to achieve proper mix consistency (Total mix liquids should not exceed the loose aggregate voids. ISSA T106 should be used to check optimum liquids.)

Table 10. Suggested application rates for slurry seal (ISSA 2005)

AGGREGATE TYPE	LOCATION	SUGGESTED APPLICATION RATE
Type I	Parking Areas Urban and Residential Streets Airport Runways	8 - 12 lb/yd^2 (4.3 – 6.5 kg/m^2)
Type II	Urban and Residential Streets Airport Runways	10 - 18 lb/yd^2 (5.4 – 9.8 kg/m^2)
Type III	Primary and Interstate Routes	15 - 22 lb/yd^2 (8.1 – 12.0 kg/m^2)

MICRO-SURFACING

Description and Appropriate Applications

Micro-surfacing is a high-performance slurry seal that uses faster-breaking, polymer-modified emulsion and chemically-consistent 100% crushed aggregate that is compatible with the relatively-unstable, fast-breaking emulsion. Micro-surfacing has advantages over slurry seal because roads can be returned to traffic faster and the stability and resilience of the mix allows to fill deeper ruts and stands up better under traffic and adverse weather at crack edges. Disadvantages are that the materials are more expensive and it is less forgiving when placement errors occur or when hand-work is necessary. Also, augers are required in the spreading box to distribute the mix.

Micro-surfacing can be applied to roads of any traffic volume. It can be especially useful in busy intersections and other locations that must be reopened to traffic quickly after construction. Micro-surfacing can be used for nighttime construction, while slurry seal cannot.

Table 11. Micro-surfacing advantages and disadvantages compared to slurry seal

Advantages	Disadvantages
Traffic can return to newly-treated road usually within 1 hour of micro-surfacing application	Materials are more expensive and less available
Night work is possible because curing can occur at night	Less forgiving if placement errors occur or hand-work is required
More resilient	The spreader box must have augers
Can fill deeper ruts because the cured binder is stiffer and more stable	
Fills in shallow ruts	
Levels rolled-down cracks	
Fills longitudinal cracks	

Design Considerations

Design considerations are similar to those of slurry seal, except that micro-surfacing is appropriate for higher-volume roads where long service life, quick return of traffic to the treated surface, and possible nighttime construction are important. Also, micro-surfacing is often a better choice for deeper ruts, especially those that are more than 1 inch deep.

The asphalt binders that are used in micro-surfacing are polymer-modified, relatively-unstable, and highly-reactive. Slurry seal binder breaks (that is the oil in the emulsion coalesces) when the water evaporates out of the emulsion. By contrast, micro-surfacing binder has what is sometimes described as a “chemical break” where the binder coalesces on the aggregate before the water evaporates because the binder and the aggregate have opposite electrical charges; therefore, the binder is attracted to the aggregate. Aggregate consistency is important to ensure that the micro-surfacing emulsion breaks predictably.

Laboratory evaluation of the compatibility of the emulsion with the aggregate is especially important for micro-surfacing. Usually, the emulsion supplier will provide necessary compatibility checks.

Micro-surfacing emulsion is usually required to meet the AASHTO CSS-1h and be polymer modified. Additional requirements are often added, such as having a minimum percentage of polymer solids by weight, a slightly higher residue percentage after distillation, and meeting the requirements of the AASHTO T53 Ring and Ball Softening Point Test for a certain temperature (such as 135°F).

Construction Guidance

Construction requirements for micro-surfacing are similar to those for slurry seal. The placement machine must have augers in the spreader box to keep the material fluid and moving until it is fully spread over the width of road that it is being placed. Because the material is less forgiving with regard to placement errors and hand-work, a more experienced placement crew is preferred. Greater care should be taken to remove excess dust from the road surface, as it may cause the unstable micro-surfacing emulsion to break more quickly than intended. Traffic control requirements will likely be lessened because traffic may be returned more quickly to the road.

Literature Review Documentation

The organizations that were included in the literature review for micro-surfacing included the following:

- Kansas Department of Transportation (KDOT)
- Missouri Department of Transportation (MoDOT)
- Nebraska Department of Roads (NDOR)
- Minnesota Department of Transportation (Mn/DOT)
- South Dakota Department of Transportation (SDDOT)
- Illinois Department of Transportation (IDOT)
- Valley Slurry Seal Co.
- Kansas City, Missouri Department of Public Works
- City of Chesterfield, Missouri
- International Slurry Surfacing Association (ISSA)

The Iowa DOT supplemental specification for slurry seal (SS-09003) was compared to the documents obtained from the above sources. At the conclusion of the literature review, it was found that deviations from the Iowa DOT supplemental specification occurred most frequently in sections 01055.02 Materials, 09003.03 Construction, and 09003.05 Basis of Payment. The following are the articles (and one individual section) where deviations were found:

- 09003.02, A Polymer Modified Emulsified Asphalt
- 09003.02, B Aggregate
- 09003.02, C Mineral Filler
- 09003.02, F Composition and Quality of Mixture
- 09003.03, B Limitations
- 09003.03, D Preparation of Surface
- 09003.03, E Test Strip
- 09003.03, F Spreading
- 09003.03, G Opening to Traffic
- 09003.05 Basis of Payment

The greatest number of deviations from the Iowa DOT supplemental specification came in articles 09003.02, F Composition and Quality of Mixture, 09003.02, B Aggregate, and 09003.03, D Preparation of Surface. The primary differences that were encountered in article 09003.02, F Composition and Quality of Mixture were residual asphalt content, mineral filler content, and aggregate application rate. NDOR, Mn/DOT, SDDOT, IDOT, Valley Slurry Seal Co., and the ISSA have aggregate gradations that are different from those found in the Iowa DOT supplemental specification. One interesting use of local materials was noted in the specifications for the City of Chesterfield, Missouri, where the specification mandated aggregates used in micro-surfacing to contain at least 40% air cooled blast furnace slag. This co-product is produced near Chesterfield and offers a renewable source of aggregate. The use of this material would be limited to locations where blast furnace slag is locally produced or inexpensively transported over a longer distance.

Deviations in the surface preparation article are similar to those for slurry seal and include crack sealing, pavement marking removal, and covering utility covers. Mn/DOT has a requirement in its micro-surfacing specification that mandates the construction of a 1,000 foot test section prior to commencing micro-surfacing operations. The test strip is to be placed after dark, no sooner than 1 hour after dark and no later than 1 hour before sunrise. Placing the test strip at night allows construction inspectors to check the curing time of the micro-surfacing mix.

Micro-surfacing cures through a chemical process, while slurry seals do not. Placing test sections at night is meant to eliminate the potential for a contractor to use a fast-curing slurry seal in place of micro-surfacing. A complete table indicating the primary deviations from the Iowa DOT specification for micro-surfacing is included in Appendix G.

Possible Specification Changes

Changes should be considered for the following:

- Modify the Type III gradation as recommended for slurry seal.
- Modify SS 09003.02, B, 1, 3rd bullet to allow limestone aggregate. Jahren et al. (2007) indicated that micro-surfacing with limestone aggregate performed satisfactorily and was less expensive to produce when compared to micro-surfacing with quartzite aggregate. According to Jahren et al. (2003), limestone aggregates that have less than 0.15% alumna according to Iowa Test Method 222 (X-Ray Fluorescence Test) are likely to have a sufficiently small clay content to be viable candidates for micro-surfacing aggregate. If the micro-surfacing mixture made with this limestone passes all of the other tests that are specified under the mix design procedure in SS 09003, there is reasonable assurance that the limestone aggregate would perform satisfactorily during construction and use.

SUMMARY

The recommendation for updates to Iowa SUDAS specifications for roadway rehabilitation techniques were developed after conducting a literature review, analyzing specifications from neighboring jurisdictions, and soliciting input from employees of contracting agencies, material suppliers, and contractors. A practitioner survey was conducted to identify areas of greatest interest. The results of the survey indicated that the greatest interest was for general information regarding treatment and road selection and then specific information regarding seal coats.

The following specification updates were recommended:

- Fog Seal
  - Harmonize temperature requirements with neighboring jurisdictions by allowing a lower minimum application temperature. At the high end of the range would be 50°F and 40°F would be in the middle of the range.
  - Make the specification more robust for municipal use by including a requirement to protect manhole covers, valve covers, and other appurtenances.
  - Also consider striking the word “Shoulder” from the title.
- Seal Coating
  - Include additional fine aggregate (1/4 inch and No. 4) gradations.
  - Include high float emulsions in material specifications.
  - Harmonize emulsion temperature requirements with recommendations of the American Emulsion Manufacturers Association (AEMA 2004).
  - Reduce suggested aggregate end emulsion application rates to match the experience with designed application rates developed in previous Iowa research projects (Jahren et al. 2003, 2007).
  - Specify earlier end of season limits with flexibility to make exceptions under specific circumstances.
  - Update equipment requirements.
- Slurry Seal
  - Require a higher proportion of fine material in the Type III (coarse) slurry seal gradation.
  - Harmonize requirements for component materials in mix designs and application rates with guidance from ISSA (2005).
- Micro-Surfacing
  - Require a higher proportion of fine material in the Type III (coarse) micro-surfacing gradation.
  - Adjust material requirements to allow limestone aggregate with low clay content and good wear characteristics.

The Iowa DOT is starting an effort to increase the investment in pavement maintenance. This will likely involve increased use of the maintenance treatments addressed in this report. Appropriate training and insightful project selection will enhance the success of this effort. It is recommended that treatment selection guidelines developed in previous research and the revised specifications be used and evaluated as this program ramps up.

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APPENDIX A. TMS SUMMARY

	Bituminous Fog Seal	Bituminous Seal Coat	Cold In-Place Recycled Asphalt	Slurry Seal	Thin Hot Mix Asphalt Overlay	Polymer Modified Microsurfacing	Macrosurfacing
IADOT	2306: Bituminous Fog Seal	2307: Bituminous Seal Coat	2318: Cold In-Place Asphalt Pavement Recycling	2319: Slurry Leveling, Slurry Wedge, and Strip Slurry Treatment		SS-01055: Polymer Modified Microsurfacing	
KDOT		609: Single Asphalt Surface Treatment 610: Double Asphalt Surface Treatment	604: Cold Recycled Asphalt Construction		613: Ultrathin Bonded Asphalt Surface	606: Microsurfacing Special Provision to Section 606	
MODOT	413.4: Bituminous Fog Sealing	409: Seal Coat		402: Bituminous Surface Leveling	413.7: Thin Hot Mix Asphalt Overlay 413.3 Ultrathin Bonded Asphalt Wearing Surface	413.1: Micro-Surfacing	
NDOR	513: Fog Seal	515: Armor Coat				514: Microsurfacing	
MNDOT	2355: Bituminous Fog Seal	2356: Bituminous Seal Coat				Special Provision for Micro-Surfacing	
SDDOT	330: Fog Seal	360: Asphalt Surface Treatment	370: Cold Recycling of Asphalt Concrete		Special Provision for Ultrathin Bonded Wearing Course	Special Provision for Polymer-Modified Microsurfacing	Special Provision for Macro Surfacing
WIDOT		475: Seal Coat					
IDOT		403: Bituminous Surface Treatment		Special Provision for Slurry Seal		448: Micro-Surfacing	
SUDAS		7060: Bituminous Seal Coat		7070: Emulsified Asphalt Slurry Seal			
Valley Slurry Seal Co.				Slurry Seal		Microsurfacing	Description of Macro Surfacing
Kansas City Public Works		2206.3/2206.4: Improved and Unimproved Street Chip Seal		2206.5: Improved Street Slurry Seal		2206.6: Improved Street Microsurfacing	
Omaha Public Works	405: Fog Seal	404: Bituminous Surface Treatment		406: Slurry Seal			
ISSA				A105: Emulsified Asphalt Slurry Seal		A143: Polymer Modified Micro-Surfacing	
City of Chesterfield MO					Ultrathin Bonded Wearing Course	Technical Specification for Microsurfacing	
AEMA	Brandenburg_Fog Seals	Kucharek_Chip Sealing Technology NCHRP 342_Chip Seal Best Practices	Bemanian_CIR	Anspaugh_Micro and Slurry			
ARRA			ARRA_Cold Recycling ARRA_Basic Asphalt Recycling Manual				

APPENDIX B. TMS SURVEY RESULTS

Seal Coats		**1**	**2**	**3**	**4**	**5**	**Total Points**
1	Overall guidelines	4	11	4	4	2	86
2	Design of application rates	1	2	3	2	4	30
3	Specifications for smaller aggregate			3	1		11
4	Pre-coated aggregates		1	2	2	2	16
5	Aggregate selection guidelines			2			6
6	Binder selection guidelines		1	2		1	11
Slurry Seals and Microsurfacing		**1**	**2**	**3**	**4**	**5**	**Total Points**
7	Overall guidelines		5	9	8	1	64
8	When to use slurry seal and microsurfacing	1	4	4	5	4	47
9	Local aggregates for micro-surfacing	1			1	1	8
10	Rut filling techniques	2	3	1	2	4	33
Fog Sealing		**1**	**2**	**3**	**4**	**5**	**Total Points**
11	Overall guidelines	1	2	2	5	6	35
12	Binder selection	1	1			1	10
13	Application rates		1		1	3	9
14	Considering the use of proprietary products					1	1
Overall Guidelines		**1**	**2**	**3**	**4**	**5**	**Total Points**
15	When it is appropriate to use each type of treatment and when not to use them	22	2	1	2	3	128

Total Points: Each 1 response was worth 5 points; each 2 response was worth 4 points; each 3 response was worth 3 points; each 4 response was worth 2 points; and each 5 response was worth 1 point.

APPENDIX C. SURVEY RESULTS

TAC Survey Results

Name	Organization	TMS Questions for TAC members							
		TMS Treatments used	TMS selection criteria	Asphalt Binder	Aggregate	Surface Preparation	Specifications Used	Concerns about TMS	Comments on TMS
Bruce Braun	City of Des Moines	slurry seal	Low volume residential streets in good structural condition recieve slurry seal as a maintenance treatment	CSS-1 used for tack coat in slurry seal with an application rate of 0.10-0.15 gal/sy	limestone slurry rock from Martin Marietta application rate .013 ton/sy	joints and cracks are cleaned including removing vegetation. Large cracks are sealed before treatment and full depth patching is done when required	SUDAS	cold in place recycling (CIR) not used because due to concern of utilities in roadway and it requires a surface coarse	satisfied with resulting treatment (slurry seal). Surface is good in public image because it resembles an HMA overlay
		chip seal		CSS-1h for emulsion of slurry seal applied at 0.50 gal/sy			ISSA	microsurfacing not used because aggregates are not readily available and few contractors are experienced	
Steve Salvo	Snyder and Associates	seal coat	TMS not used on arterials	CRS-2P for seal coat applications	slurry seal applications use 3/16" limestone chip	pavement surface is cleaned of debris, cracks are sealed, and full depth patching if required	ISSA	microsurfacing not used because there are few local resources for aggregate (not an economical option) also few contractors have experience required	Investing in TMS provides good value for the money one experience with CIR at Ames Airport. Was pleased with the results, pavement held up well but did experience thermal cracking
		slurry seal	TMS typically used as a temporary solution		always use pre-coated aggregate for seal coats				
		fog seal	slurry seals used in residential areas because it does not raise the surface of the road or require raising of inlets, manholes etc.	use whatever binder is recommended by SUDAS or Iowa DOT	use aggregate types that are specified by SUDAS and Iowa DOT				
		cold in place recycling (CIR)	fog seals are used for dust control						
Greg Parker	Johnson County	cold in place recycling (CIR)	traffic volume, future reconstruction maintenance schedule, pavement condition, and age all play a role in determining proper treatment	asphalt emulsions and cutbacks used (cutbacks: MC 800, MC 3000)	use pre-coated aggregate to minimize dust and create better adhesion to pavement surface	pavement surface is cleaned and patched according to need	In house specifications	fog seal not widely accepted by public because they don't understand why new pavement is being treated so soon	has been satisfied with the results of TMS applications
		seal coat						fog seal also can create the need for additional pavement marking when existing is covered by fog seal	
		slurry seal							

Contractor Survey Results

Name	Organization	TMS Questions for Contractors						
		Successful TMS Application	Unfavorable TMS Conditions	Asphalt Binder	Aggregate	Surface Preparation	Specifications Used	Concerns about TMS
Bob Wagner	Blacktop Services Co.	application of seal coat not restricted to low volume roads	pavements with significant pavement stability issues	Iowa DOT prefers to use emulsions	feels that specifications clearly list pertinent information	the surface of the pavement is cleaned of debris	Often refer to the Iowa DOT specification for seal coat	do not do microsurfacing because it is not cost effective due to the limited availability of required aggregate
		pavement can be cracked but must be structurally sound for seal coat to effectively treat distress		Blacktop services prefers to use cutbacks (MC 3000) for seal coats				
				Feels that specifications provide enough information				
Rick Burchett	STA BILT Construction Co.	seal coats effectively treat pavements that are not overly distressed, high or low volume	chip seals, slurry seals, and microsurfacing are not recommended for pavements with severe cracking or stability issues	feels that state level specifications are adequate	feels that Iowa DOT specification for aggregate may not specify most economic alternative for aggregate	recommends sealing joints before placement of treatment	Iowa DOT	full depth recycling is more effective than CIR because it can address issues of full depth cracking (CIR may not)
		slurry and microsurfacing can treat some pavement deterioration but still require structural stability. Better application for high volume roads		feels that SUDAS specifications would benefit from indicating preferred emulsion types as well as application rates, also feels that base stabilization needs to be more specific in terms of types and application rates			SUDAS	
		full depth recycling commonly used at city/county level for upgrading unpaved roads or pavement with deep cracking, seal coat placed for wearing course						

APPENDIX D. FOG SEAL SUMMARY

	Deviations from Iowa DOT Specification for Bituminous Fog Seal			
	2306.02 Materials	**2306.04 Cleaning**	**2306.06 Application**	**2306.07 Limitations**
MODOT	413.4: specifies use of SS-1h and CSS-1h emulsions			
NDOR	513.02: HFE-150, 300, 1000 and CRS-1h, CM-4 used		513.03: application of sand when necessary 3.7-12.9 lb/SY	
MNDOT	2355.2: specifies CSS-1h, and SS-1h in addition to IA spec, also specifies RC-70 for liquid asphalt		2355.3D: SS-1, CSS-1 application temps 120-175 F	2355.3A: use asphalt emulsions for air temp > 40 F
SDDOT		330.3D: protect adjacent apurtenances from asphalt		330.3A: air/surface temp at least 35 F
Omaha Public Works	405.02: specifies SS-1h, CSS-1h, MS-1, and HFMS-1 emulsions	405.03A: seal all cracks > 1/4" and repair damaged areas as directed by engineer	405.03B: application rate shall be .15-.25 gal/SY	405.03B: apply bitumen when atmospheric temp >, = 50 F

APPENDIX E. SEAL COAT SUMMARY

	Deviations from Iowa DOT Specification for Bituminous Seal Coat								
	2307.02A Aggregates	**2307.02B Bituminous Material**	**2307.04A Preparation of Surface**	**2307.04B Heating Bituminous Materials**	**2307.04C Spreading Bituminous Material**	**2307.04D Spreading Cover Aggregate**	**2307.04E Rolling**	**2307.04F One Course Seal Coats**	**2307.04K Limitations**
SUDAS	2.01: breakdown of aggregate gradation for seal coat	2.01: MC-800, ORMC 3000 cut back asphalt specified for use	3.01: criteria for preparation of existing gravel roads and priming	3.02: temperature range for CRS-2 125-170 F	1.07: surface and pavement temperature at 70 F or above		1.07: initially roll w/in 2 min after aggregate spread		1.07: seal coat shall not be placed on wet surface or in night conditions
									1.07: seal coats shall not be applied after Sept 30
KDOT							609.3i: roller coverage complete in 15 min	609.3h: more specific breakdown for rates of application (see table 608-1)	609.3l: more specific seasonal/weather limitations
							609.3i: don't turn rollers on sealed surface		
MODOT			409: working cracks & cracks >= 3/8" filled before placement			409.2.5: max time interval between applying binder & spreading agg. (30s)	409.5.5: rolling immediately follows spreading		409.1: guidelines for selecting bituminous material based on AADT
							409.5.5: don't turn rollers/haul trucks on sealed surface		409.5: restrictions for roads receiving seal coats
									409.5.3: examples of chip seal failures
NDOR						515.03.4: cover agg. applied w/in 1 min. after binder	515.03.5: roller coverage complete in 15 min		
MNDOT				2356.3D: wider temp range for CRS-1, 2 (125-185 F)		2356.3E: cover agg. applied immediately after binder		2356.3E: 40-50 lb application rate for cover agg.	2356.3A: operations limited to May 15 to Aug. 31
									2356.3A: temp = 70F and humidity <75%
SDDOT			360.3C: manhole covers, water shut valves etc. should be covered before application	360.3D: temp range for asphalt 120 - 180 F		360.3E: cover agg. Applied w/in 5 min or less after binder			360.3A: specific seasonal/ weather limitations for agg. types
IDOT		403.02: High Float Emulsion (HFE 90, 150, 300) among recommended materials		403.07: different temp ranges for bituminous material					403.04: operations limited to May 1 to Oct 1, additional criteria for work Oct 1 to 30
KC Public Works	2206.3B2: 100% crushed aggregate including limestone, sandstone, lightweight agg., basalt, granitic material, steel slag, gravel, or chat	2206.3B1: anionic emulsion RS-2 specified	2206.3C: areas where base failure has occurred or where surface is broken out shall be repaired prior to sealing operation					2206.3D2: emulsified asphalt applied at rate between .28-.35 gal/SY	
	2206.3B2: difference in gradation (see IA sec. 4109 gradation No. 20)							2206.3D2: cover aggregate applied between 18-25 lb/SY	
	2206.4C: specified gradations for single and double applications								
Omaha Public Works		404.02B: specifies RS-1, RS-2, HFRS-2 and CRS-1 emulsions	404.03A: seal all cracks > 1/4" and repair damaged areas as directed by engineer						404.03B: apply bitumen when atomospheric temp =, > 50 F

APPENDIX F. SLURRY SEAL SUMMARY

	Deviations from Iowa DOT Specification for Slurry Seal							
	2319.02A Asphalt Emulsion	**2319.02B Aggregate**	**2319.02H Asphalt Binder Content**	**2319.04 Preparation of Surface**	**2319.05 Tack Coat**	**2319.06 Composition and Rate of Application**	**2319.07 Limitations**	**2319.09 Application of Slurry Material**
SUDAS		2.01C: Type 1 and 2 specified are different than IA DOT gradation #22					1.07: slurry seal shall not be placed during night conditions	
MODOT							402.1.1: intended for use on roadways w/ less than 3500 AADT	
							402.1.2: further breakdown for slurry mixes based on AADT	
MNDOT							do not use when existing surface is unstable with moderate or severe cracking	
IDOT		gradation other than IA No. 22, 23		pavement markings shall be removed before placing slurry seal		slurry seal applied over entire width of each lane at a rate of 20 lb/SY	placement done between May 1 and Oct 15	for projects > 100,000 SY test strip needs to be applied at least one day before starting project
				bumps > 1/2" shall be removed by grinding				specific guidelines for finished product including excessive streaking criteria
				joints/cracks > 3/16" shall be cleaned and sealed (apply sealant when temp 40-85 F)				slurry seal shall cure for min. 7 days before placing permanent pavement markings
Valley Slurry Seal Co.	2.01a: specifies use of CQS-1H grade asphalt eumulsion (cationic quick setting emulsion designed for slurry seals)	2.01c: type I aggregate typically used for parking lot resurfacing	2.01c: asphalt content for type I 10-12%, type II 7.5-13.5%, type III 6.5-12%	2.05: all surface metal utility covers shall be protected before slurry seal application			2.05: should not be placed if pavement or air temp < 55 F and falling	
		2.01c: type II typically used for parking lots, streets, and arterials					2.05: can be placed when pavement temp and air temp > 45 F and rising	
		2.01c: type III typically used for arterials and highways						
KC Public Works	2206.5B1: quick set emulsified asphalts QS-1h and CQS-1h specified	2206.5B2: difference in gradation Type I and Type II (see Sec 4109 in IA DOT Spec)					2206.5B8: slurry seal not applied when air/pavement temp < 60 F and falling or when relative humidity > 80%	2206.5B5: nice table used to display application rates for Type I and Type II aggregates (suggest using in IA)
		2206.5B3: chemically active: hydrated lime, ammonium sulfate chemically inactive: limestone dust, fly ash, rock dust						
Omaha Public Works		406.02: fine aggregate shall be crushed limestone, quartzite, chat, dolomite or combination thereof		406.03: seal all cracks > 1/4" and repair damaged areas as directed by engineer				
ISSA	4.1: specifies SS-1, CSS-1, and CQS-1h emulsions	4.2.3: Type I and Type II gradations different than IA fine slurry gradation		10.3: pre-treat cracks w/crack sealer prior to slurry seal application	10.2: tack coat not required unless surface is extremely dry and raveled or is concrete or brick	5.2.5.3: good tables displaying mix design info and rate of application	8: no application when air/pavement temp = 50 F and falling, can apply when air/pavement temp > 45 F and rising	
		4.3: hydrated lime, limestone dust, fly ash specified as mineral fillers						

APPENDIX G. MICRO-SURFACING SUMMARY

	Deviations from Iowa DOT Specification for Polymer Modified Microsurfacing -- SS - 09003, Oct 20, 2009.									
	09003.02A Polymer Modified Emulsified Asphalt	**09003.02B Aggregate**	**09003.02C Mineral Filler**	**09003.02F Composition and Quality of Mixture**	**09003.03B Limitations**	**09003.03D Preparation of Surface**	**09003.03E Test Strip**	**0900e.03F Spreading**	**09003.03G Opening to Traffic**	**09003.05 Basis of Payment**
KDOT			606.2: use any recognized brand of non-air-entrained portland cement	606: mix design (table 6-1) now has same criteria as IA spec and temp of 50 F for placement also the same	606.3g: construct microsurfacing from May 1 to Oct 15			606.3d: additional acceptance criteria for surface, joint, and edge irregularities		606.4: material used to correct surface deficiencies will not be measured for payment
				606: mix proportioning (table 6-2) has 15 lb/SY min for mineral agg., 6.5% residue by wt. for mod. Emulsion, and 1% min by wt. dry agg.				606.3e: material used to fill wheel ruts needs to cure min 24 hrs before full width coverage		
MODOT					413.2: Type II (light 1 pass microsurfacing) typically used for light traffic (ADT<3500)	413.2: surface preparation should include crack sealing or filling				
						413.2: pavement markings should be removed before microsurfacing				
NDOR		514.02: different gradation for crushed aggregates	514.02: allow use of Type IP portland cement as mineral filler					514.04: ruts > 1" deep need 2 applications of microsurfacing		514.06: other additives will not be measured for payment, considered subsidiary to item
MNDOT		S-1.2B: has 2 additional gradations not specified in IA spec	S-1.2C: specifies hydrated lime as acceptable mineral filler	S-1.3A: residual asphalt content 5.5-10.5%, mineral filler .25-3.0%	S-1.4B9: don't start work after Sept 15	S-1.4B5: apply tack coat to all PCC surfaces	S-1.4B4: 1000' long test strip one lane wide for each machine used on project. Begin after dark no sooner than 1 hr after dark and no later than 1 hr before sunrise		S-1.4B8: penalty deductions for contractor's failure to produce acceptable surface	
						S-1.4B5: only apply tack coat to ACC surfaces if directed by the engineer	S-1.4B4: additional test strip requirements (ie. Engineer inspects test strip after 12 hrs of traffic)			
						S-1.4B7: protect drainage structures, monument boxes, water shut offs etc.				
SDDOT		SP II.B: different gradation specified		SP II.G: aggregate applied 15-30 lb/SY	SP III.A: microsurfacing should not be placed before June 1 or after Sept 15			SP III.D: ruts > 1/2" should be filled with a rut box with rut fill		
IDOT		448.02: different gradation and separate gradation for "rutfill" mix		448.05: application rate for aggregate 15-50 lb/SY	448.06: application from Mar 31 to Oct 31, temp > 50 F			448.08: if rut filling, microsurfacing shall be performed in two operations		
Valley Slurry Seal Co.	2.02a: asphalt emulsion should be a polymer modified quick setting cationic asphalt emulsion	2.02d: aggregate shall be manufactured crushed stone such as granite, slag or limestone	2.02c: mineral filler can be any recognized brand of non-air entrained Portland cement or hydrated lime	2.04: residual asphalt 5.5-9.5%, mineral filler 0-3.0% by dry mass of agg.						
		2.02d: type II gradation is similar to IA spec type III is different		2.07: rutting of 12.5 mm or more must be filled prior to microsurfacing using type II aggregate						
				2.07: at least 12 hrs of traffic compaction should follow filling of ruts before surface course						
				2.07: type II app. rate 7-10 kg/m2, type III app rate 13-17 kg/m2						
				2.07: for concrete pavement app rate is 16 kg/m2 for type III						
KC Public Works			2206.6B3: mineral filler shall be any recognized brand of non-air-entrained Portland cement or hydrated lime	2206.6B6: good use of table for mix proportions (suggest using for IA spec)	2206.6B9e: micro-surfacing shall not be applied if air/pavement temp < 60 F and falling or if relative humidity > 80%	2206.6B9b: if pavement is extremely oxidized and raveled or is concrete or brick, a tack coat may be required at discretion of engineer				
City of Chesterfield MO		2.2A: aggregate must contain at least 40% air cooled blast furnace slag (ACBFS) (renewable source for aggregate if available, 3 companies produce it in Muscatine, IA)		2.1C: emulsified asphlat content 6.0-9.0%	3.1: apply when ambient air temp between 60-100 F and when relative humidity below 80%	3.3C: utility covers, manholes, grated inlets, curb inlets etc. must be protected from application\				
				2.3: specifies range for mineral filler to be 1.0-3.0%						
ISSA		4.2.1: specifies granite, slag, limestone, chat for use as aggregates	4.3: mineral filler can be any recognized brand of non-air entrained Portland cement or hydrated lime	5.1: "ISSA can provide a list of laboratories experienced in Micro-surfacing design"	8: no application if air/pavement temp < 50 F and falling, but can apply if air/pavement temp 45 F and rising	10.2: tack coat not required unless surface is extremely dry and raveled or is concrete or brick				
		4.2.2: sand equivalent is 65 min (IA is 60)		5.2: asphalt content 5.5-10.5% by wt., mineral filler 0.0-3.0% by agg. wt.		10.3: it is advisable to pre-treat cracks in the surface with crack sealer prior to application				
		4.2.3: Type II is the same as IA gradation but also has coarser Type III gradation		5.2: tables used to display mix design criteria and application rates would be useful in IA spec so information is easier to find						