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Training development for pavement preservation: chip sealing and fog sealing

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Training development for pavement preservation: chip sealing and fog sealing

by

Angel Morandeira

A thesis submitted to the graduate faculty

In partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Major: Civil Engineering (Construction Engineering and Management)

Program of Study Committee:
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Iowa State University

Ames, Iowa

2012

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ABSTRACT

The benefits of pavement preservation are only achieved if properly selected, designed, and applied. In some cases there is a lack of training when conducting one of these steps and the objective of applying pavement preservation techniques gets hampered. Literature on pavement preservation is extensive, but from a training point of view there is no structured approach on how to train people for selecting, designing, and applying pavement preservation techniques.

The objective of the research is to develop a training learning management system that addresses pavement preservation treatments (chip seals, fog seals, slurry systems, and crack seals and fills) as they are dealt with during the phases of selection, design, and construction. This thesis will focus on training for chip seals and fog seals. Although Iowa was used as a case study, the findings can be applied in other locations.

To begin the study, it was critical to identify the staff divisions to be trained and the treatments to be included. Through several meetings with the agency three staff divisions were identified. The staff divisions are: the maintenance staff (in charge of selection), design staff, and construction staff. Also, the treatments mentioned before were identified as the focus of the study due to their common use.

Through means of needs analysis questionnaires and meetings the knowledge gap and needs of the agency were identified. The training presentations developed targets such gap and needs as the primary focus. The concepting (selection) training focuses on providing the tools necessary, such as life cycle cost analysis and asset management, to help make proper selections. The design trainings focus on providing the information necessary on the properties of the materials (mostly binders and aggregates) and how to make proper material

selection. Finally, the construction trainings focus on providing equipment calibration procedure, inspection responsibilities, and visual images of poor and best practices.

The research showed that it is important to train each division staff (maintenance, design, and construction) separately as each staff division has its own needs and interests. Also, it is preferred if each pavement preservation treatment is approached on its own. The research also determined that it is critical to create a structured plan aimed to develop a structured learning management system. It was also found that the results of this research are applicable in many locations across the nation, not just Iowa. Finally, it is recommended to research for the performance of pavement preservation treatments pre and post-training to compare their results and verify the effectiveness of the learning management system.

CHAPTER 1. INTRODUCTION

1.1 OVERVIEW

This chapter presents the problems that lead to the research, the goal and objectives of it, the methodology followed to complete it, its importance or significance to the industry, and the scope of the research.

1.2 CURRENT PROBLEMS

Existing pavement preservation literature includes benefits, application process, design, materials, among many other subjects. Unfortunately, information in regards to training for pavement preservation is scarce and no research has been conducted to find appropriate training methods of pavement preservation training. Many agencies and institutes conduct occasional training on pavement preservation, but there are limited examples and they are relatively unstructured.

This research effort will develop a structured learning management system (LMS) using the Iowa Department of Transportation (DOT) as a case study. Highways and roadway agency staff members from various staff divisions will benefit from the findings of this research. The staff divisions involved are maintenance staff (who select the road and treatment to be applied), design staff, and construction staff. The findings from this research will help develop professionals on proper selection, design, and application of pavement preservation treatments for the purpose of keeping roads at high levels of performance. Although pavement preservation includes many different treatments, the research will focus on chip sealing, fog sealing, slurry systems, and crack sealing and filling, and the thesis will focus on the first two. Although the case study research was developed for Iowa, the lessons learned can be implemented in other locations where the project phases and project types are

similar. “Theory developed from case study research is likely to have important strengths like novelty, testability, and empirical validity, which arise from the intimate linkage with empirical evidence” (Eisenhardt 1989).

1.3 GOALS AND OBJECTIVES

The research objective is to develop a LMS that addresses pavement preservation treatments (chip sealing and fog sealing) as they are dealt with during the phases of selection, design, and construction. Although specific examples are given for a system developed for the Iowa DOT, the concept could be applied by other transportation agencies. Each staff division (maintenance, design, and construction) will need their own training on pavement preservation treatments in a way that fits their needs appropriately. Also, the training method used for each staff division could vary. For example, the construction division may benefit from an on-demand short video that they can watch right before application, while maintenance may benefit more from a longer face-to-face lecture where they can share opinions and experiences.

1.4 METHODOLOGY

The methodology described below follows the Job Training Structure described in the ASTD Training Development Handbook (1996). The Job Training Structure mainly consists of seven stages. It begins with a Needs Analysis which will be the training gap analysis to determine what areas of knowledge need to be worked. The second stage consists of a Job Analysis to determine the best training approach. These first two stages have been combined in this research as it will be discussed later. The next two stages, Course Design and Material Preparation, consist on developing the set of training tools and materials to be provided. The fifth step is called Validation and it will consist on the feedback received from the prepared

material. Thereon the next step would be to adjust the material to the feedback received, called the Presentation step. Finally, the structure ends with the Evaluation which will consist on evaluating if the training was beneficial to the users. The primary reason for developing and using a job-training program is to acquire the knowledge and skills required to perform the job as quickly as possible (Nolan, 1996).

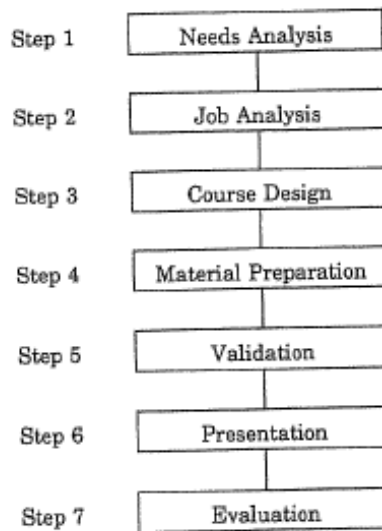


Figure 1: Job Training Structure (Nolan 1996)

As mentioned before, the steps described will be undertaken using the Iowa DOT as a case study. Robert Yin (2009) identified the conditions to which a case study would apply to a certain research question. The conditions applicable for case study research are: the question should be stated as a how or question, the research does not require control of behavioral events, and it should be focused on contemporary event (Yin 2009). All these conditions are met in this research.

In order to be able to develop an appropriate LMS the knowledge gap within the agency needed to be identified. In order to identify this gap a training needs/gap analysis was

conducted. By means of a questionnaire consisting of “rate your knowledge” answers (for example: strongly agree ... strongly disagree) the research team was able to identify what is already of knowledge to the staff division and what knowledge is missing. Three questionnaires (concepting, design, and construction) were developed. The questionnaires not only ask for technical knowledge on the techniques, but also for what would be considered the most appropriate training method (combining stages one and two of the Job Training Structure mentioned before).

Questionnaires or surveys are commonly recommended to be used along with case studies as they meet the same conditions mentioned before (Yin 2009). “A questionnaire is not just a list of questions or a form to be filled in. It is essentially a measurement tool, an instrument for the collection of particular kinds of data” (Oppenheim 1992). These needs analysis questionnaires are the most important piece of the research as they portray the current level of knowledge within the agency.

Two meetings with DOT staff helped complement the questionnaires as personnel were able to express their opinions verbally on what could be adopted and improved. The first meeting took place December 15, 2011 with the majority of the discussion focusing on the needs for the construction staff training. Due to time constraints, the needs analysis was conducted verbally during this meeting. The next meeting was held on June 19, 2012 with both maintenance staff and design staff. Questionnaires for both concepting and design were handed out, received and analyzed. Also, staff members were able to provide verbal input on how to improve the pavement preservation training program.

The state of Iowa had several pavement preservation projects that include chip sealing and fog sealing on District 2 beginning in spring 2012. These projects were visited and they

served as an opportunity to informally interview the inspector, superintendent or anyone in charge of the application. It also served as an opportunity to view the current practices of the industry in regards to pavement preservation application and how they could be improved.

While gathering information on the techniques and the knowledge gap, the development of the training materials (presentations) was also being conducted. The author developed a total of nine presentations. One presentation targeting concepting training (road and treatment selection), three for fog sealing training (overall information, design, and construction) and five for chip sealing (overall information, variations, design, design example, and construction).

After developing the training presentation they were presented to members of the agency. The attendees had the opportunity to provide feedback on ways to improve the content of the presentations. With the provided feedback a final adjustment has been applied to the training materials. Finally the training presentations will be combined into a learning management system and put to the test.

With that said, one could say that the research has followed the action research methodology (Figure 2). The first cycle consisted in identifying the problem, gathering the data, preparing the training modules, and conducting the first presentation in front of future users. The second cycle consisted on improving such training modules with the feedback obtained from the first presentation, leading to the final product. In the future, if updates need to be made to such modules, a third cycle would take place consisting on gathering new data and improving such modules. More cycles can be added as time passes by.

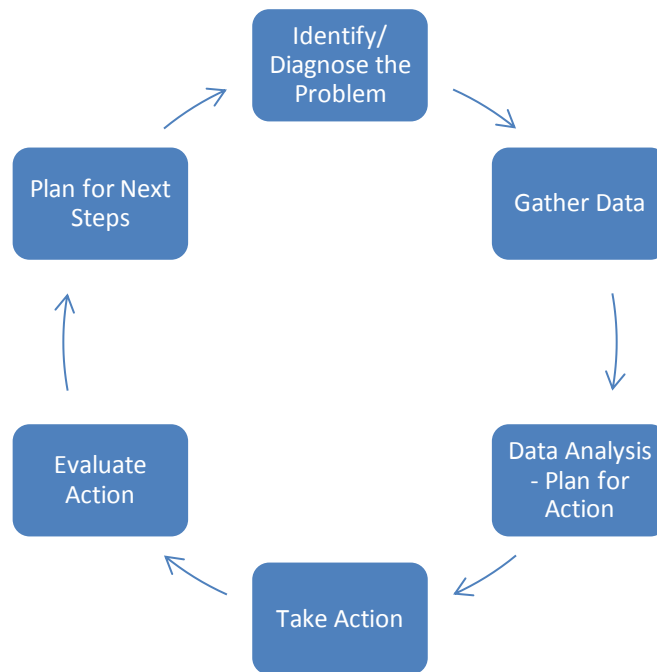


Figure 2: Action Research Cycle (adapted from Azhar et. al. 2010; Ferrance 2000)

With the training presentations developed, the next objective was to identify the degree to which such training program assimilated the needs of other locations. In an effort to create a training program applicable to several road and highway agencies telephone interviews were undertaken. The following state's road and highway authorities were contacted: Florida, Indiana, Minnesota, Missouri, North Carolina, Oklahoma, Tennessee, Texas, and Utah. Each state has its own way of managing pavement preservation projects and not all states apply the same treatments but there is some underlying commonality. The findings of these interviews will be discussed in Chapter 2.

1.5 SIGNIFICANCE OF THE RESEARCH

The research provides a basis for developing a structured LMS for training purposes on pavement preservation. Currently there is little research on the training side of pavement preservation strategies. The research will contain information on the training side of

pavement preservation in its three major phases: selection, design, and construction. The LMS appropriate for national applications was developed. It was applied to the state of Iowa.

From an industry point of view, the research will provide highway and roadway agencies with a tool to improve the performance of their pavement preservation program. The research could benefit the industry by complementing a well-established program, preparing personnel, effective fund and asset management, and increasing road users satisfaction. At the end, agencies are looking for means of improving their pavement performance while providing public satisfaction.

Face validity will provide validation to the research. This approach allows for nonresearchers to approve/disapprove the validity or credibility of the research steps and results. Iowa DOT staff members have viewed the presentations and approved their content. “The first phase often collects data through a survey or a group of interviews with experts, which are compiled by the researcher. In the second phase the same experts receive all data and are asked to provide further comments” (Lucko and Rojas, 2010).

As stated above, the methodology assimilated the approach of an action research approach where practitioners determine the validity of the results. Practitioners, or future users, are to determine if the material developed is effective or not. In action research truth is premised upon utility (Azhar et. al. 2010).

1.6 THESIS SCOPE

Following the introduction chapter, the thesis is divided into eight additional chapters which are:

Chapter 2. Executive Summary: An overview of the various steps taken to meet the goal of the research.

Chapter 3. Literature Review: An overall review of the subject matter of the research. The literature review will contain: (1) the principles of adult training and learning management system development, (2) the definition and characteristics of pavement preservation, and (3) important aspects of chip sealing and fog sealing as pavement preservation treatments.

Chapter 4. Learning Management System Development: The overview, development, result, and analysis of the learning management system created for this research.

Chapter 5. Concepting Training: The needs analysis (methodology), results, and development of the concepting training module.

Chapter 6. Chip Sealing - Design: The needs analysis, results, and development of the training modules for designing chip seals.

Chapter 7. Chip Sealing - Construction: The needs analysis, results, and development of a training module for the application of chip seals.

Chapter 8. Fog Sealing – Design and Construction: The needs analyses, results, and development of both training modules (design and construction). Design and construction of fog seals have been combined in one chapter since the design of a fog seal is usually undertaken by the manufacturer and some of the information on construction will have already been covered in Chapter 7.

Chapter 9. Summary: A summary of the results and the findings of the research.

Chapter 10. Conclusion, Limitations, and Recommendations: A discussion of the conclusions, the limitation of the research, and how it could be taken a step further improved.

Following the thesis chapters an appendix section includes two papers to complement the thesis. Both papers were written by the author in collaboration with other authors.

APPENDIX A provides a brief explanation of the methodology of the research and the results obtained, while serving as a summary of chapters 5 through 8. APPENDIX B provides an analysis on how the authors were able to develop a learning management system for the purpose of this research. Appendix C provides a demonstration of how two methodologies were combined to develop the research project methodology used. Appendixes D, E, and F represent the needs analysis questionnaires developed for concepting, design, and construction training respectively (although this last one was not used). Appendix G provides the training presentations developed in the following order: (1) Concepting, (2) Seal Coat – Overall, (3) Seal Coat – Variations, (4) Seal Coat – Design, (5) Seal Coat – Design Example, (6) Seal Coat – Construction, (7) Fog Seal – Overall, (8) Fog Seal – Design, and (9) Fog Seal – Construction.

CHAPTER 2 EXECUTIVE SUMMARY

2.1 OBJECTIVE

The objective of the research is to develop a training oriented LMS that addresses pavement preservation treatments (specifically chip sealing and fog sealing) as they are dealt with during the phases of selection, design, and construction.

2.2 BACKGROUND

With an increasing effort to keep roadways at high performance levels (good condition), transportation and highway agencies are increasingly focusing on pavement preservation. Even though there are many pavement preservation treatments available, there are few structured training programs to aid on the selection, design, and application of them. When pavement preservation projects fail to provide the expected benefits, some will argue that this underachievement can be attributed to a lack of experience, knowledge, or training of those involved.

This research project aims to address this issue by developing a LMS focused on providing the tools and knowledge necessary to prepare the trainee road or highway agency employee to participate effectively in pavement preservation activities. When developing such LMS, it is important to consider the intended audience. In this case, the audience is expected to be adults with some experience, which may not necessarily include pavement preservation. Also, it is important to consider the availability and schedule of the audience before making decisions about how to approach the training program.

2.3 METHODS

As mentioned in Chapter 1, the methodology used in this research follows a combination of the action research methods along with the job training structure. The job

training structure allows for the development of a training program in a quick and effective manner that takes into account the current knowledge and experience level of the trainees. The action research method allows for the continuous development of a process and improvement of results. Figure 3 represents the combination of both methods as it applies to this research. Please refer to Appendix C for more information on how Figure 3 was developed.



Figure 3: Research Method

The first cycle starts by identifying/diagnosing the problem (need for a pavement preservation training program). Then, through means of questionnaires and meetings, data were gathered regarding the level of knowledge that prospective trainees have on pavement preservation in each of its phases. Data was analyzed to determine areas that needed to be strengthened. With the data analyzed, it was important to create a course structure that would satisfy the needs, responsibilities and schedules of the trainees. With a structured course,

several training presentations or modules were developed for each treatment in each of its phases. To validate the modules, the developed presentations were presented to practitioners. Practitioners provided the research team with feedback regarding areas of improvement and possible changes to the presentations, which in turn ended the first cycle.

The second cycle consisted on improving the previously developed presentations. For the second cycle the problem consist of identifying the improvement needed and the data is gathered with the feedbacks received. The course could be restructured, if necessary, in case the feedback received leads to this conclusion. This was not the case in this research project. With the feedback received, most of the updates and changes will come in the training module development phase. After the modules have been adjusted according to the feedback received, they were presented for final implementation and further feedback.

The development of the needs analysis questionnaires was critical for determining how the training presentations take shape. When developing the needs analysis questionnaires, the research team analyzed the literature on pavement preservation and each treatment, and structured the statements and questions around the most relevant information. Subjects consistently repeated in various sources were considered to be most relevant and, thus, were included in the questionnaires. Also, professionals with knowledge in the field provided their input in regards to the questionnaires before they were actually distributed.

2.4 OUTCOMES

The research objective has been attained. The training oriented LMS for pavement preservation has been developed for the Iowa DOT and will be implemented by the agency soon. The training program will serve the purpose of preparing practitioners for the

responsibilities of selecting, designing, and constructing/applying pavement preservation techniques.

More importantly, the research has developed a method of creating a training program that addresses the needs of a certain group. Due to the methods used in the research, the training modules developed target specific needs of the future trainees. The steps taken in this research are not solely effective for pavement preservation training. The same steps can be put into practice in other fields where conditions are similar. The main advantage of the method presented is that it allows for continuous iterations of the product until arriving at a final product, unlike a trial-and-error approach which could require more drastic changes. For more information on the outcomes, please refer to the conclusions on Chapter 10.

2.5 NATIONWIDE STATE HIGHWAY AUTHORITY NEEDS

In an effort to develop a learning management system that could potentially address state highway authority needs on a nationwide basis, various agencies have been contacted. Through phone interviews, questions in regards to the types of treatments commonly used, project phases, current pavement preservation training (if any), and the possible implementation of an online training program were asked and the results have been summarized in Table 1. The results for Iowa were obtained through face to face interviews.

Table 1: Nationwide Effort

Agency	Treatments Used	Project Phases	Current Training	Possibility of Online Training
Florida DOT	Mostly mill and fill	Selection, design, and construction (3 staff groups)	Non major, other than an occasional meeting	Yes
Indiana DOT	Chip seals, microsurfacing, crack seal/fill, fog seals	Three phases (3 staff groups). Chip seals and crack seal/fill go through design.	Occasional district training. Sponsored NHI classes in the past.	Yes
Iowa DOT	Chip seals, micro, crack seal/fill, fog seal, slurry seal, thin overlay	Three phases (3 staff groups). Chip seals and crack seals/fill designed in-house.	No formal training. Occasional district meetings.	Yes
Minnesota DOT	Crack seal/fill, chip seals, micro, HMA overlay	Three phases (3 staff groups). Try to design as much in-house as possible.	No formal training. LTAP Centers provide occasional courses.	Yes
Missouri DOT	Fog seals, chip seals, overlays, crack seal/fill, micro	Three phases (3 staff groups), but only “high level projects” go through design (chip seal and micro).	Existent Chip Seal Best Practices conducted occasionally.	Yes, at low cost
North Carolina DOT	Micro, chip seals, crack seal/fill	Three phases (3 staff groups), only “high level” go through design (chip seal and cracks seal/fill)	2003 – Training from an NHI official. Since – every other year a maintenance meeting is held	Yes, at low cost
Oklahoma DOT	Micro, crack seal/fill, thin overlay	Three phases (3 staff groups). Treatments applied on interstates or roads with AADT>40,000 go through design	Mostly on-the-job training. Use NHI material for reference but complain of it being lengthy	Yes

Table 2: Nationwide Effort (Continued)

Agency	Treatments Used	Project Phases	Current Training	Possibility of Online Training
Tennessee DOT	Micro, chip seal, cape seal, fog seal, crack seal/fill	Three phases (3 staff groups), maintenance proposes roads and pavement coordinator selects roads.	Occasional training in micro. Use the NHI content as reference.	Yes
Texas DOT	Chip seals, crack seal fill, thin asphalt overlay	Three phases (3 staff groups). Only some treatments are designed (i.e. chip seals)	University of Texas provides training of pavement preservation.	No, satisfied with their current training program
Utah DOT	Chip seal, micro, thin HMA	Three phases, same approach as Tennessee	One annual training meeting for all treatments	Yes

Except for the Florida DOT, all other agencies contacted apply the same or similar treatments to the ones researched. Also, all agencies contacted use the traditional three stage project phases (selection, design, and construction) for their high level treatments. The difference is mostly found in what each agency considers to be a high level project. A high level treatment is one which will require more attention due to local conditions or perceptions. For example, the Missouri DOT considers microsurfacing and seal coating to be high level, while Indiana and North Carolina consider chip sealing and crack sealing or filling to be high level. The high level determination may also come from road characteristics. For example, in Oklahoma interstates or roads with an AADT of more than 40,000 will go through an in-house design phase. Projects not considered high level will not be designed in-house by the agency and the supplier will be responsible for its design.

When referring to the training side of pavement preservation, each agency was quite different. For example, the Utah DOT and the Texas DOT have yearly training sessions on

various treatments. For both Utah and Texas their training sessions are state oriented with all their cases and examples coming from that state. On the other hand, Missouri, North Carolina, and Tennessee have occasional training sessions on one of their high level treatments. Missouri calls their training sessions a “best practices” session to go over what should and should not be done for a predetermined pavement preservation treatment. Indiana, North Carolina, Oklahoma, and Tennessee use most of their content from the NHI PPTCG. Finally, all agencies mentioned they will benefit from having an online training course that could be accessible at any time, except for Texas who is satisfied with their current training program offered by the University of Texas.

CHAPTER 3 LITERATURE REVIEW

3.1 INTRODUCTION

The first section will include some of the basics and principles of developing adult training materials and learning management systems. The second section of this chapter will provide information on typical road deterioration and the importance of applying pavement preservation treatments. The third and fourth sections will provide information on both chip seals and fog seals in the following topics: definition, distresses addressed, advantages and disadvantages, materials, and equipment.

3.2 LEARNING MANAGEMENT SYSTEMS, ADULT LEARNING, AND ONLINE LEARNING

The objective of the research includes the development of a LMS. One important aspect to consider is the fact that the people to be trained are adults with years of experience, although not necessarily in pavement preservation. With this said it is critical to review the existing literature in regards to LMS development and adult learning and how it differs from youth learning (school and college). Since some training is expected to be conducted online, a literature review on creating effective online learning has been included.

3.2.1 Learning Management Systems (LMS)

Learning networks are groups of people who use the internet and other resources to communicate and collaborate in order to build and share knowledge (Hiltz and Turoff 2002). A learning network may be composed of classroom interactions, online interaction, or, preferably, a combination of both. It is important to select an appropriate training method when developing a LMS. LMS's are sophisticated engineered learning services for educating and training purposes (Avgeriou et. al 2003; Lonn and Teasley 2009).

Trainee's needs and time flexibility will be major factors when developing the system. LMS's have been adopted in order to fulfill certain needs and requirements of increasing demands for effective, fast, and pedagogically correct education and training (Avgeriou et. al. 2003). For example, a group of people with certain needs and the ability to have face to face meetings will require a different training approach than a group without the same time flexibility.

3.2.2 Adult Learning

In contrast to children and teens, adults have a distinctive way of learning. Much of their learning comes from experience and factors they can relate to. Concentration on experience rather than age is a key factor in adult learning (Thijssen 1992). In 1991 Stephen Lieb identified key principles of adult learners that still apply today. Some of these principles are: adults are autonomous and self-directed, adults have accumulated experience and knowledge, adults are goal-oriented, adults are relevancy-oriented, and adults are practical. Perhaps the most important principle is that related to experience and knowledge. If a person has a strong concentration of experience, this would imply that the person has more knowledge, more skill, and is more emotionally involved (Thijssen 1992).

Another distinction adult learners have from younger learners are the motivators that drive them to learn more. Rothwell (2008) identified six motivators that encourage adults to gain more knowledge. These motivators are: build social networks, meet expectations (i.e. from supervisors), advance in career (i.e. promotion), be stimulated, help others, and learn for own enjoyment. In the case of this research, perhaps the motivator that would encourage trainees to learn is that of meeting expectations. For anyone that receives the training

developed in this research, the agency will have a set of expected knowledge outcomes the trainee should acquire.

3.2.3 Online Learning

An online learning environment is different from a classroom learning one. Online learning can be defined as educational activities which are done by distributing the material via electronic tools and environments such as the internet (Gümüs and Okur 2010). Although this distinction is inevitable, it should not infer that online learning will be less effective.

What is clear is that the factors that enhance the educational experience in classrooms (community, feedback, expectations, and chance of success) are equally important in online learning (Perry and Pilati 2011).

For an online learning environment to be effective it should include certain elements. Nick Traenkner (2010), Chief Officer of Wide Area Media, has been developing online training systems since 1994 and has determined six elements an effective online learning system should include. These elements are: content, testing (to ensure the trainee watched the content), controllable work flow (navigation between content and tests), evaluation (feedback on the performance of the course), data collection and reporting, and certification (to prove completion)

3.3 PAVEMENT PRESERVATION AND ROAD DETERIORATION

Pavement preservation is a network level, long term strategy that enhances pavement performance by using integrated and cost-effective practices that extend pavement life, improve safety, and meet road user expectations (MAP-21 2012). It's worth noting that pavement preservation does not enhance the structure of the pavement. Pavement

preservation serves to keep the road in good condition before it deteriorates to a level where repairing or rebuilding it would be necessary and costly.

Typical road deterioration has a distinctive behavior. As seen in Figure 4, the first 75% of the pavement's life suffers a 40% drop in quality or a drop from excellent to fair condition. Then, in approximately the next 15% of its life the quality drops 40% more going from fair to very poor on the brink of failure (Galehouse et. al. 2003). What pavement preservation techniques aim to prevent is this sudden drop in the quality of the pavement.

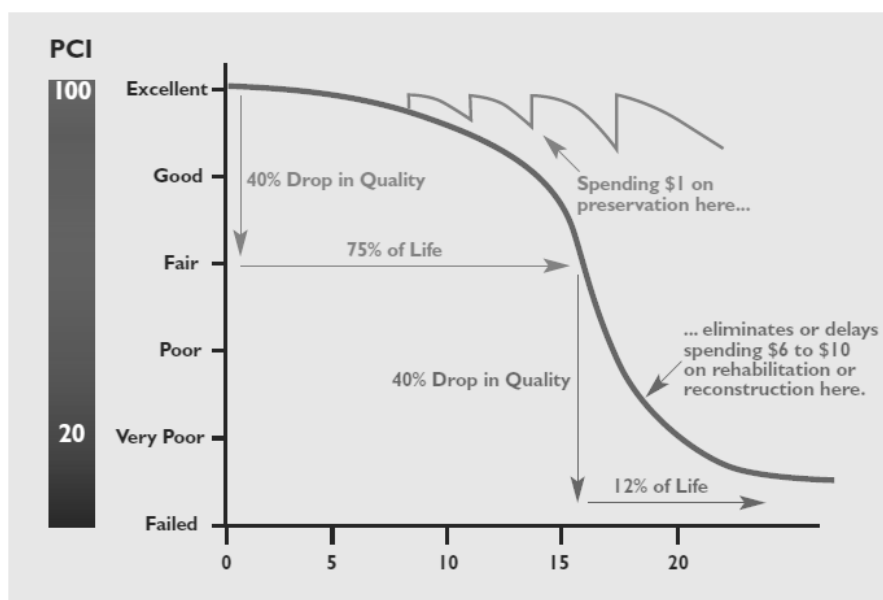


Figure 4: Road Deterioration Curve (Galehouse et. al. 2003)

How does pavement preservation work? As seen in Figure 4, a treatment is applied while the road is still in good condition. The road's life will be extended a certain amount of time depending on the treatment applied. After that time a treatment is again applied on the surface which could be the same treatment or a different one, this will depend on road conditions as it will be explained later. The purpose is to continuously apply road treatments at low cost keeping the road at the good condition level (Galehouse et. al. 2003; Hicks et. al.

2000). If no treatment is applied the road will reach a point where rehabilitation or reconstruction will be required (also known as corrective maintenance) with a possible cost of six to ten times that of pavement preservation techniques (Galehouse et. al. 2003; Hicks et. al. 2000).

3.4 CHIP SEALS

A chip seal consists of a layer of asphalt binder that is overlaid by a layer of embedded aggregate that furnishes protection to the asphalt layer from deterioration and creates a skid resistance surface (Gransberg and James 2005; Jahren et. al. 2007; Wood et. al. 2006). Although the definition refers to the most common application of chip seals, varieties do exist. Some of these variations are: double seals, raked-in seal, inverted seal, sandwich seal, cape seal, and the geotextile-reinforced seal (Gransberg and James 2005; MTAG 2007). The state of Iowa mostly uses single seals and occasional double seals. The research will focus on single seals while occasionally mentioning double seals.



Figure 5: Chip Seal Application (photo taken by author)

3.4.1 Distresses Addressed by Chip Seals

Chip seals commonly address the following distresses: low to medium cracking, low raveling, and bleeding (Shropshire et. al. 2011; Rizzuto 2008). Transverse cracking is an effect of thermal expansion and/or shrinkage and longitudinal cracking is an effect of structural failure. Raveling, also known as weathering, occurs when aggregate or binder wears away due to oxidation, traffic, or snow plow. Bleeding occurs when binder is pushed to the surface due to the high content of binder. Refer to Figure 6 for an example of a road with low cracking and low raveling. This road could be a good candidate for a chip seal application.



Figure 6: Road With Minor Cracks (photo taken by author)

3.4.2 Advantages and Disadvantages

Chip seals, as any other application, provide multiple advantages while also having some disadvantages. Refer to Table 3 for the advantages and disadvantages of chip seals.

Table 3: Advantages and Disadvantages of Chip Seals (Shropshire et. al. 2011)

Advantages	Disadvantages
Protects asphalt pavement from deteriorating weather effects.	Does not address large cracks or rutting .
Lower cost when compared to other treatments.	Design and construction processes potentially create more room for errors.
Increases surface friction.	Tends to be noisy.
Provides a waterproof membrane.	Poor embedment can cause dust and flyrock.
Provide short trafficking time when compared to other treatments.	Creates poor background for pavement marking.

3.4.3 Materials

Asphalt binder and cover aggregate are the two main materials used in the application of chip seals. Asphalt binders can be asphalt emulsions or cutback asphalt. The use of the later has declined rapidly because it includes costly and potentially harmful solvents such as fuel oil and kerosene (Wood et. al. 2006). Asphalt emulsions consist of asphalt cement,

water, and emulsifying agents (surfactants). Asphalt cement in asphalt emulsion make up approximately 67% of the mix. The emulsifying agent will determine the electric charge of the emulsion. It is critical to select an aggregate and a binder with opposite charges, commonly referred to as binder-aggregate compatibility (Gransberg and James 2005).

Cover aggregate should be hard, clean, and dust free. The Iowa DOT and other agencies specify the use of crushed stone or gravel with sizes ranging from 3/8 to 1/2 inch. Also, it is recommended to select a one-sized aggregate gradation as it allows for easier quality maintenance (Gransberg and James 2005). Another important characteristic to look for when selecting the aggregate is its shape. A cubical aggregate is preferred over a flat shaped aggregate as these last ones tend to lay on their flat side (Wood et. al. 2006). Also, an angular aggregate is preferred over a round aggregate as they lock better between themselves, have more adherence surface, and tend to roll less (Shuler et. al. 2011). These material properties with image examples will be covered with more detail in Chapter 6.

3.4.4 Equipment

The application of chip seals includes the use of several pieces of equipment. The first equipment to be used is the sweepers. These are used to prepare the surface by reducing the amount of dust so that the asphalt binder adheres better. After the surface has been prepared, the actual application can proceed. An asphalt distributor will spray the asphalt binder on the surface and close behind it a chip spreader with a truck attached will spread the aggregate over the fresh binder (see Figure 7). To embed the aggregate into the binder, rollers continuously pass the recently applied chip seal across the whole width of the lane. The importance, calibration, and inspection of the equipment are critical and will be discussed in Chapters 7.



Figure 7: Asphalt Distributor Followed by Chip Spreader (photo taken by Cliff Plymesser)

3.5 FOG SEALS

A fog seal is an application of diluted asphalt binder. The diluted asphalt will usually consist of a 50:50 (emulsion:water) diluted emulsion. Fog seals help fill small voids left by wearing of aggregate and/or binder and protect the pavement from weather deterioration (Brownridge and Fox 2011; Caltrans 2003; Jahren et. al. 2007). Another application of fog seals used in Iowa, as in other states, is to be sprayed a short time after a chip seal is applied to help retain the aggregate in place and prevent dust from coming off the chip seal, also referred to as dust coat or flush coat (Caltrans 2003; Rizzuto 2008; Shuler et. al. 2011). In this case dilution might be different.

3.5.1 Distresses Addressed by Fog Seals

A fog seal application will only address those distresses that are least severe. These distresses are: few tight cracks, low intensity raveling, and oxidation. Unlike chip seals, fog seals do not address bleeding since adding more binder to an already binder-rich surface will increase its bleeding severity.

3.5.2 Advantages and Disadvantages

Fog seals have both advantages and disadvantages. Table 4 provides a list of the advantages and disadvantages of fog seals.

Table 4: Advantages and Disadvantages of Fog Seals (Shropshire et. al. 2011)

Advantages	Disadvantages
Reduces surface permeability.	Skid resistance is reduced after application.
Creates a good background for pavement markings.	Ineffective against pavements with high levels of distresses.
Inexpensive when compared to other treatments.	Curing time is longer than chip seals, thus trafficking will require more time.
Mitigates aggregate raveling.	
Provide short trafficking time when compared to other treatments.	

3.5.3 Materials

The primary material in a fog seal application is an asphalt emulsion. The mix used will normally consist of a slow settling emulsion, thus giving the diluted asphalt time to penetrate the surface. Other types of binder include gilsonite and rejuvenating products such as Reclamite[®], Topien C[®], and PASS[®] (Caltrans 2003; Shropshire et. al. 2011). Gilsonite is a naturally occurring asphalt ore with high resin content that results in unique binding and preservation characteristics (Cline 2011).

Water is another important material in a fog seal mix. Clean potable water should be used to dilute the emulsion. Sand is also commonly used in fog seal applications. Some agencies' fog seal projects may require the application of a layer of sand with a fog seal application to restore the skid resistance previously lost in the actual fog seal application. More on fog seal materials will be discussed in Chapter 8.

3.5.4 Equipment

The fog seal application is normally composed of a single piece of equipment, the asphalt distributor. When sand is used, spreaders will also become part of the equipment. Another piece of equipment used in the application of fog seals are sweepers. These could be used prior to application to prepare the surface or after the application of the sand layer to remove excess sand.



Figure 8: Distributor Truck with Sand Blotters (photo taken by author)

3.6 MOST RELEVANT LITERATURE FOR TRAINING PURPOSES

The author has determined that, among the literature reviewed throughout the research, the following reports, manuals, and/or presentations fit a pavement preservation training profile to a high degree. The Minnesota Seal Coat Handbook (Wood et. al. 2006), Texas Seal Coat and Surface Treatment Manual (Webb 2010), and Caltrans Division of Maintenance Guidelines (Caltrans 2003; MTAG 2007) provide an overview with various images of common practices in the application of chip seals and fog seals. Also, the following two reports provide information on a more technical side of chip sealing: NCHRP 342 (Gransberg and James 2005) and NCHRP 680 (Shuler et. al. 2011). Finally, the modules found in NHI's Pavement Preservation Treatment Construction Guide (2007) provide

information on the application on some of the available treatments, including chip sealing and fog sealing, on a national level. Most of the content on the developed training presentations was extracted from such literature.

CHAPTER 4. LEARNING MANAGEMENT SYSTEM DEVELOPMENT

4.1 INTRODUCTION

A learning management system (LMS) is a network of information where groups of people can use a mode, such as the internet, to communicate and collaborate in order to build and share knowledge (Hiltz and Turoff 2002). To properly design an effective LMS, it is important to understand the needs of the intended users. In this case the users will have different needs and responsibilities, based on their role (selection, design, or construction) in a pavement preservation project.

The purpose of this chapter is to demonstrate how the pavement preservation LMS was developed for this thesis. The first section of this chapter will describe the pavement preservation project structure identified at the beginning of the research. The second section will describe the major responsibilities and needs for each staff division (maintenance, design, and construction) identified in the first section. The third section will provide a description of the models that were used as templates for the LMS. Finally, the last section will describe the structure identified to develop the LMS throughout the research. For more information on the content included in this chapter please refer to Appendix B (TRB Paper).

4.2 PROJECT STRUCTURE AND STAFF DIVISIONS

A typical pavement preservation project goes through three main phases. The first phase is road and treatment selection (called concepting in this research). This phase mainly consists of selecting which roads will be treated with pavement preservation techniques and the treatment to be used on each road according to the available budget and other factors.

After the road and the treatment have been selected, the treatment needs to be designed according to the current conditions of the pavement. This design can either be

conducted in-house or by the supplier/manufacturer. As it will be described later, fog seals are normally designed by the supplier while chip seals are designed in-house. After the design is finished, the treatment is ready for application. During the application certain steps and practices should be followed to achieve benefits and proper performance.

With knowledge of the project structure and a meeting held in October 18, 2011 with members of the agency, the three main staff divisions were identified as the primary audience (trainees). The three staff divisions are: maintenance staff (who are in charge of project selection or concepting), design staff, and construction staff. Each staff division will need to be trained separately since their responsibilities within a pavement preservation project are different.

4.3 RESPONSIBILITIES AND NEEDS PER STAFF DIVISION

Now that the staff divisions have been identified, the following subsections describe the responsibilities of each staff division and their expressed needs in regards to pavement preservation.

4.3.1 Maintenance Staff

As mentioned, maintenance staff is in charge of selecting roads and treatments for pavement preservation. Their responsibilities can be summarized in what is known as the three R's of pavement preservation: the right treatment for the right road at the right time. In other words, their main responsibility is to match a road with its appropriate treatment at its right time. Proper selection is the first step to achieve effective pavement preservation performance and the benefits that come with it.

The main idea behind a training module directed to the maintenance staff is to provide them with various tools that will help in project selection. The module developed

introduces several subjects such as treatments and distresses, but it mainly provides the trainee with tools such as life cycle cost analyses, windshield surveys, asset management, and decision matrices to help make appropriate selections. The module has been developed in a way it can be used in face to face meetings so that each attendee can share their experience with road and treatment selection.

4.3.2 Design Staff

Although not every treatment is designed in-house, design staff will need to know the idea behind a proper design. Their main responsibilities are materials selection and the overall design process. Assuming the maintenance staff made proper road, treatment, and time decisions, the design staff is next in line to keep the project headed in the right direction. Proper design is the second step to achieve effective pavement preservation performance and the benefits that come with it.

For chip seals, the main idea behind a training module for the design staff is to provide them with information on material properties and selection and to introduce a structured chip seal design process. Fog seals, on the other hand, are commonly designed by the supplier so the module focuses on the various materials used on fog seal applications. Also, the design training modules have been developed in a similar approach to the concepting one, allowing trainees to share their design experiences.

4.3.3 Construction Staff

The construction staff is in charge of the actual application of the treatment on the pavement. Their responsibilities include conducting proper inspection to the equipment and the application process to guarantee proper application. Proper application is the last piece to

the puzzle for achieving effective pavement preservation performance and the benefits that come with it.

The main objective behind the construction training modules is to describe what makes a proper application and the factors and features that need to be inspected to assure good performance. The modules developed are directed more towards inspectors, but can serve to anyone involved in the actual application of each pavement preservation treatment. The modules identify the inspector's duties, proper calibration processes, and provide best practices and poor practices examples. For the construction staff it was critical to have visual images they could relate to and remember in the field. Also, the module has been developed for online training so that the viewers have the flexibility of watching them days or hours before application. Refer to Chapters 7 for the reason behind this decision.

4.4 MODELS AND TEMPLATES

With the staff divisions identified, their respective needs and responsibilities, and an idea of the content to be included in the modules, the next step was to develop a structured LMS focused on training for pavement preservation. Before starting to develop the LMS, it was desired to search for existing LMS's or similar pavement preservation information guides that could serve as models or templates. The Upper Great Plains Transportation Institute (UGPTI) and the National Highway Institute (NHI) have structured pavement preservation information archive. Although not necessarily aimed at training, they both serve as models.

UGPTI's and NHI's system is structured similar to what has been described so far. NHI's system is divided into each treatment and within each treatment there are sections of information. Even though the sections are not categorized into selection, design, and

construction they serve the purpose of combining similar information into subcategories. UGPTI's system is similar to the one described for NHI.

4.5 RESULTS

With the information collected, a structure such as the one presented in Table 5 was developed. Table 5 represents the training presentation structure developed as the backbone to the LMS and also served to keep track of the research progress. Each treatment will have four training presentations. Each presentation will focus on a specific phase of the project (concepting, design, and construction) plus there will be an introductory presentation on each treatment. Note that concepting just has one presentation combining all four treatments since the objective at this point of the project is to select the treatment. As seen in the table and as mentioned before, chip seals have two presentations in both treatment introduction and design. An X marks an available presentation.

Table 5: Presentation Development Matrix

Presentation Category	Treatments			
	<i>Seal Coating</i>	<i>Fog Sealing</i>	<i>Slurry Systems</i>	<i>Crack Sealing/Filling</i>
<i>Treatment Intro</i>	x	x	x	x
<i>Concepting (Selection)</i>	x			
<i>Design</i>	x	x	x	x
<i>Construction</i>	x		x	x

Other matrixes were also developed to keep track of each step followed to develop the final training modules. As described in Chapter 1, the methodology consisted of various steps that included a needs analysis and evaluation. Table 6 and Table 7 present the matrix developed to keep track of the needs analysis and the evaluations.

Table 6: Needs Analysis Matrix

Project Phase	Status			
	<i>Started</i>	<i>Completed</i>	<i>Delivered</i>	<i>Received</i>
<i>Concepting (Selection)</i>	x	x	x	x
<i>Design</i>	x	x	x	x
<i>Construction</i>	x	x	x	x

Table 7: Evaluation Development Matrix

Presentation Category	Treatments			
	<i>Seal Coating</i>	<i>Fog Sealing</i>	<i>Slurry Systems</i>	<i>Crack Sealing/Filling</i>
<i>Concepting (Selection)</i>	x			
<i>Design</i>	x	x	x	x
<i>Construction</i>	x	x	x	x

Table 6 was used to keep track of the needs analysis questionnaire used in the research. One aspect to remember is that no questionnaire was handed out to the construction staff, instead a face to face meeting served as a substitute. It was of high importance to keep track of such questionnaires as they were the most important part of the research. Without knowing what the knowledge gap and needs were the research results would have been completely different. Chapter 5, 6, and 7 contain the results of such questionnaires.

As mentioned in Chapter 1, each presentation is followed by an evaluation to test the knowledge gained. Table 7 served to keep track of the evaluation development. The introductory presentations for each treatment do not contain an evaluation as they will be optional. Also, the evaluation on chip sealing design will only test the first of the two presentations, not the one dedicated to the step by step design process. Each evaluation consists of less than ten multiple choice or true/false questions for the viewer to answer shortly after viewing the presentation. An X marks a completed evaluation.

4.6 SUMMARY

Through several steps of data gathering, a structure for the LMS to be developed was identified. Table 5 summarizes the needs identified in the research process using other LMS's as a comparative model. Most of all, Table 5 represents the structure behind the training modules developed for the LMS on pavement preservation. As seen in the table, each treatment needs to be approached separately and in each of its stages (selection, design, and construction).

CHAPTER 5. CONCEPTING TRAINING

5.1 INTRODUCTION

As mentioned before, concepting refers to road and treatment selection. The goal of the concepting training is to prepare the maintenance staff on selecting the right treatment for the right road at the right time (also known as the three R's of pavement preservation). Subjects incorporated in the concepting training module include road behavior, 3R's of pavement preservation, road selection process, road conditions and distresses, treatment overview, decision matrixes, and timing.

The first section of this chapter describes the methodology used to determine the knowledge gap on such matter. The second section shows the results obtained and how the module was developed based on such results. The last section will provide a summary of the development of concepting training.

5.2 METHODOLOGY

To determine the knowledge gap within the maintenance staff of the Iowa DOT a questionnaire was developed to analyze the current level of knowledge on the subjects mentioned before. The questionnaire consisted of nine questions where the respondents had to select their level of understanding, confidence, or experience on regards to different aspects. For example, a statement could read: "I have a clear understanding of the different distresses a road can experience and their causes". The respondents then had to select if they strongly agreed, agreed, felt neutral, disagreed, or strongly disagreed with the statement presented.

Also, after the knowledge questionnaire the respondent had to rank (from 1 to 5) which training technique he/she considered most effective (1 being most effective). The

choices presented were: full day face to face with quizzes, short face to face with online references, online course with a followed face to face or video conference, complete online course with quizzes, or a quick online video. Finally, the respondent had to rank the same options (from 1 to 5) by which technique would be more realistic and convenient. This distinction between effectiveness and convenience was necessary to determine the time flexibility of the future trainees. For a better understanding of the questionnaire developed for concepting training please refer to Appendix D.

5.3 RESULTS

A total of 21 questionnaires were received and tallied. As presented in Table 8, some numbers stood out and they are presented in bold red. One aspect to point out is that the majority of the respondents did not strongly agree, disagree, or strongly disagree with any of the statements, most of them are within the agree or neutral level. Another aspect to keep in mind is that the questionnaire developed could change depending on the agency to be trained and the division to be trained. It is strongly suggested to refer to Appendix D while looking at Table 8 to understand how each subject was stated. Table 8 presents the subject of each statement for purposes of simplicity. The following sections will provide information on what was included in each subject of the concepting training module.

Table 8: Concepting Needs Analysis Results

Concepting Needs Analysis Results						
# Subject	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Total
1. PP Importance	4	14	2	1	0	21
2. Experience	2	7	6	6	0	21
3. Road Deterioration	3	9	6	3	0	21
4. 3R's	3	9	9	0	0	21
5. Selection Confidence	4	5	8	4	0	21
6. Road Distresses	3	7	10	1	0	21
7. Treatments						
a. Crack Fill/Seal	3	14	3	1	0	21
b. Slurry Systems	2	8	7	4	0	21
c. Seal Coating	2	5	10	4	0	21
d. Fog Seal	1	11	6	3	0	21
8. Decision Matrices	0	6	11	4	0	21
9. Timing	2	16	3	0	0	21

5.3.1 Pavement Preservation Importance

Although the majority of the respondents agreed they understand the importance of pavement preservation, the training module opens by defining what pavement preservation is and its benefits. The objective in this case becomes more of knowledge leveling, getting everyone to the same level of understanding. For the department it was critical that everyone knew why pavement preservation was being incorporated. It was important to point out that applying pavement preservation will not add any structural value to the road, the same way painting a house will not add any structural value to the house structure.

Some of the benefits mentioned in the module are: road life extension, less cost compared to a rehabilitation/reconstruction approach, convenience and public satisfaction, and less waste generated when compared to rehabilitation/reconstruction approach. It was

also important to point out that such benefits will only be achieved if an integrated effort took place between road selection, design, and construction. As a summary, the main goal of concepting training is to prepare maintenance staff in making the right treatment selection for the right road at the right time.

5.3.2 Experience

Identifying the level of experience within the staff member was a key factor in this research. Even though this factor cannot be addressed directly in the training module, it helped identify how many of the respondents have previous experience with pavement preservation treatments. Unfortunately no specific level stood out; nonetheless it was important to know that there are members with experience that can be shared. This can potentially be part of the instructional design where the more experienced ones can guide the less experienced.

5.3.3 Road Deterioration

Respondents agreed that they understood road deterioration and behavior through time. Similar to section 5.3.1, the objective becomes more of knowledge leveling. Anyways, this subject is critical in order to understand the main point of pavement preservation and it was necessary to show a typical road deterioration curve and point out its most critical elements. The same figure as the one presented in Chapter 3 (Figure 4) was presented in the training module. In this figure, the drop in road quality is eye-catching and serves its purpose of identifying that time plays a key role in pavement preservation strategies. It was critical to point out the difference between preventive maintenance and corrective maintenance (especially in terms of costs and time) and this figure served that purpose.

Nonetheless, pavement preservation could be applied to a pavement in fair to poor condition as a holding strategy. Many agencies will use a slurry seal, fog seal, or a crack seal to hold the pavement at its current condition for a short period of time until funding becomes available for a corrective approach.

5.3.4 The 3R's of Pavement Preservation

As mentioned before, the first step of pavement preservation is to select the right treatment for the right road at the right time (3R's of pavement preservation). It is important to understand that in order to achieve the maximum benefits of pavement preservation these 3R's need to be achieved along with a proper design and application. Not every treatment will work on every road. Matching road with treatment will be discussed in the following section.

Selecting the right time might be the biggest challenge of the selection phase. Most of the times engineering judgment plays a key role in determining when to apply such treatments. More on treatment timing will be discussed in section 5.3.9.

The results of the questionnaire did not show any inclination towards a certain level of knowledge. Respondents were evenly distributed between agree and neutral levels. Again, this subject also becomes one for leveling the knowledge. Nonetheless, the 3R's of pavement preservation are considered to be a must-know subject in the industry and the primary goal of the maintenance staff.

5.3.5 Selection Confidence

This section in the questionnaire asked the respondents to identify how confident they felt when selecting the right treatment and/or the right road. With 12 out of 21 respondents within the neutral and disagree level it was important to provide trainees with some of the

tools available to help on the selection process. Confidence is not easily approached when developing adult training modules, but by providing them with more tools for their toolbox, trainees might feel more comfortable when making decisions. The tools presented are asset management programs, traditional windshield surveys, life cycle cost analysis, and decision matrices (this last one will be discussed in section 5.3.8).

5.3.5.1 Asset Management Programs

Asset management is defined as a strategic and systematic process of operating, maintaining, and improving physical assets, with engineering and economic analysis based upon quality information, repair, rehabilitation, and replacement actions to achieve and sustain a desired state of good repair over the lifecycle of the asset at minimum practicable cost (MAP-21). For purposes of this research a focus will be set on the allocation of resources and funds. The question to be answered is: how are the resources and funds going to be distributed? Figure 9 provides an example of the road network in Belmont, California. Roads are categorized by their pavement condition index (PCI), thus providing the city with information on what roads need corrective treatments and what roads could benefit from a pavement preservation approach. Those roads in blue and green could be good candidates for pavement preservation while roads in red are in need of rehabilitation based solely on their PCI.

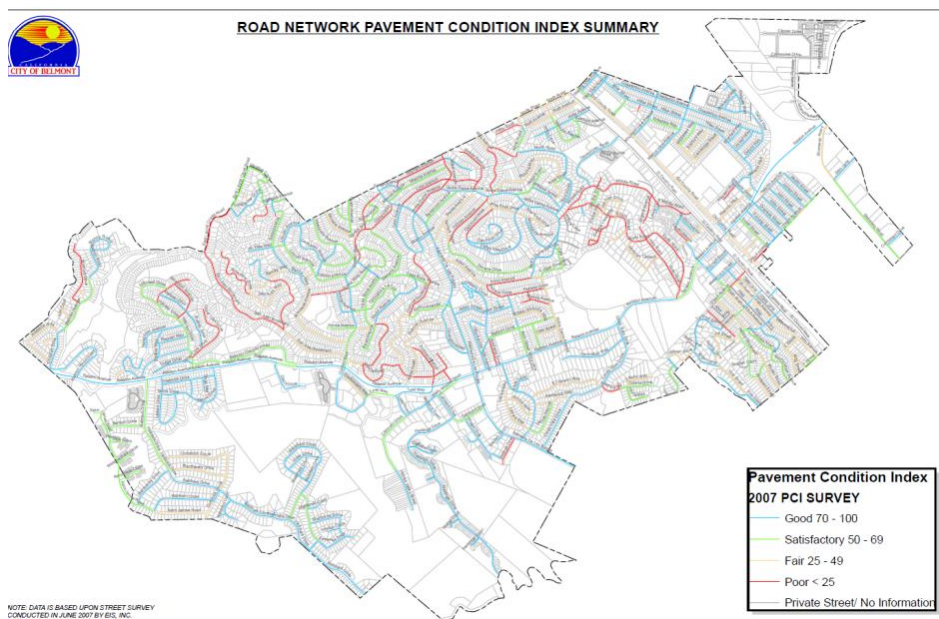


Figure 9: City of Belmont's Road Network (City of Belmont 2007)

The PCI along with the international roughness index (IRI) and the friction or skid number are the three most commonly used road condition indicators (Tighe and Gransberg 2012). These three indicators should not be the only factors used for road selection. Other factors to consider are: traffic volume (average annual daily traffic or AADT), average traffic speed, road classification (primary, secondary, residential, etc.), proximity to businesses and residences, and available budget.

Roads with high traffic volumes and high speeds can increase the probability of aggregate dislodgement, thus not making them recommendable for treatments with large aggregate particle size like chip seals. Road classification and proximity to businesses contribute to the hierarchal level of the road, thus roads higher on the hierarchy level will probably receive priority. The available budget will determine the budget distribution for preservation and construction projects. Any information gathered from the road system will serve as a tool to select the right road.

5.3.5.2 Windshield Survey

As the name suggests, a windshield survey consist of driving around the network and documenting the current condition of the roads. One of the primary benefits of conducting a windshield survey is that it provides an actual visual image of the road condition. Nonetheless, background information on the road characteristics (road type, AADT, etc.) should also go along with the survey.

5.3.5.3 Life Cycle Cost Analysis (LCCA)

Life cycle cost analysis (LCCA) models and furnish pavement managers with measurable failure criteria to estimate service life based on performance (Pittenger and Gransberg 2012). Although performance measures are outside the scope of this research, the research assumes the agency utilizes measures to determine the performance of their pavement preservation projects. The first cost of the project will influence the decision made on a large scale, nonetheless a LCCA will provide more information in regards to cost and service life. The equation presented below (Pittenger and Gransberg 2012) takes into account the first cost and how it is allocated through the lifespan of the application (refer to equation 1). The discount rate (i) in the equation can be taken in accordance to FHWA recommendations or a reasonable judgment by the agency. The service life (n) will most likely depend on previous experience. (EUAC = equivalent uniform annual cost)

$$EUAC = \sum P * \left[\frac{i(1+i)^n}{(1+i)^n - 1} \right] \quad (1)$$

5.3.6 Road Distresses

Close to 50% of the respondents are on the neutral level of understanding on regards to road distresses and their causes. The training module goes over six of the major distresses

found in pavements. It provides a definition, probable causes, and images trainees can relate to. The following table (Table 9) summarizes the content included in this section.

Table 9: Distresses Definitions and Causes (Jahren and Plymesser 2007)

Distress	Definition	Cause
Oxidation	Binder becomes brittle and aggregate can be easily removed, light gray appearance	Exposure to sun and water
Raveling	Also known as weathering, binder has worn away	Oxidation, traffic, snow plow
Pocking	Loss of fines	Oxidation
Rutting	Surface depression that runs parallel to traffic, usually in the wheel path	Unstable mix, structural failure, or insufficient compaction
Bleeding	Binder pushed to the surface	Mix rich in binder
Cracking	May run parallel (longitudinal) or perpendicular (transverse) to traffic	Longitudinal – structural failure. Transverse – thermal failure.

5.3.7 Treatments

The questionnaire asked respondents to provide their level of confidence on knowing when it would be the right moment to apply each treatment. As mentioned before not every treatment works with every road. The following is the description offered on regards to chip seal and fog seal applications.

5.3.7.1 Chip Seals

Chip seals are commonly used in low volume low speed roads, although they have been successfully used at higher volumes and speeds (Shuler 1991; Gransberg and James 2005; Transit New Zealand 2005; MTAG 2007). Chip seals typically perform well in pavements experiencing low to medium cracking, low raveling, and/or bleeding. Their

performance is greatly affected in pavements experiencing rutting as binder will concentrate in the wheel path where the depression is located.

Single seals and double seals are the two most common types of chip seals. Refer to Appendix G-3 for more information on other types of chip seals. A double seal should be considered when the road requires substantially higher sealing ability or has higher traffic volumes or higher truck volume (Shuler et. al. 2011). Also, in roads where there is a high amount of truck traffic a double seal may be more appropriate as it provides a more robust layer (Gransberg and James 2005). In this last case, special care should be given to the amount of binder applied as extra binder will create bleeding issues. In any other normal case a single seal should work well if designed and applied correctly.

5.3.7.2 Fog Seals

Unlike chip seals, more than 50% of the respondents answered they felt confident when selecting fog seal as a treatment. This could still represent a limitation as potential trainee may feel overconfident when selecting the treatment and make a wrong selection. Fog seals perform well in any type of road as long as it is still in good condition with few to no tight cracks and no rutting or bleeding. Fog seals are commonly used in roads experiencing few tight cracks, oxidation, or raveling as these pavements could benefit from an application of binder. Pavements experiencing bleeding should not be applied with a fog seal as the pavement is already rich in binder. Also, pavements experiencing rutting may not benefit from a fog seal as the binder will concentrate on the zone where the depression is located.

A dust coat or a flush coat is another fog seal application. This fog seal practice is applied after a chip seal as it prevents the generation of dust from the chip seal and can

potentially help lock the chips in place. Another benefit of this application is that it reduces the chances of aggregates being dislodged and damaging vehicles.

5.3.8 Decision Matrices

Decision matrices are the fourth tool presented in this module to help staff members make good selections. Figure 10 shows an example of a decision matrix that matches the current conditions of a specific road with its most appropriate treatment. For example, say there is a medium volume road (between 2,000 and 5,000 AADT) experiencing raveling and very few tight cracks. According to Figure 10 this road, with its current conditions, would be a good candidate for a fog seal or a microsurfacing application.

Generalized decision matrix for selecting appropriate TMS solutions

Factor	Fog seal	Seal coat	Slurry seal	Micro-surfacing	Thin HMA overlay
Traffic	AADT < 2,000	↑	↑	↑	↑
	2,000 < AADT < 5,000	↑	↔*	↔*	↑
	AADT > 5,000	↑	↔†	↔*	↑
Bleeding	↓	↑	↑	↑	↑
Rutting	↓	↓	↑	↑	↑
Raveling	↑	↑	↑	↑	↑
Cracks	Few tight cracks	↑	↑	↑	↑
	Extensive cracking	↓	↑	↓	↓
	Alligator cracking	↓	↔	↓	↓
Low friction	May improve [†]	May improve	May improve	May improve [§]	May improve
Price (\$/yd ²)**	\$0.10–\$0.80	\$0.80	\$0.90	\$1.50	\$4.40

↑ Recommended ↓ Not recommended ↔ Marginal

*There is a greater likelihood of success when used in lower speed traffic.

†Not used in Iowa, but other states have seen success.

‡Fog seal will reduce friction for the first few months until traffic wears binder off of the tops of aggregate.

§Micro-surfacing reportedly retains high friction for a longer period of time.

**Prices were obtained from interviews and anecdotal evidence from author.

Figure 10: Decision Matrix Example (Jahren 2007)

These matrices are only meant to be used as references. There are other factors to consider when making proper treatment selection. They include cost, material and labor

availability, traffic speed, frequency of turning movements, stops, experience, and time. Some treatments are more expensive than others and some will take longer to apply and be opened to traffic. Chip seals are particularly susceptible to damage by stopping and turning vehicles, since the aggregate may dislodge relatively easily.

Out of eleven respondents who felt neutral about the effectiveness of decision matrices, four had never seen them. As part of the module development process the same decision matrix was provided with an example similar to the one previously described.

5.3.9 Timing

As mentioned before, timing is of essence when it comes to pavement preservation. The vast majority of the respondents understand the importance of timing the application effectively so, again, this is a case of leveling the knowledge. In this case, module development focused on reinforcing the difference between corrective and preventive maintenance. Corrective maintenance can be defined as the maintenance performed once a deficiency (i.e. sever rutting, extensive cracking or raveling, etc.) has occurred (Hicks et. al. 2000). A recommended measure of treatment timing is to keep track of pavement condition (similar to asset management) and to use a cost approach comparing the cost of delayed maintenance versus early maintenance. Also, it was critical to point out that pavement preservation is not a once in a lifetime application and it should be applied routinely (as seen in Figure 11).

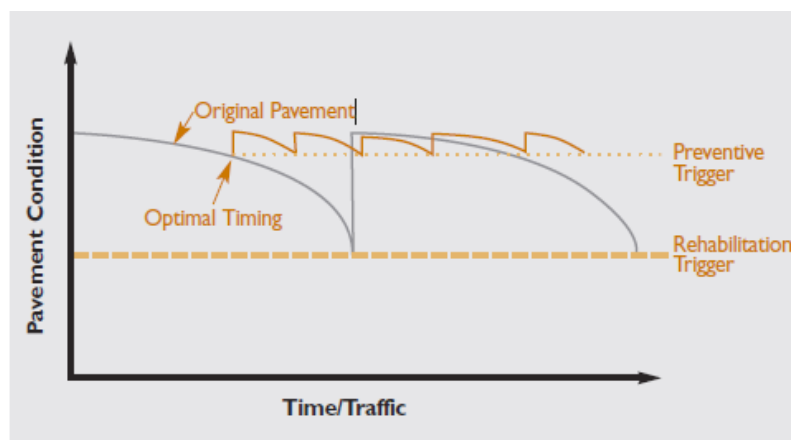


Figure 11: Pavement Preservation Continuation Concept (Galehouse, et. al. 2003)

5.3.10 Training Approach

As mentioned before, respondents ranked five training techniques according to their effectiveness and convenience. Table 10 shows the results of this set of questions where an inverse point scale was used (1 is most effective/convenient = 5 points ... 5 is less effective/convenient = 1 point). Respondents could rank more than one training at the same level. The results show the total for each training technique. Please refer to Appendix D for more information. From the results it is apparent that a full day face to face and an online video are the least effective and convenient training methods for road and treatment selection. A short face to face meeting with online material for reference seems to be both effective and convenient.

Table 10: Concepting Training Techniques Results

Effective Training Technique:	
<i>Full day face-to-face with quizzes.</i>	62
<i>Short face-to-face with online references.</i>	76
<i>Online course with a follow up meeting.</i>	72
<i>Online course with quizzes and discussion boards.</i>	67
<i>Quick online video.</i>	54
Convenient and Realistic Training Technique:	
<i>Full day face-to-face with quizzes.</i>	55
<i>Short face-to-face with online references.</i>	80
<i>Online course with a follow up meeting.</i>	69
<i>Online course with quizzes and discussion boards.</i>	64
<i>Quick online video.</i>	63
<i>Scale: 1-5pts, 2-4pts, 3-3pts, 4-2pts & 5-1pt.</i>	

On a meeting held in June 19, 2012 maintenance staff indicated the need to have short face to face meetings where staff members could share their experiences and the results reflect such need. This short face to face meeting will allow them to share their road and treatment selection process, information to take into account, practices to do, practices to avoid, and other experiences that would benefit the road and treatment selection process. Also, these meetings will help those with less experience obtain knowledge from those with more experience.

5.4 SUMMARY

Results show there is a wide variety of experienced and inexperienced members within the maintenance staff. The developed training module targets with emphasis those subjects where respondents lack confidence and/or knowledge and reinforces those that respondents already feel comfortable with. The training module has been developed in a way

that can be used as a face to face presentation and also as a future online reference, thus meeting the demands of the training technique selected as the most effective and convenient. Please refer to Appendix G-1 for the developed concepting training module.

CHAPTER 6. CHIP SEAL DESIGN TRAINING

6.1 INTRODUCTION

The goal of the design training modules is to prepare the design staff on the proper design process of the treatments under study. Subjects incorporated in the chip seal design training module include asphalt binder properties and selection, aggregate properties and selection, aggregate-binder compatibility, and step by step design procedure. It is important to point out that the goal of a proper chip seal design is to determine aggregate and binder application rates that will lead to aggregate embedment of 70% after rolling and trafficking (McLeod 1969; Gransberg and James 2005; Wood et. al. 2006).

The first section of this chapter describes the methodology used to determine the knowledge gap on chip seal design. The second section shows the results obtained and how the module was developed based on such results. The last section will provide a summary of the development of the chip seal design training.

6.2 METHODOLOGY

To determine the knowledge gap within the design staff of the Iowa DOT a questionnaire was developed to analyze the current level of knowledge on the subjects mentioned before. The questionnaire consisted of eight questions where the respondents had to select their level of understanding, confidence, or experience on regards to different aspects. For example, a statement could read: "I am familiar with the different types of aggregate gradation and properties". The respondents then had to select if they strongly agreed, agreed, felt neutral, disagreed, or strongly disagreed with the statement presented.

Also, after the knowledge questionnaire the respondents had to rank (from 1 to 5) which training technique they considered most effective (1 being most effective). The

choices presented were the same as the ones mentioned in the previous chapter. Finally, the respondents had to rank the same options (from 1 to 5) on regards to which technique would be more realistic and convenient. This distinction between effectiveness and convenience was necessary to determine the time flexibility of the future trainees. For a better understanding of the questionnaire developed please refer to Appendix E.

6.3 RESULTS

A total of seven questionnaires were received and tallied. As presented in Table 11, some of the results stood out and they are presented in bold red. One aspect to point out is that a high number of respondents often disagreed with the statements presented in the questionnaire which could represent a substantial lack of pavement preservation design knowledge within the department. It is important to keep in mind that this might not be the case for every highway and roadway agency. The following sections will provide information on what was included in each subject of the chip seal design training module. As in the previous chapter, please refer to Appendix E for the actual statements presented in the questionnaire. Table 11 only presents the subject of each statement for simplicity purposes.

Table 11: Design Needs Analysis Result

Design Needs Analysis Results						
<i># Subject</i>	<i>Strongly Agree</i>	<i>Agree</i>	<i>Neutral</i>	<i>Disagree</i>	<i>Strongly Disagree</i>	<i>Total (verification)</i>
1. PP Importance	3	3	1	0	0	7
2. Experience	1	2	2	2	0	7
3. Emulsions	0	0	2	5	0	7
4. Aggregates						
<i>a. Slurry Systems</i>	0	1	1	5	0	7
<i>b. Seal Coating</i>	0	0	2	5	0	7
5. Design Calculation						
<i>a. Seal Coating</i>	0	0	2	4	1	7
6. Reviewing Iowa DOT Specs						
<i>a. Crack Fill/Seal</i>	0	4	1	2	0	7
<i>b. Slurry Systems</i>	0	2	2	3	0	7
<i>c. Seal Coating</i>	0	1	3	3	0	7
<i>d. Fog Seal</i>	0	2	3	2	0	7
7. Aggregate-Binder Compatibility						
<i>a. Slurry Systems</i>	0	3	1	3	0	7
<i>b. Seal Coating</i>	0	4	1	2	0	7
8. Aggregate &/or Binder Selection						
<i>a. Slurry Systems</i>	0	0	2	5	0	7
<i>b. Seal Coating</i>	0	0	2	5	0	7
<i>c. Fog Seal</i>	0	0	2	5	0	7

6.3.1 Pavement Preservation Importance

Since the majority of the respondents strongly agree or agree they understand the importance of pavement preservation, this subject's goal becomes more of leveling the knowledge within the agency. For the department it was critical that everyone knew why pavement preservation was being incorporated. It was evident that each module needed to start by stating why it is important to have an effective pavement preservation program in each stage. This module on chip seal design also includes why a proper design should

accompany a proper selection and application. A proper selection and application will be of no effect if the design was not conducted properly.

6.3.2 Experience

Identifying the level of experience within the staff member was a key factor in this research. Even though this factor cannot be addressed directly in the training module, it helped identify how many of the respondents have previous experience with pavement preservation treatments. Although no specific level stood out, it was important to know that there are members with experience that can be shared.

6.3.3 Asphalt Binders

Five out of seven respondents disagreed they had an understanding of the different types of emulsions. This subject became an important point to address. The module presents the two types of binders that could be used in a chip seal application (cutbacks and emulsions), but provides more focus on emulsions since these types of binders are used more often. Finally it provides information on a polymer modified emulsion.

6.3.3.1 Cutbacks

A cutback binder is basically asphalt cement dissolved in a solvent, typically kerosene or fuel oil. Rapid curing cutbacks use fuel oil while medium curing cutbacks use kerosene. A cutback asphalt binder commonly consists of 85% asphalt with the rest being cutter. The amount of cutter in the mix affects the viscosity, thus more cutter content the less viscous or more fluid the mix is. The use of cutbacks has declined due to environmental and health risks. As mentioned before, cutbacks are not the focus of this module.

6.3.3.2 Emulsions

Emulsions consist of asphalt particles dispersed in water, chemically stabilized, and suspended by emulsifiers. An emulsion mix is typically composed of one-third water and emulsifier and 2/3 asphalt. Emulsions are classified by their electrical charge, settling speed, high-float availability, and viscosity. Those emulsions that are positive charged (+) are referred to as cationic emulsions and emulsions negatively charged (-) are anionic emulsions. A cationic emulsion is used more often since the aggregate commonly used for chip seals is negatively charged. Also, cationic emulsions are less sensitive to weather and stabilize quicker than anionic emulsions.

For chip seals it is highly common to find rapid setting emulsions. The reason is that rapid setting emulsions will provide the quickest chip retention. Thus less aggregate will dislodge while waiting for the binder to cure. Another classification is the availability of using a high-float emulsion. High float emulsions contain chemicals that allow for a thicker asphalt layer and are recommended when using dusty aggregates. Viscosity is another measure when classifying emulsions. Viscosity is designated by the numbers 1 and 2, where 1 is lower viscosity thus more fluid. The amount of water in the mix will alter the viscosity of the mix. The most common emulsion used for chip sealing is a CRS-2, which stands for cationic rapid setting emulsion with high viscosity.

The training module defines each of the classifications mentioned before. As it will be seen later, proper selection of which binder classification to use is critical to have optimum binder-aggregate compatibility. The module also presents an animation of how emulsions work explaining step by step how the chip particles, emulsifiers, and surface interact.

6.3.3.3 Polymer Modified Emulsions

The last subject presented under the binder section is the polymer modified emulsions. A polymer modified emulsion can be used for different reasons. The residual asphalt from a polymer modified emulsion will have a higher viscosity when compared to that of a non-polymer modified emulsion. The polymer will also provide better chip retention as particles are more tied together. Finally, when emulsions are polymer modified they create a more flexible pavement that can withstand heavier loads without failing. A polymer modified emulsion is designated with a P suffix. For example, a CRS-2_p is a cationic rapid setting polymer modified emulsion with high viscosity. The module also presents an animation that shows how polymers work in an emulsion.

6.3.4 Aggregates

Understanding aggregate properties and selection is critical when designing chip seals. The aggregate used for chip seals should have certain properties to achieve the best result. In this section aggregates (chips) are explored in their most important properties to consider when designing chip seals and visual images are provided to complement such explanations.

6.3.4.1 Aggregate Type

The best type of aggregate for chip seals is a hard, clean, and dust free aggregate. The aggregate will take on large amounts of load and transfer them to the existing pavement. A soft aggregate will not be able to perform such function. The chips selected should be clean and dust free to avoid any unwanted matter occupying chip space. Although this subject of cleanliness will also be covered in the construction training it is important for designers to select a material that typically has low content of dust and clay as it will affect the adherence

to the binder. For example, the Iowa DOT specifies the use of clean crushed stone or gravel in their specifications.

6.3.4.2 Gradation and Size

Binder will occupy the gaps that are left between aggregate particles. A well graded aggregate will provide the least amount of voids, thus leaving little space for the binder to settle in between chips. It is commonly recommended to use one-sized aggregates (two-sized aggregates are also recommended). Nevertheless, as mentioned before, graded aggregate has also performed successfully. Making reference to Figure 12 and Figure 13, a difference in aggregate configuration can be seen between one-sized and well graded chip seals. The use of well graded aggregate could be more susceptible to chips with little binder adhesion which can cause “flyrock”, is harder to work with, and requires more quality control.



Figure 12: One-sized Chip Seal Application (Wood et. al. 2006)



Figure 13: Well Graded Chip Seal Application (Wood et. al. 2006)

By looking at the cross sections of both cases (Figure 14 and Figure 15) it is clear that binder-aggregate adherence may not be fully achieved in a well graded chip seal. In this case the smaller chips are occupying spaces between bigger chips and some are lying on top of the larger ones with no binder contact, potentially leading to windshield damage.



Figure 14: Well Graded Chip Seal Cross Section (Wood et. al. 2006)

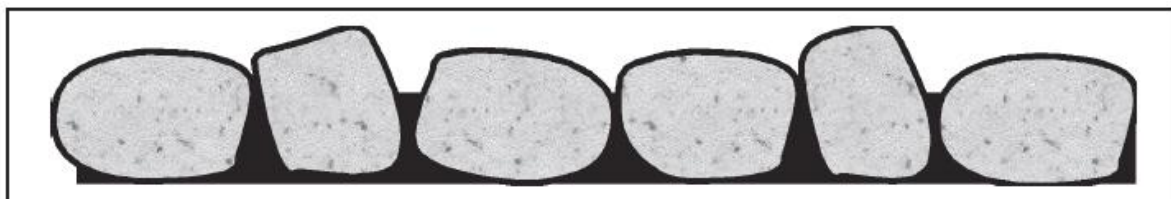


Figure 15: One-sized Chip Seal Cross Section (Wood et. al. 2006)

6.3.4.3 Aggregate Shape

When selecting an aggregate it is important to consider the shape of the chips. In the case of a chip seal it is critical to look at its flatness and angularity. A particle will always tend to lay on its flat side, like a football. On a chip seal application, as traffic passes over it

chips will slowly be oriented to their flat side. If the chips are too flat then the aggregate will submerge into the binder thus causing the application to bleed (Figure 16).

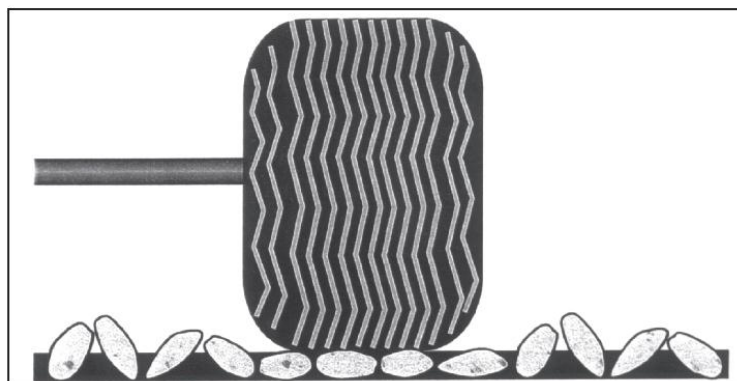


Figure 16: Flat Particles Effect (Wood et. al. 2006)

The second factor to consider when looking at the particles' shapes is their angularity. The particles can range from round shapes to angular shapes. A round shaped aggregate is more susceptible to being rolled and tend not to lock together as tight as angular shapes. On the other hand, angular shapes offer better interlocking resistance between them which contributes to its resistance on being rolled and provide more surface area for binder adherence. Angular shaped aggregates are usually preferred over round aggregates for these reasons. There are some few cases where round aggregate is preferred like, for example, city streets where rough surfaces are not desired or roads with continuous snowplow.

6.3.5 Design Process and Calculations

In a meeting held in June 19, 2012 with the design and maintenance staff members, they expressed the desire to utilize a step by step design process similar to the one described in the Minnesota Seal Coat Handbook instead of relying on previously determined application rates. On top of that, the needs analysis showed that out of seven respondents none strongly agreed or agreed on having knowledge of an actual design calculation process.

At this point it was decided to develop a separate module that goes through an example step by step design process to obtain application rates for both aggregate and binder.

What follows is a brief description of each step. Some steps could be altered as they could be done earlier in the process. The formulas have been omitted in the following sections. For the formulas used in the following steps and an example of the chip seal design process please refer to Appendix G-4.

The design procedure recommended is based on one first presented by Norman McLeod in the late 1960's in a paper titled "A General Method of Design for Seal Coats and Surface Treatments" (McLeod 1969). Ever since it has been adopted and adapted by the Asphalt Institute, Asphalt Emulsion Manufacturers Association, and the Strategic Highway Research Program (Wood et. al. 2006).

6.3.5.1 Median Particle Size

The first step when designing a chip seal is to determine the gradation of the aggregate to be used. In this design process it is assumed the aggregate is one-sized. When plotting the percent passing versus sieve opening graph, such graph should have a one-size behavior showing a sudden high increase in percentage at some particular sieve opening. The opening corresponding to 50% passing is defined as the median particle size (MPS).

6.3.5.2 Flakiness Index

As mentioned before, particles tend to lay on their flat side. The percent, by weight, of flat particles is defined as the flakiness index (FI). A small sample of the aggregate is passed through a slotted testing plate (Figure 17) and the weight of the chips that passed is compared to the total weight of the sample.

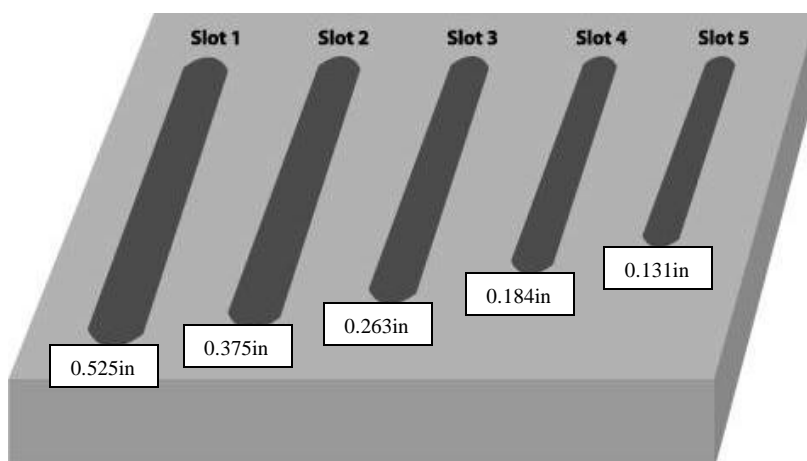


Figure 17: Flakiness Index Slotted Testing Plate (Jahren and Chung 2003)

6.3.5.3 Average Least Dimension

The average least dimension (ALD) represents the chip seal thickness at the wheel path. It is calculated as an adjustment to the MPS considering the FI.

6.3.5.4 Bulk Specific Gravity

The bulk specific gravity (BSG) could be determined using the AASHTO T84 test. The lower the BSG is the less weight density an aggregate has. In other words, if the BSG is low then the number of pounds of aggregate needed to cover an area is less. Refer to Table 12 for typical BSGs of various aggregates.

Table 12: Typical BSG for Aggregates (Wood et. al. 2006)

Aggregate type	Class A			Class B		Class C	
	Granite	Quartzite	Trap Rock	Limestone	Red Rock	Pea Rock	
Bulk Specific Gravity	Min.	2.60	2.59	2.95	2.40	2.50	2.55
	Max.	2.75	2.63	2.98	2.67	2.52	2.66
	Avg.	2.68	2.62	2.97	2.61	2.51	2.62

6.3.5.5 Loose Unit Weight

The loose unit weight (LUW) is a measure of the weight occupying a determined volume. This measure is needed to calculate the void percentage in between the aggregate particles. This space will later be occupied by the binder. The LUW is determined with the

ASTM C29 test where three cylinders of equal volume are filled with aggregate and weighed to determine an average unit weight by volume.

6.3.5.6 Voids in the Loose Aggregate

The voids in the loose aggregate (VLA) takes into account the BSG and LUW. It is a measure of the percentage of voids in a chip seal application,. The VLA commonly goes from 50% when placed to 30% when rolled and finally 20% when opened to traffic. At the time of design a VLA close to 50% is recommended.

6.3.5.7 Traffic Waste Factor

The traffic waste factor (TWF) addresses the aggregate that gets dislodge off the road due to trafficking on a fresh seal. A waste factor of 5% (TWF=1.05) is commonly used for residential roads and 10% (1.10) for higher speed roads.

6.3.5.8 Aggregate Application Rate

The aggregate application rate (AAR) determines the amount of aggregate that would be needed to cover an area of pavement with a one-stone thick layer. The AAR takes into account the VLA, ALD, BSG, and TWF. It is commonly expressed in pounds per square yard (lb/yd²).

6.3.5.9 Traffic Volume Factor and Pavement Condition Factor

Both factors are determined with road characteristics and properties. The traffic volume factor (TVF) helps determine how much binder will be needed. Higher traffic volumes reduce the amount of binder needed since aggregates are more easily pushed to their flat side. Refer to Table 13 for typical values of TVF.

Table 13: Typical Traffic Volume Factors (Jahren and Chung 2003)**Traffic Volume Factor Table**

Traffic Volume (number of vehicles per day)	<i>TVF</i>
under 100	0.85
100 to 500	0.75
500 to 1,000	0.70
1,000 to 2,000	0.65
over 2,000	0.60

As the name says, the pavement condition factor (PCF) takes into account the condition of the road. Newer smoother roads with less cracks and voids require less binder. Older pavements with more cracks and voids will require more binder as it will soak into cracks and voids. Table 14 provides common PCF values.

Table 14: Typical Pavement Condition Factors (Jahren and Chung 2003)**Pavement Condition Factor Table**

Pavement Surface Condition	<i>PCF</i>	
	U.S. Units	S.I. Units
Black, flushed asphalt	-0.01 to -0.06 gallons/yd ²	-0.04 to -0.27 liters/m ²
Smooth, non-porous	0.00 gallons/yd ²	0.00 liters/m ²
Slightly porous, oxidized	0.03 gallons/yd ²	0.14 liters/m ²
Slightly pocked, porous, oxidized	0.06 gallons/yd ²	0.27 liters/m ²
Badly pocked, porous, oxidized	0.09 gallons/yd ²	0.40 liters/m ²

6.3.5.10 Aggregate Absorption Factor

Aggregates absorb some of the binder applied in a chip seal, therefore an adjustment needs to be made for those aggregates with high absorption rates. The aggregate absorption factor (AAF) is determined using the same AASHTO T84 test used when determining the BSG. As a general assumption, if the absorption is 1.5% or higher then an AAF of 0.02gal/yd² is recommended. For absorptions less than 1.5% no adjustment is recommended.

6.3.5.11 Asphalt Content of Binder

As mentioned before, cutbacks have an asphalt content in the binder (ACB) of 85% while emulsions have 2/3 (67%) of the binder composed of asphalt. Due to the decrease in the use of cutbacks, the ACB will be 67% most of the times.

6.3.5.12 Binder Application Rate

As in the aggregate application rate (AAR), the binder application rate (BAR) determines the amount of binder required to cover the aggregate up to 50% of its thickness before rolling. The BAR is commonly expressed in terms of gallons per square yard (gal/yd²). Both the BAR and the AAR need to be checked in the field and adjusted if necessary.

6.3.5.13 Field Adjustments and Summary

Although binder and aggregate application rates have been determined with this method, they will need to be verified and adjusted in the field. Pavement and weather conditions may alter both application rates. The McLeod method presented is one of various design methods available for chip seal design. The modified Kearby method follows a similar process and is commonly used in Texas (Webb 2010). The Hanson method also takes a similar approach and is commonly used in New Zealand and other locations (Transit New Zealand 2005).

6.3.6 Methods of Adjustment

The sand patch method (ASTM E965; TNZ T/3) is a measure of the surface macrotexture (Gransberg and James 2005, Transit New Zealand 2005, etc.). The process consists of spreading a determined volume of sand or glass beads on the surface. The larger the circle becomes, less voids are present thus less binder adjustment is necessary. The sand patch method is commonly used as a performance measure as it provides immediate results

of the texture depth. Nonetheless, the sand patch method can be used in pre-seal surfaces to adjust the binder application rate (Gransberg 2007; Transit New Zealand 2005). There are other methods of pavement texture measurement, but they have not been included in the training module.



Figure 18: Sand Patch Method Before and After (Transit New Zealand 2005)

6.3.7 Agency Specification Review

Three out of seven respondents do not feel comfortable reviewing the specs of a chip seal project, while other three are kind of in between. The module present what the specs determine as appropriate application rates for both aggregate and binder on either single or double coats. It is important for design personnel to be able to review and interpret the specifications of their respective agency. Currently, the Iowa DOT specs determine an aggregate application rate of $30\text{lb}/\text{yd}^2$ and a binder application rate of $35\text{gal}/\text{yd}^2$ (Iowa DOT Specification 2307). The specs also mention that the application rates provided can be changed by an engineer's recommendation. This final statement is important in case a design process like the one described before would be implemented in a near future.

6.3.8 Aggregate-Binder Compatibility

Most respondents agreed they understood the importance of proper aggregate-binder compatibility. Although no separate section was provided for this subject, when binders and aggregate were presented the importance of such matter was reinforced for knowledge leveling purposes. It is critical to select a binder with the opposite electric charge of that in the aggregate for the binder to adhere to the aggregate properly.

6.3.9 Aggregate and Binder Selection

Different factors come into play when selecting both the aggregate and binder to be used in a chip seal. With most of the respondents disagreeing with the statement that they feel confident in selecting those materials, it is important to mention all the factors to consider for proper selection. Most of the factors have already been presented to this point and they are: aggregate-binder compatibility, aggregate shape, type, and size, and binder type. Other factors to consider are: cost, aggregate availability, and material transportation distance. These last two factors will affect the overall cost and should always be considered.

6.3.10 Training Approach

As mentioned before, respondents ranked five training techniques according to their effectiveness and convenience. Table 15 shows the added results of this set of questions where an inverse point scale was used (1 is most effective/convenient = 5 points ... 5 is less effective/convenient = 1 point). For example, a full day face to face with quizzes received a total of 13 points on effectiveness from seven received questionnaires. Five respondents ranked this option at number 5 (1 point each) and two ranked it at number 2 (4 points each), totaling 13 points. From the results it is apparent that a full day face to face is the least effective and convenient training methods for the design staff.

Table 15: Design Training Techniques Results

Effective Training Technique:	
<i>Full day face-to-face with quizzes.</i>	13
<i>Short face-to-face with online references.</i>	23
<i>Online course with a follow up meeting.</i>	25
<i>Online course with quizzes and discussion boards.</i>	24
<i>Quick online video.</i>	22
Convenient and Realistic Training Technique:	
<i>Full day face-to-face with quizzes.</i>	13
<i>Short face-to-face with online references.</i>	24
<i>Online course with a follow up meeting.</i>	23
<i>Online course with quizzes and discussion boards.</i>	24
<i>Quick online video.</i>	24
<i>Scale: 1-5pts, 2-4pts, 3-3pts, 4-2pts & 5-1pt.</i>	

On a meeting held in June 19, 2012 design staff agreed with maintenance staff on the need to have short face to face meetings where staff members could share their experiences. This short face to face meeting will allow them to share good practices and issues faced while designing pavement preservation techniques. Due to this consideration, a quick online video was not considered although it had similar results to other techniques according to the questionnaire. The module has been prepared to be easily converted into an online module even though it is currently configured as a short face to face presentation.

6.4 SUMMARY

Results show that design staff members could benefit from effective training in chip seal design. With a large number of results indicating the need for more overall knowledge in chip seal design, it was critical to develop a training module that provides the knowledge outcomes required to effectively design chip seals. It was important to target subjects like

binder characteristics, aggregate properties, material selection, and the overall design process. A second design module has been prepared as a response to the request to incorporate the design process described in the Minnesota Seal Coat Handbook. The goal in a chip seal design is to determine application rates that will create a layer consisting of 50% average chip height embedded in the binder before rolling and 70% after. This goal has been included in the module as an important opening point.

CHAPTER 7. CHIP SEAL CONSTRUCTION TRAINING

7.1 INTRODUCTION

The goal of the construction training modules is to prepare the construction staff (mostly inspectors) on the proper application process of the treatments under consideration. Subjects incorporated in the chip seal construction training module include road conditions prior to treatment, pre-application, equipment inspection, equipment calibration, application, post-application, best practices versus poor practices, and troubleshooting. It is important to point out that the goal is to apply the treatment according to specifications and design in order to maximize the pavement preservation benefits. Successful chip seal construction depends on a combination of rational science and qualitative judgment (Shuler and Lord 2010).

The first section of this chapter describes the methodology used to determine the knowledge gap on such matter. The second section shows the results obtained and how the module was developed based on such results. The last section will provide a summary of the development of the chip seal construction training.

7.2 METHODOLOGY

As mentioned before, no questionnaire was handed out for the construction staff to fill out. Please refer to Appendix F for the questionnaire that would have been used for construction. Instead, a meeting held in December 15, 2011 with members of the construction staff was taken as an alternative method to obtain the information required due to time constraints. In this meeting, construction staff personnel expressed areas in which pavement preservation treatment applications could be improved and areas that could be incorporated in the training module. Also, in the meeting, construction staff members

specified clearly the training method that would benefit them the most according to what fits their work schedule. Such results will be analyzed in the next section.

7.3 RESULTS

The construction staff mentioned some points that they found to be of high importance for the application of pavement preservation strategies. The importance of knowing what to look for before, during, and after the construction process is critical when applying any treatment correctly. Construction staff members mentioned the need to have a standardized process of calibrating equipment. Also, they mentioned that it would be beneficial to have a section comparing poor practices to good practices in order to have visual images of aspects they should be looking for.

Finally, it was critical for them to have a specific training method. Since the construction staff only knows about the project to which they have been assigned a few days before the actual application, it is impractical to have a training meeting. Due to this fact, the quick online video was judged to be the most effective and convenient method of training. More on this matter and the content included in each section is included in the following sections.

7.3.1 Pavement Preservation Importance

Like the other presentations developed, the chip seal construction module opens by expressing the importance of pavement preservation. More so, it focuses on the importance of having the knowledge necessary to properly apply a chip seal treatment. It also establishes the expected viewer outcomes. The trainee should be able to understand the overall construction procedure followed in a chip seal, identify good and poor application, and be

ready for any possible setbacks. Finally it is critical to understand that a properly selected and designed treatment will only achieve benefits if it is properly applied.

7.3.2 Conditions Prior to Treatment

It is critical for road conditions to be checked before beginning any sort of application. As mentioned before, chip seals do not address major cracks, potholes, or rutting problems so these major distresses need to be addressed some time before the chip seal application. Also, it is common to seal cracks prior to application to avoid binder concentration in these areas. Minor cracks may not be sealed prior to application but no organic or unwanted material should be present inside cracks as they will affect the performance of the treatment. The surface should also be clean and dry. Sweepers are usually used to clean the surface prior to application.

Another aspect to monitor is weather. High winds will affect the application process as binder and chips will not be applied uniformly. Also, if there is enough probability of rain the application should not begin as rain water will affect the binder composition and performance. Finally, in order for the binder to cure properly the recommended surface and air temperature is a temperature above 40°F.

7.3.3 Pre-Application and Equipment Inspection

After all the road and weather conditions have been met, it is important to prepare the pavement for the application. A good starting point is to set up the traffic control plan according to the Manual on Uniform Traffic Control Devices (MUTCD) or specification. Depending on the road type and its geometry each traffic control plan will be different.

Another aspect to inspect is the aggregate size. According to the specifications and design either a one-sized or two-sized aggregate could have been selected. If the aggregate in

the trucks does not meet the required gradation, the application will be greatly affected. Refer back to Figure 12 for an example of a one-sized aggregate sample.

Utilities, if any, need to be covered prior to application. Common materials used to cover manholes and other utilities include: cut roofing felt, sand, and plastic. Whichever method is used, the purpose is to cover utilities with an easily removed material that will not damage the chip seal application. One more factor to verify before application is the proper function of the equipment (calibration will be covered in the next section).

7.3.3.1 Asphalt Distributor

An asphalt distributor has many features that need to be properly checked for proper function. Spray bar height is critical for achieving a single layer or a double layer of asphalt as seen in Figure 19 (NHI Pavement Preservation Treatment Construction Guide) for single and double chip seals respectively. If the bar is too low then there's a risk of not covering the whole width of the road, on the other hand if it is too high then it creates an overlapped spray pattern.

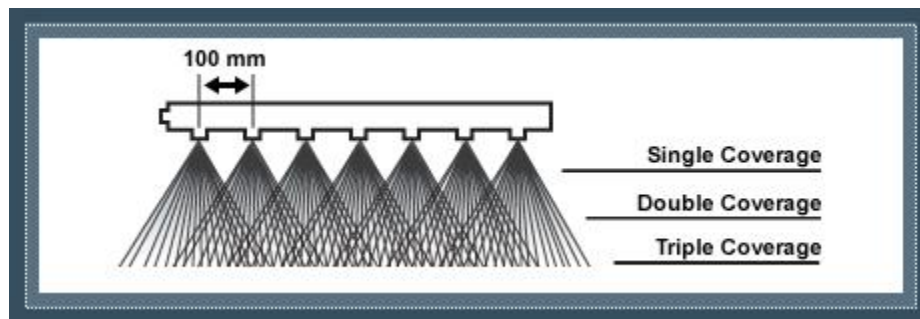


Figure 19: Spray Bar Height (NHI PPTCG 2007)

The spray bar is composed of nozzles through which the binder is applied. Nozzles also need to be checked for proper function. Each nozzle should have no clogs and applying binder at the proper pressure. Clogged nozzles with varying pressures will produce an

irregular application. Also, each nozzle should be set at the same angle in order to achieve uniform application. Typical angles range from 15° to 30° as seen in Figure 20.

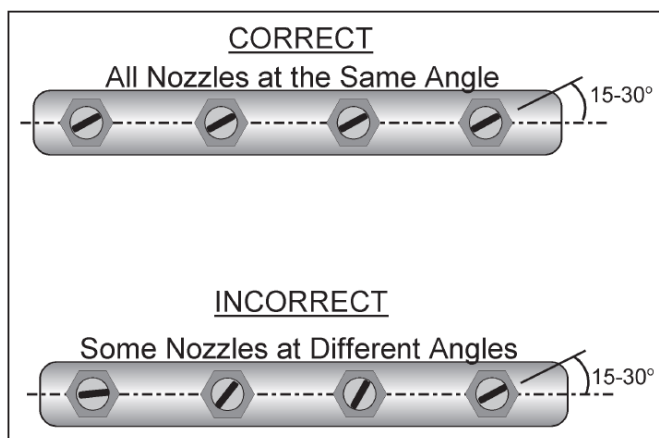


Figure 20: Nozzle Angles (Wood et. al. 2006)

7.3.3.2 Chip Spreader

Chip spreaders need to have their settings checked as well. Gate controls and settings should be checked to ensure that chips will be spread uniformly. Also, the truck hookup hitch should be checked to make sure it works properly (Figure 21). A chip seal consists of a continuous application and truck exchanges need to be conducted quickly.



Figure 21: Truck Hook-Up Hitch on Chip Spreader (photo taken by author)

7.3.3.3 Trucks

Truck boxes should be clean and should only carry aggregate. Most importantly, it is critical to have enough trucks on hand to allow for a continuous application. If trucks are not ready then binder will cure before chips are applied.

7.3.3.4 Rollers

Pneumatic rollers are preferred over steel wheel rollers. Two major reasons for this preference are that steel rollers can break aggregate particles thus dislodging pieces of them, and pneumatic rollers conform to the shape of the road thus applying embedment pressure more evenly despite irregularities. Also, all tires in the rollers should be inflated to the same pressure for the embedment to be uniform.

Perhaps the most important factor is to understand that one roller is insufficient. Several studies (Gransberg et. al. 2004; Gransberg and James 2005, Shuler et. al. 2011) have identified methods of determining the number of rollers necessary to provide proper embedment while keeping up with the operation. Gransberg et. al. (2004) developed Equation 2 for determining the number of rollers. In this equation, P stands for the distributor

production in miles per hour (mph), X stands for the shot width in yards (yd), and A is the roller linger time in square yards per hour (yd^2/hr). Some agencies have determined values for A ranging from 1,000 to 5,000 yd^2/hr (Gransberg et. al. 1998). Finally, the 1760 is the conversion factor in yards/mile. Equation 3 (Shuler et. al. 2011) follows the same approach, only the conversion factor (6.67) converts square feet per minute (ft^2/mn) to yd^2/hr .

$$N = \frac{1760PX}{A} \quad (2)$$

$$N = \frac{6.67PX}{A} \quad (3)$$

7.3.3.5 Sweepers

Sweepers will commonly be used before application to clean dust and debris and after application to sweep off loose chips. It is important to check the bristles' lengths. If bristles are too long they can dislodge chips when removing any excess materials. On the other hand, short bristles will not serve the purpose of the sweeper.

7.3.4 Equipment Calibration

One of the important points that the construction staff pointed out was the need to have a standardized method of calibrating the equipment. In a chip seal application, both the asphalt distributor and the chip spreader need to be calibrated to provide a uniform application. Various methods of equipment calibration exist (Wood et. al. 2006, Shuler et. al. 2011). The chip spreader calibration described follows the process described in the Minnesota Seal Coat Handbook (Wood et. al. 2006). The asphalt distributor calibration process described follows the process described in the NCHRP-680 report (Shuler et. al. 2011).

7.3.4.1 Chip Spreader Calibration

The chip spreader calibration process described in the Minnesota Seal Coat Handbook starts by spreading chips at the design application rate over 12” by 36” rubber mats (Figure 22) that extent through the entire width of the chip spreader. It is critical that the spreader travels at the same speed to be traveled during application. The application should appear one-stone thick. Then chips in each rubber mat are emptied into one-gallon plastic bags and weighed (Figure 23 and Figure 24). Finally, each weighed bag (converted into pounds per square yard) allows for its corresponding gate to be adjusted so that the spreader drops the same amount of aggregate satisfying a one-stone thick layer. It is recommended that this calibration procedure be conducted the day before construction or, at least, an hour before application to reduce delays.



Figure 22: Rubber Mats Used for Calibration (Wood et. al. 2006)



Figure 23: Emptying Rubber Mats (Wood et. al. 2006)



Figure 24: Chip Weighing (Wood et. al. 2006)

7.3.4.2 Asphalt Distributor Calibration

After all the distributors elements have been configured (nozzle angle, spray bar height, etc.) the calibration process can begin. The method described in the NCHRP-680 report requires calibration longitudinally and laterally. For the lateral calibration, containers lined with plastic bags are placed under each nozzle and emulsion is sprayed until containers are approximately 75% full. Each weighed container should be within 10% of the average of all bags (Shuler et. al. 2011). Adjustments are made if necessary.

For longitudinal calibration, the initial volume of the distributor is measured. Binder is sprayed into the containers used for lateral calibration for approximately 50 feet. When stopped, the final volume is measured. The difference in volume in terms of gal/yd² is compared to the design application rate. Also, this measure should equal the application rate shown in the distributor's computer if using a computer controlled distributor. This measure should be within 5% of the design application rate (Shuler et. al. 2011).

7.3.5 Test Strip

After both distributor and spreader have been calibrated, it's recommended to perform a test strip. The process starts by applying approximately 50 feet of binder at designed application rate followed by an application of aggregate with the calibrated chip spreader. The next step is to verify the height of the binder compared to the chips. Binder should rise more than half the aggregate thickness but without reaching the top (Figure 25). At this point adjustments should be made, if necessary.

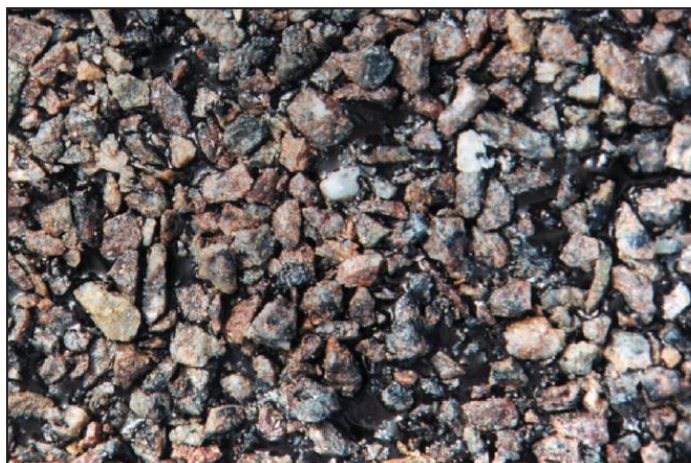


Figure 25: Correct Amount of Binder (Wood et. al. 2006)

7.3.6 Application

It is critical for the trainee to understand that a proper application is obtained by having a continuous application with the least number of interruptions. The application should look uniform, both transversely and longitudinally. To obtain this uniformity, the application should start and end on a piece of tar paper or roofing paper as shown in Figure 26. If the equipment is calibrated properly, further inspection includes constantly checking for plugged nozzles and making sure the distributor and spreader match speeds.



Figure 26: Application End on Mat (photo taken by author)

Also, it is important to make sure that there are enough trucks in line. If the spreader has to wait for trucks to arrive, the binder will start to cure before any chips are applied. As the chip seal is being applied it is important to make sure that no binder is on top of the aggregate. Having binder over the aggregate might indicate that either there is too much binder being applied or not enough chips. More on issues and remedies will be discussed in a later section.

As mentioned before, rollers are sometimes considered the most important piece of equipment in a chip seal operation. It is critical to make sure that the rollers being used in the process cover the whole width of the road and that they are traveling at a moderate speed (refer to Figure 27). Also, it is important to have good control over the number of stops and turns made over the applied chip seal. Each turn and stop may cause chips to be dislodged. Pneumatic rollers are recommended over steel wheeled rollers.



Figure 27: Three Rollers in Chip Seal Operation (photo taken by author)

7.3.7 Post-Application

After the aggregate is properly embedded and there is sufficient bond between the chips and the binder, sweeping can begin. It is important to have properly working sweepers to ensure that any excess aggregate is removed from the surface. Aggregate that is left behind, may become “flyrock”, which in turn damages windshields, causing road user complaints.



Figure 28: Windshield Damage Cause by Loose Chips (MTAG 2007)

After the surface has been properly swept, markings can be placed on top of the chip seal. It is a common practice to apply a fog seal application after a chip seal (normally the next day) as this will not only create stronger chip retention but also provides a dark background for road markings. All construction related signs should be changed to speed reduction signs when opening the road to traffic and a pilot car should be used to keep control of traffic and speed. At this point the chip seal will benefit from some extra embedment provided by traffic at low speeds.

Although opening the road to traffic sounds easy and harmless, it is critical to manage the opening time effectively. Early opening will create aggregate dislodgment problems. The Montana Sweep Test is the most direct method as it sweeps the actual surface and considers the road ready for traffic when less than 10% of chips are dislodged (Shuler and Lord 2010). Recent studies (Shuler and Lord 2010) have shown that moisture content might be the best indication of when the road is ready for traffic. The results showed that when the chip seal reaches approximately 75 to 85 percent water loss, then sufficient bond has been created

between the binder and the aggregate, and the surface is ready for traffic. The method of calculating moisture content on a chip seal is outside the scope of this research.

7.3.8 Poor Practices vs. Best Practices

In this section the objective was to present various images of best practices and poor practices. The intention is to provide the viewer with enough visual representation of what should and should not be done in a chip seal project. Figure 29 is an example of a good result. It shows a uniform application showing no flushing or bleeding.



Figure 29: Good Chip Seal Result (Rizzuto 2008)

On the other hand, Figure 30, Figure 31, and Figure 32 are all examples of poor practices or poor results in a chip seal application. Figure 30 shows a chip seal that used an aggregate that did not pass the gradation test. In other words, the aggregate used for this project has too many fines, thus creating dust. This represents a problem for the chip seal's integrity as there is a risk that aggregate and binder did not adhere properly, and also presents a problem on a level of public complaints due to fugitive dust.



Figure 30: Dusty Aggregate Chip Seal (Wood et. al. 2006)

Figure 31 is also an example of a poor application. This application was, most probably, too rich in binder. A chip seal with too much binder will create bleeding or flushing in the wheel path at first. Although, away from the wheel path the chip seal looks well it is just a matter of time before other distresses begin to appear triggered by the composition of the chip seal.



Figure 31: Bleeding Chip Seal (Webb 2010)

Figure 32 shows improper chip seal application on special situations. In this case a roundabout was completely covered with binder by the distributor and will next be applied

with aggregate. At this point, the binder has already started to cure on the first areas it was applied and aggregate will not adhere properly. Although roundabouts are not common, they require a specific method for applying a chip seal. This proper method is presented in the module to provide a best practice example after presenting this poor practice image. Please refer to Appendix G-6 for this proper roundabout example.



Figure 32: Incorrect Roundabout Application (Wood et. al. 2006)

7.3.9 Common Issues and Remedies

This section presents many of the issues that could occur during application and ways to remedy them. The training module does not provide trainees with all possible issues and remedies, but it does provide an external reference (NHI PPTCG) for a more complete list of issues and remedies. The following are a few of the examples provided in the module.

Figure 33 shows a binder application with a streaky appearance. This could be an issue for a chip seal application as the binder is not being uniformly applied. Possible remedies may be to adjust the bar height and/or adjust the nozzle angles. As mentioned before, asphalt bleeding is another issue and the remedy is to adjust the binder application rate for future applications.

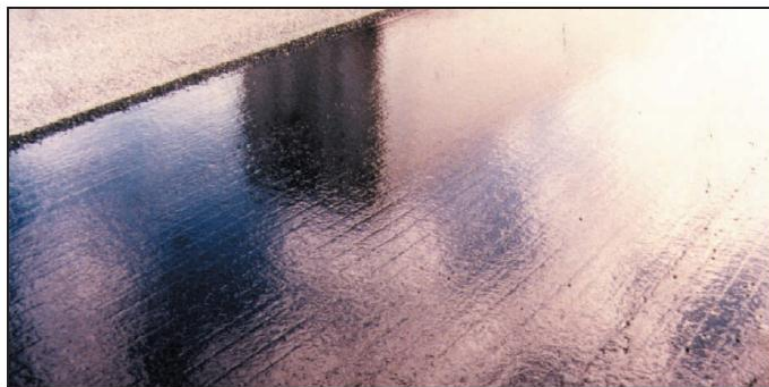


Figure 33: Streaky Binder Appearance (Wood et. al. 2006)

Another issue that may be experienced in a chip seal project is the loss of aggregate. This may be the result of a low binder application rate or poor rolling. Remedies to this issue could be to either apply more binder or change the rolling technique, depending on what the cause of the issue is. Dislodged chips are also a common issue experienced in chip seal projects. In this case chips are being dislodged from the surface after the binder has started to cure or has already cured. One of the probable remedies is to start sweeping at a later time, thus delaying traffic time. Another remedy, if traffic has already started, is to reduce its speed. As mentioned before, a NHI reference is provided in the module to give access to a more extensive list of issues and remedies.

7.3.10 Training Approach

Construction staff expressed the need to have a presentation or a video they can look at any time the day before the project and not worry about meeting at some time. Although the module has been prepared for on-demand purposes, it also serves to review important points if there were to be a construction staff meeting within the agency at some point in time.

7.4 SUMMARY

The module developed addresses key points in the main three stages of treatment application (pre-application, application, and post-application). The module also addresses equipment calibration and rolling requirements, which are factors considered to be critical in a chip seal application. It was important to present visual images of best and poor practices so that trainees have images to relate to during field operations. Finally, since inconveniences are almost always likely to appear, possible issues and remedies were presented.

Thanks to a very direct and clear request from the construction staff, selecting a training approach was not a challenge. The module has been prepared so that it can be viewed on-demand for approximately fifteen minutes any time before application.

CHAPTER 8. FOG SEAL DESIGN AND CONSTRUCTION

8.1 INTRODUCTION

As mentioned in Chapter 1, fog seal design and fog seal construction have been combined in one chapter. The goals for both the fog seal design and construction training modules are the same as the chip sealing design and construction modules. One aspect to clarify is that a fog seal design normally consists of selecting a dilution and application rate and not a formal design per se. The training module developed for fog sealing design is intended to give trainees a view on what materials are available for fog sealing with focus on emulsions. Also, much of the content on fog sealing construction has already been covered in Chapter 7. Although this repeated material is presented in the fog seal construction training module, it will not be repeated with all the details in this chapter.

Subjects incorporated in the fog seal design training module include asphalt binder properties and selection and specification review. It is important to point out that a fog seal is an application of binder that is often diluted where dilution rates will vary depending on the binder selected and the intended purpose of the fog seal. Subjects incorporated in the fog seal construction training module include road conditions prior to treatment, pre-application, equipment inspection, equipment calibration, application, post-application, best practices, and troubleshooting. It is important to point out that the goal of a proper application is to apply the treatment according to specifications in order to maximize pavement preservation benefits.

The first section of this chapter describes the methodology used to determine the knowledge gap on both fog seal design and construction. The following two sections show the results obtained for each phase and how the modules were developed based on such

results. Subjects that have been repeated from Chapter 7 will only be mentioned and briefly explained. The last section will provide a summary of the development of the fog seal design and construction training modules.

8.2 METHODOLOGY

The methodology followed for both design and construction is the same as the ones followed for chip sealing design and construction; a summarized explanation follows.

8.2.1 Fog Seal Design Methodology

To determine the knowledge gap within the design staff of the agency, a questionnaire was developed to analyze the current level of knowledge on the subjects mentioned before. The questionnaire consisted of eight questions where the respondents had to select their level of understanding, confidence, or experience on regards to different aspects.

Also, after completing the knowledge questionnaire, the respondents were asked to rank which of the training techniques they considered most effective. Please refer to the previous chapters or Appendix E for the training options presented in the questionnaires. Finally, the respondents had to rank the same options in regards to which technique would be more realistic and convenient.

8.2.2 Fog Seal Construction Methodology

As mentioned before, no questionnaire was handed out for the construction staff to fill out. Instead, a meeting held in December 15, 2011 with members of the construction staff was taken as a substitute for the needs analysis questionnaire. Appendix F represents the questionnaire that would have been used for construction. In this meeting construction staff personnel expressed subjects in which pavement preservation treatment applications could be

improved and subjects that should be incorporated into the training modules. Also, in the meeting, construction staff members clearly specified the need for an on-demand training approach.

8.3 FOG SEAL DESIGN RESULTS

Referring back to Table 11 (Chapter 6) the fog seal design training needed to focus on the available emulsion types that can be used. As mentioned earlier, agencies do not normally perform any in-house design for a fog seal application. Anyhow, it is important for the design staff to have knowledge of the different emulsion variations and other materials available for a fog seal application. Also, it is important to look at the specifications (Iowa DOT in this case), understand them, and have some level of understanding of how it stands when compared to existing dilution and application rates elsewhere.

8.3.1 Emulsions and Other Materials

With the majority of respondents showing the need to increase their knowledge on emulsions, this section was of special attention. A typical fog seal is composed of two primary materials: binder and water. In some cases (most cases for highway construction) a third material is used: sand. This section will explore the role of each material in a fog seal project while providing more focus on emulsions.

8.3.1.1 Binders for Fog Seals

Binders used for fog seal projects are normally slow setting emulsions. The reason for using a slow setting emulsion is that a fog seal works by penetrating the aged pavement to improve binder properties while providing a sealing and waterproofing layer to prevent further deterioration. The slow set allows more time for penetration. The most common types of emulsion used for fog sealing are CSS (cationic slow setting) and SS (anionic slow

setting). The anionic emulsion usually takes longer than the cationic emulsions to cure. In Iowa, the two most common types of emulsions used for fog sealing are SS-1 and CSS-1. Both have low viscosity which aids penetration into the pavement.

On the other hand, other states like California (Caltrans 2003) may specify using harder base asphalt emulsion such as SS-1h and CSS-1h. Specifying the use of harder based emulsions provide a lower penetration number, a stiffer layer, and a less susceptible pavement to hot weather problems (Blades and Kearny 2004). Other states that have many roads with higher traffic volumes may benefit from a thicker layer to obtain the full benefit of a fog seal. In this case a high float emulsion (HF) provides a thicker layer with less flexibility.

Another binder that is sometimes used is a gilsonite seal, commonly referred to as a GSB-88. Gilsonite is a non-toxic, naturally occurring, 99.85% pure mineral asphalt ore that when combined with light oils and plasticizers (GSB-88) aids in the rejuvenating and flexible properties of the pavement (Cline 2011). One significant advantage of GSB is that it prolongs the life of the pavement when compared to traditional fog seals. On the other hand, this application costs more and has only been found in mines located in Utah and Saudi Arabia.

A recent study (Cline 2011) showed that although the initial cost of a GSB application is higher than that of a traditional fog seal, the value of such investment is higher since the life expectancy is higher (refer to Figure 34 and Figure 35). For example, according to Figure 34, the useful life of a GSB-88 is of approximately four (4) years with an initial cost of \$1/yd². This will result in the lowest equivalent annual cost (\$0.25/year) of the treatments studied, shown in Figure 35. This brings back the term of life cycle analysis. With higher life expectancy, the equivalent annual cost decreases.

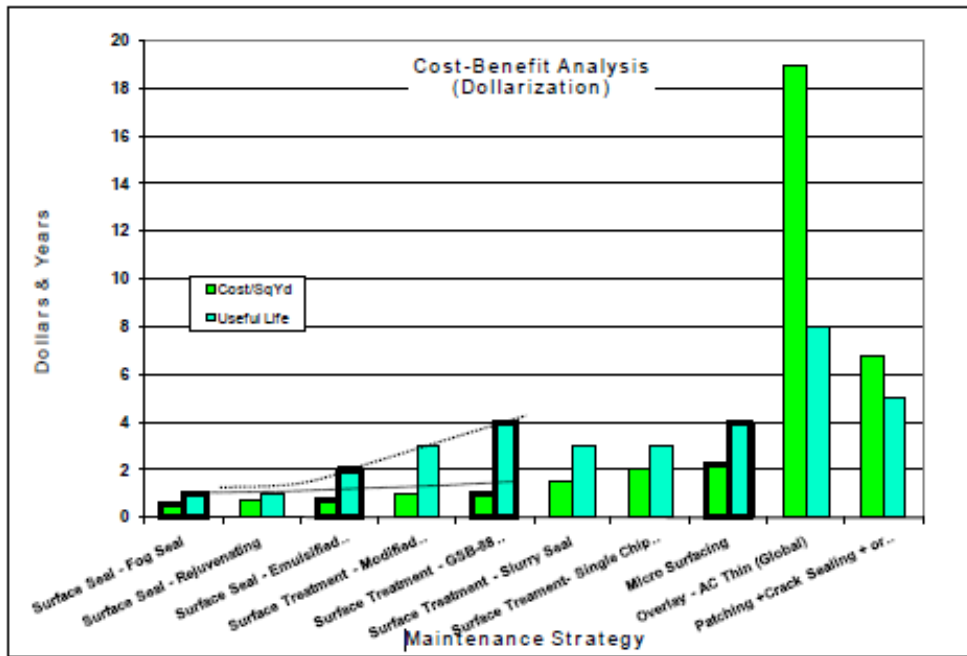


Figure 34: Cost-Benefit Analysis (Cline 2011)

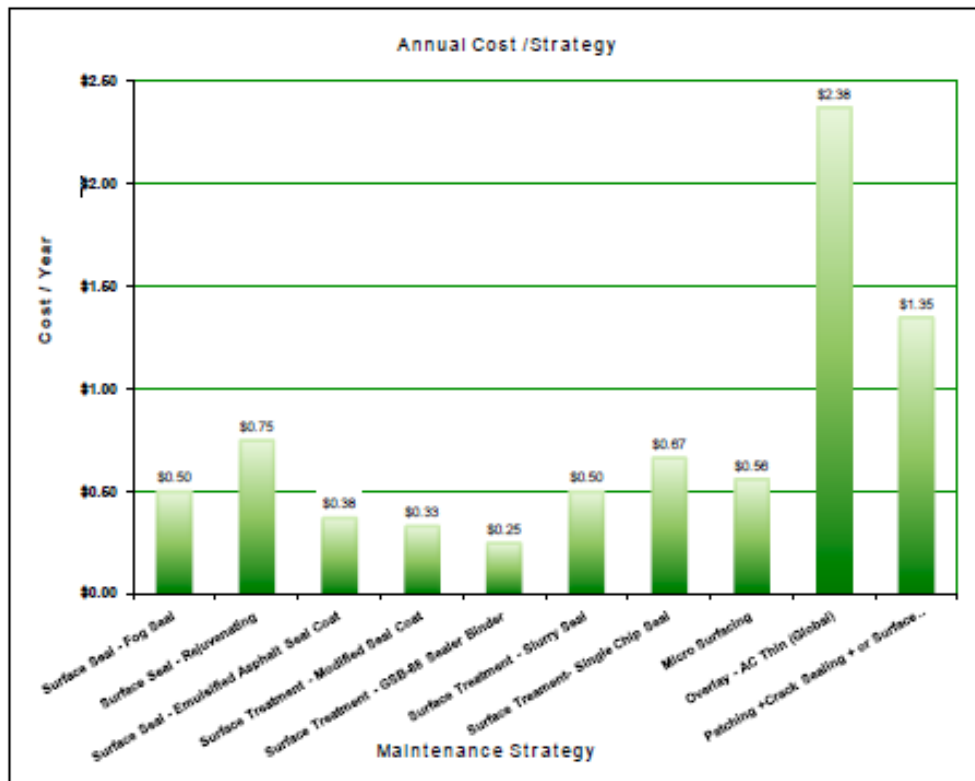


Figure 35: Annual Cost Analysis (Cline 2011)

8.3.1.2 Water

Since a fog seal binder usually consists of a diluted emulsion, the second material to consider after the binder is water. It is highly recommended to use potable water. Potable water reduces the risk of altering the chemical composition of the emulsion. Also, the right amount of water is critical as various dilution rates behave differently in the field. Too little water will not sufficiently decrease the viscosity of the binder to penetrate the voids in the surface. Meanwhile, adding too much water will create a highly fluid mix that may run down cross slopes to the sides of the road.

8.3.1.3 Sand

A sand application combined with a fog seal is commonly used in many agencies. A fog seal application will reduce the skid resistance of the pavement, thus applying a sand cover will restore some of that lost skid resistance to the pavement. Sand may be applied within the binder application or it could be applied shortly after. More on sand application will be covered in section 8.4.

8.3.1.4 Rejuvenators

A fog seal is also called a rejuvenating seal when it utilizes rejuvenating solutions in its mix. Rejuvenators such as Reclamite®, PASS®, and Topien C® are available in the industry. Rejuvenators soften the binder, reduces its viscosity, improve flexibility, and reduce the likelihood of cohesive failure (Caltrans 2003).

8.3.2 Specifications

The module presents the current specified dilution and application rates for fog seals in Iowa. The current specifications state: “The dilution rate is one part of asphalt emulsion to four parts of water ... The diluted asphalt emulsion shall be applied at the rate of 0.12 gal/yd²

(0.5L/m²) of pavement surface” (Iowa DOT Specification 2306). The presentation also presents other dilution and application rates commonly found in the industry (Table 16).

Table 16: Common Dilution and Application Rates (Valley Slurry Seal Co.)

Dilution (all in lt/m2)	Tight Surface	Open Surface
residual	0.04-0.15	0.13-0.22
50	0.15-0.5	0.4-1
40	0.2-0.55	0.5-1.3
25	0.25-0.9	0.8-2
20	0.3-01.15	1-2.6

8.4 FOG SEAL CONSTRUCTION RESULTS

Some of the knowledge gap results for the construction side of fog sealing are similar to those found for chip sealing. Although the process is much simpler than that of a chip seal, the project needs to be inspected in its three main phases: pre-application, application, and post-application. As in the chip seal module, other topics that were included are: best practices and common issues and remedies. Two differences that stand out are the calibration process and water testing in case water needs to be added to the mix.

8.4.1 Conditions Prior to Treatment

As for chip sealing, there are certain road conditions that should be met prior to treatment. Road should be clean and dry with any major distresses previously addressed. It is important to remember that a fog seal only addresses minor distresses. Also, if a pavement is showing signs of bleeding, a fog seal should not be applied as adding more binder will only worsen the situation. The minimum recommended surface and air temperature is 60°F. This number is higher than that for chip seals since fog seals take longer to cure and lower

temperatures will further delay the curing time. As for chip seals and any other treatments, if there is the presence or possibility of rain or high winds, the application should not start.

8.4.2 Pre-Application and Equipment Inspection

This section is similar to the one presented for chip seal construction (section 7.3.3). For a fog seal it is critical to verify that there are no drainage problems. Since a fog seal is an application of diluted asphalt, the mix is less viscous which increases the risk that binder may accumulate in depressions. Also, if sand will be used it is important to verify that the aggregate is composed of only fine clean particles.

As for equipment inspection, the same binder distributor equipment inspection responsibilities presented in Chapter 7 apply. It is critical to check for bar height, pressure, nozzle angles, and the possibility of any clogged nozzles. In case water needs to be added to the diluted binder, it is important to make sure water is not added in a way it creates a bubbly or foamy solution. If sand will be applied with a spreader, the gates should be checked to make sure they are spreading the right amount of sand.

8.4.3 Equipment Calibration

The asphalt distributor calibration presented follows the steps presented in NHI's PPTCG (2007). This calibration process is similar to the one presented in Chapter 7 for a chip seal application. The process starts by weighing a 1yd² mat and laying it on a road segment. The next step is to apply the fog seal over it and weighing the mat again. The difference in weights provides the weight of binder per square yard which then is converted to gal/yd². This number is then verified against the specified application rate and adjusted accordingly.

8.4.4 Water Testing

In the case that water needs to be added to the mix, it is important to select the right type and quantity of water. Although the term “type of water” seems eccentric, not any type of water can be added to a fog seal mix. The water, not only is recommended to be potable, it also needs to be compatible with the mix. NHI’s PPTCG provides a method for determining if the water to be added will be compatible with the fog seal mix.

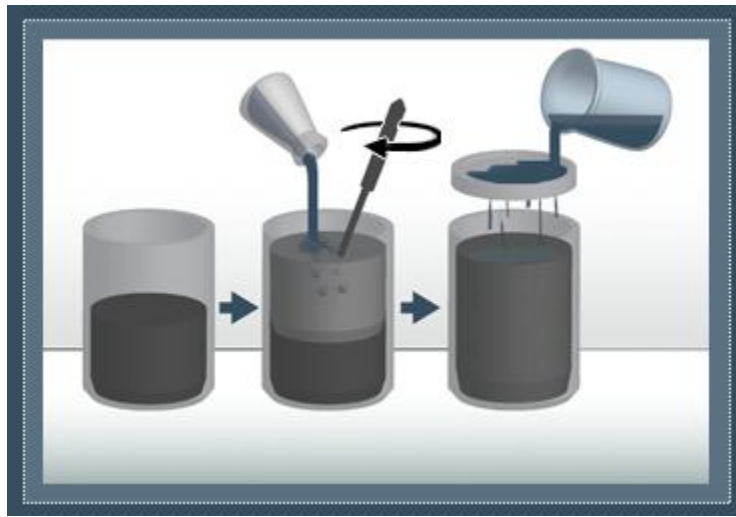


Figure 36: Water Compatibility Test (NHI PPTCG 2007)

The process starts by mixing the emulsion and the water in a one liter can. The mix is stirred for about two to three minutes. The resulting mix is then poured through a pre-wetted 150 mm sieve. If more than 1% of material, by weight, is retained on the sieve then the water is not compatible, has altered the chemical composition of the emulsion, and should not be used (NHI PPTCG 2007).

8.4.5 Application

The construction responsibilities during application of a fog seal are very similar to those presented for the application of a chip seal. The inspector needs to make sure the

application is uniform. It is a good practice to have the application start and stop in building paper. As in a chip seal application, it is critical to constantly check for clogged nozzles. Finally, in cases where sand is being used it is important not to have binder on top of the sand. The purpose of using sand is to improve the skid resistance, so sand should be lying on top of the binder.

8.4.6 Post-Application

Unlike chip seals, fog seals can take a long time to cure. Opening the road to traffic too early will tear the fresh seal away from the pavement surface. After the fog seal has cured, the construction related signs can be changed to speed reduction signs, markings can be applied, and the road can be opened to traffic while keeping a maximum speed of approximately 25 miles per hour. In case sand is used, sweeping should begin after sufficient bond has been created between the pavement, aggregate, and binder to prevent removal.

8.4.7 Poor Practices vs. Best Practices

In this section the objective was to present various images with poor practices and best practices. The intention is to provide the viewer with enough visual representation of what should and should not be done in a fog seal project. For example, Figure 37 and Figure 38 show examples of proper fog seal applications. Figure 37 shows a fog seal application on a road still in good condition while Figure 38 shows a fog seal application on a pavement where the cracks have been previously sealed. Also, Figure 39 shows a good example of a proper fog seal application with sand applied immediately after.



Figure 37: Road Fog Seal (NHI PPTCG 2007)



Figure 38: Fog Seal on Parking Lot (photo taken by author)



Figure 39: Fog Seal with Sand (Brownridge and Fox 2011)

As there are best practices, there are also poor practices. The following images show examples of poor practices. Figure 40 shows a fog seal application where the nozzles are not aligned at the same angle. The area farthest to the side will get substantially a larger amount of binder than the rest of the segment. Figure 41 shows a fog seal application on the road shoulder and, although shoulders do not require the same level of concern as roadways, the fog seal will not perform as well as if the pothole would have been previously addressed.



Figure 40: Inappropriate Nozzle Angle Alignment (MTAG 2007)



Figure 41: Fog Seal Poor Practice (NHI PPTCG 2007)

8.4.8 Common Issues and Remedies

Most of the issues and remedies presented have also been presented as common issues and remedies for a binder application phase of a chip seal application. Splattering and streaking are some of these issues appearing on both training modules. Other issues like bleeding and high viscosity could also occur in a fog seal application. If the pavement experiences bleeding shortly after application, then an appropriate remedy could be to lower the application rate.

8.4.9 Training Approach

As mentioned before, the design staff will benefit most from a short face to face meeting with future online references. The fog seal design module has been prepared to serve such purpose. For more information in regards to this decision please refer back to Chapter 6. On the other hand, the construction staff was very clear about having on-demand training modules. The fog seal construction module has been prepared as a short video that could be viewed shortly before application time. For more information in regards to this decision please refer back to Chapter 7.

8.5 SUMMARY

Although fog seals are not commonly designed in-house it was important to provide information on the various types of emulsions that could be used for fog seal projects. Also, it was important to demonstrate how the specifications in regards to dilution and application rates compare from location to location.

As for fog seal construction, the inspector has a number of responsibilities to help ensure a uniform and steady application. Some of the responsibilities should not be different from other pavement preservation treatments. Nevertheless, it is important to understand how aspects like equipment calibration and adding water can affect the application. As for best practices and poor practices (also called Do's and Don'ts) Caltrans provides a well-developed list to guide inspectors (refer to Table 17).

Table 17: Do's and Don'ts of Fog Seals (Caltrans 2003)

Do check water compatibility before dilution.
Do check dilution - has it been done, by whom, and when?
Do ensure that there is no contamination of the base emulsion by water, oils, or other liquids.
Do prevent contamination by other emulsions.
Do protect emulsions from freezing or localized boiling due to the application of direct heat.
Do heat emulsion gently and ensure heating coils are under the liquid level (max 50°C (122°F)).
Do load from the bottom of tankers or sprayers to avoid foaming.
Do check equipment and nozzles.
Do check application rates.
Do exercise proper traffic control.
Do ensure the know-how is available on the job.
Do add water to emulsion, not emulsion to water.
Don't store diluted emulsion longer than 24 hours.
Don't continuously stir or circulate emulsion.
Don't apply emulsion if air temperature is <10°C (50°F) and pavement temperature <15°C (59°F).
Don't apply emulsion if rain or cool temperatures are imminent.
Don't continue application if adequate breaking period is not available.
Don't open treated surface to traffic until coefficient of friction is at least 0.30 as determined by CT 342.

CHAPTER 9. SUMMARY

9.1 OVERVIEW

This chapter will provide an overview of how the learning management system development process was applied in response to the needs presented by the Iowa DOT. The summary has been organized in the same way chapters were divided.

9.2 LMS DEVELOPMENT FOR PAVEMENT PRESERVATION

Creating presentations is only part of the entire process required to develop a LMS. A structured process is required in order to develop a LMS. This research effort used a step by step process to identify the roles and needs of the future audience by means of needs analysis questionnaires and meetings. By using a combination of questionnaires, meetings, and literature review it was possible to identify the distribution of the training material and the content that should be included. Finally, when developing a LMS it is important to choose the correct training method to use (online, face to face, etc.), as each audience will have different needs and schedules.

9.3 CONCEPTING TRAINING

The needs analysis questionnaire identified several topics that needed to be addressed in a concepting training. Understanding road distresses causes, treatment functions, and the connection between both of these factors is critical to making a proper road and treatment selection. Not all treatments behave and perform the same on every road.

Perhaps the most important subject on which to provide effective training is on selection tools. The results showed that many respondents do not feel confident when selecting which treatment to use. The concepting training module provides four tools to help on the selection process. It is important to understand that these are only tools and do not

necessarily mean the outcome of using one tool is the only solution. It would be recommended that more than one tool is used before a decision is made in order to obtain various points of view. The four tools presented are:

- Windshield survey – visual inspection of the road
- Asset management – a record of how the resources have been distributed throughout the road network
- Life cycle cost analysis – takes into account the life expectancy of the treatment, not just the first cost
- Decision matrixes – matrixes developed through historical research data

9.4 CHIP SEAL DESIGN TRAINING

Chip seals are commonly designed in-house so a chip seal design training will cover a considerable amount of content. From the needs analysis results, it is clear that the following topics need to be included in a chip seal training module: emulsion properties, aggregate properties, and binder and aggregate selection. The module that was prepared includes the properties of typical binders that are used for chip seals focusing on emulsions rather than cutbacks because emulsions are more commonly used. It also includes the properties a proper chip seal aggregate should have and the importance of its compatibility with the binder that is to be used. This compatibility between aggregate and binder will be the most important factor when selecting both materials.

In an effort to include a formal chip seal design process, and as requested by design personnel, a training presentation on a structured chip seal design process has been developed. A step by step design example is covered in a separate training module utilizing a modified version of the McLeod method presented in the Minnesota Seal Coat Handbook. It

is important to understand that this process is commonly used for quantity calculations (estimation) and some locations, such as Minnesota, use it as the basis for their chip seal design.

9.5 CHIP SEAL CONSTRUCTION TRAINING

Although no needs analysis was distributed and collected for the construction phase, training needs were identified. As it was mentioned before, the construction staff will benefit from a standardized equipment calibration procedure. The chip sealing construction training module presents a step by step process for calibrating both the asphalt distributor and the chip spreader. The chip spreader calibration method presented follows the method presented in the Minnesota Seal Coat Handbook and the distributor calibration method follows the method described in the NCHRP-680 report. Similar calibration methods to the ones presented were found in other sources.

Also, the construction staff will benefit from examples of best and poor practices. By providing several images of best practices and poor practices (what to do and what not to do) viewers can associate what they are looking at in the field with what they have seen in the modules. If they identify a poor practice during the application process, they can create a remedy plan before the process continues.

Due to time constrains for this staff division, it is necessary to have on-demand training modules. Personnel in charge of the construction inspection of pavement preservation treatments are usually notified about the project only few days before the project starts. It is important for them to have on-demand online reference to which they can refer quickly before the start of construction. The presentation has been developed so that it can be viewed days or even hours before construction begins.

9.6 FOG SEAL DESIGN AND CONSTRUCTION TRAINING

Unlike chip sealing, fog sealing will not require extensive design training. A fog seal application is normally designed by the supplier with most of it being the selection of pre-established application rates. Nevertheless, the fog seal design training includes a review of the various types of binders that could be used for fog seals and their advantages and disadvantages.

A fog seal construction training is not as extensive as a chip seal construction training mainly because the process is less complicated, consisting of one piece of equipment: the distributor. Most of this training module is repeated material from the chip seal construction module in regards to equipment calibration, equipment inspection, and pre-application. On the other hand, the poor practices and best practices examples are different. Also, a section on water testing was added in the case water needs to be added to the mix to increase its dilution rate.

CHAPTER 10. CONCLUSIONS, LIMITATIONS, AND RECOMMENDATIONS

10.1 OVERVIEW

The following sections of this chapter describe the conclusions drawn from the research results, the limitations of the research, the immediate impact of the research, the long-term impact of the research, and recommendation for future research.

10.2 CONCLUSIONS

The research objective was to develop a learning management system that addresses pavement preservation treatments (chip sealing and fog sealing) as they are dealt with during the phases of selection, design, and construction. The goal of the research was attained.

From the research steps taken, it was clear that each pavement preservation treatment needed to be a separate training focus, except during the concepting (selection) phase. It was also obvious that each staff division needed to be trained individually. What concerns the maintenance staff when selecting roads and treatments do not necessarily concern the construction staff. Nonetheless some aspects, like the importance of utilizing pavement preservation techniques, should be known by everyone and they have been included in each presentation. From a training perspective, it is ideal to identify the interests and expected outcomes of the trainees as it is not recommended to overwhelm the audience with unnecessary information. Also, it is critical to consider the needs and constraints of each audience to determine the most feasible training method.

Perhaps most importantly, the research has presented a method that could be used to implement other training programs, not only pavement preservation. The needs analysis questionnaires developed provide a structured approach to identify the needs and knowledge gap of trainees and the most suitable training method. These questionnaires can be adapted

for other training purposes. After developing the training presentations based on the needs analysis results, it was important for the development process to validate such presentations with the approval of the agency. This validation step is highly recommended as it provides entity commission by receiving the approval of the intended audience.

10.3 LIMITATIONS

It is important to consider the limitations of the research and its results. One potential limitation of the research is the possibility of questionnaire respondents feeling overconfident about some of their knowledge when they responded to some of the statements. This is one of the main disadvantages of opinion-based questionnaires. For example, some respondents might have felt overconfident about understanding proper road and treatment selection. This could result in the possibility of making wrong selections on a future occasion.

Another limitation is the fact that the Iowa DOT design staff is relatively small compared to the construction or maintenance staffs, as seen in the seven design questionnaires received versus the twenty-one questionnaires received for concepting. Also, in some instances, the meetings held did not include representatives from all the districts, as districts 2 and 3 demonstrated the most interest in the research project. A larger staff could have yielded different results. Finally, there is a limitation in regards to the training presentations developed. Locations that do not apply any of the treatments for which presentations were developed (i.e. Florida), will likely not use such presentations. In any case, the methodology developed in the thesis could be followed to develop an LMS that is applicable for a particular location for treatments that are used in that location.

10.4 IMMEDIATE IMPACT

The example learning management system that was developed for Iowa is ready to be implemented. By early 2013 the training modules can be put into use for pavement preservation projects that include chip seals, fog seals, slurry systems, and/or cracks seals and crack fills.

10.5 LONG-TERM IMPACT

The research may serve as a starting point to identify the pavement preservation training needs on a nationwide basis. Although the findings of this research can be applied in many locations outside of Iowa, there might be places that require other methods of trainings than those proposed in this research project. Also, the research will provide an indirect benefit of improving the performance of the road system. With more people properly trained, the performance of the treatments should positively increase.

The methodology followed in this research project lead to develop a training program satisfying the needs of the transportation agency for pavement preservation. The same methodology used to develop the pavement preservation training program can be used as a model for other training programs, not just pavement preservation. For example, if a transportation agency would like to implement a training program for shoulder maintenance, the method used in this research can help establish an appropriate training program for shoulder maintenance.

10.6 RECOMMENDATIONS AND FUTURE RESEARCH

It is recommended to put the LMS developed for Iowa into practice. Also, it is recommended to make the LMS available for other locations that could benefit from it. Most of the states contacted agree they would benefit from an online training program for

pavement preservation. Due to the fact that the research focused on a roadway and transportation agency subject (pavement preservation), the author recommends using the same methodology for the implementation of other training programs within the transportation field of practice. Nonetheless, the methodology followed could be as effective in other fields of practice outside transportation.

A recommendation for future research is to give continuation to this research on a performance level. A proper analysis of the effectiveness of the training program can be determined by gathering data in regards to the performance of the treatment (i.e. life of the treatment) and comparing that data to the time before training was established. Also, the development of an updated version of a chip seal design process that uses the modified McLeod method and other methods as a basis would yield new results in the design sector. Another recommendation is to repeat the process developed under this research project in other locations to develop a nationwide pavement preservation training program. The method has only been applied in the state of Iowa; no examples represent the definite needs of other locations. On the other hand this research has explored the degree to which the LMS developed could be applied elsewhere in the future.

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**APPENDIX A TRB PAPER: TRAINING PROGRAM TO SUPPORT PREVENTIVE
MAINTENANCE**

Training Program to Support Preventive Maintenance

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ABSTRACT

Preventive maintenance of bituminous pavements includes a set of cost-effective surfacing techniques that can be used to extend life (1). Currently, many road and highway authorities intend to incorporate preventive maintenance strategies into their program, but in order to do so they need knowledgeable staff to implement and continue the program. The goal of the research is to provide the training components necessary to develop a learning management system for preventive maintenance within the department. An important step of this research is identifying any knowledge gaps employees might have that would inhibit their performance. A preventive maintenance project passes through three phases on its way to completion: concepting/selection, design, and construction. This paper explains how knowledge gaps for the three project phases has been identified and the training modules have been developed. The training focuses on the following four preventive maintenance treatments: slurry systems, chip seals (seal coats), crack fill/seals, and fog seals. It is evident that each segment of training has different requirements; these are explained in the paper using a training program development for Iowa DOT as an example.

INTRODUCTION

Preventive maintenance of bituminous pavements includes a set of cost-effective surfacing techniques that can be used to extend life (1). It should be pointed out that preventive maintenance techniques do not enhance structure of the pavement's surface. Preventive maintenance treatments are used as a mean to preserve the road in good condition before it deteriorates to a degree where repairing or rebuilding it would be costly (Refer to **Figure 42**).

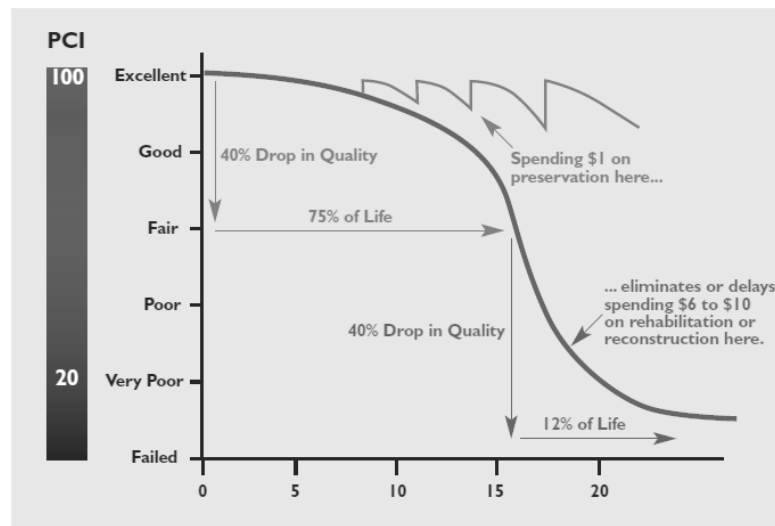


Figure 42: Road Deterioration Curve (2)

These techniques will serve to mitigate some of the common distresses found in most roads. Minor to average cracking, raveling, rutting, oxidation, and bleeding are some of the most common pavement distresses. It is important to know that not all treatments repair every distress. This matching of distress and treatment is one of the most important distinctions when selecting which treatment to apply.

A number of thin maintenance surfacing treatments can be used for preventive maintenance. For the purpose of this study the focus will be on the following four treatments: slurry systems, chip seals (seal coats), crack fill/seals, and fog seals.

Slurry system treatments are generally defined as a mixture of aggregate, emulsion, water, and additives. Slurry systems specifically include slurry seals and micro-surfacing. Slurry seals and micro-surfacing are very similar with major differences in the way they cure, their durability, and the thickness that may be applied in ruts (3). Slurry systems are best used for filling ruts and applying on full width surfaces, but they can be more expensive compared to other treatments.

Crack filling/sealing is different from the other mentioned treatments as it is never used as a full surface treatment. Crack filling/sealing is defined as an application of material (usually hot rubber or asphalt emulsion) to a crack in a pavement in order to seal the road from moisture penetration and ultimately preserve the sub grade of the pavement. Crack fill/seals are cost-effective and in some cases are needed before application of other preventive maintenance treatments.

A chip seal, also known as seal coat, consists of a layer of asphalt binder that is overlaid by a layer of embedded aggregate that furnishes protection to the asphalt layer from deterioration and creates a skid resistant surface (4). The advantages of using chip seals are the quick traffic return time and lower cost compared to slurry treatments, but chip seals can be dusty and have a risk of having loose aggregate or “flyrock”. Fog sealing is the light application of a diluted asphalt emulsion over an existing pavement surface or a recently applied chip seal. Fog seals improve the imperviousness of the pavement and prevent sand particles from raveling from the pavement’s surface, but a concern is that fog seals may decrease the pavement’s skid resistance, at least temporarily after application.

This research will focus on the development of the components that will be incorporated in a learning management system to address preventive maintenance training concerns within the Iowa DOT. When developing a learning management system it is important to define the interaction between training methods and trainees in order to establish an effective regimen. Some trainees will have some needs and constraints that others will not. In order to provide efficient, effective, and attractive learning systems, the design and presentation of the content becomes more important (5).

Current Training Status for Iowa DOT

The preventive maintenance techniques of interest for this research have had little use by the Iowa DOT since 1999. Currently, the Iowa DOT is starting to incorporate preventive maintenance strategies into its program, but in order to do so, knowledgeable staff members are needed to implement and run the program. Due to retirements and personnel changes throughout the past decade, the department now lacks experienced staff in all phases of preventive maintenance projects including project selection (concepting), design, and construction. In order to further the implementation of a strong preventive maintenance program, the Iowa DOT is seeking to first start an appropriate training program.

OBJECTIVE

The objective of this research is to develop a learning management system that addresses four preventive maintenance techniques (chip seals, fog seals, slurry systems, and crack filling/sealing) as they are dealt with during the project phases of selection, design, and construction. To accomplish this primary goal the current knowledge gap in the department in regard to preventive maintenance must be identified. Once this has been done through needs analysis, the development of training modules will focus on reiterating basic knowledge and addressing such gaps. In order to validate the effectiveness these modules, evaluations and feedback will be developed.

METHODOLOGY

The methodology used in this research follows a similar pattern to the one described in a traditional instructional system development (ISD) model. The ISD model consists of 5 steps: needs analysis, design, development, implementation, and evaluation (6). As a

summary, the research effort will include on determining the knowledge gap (needs analysis), designing a structure to be used for the development of the training modules (refer to **Table 18**), developing such modules, implementing and presenting them, and finally obtaining feedback while providing evaluation to determine the knowledge gained.

Presentation Development Matrix				
Presentation Category	Treatments			
	<i>Seal Coating</i>	<i>Fog Sealing</i>	<i>Slurry Systems</i>	<i>Crack Sealing/Filling</i>
<i>Introduction</i>	x	x	x	x
<i>Concepting (Selection)</i>	x			
<i>Design</i>	x	x	x	x
<i>Construction</i>	x	x	x	x

Table 18: Structure used for training development (x = completed)

The most important step for this process will be determining the knowledge gap that exists in the organization. A series of needs analysis questionnaires were developed and handed to Iowa DOT personnel in a meeting that addressed both project selection (concepting) and designing preventive maintenance treatments. In the case of the construction division, a meeting with the personnel in charge was held where they expressed their needs for improvement in training. In this case, this meeting was used as an equivalent to a needs analysis questionnaire.

In order to validate the compiled training information an evaluation will be conducted along with an individual feedback survey. Each training module will have an evaluation in the form of a short, multiple choice quiz. The quizzes are used to test the recipient and prove they achieved the intended level of knowledge from the module. These evaluations will be a permanent part of the learning management system. A feedback survey is also conducted to gain recipient perspectives of the usefulness of the training module. The information from the feedback survey is used to refine the training modules so they best suit the intended audience. Meetings with staff of the Iowa DOT have been held in order to conduct feedback surveys and test the developed training material.

Introduction to Treatments

As a way to establish knowledge uniformity within the Iowa DOT, an introduction training module was developed. This module is intended to give all Iowa DOT employees, regardless of division, a basic understanding of each preventive maintenance treatment. The information presented in the introductory training modules includes treatment definition, materials, placement methods, timing, distresses addressed, and weather limitations during application. All employees will be encouraged to view the introductory training modules before moving on to the more job specific modules.

Concepting

For the purpose of this study concepting is defined as the process of selecting a preventive maintenance treatment for a pavement. Within the Iowa DOT this process is accomplished jointly by both the design professionals and the maintenance crews for a specific district. This training module is intended to provide the targeted staff with tools, best practices, and proper information to select a specific treatment. The module discusses the 3R's of preventive maintenance; the right treatment on the right road at the right time. **Figure 42** is used in this module to help describe the importance of the 3R's and the importance of having a structured asset management – pavement management system. Decision matrices (**Figure 43**) are also presented in this module as an example of a helpful tool in selecting a preventive maintenance treatment.

Factor		Fog seal	Seal coat	Slurry seal	Micro-surfacing	Thin HMA overlay
Traffic	AADT < 2,000	↑	↑	↑	↑	↑
	2,000 < AADT < 5,000	↑	↔ [†]	↔ [†]	↑	↑
	AADT > 5,000	↑	↔ [†]	↔ [†]	↑	↑
Bleeding		↓	↑	↑	↑	↑
Rutting		↓	↓	↑	↑	↑
Raveling		↑	↑	↑	↑	↑
Cracks	Few tight cracks	↑	↑	↑	↑	↑
	Extensive cracking	↓	↑	↓	↓	↑
	Alligator cracking	↓	↔	↓	↓	↓
Low friction		May improve [‡]	May improve	May improve	May improve [§]	May improve
Price (\$/yd ²) ^{**}		\$0.10–\$0.80	\$0.80	\$0.90	\$1.50	\$4.40

↑ Recommended ↓ Not recommended ↔ Marginal

[†]There is a greater likelihood of success when used in lower speed traffic.
[‡]Not used in Iowa, but other states have seen success.
[§]Fog seal will reduce friction for the first few months until traffic wears binder off of the tops of aggregate.
[§]Micro-surfacing reportedly retains high friction for a longer period of time.
^{**}Prices were obtained from interviews and anecdotal evidence from author.

Figure 43: Decision matrix example (1)

Design

The design phase of a preventive maintenance project is conducted either in-house or by a supplier depending on the treatment. Some treatments can be designed in-house (chip seals, crack fill/seals), while others are designed by the supplier that is engaged by the contractor (slurry systems, fog seals). Regardless of the treatment, the basic design process, application rate determination, and selection of materials (binders and aggregates) is described in each training module.

Construction

The construction training modules are focused solely on the placement of the preventive maintenance treatment. The modules are intended to provide an inspector with accurate and sufficient information to supervise a preventive maintenance project. The information is also developed so that it can be viewed “on-demand”; meaning the information can be delivered via the Internet shortly before the commencement of a project. This is because often construction inspectors are not selected for particular projects a few days before the project start date. This is due to uncertainties about schedule and personnel availability. The construction training modules contain information on machine calibration, application rates, placement conditions, and other best practices. This approach was adopted to conform with requests from construction personnel during meetings where training issues were discussed.

RESULTS AND DISCUSSION

From the needs analysis questionnaires a number of observations can be made. Starting with the results obtained from the concepting needs analysis it is apparent that Iowa DOT personnel generally feel that they understand the importance of preventive maintenance, road deterioration behavior, background information on crack filling/sealing and fog seals, and the need to properly time treatments (**Table 19**). On the other hand, the analysis shows that they are less confident about selecting the right treatment, matching distresses with treatments, using decision matrices as a tool, and overall information on seal coating (chip seals). In fact, four of the respondents had never seen an example of a decision matrix that could be used as a guideline (similar to the one on **Figure 43**).

# Subject	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1. PM Importance	4	14	2	1	0
2. Experience	2	7	6	6	0
3. Road Deterioration	3	9	6	3	0
4. 3R's	3	9	9	0	0
5. Selection Confidence	4	5	8	4	0
6. Road Distresses	3	7	10	1	0
7. Treatments					
a. Crack Fill/Seal	3	14	3	1	0
b. Slurry Systems	2	8	7	4	0
c. Seal Coating	2	5	10	4	0
d. Fog Seal	1	11	6	3	0
8. Decision Matrices	0	6	11	4	0
9. Timing	2	16	3	0	0

Table 19: Concepting needs analysis results

The questionnaire also requested that the respondents rate which training technique would they find more effective and the most convenient. From the options provided (**Table 20**), it is clear that a short face-to-face meeting with online references for future access is not only the most effective method but also the most convenient from their point of view. This was also confirmed in meetings for the selection and concepting phase as well as the design phase. Respondents were requested to rate the methods from 1 to 5, with 1 being the most effective or convenient. For purposes of analysis, an inverse point scale was assigned to their rating (1=5points while 5=1point).

Effective Training Technique:	
<i>Full day face-to-face with quizzes.</i>	62
<i>Short face-to-face with online references.</i>	76
<i>Online course with a follow up meeting.</i>	72
<i>Online course with quizzes and discussion boards.</i>	67
<i>Quick online video.</i>	54
Convenient and Realistic Training Technique:	
<i>Full day face-to-face with quizzes.</i>	55
<i>Short face-to-face with online references.</i>	80
<i>Online course with a follow up meeting.</i>	69
<i>Online course with quizzes and discussion boards.</i>	64
<i>Quick online video.</i>	63
<i>Scale: 1-5pts, 2-4pts, 3-3pts, 4-2pts & 5-1pt.</i>	

Table 20: Concepting training method results

In the case of the design phase, the needs analysis shows that respondents perceive they have the knowledge necessary to review Iowa DOT specifications with regard to crack sealing/filling and that they have the knowledge necessary to understand about aggregate and binder compatibility issues for seal coats. The results also show that respondents are not comfortable with aggregate and/or binder selection for slurry systems, seal coats, and fog seals. Also, they expressed interest in designing application rates for seal coats mentioning the Minnesota Seal Coat Handbook(7) as a possible reference.

The option of full day face-to-face sessions with quizzes stood out as an option that they did not find effective or convenient. All other options had very similar results varying by less than 3 points. As a result of this input the approach taken by the authors was to develop a presentation and a video lecture that could be used in both situations: face-to-face and online.

Finally, in the case of the construction personnel they were very adamant about having on-demand videos based on the needs analysis that was conducted verbally. The reason for this decision is that personnel are only assigned to a project a few days before work begins and they do not wish to receive training unless it is relevant to their assignment. With regard to what were their needs, two aspects stood out. Equipment calibration was a

factor that needed to be incorporated. Probably the most important one was the need for visual interpretations of best practices and poor practices, providing images that would help them in the inspection of the job that they will perform.

CONCLUSION

Many road and highway authorities are using preventive maintenance techniques and increased staff training would be helpful. In this research project, a template for a learning management system has been developed to address this need. An example system is being developed for the Iowa DOT. In developing this example system, a knowledge gap has been identified for all three phases of preventive maintenance projects (concepting, design, and construction) and the training modules have been developed to address the current training needs. It is evident that employees involved with each phase have different needs and different perspectives on what they consider to be the major issues and concerns about various preventive maintenance techniques and what would be the most appropriate method of training.

In the future the developed training modules could be incorporated into a learning management system which could track training progress on preventive maintenance treatments. An expected outcome is that better training would result in better inspection and contract administration which would ultimately result in more successful and long-lasting preventive maintenance treatments.

ACKNOWLEDGEMENT

The Iowa DOT sponsored the research described in this paper. Also, Fracis Todey and other Iowa DOT staff served on the technical advisory committee for this project. Tim Hoerner (North Dakota State University) and Jeff Lemna (The Walsh Group) provided information on the development of learning management systems. Dr. Douglas Gransberg (Iowa State University), Keith Knapp & Omar Smadi (Iowa State University Institute for Transportation), Jim Rowing (Peter Kiewit, Inc), and Dan Gee (Gee Asphalt) provided overall information on regards to current preventive maintenance and training practices. Bill Rosener (Asphalt Paving Association of Iowa) gave us an opportunity to present our research in the Greater Iowa Asphalt Conference. Their support is gratefully acknowledged.

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**APPENDIX B TRB PAPER: LEARNING MANAGEMENT SYSTEM
DEVELOPMENT FOR PAVEMENT PRESERVATION APPLICATIONS**

Learning Management System Development for Pavement Preservation Applications

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ABSTRACT

A learning management system (LMS) is a network of information where groups of people can use a mode, such as the internet, to communicate and collaborate in order to build and share knowledge (1). Currently, the Iowa Department of Transportation (DOT) is seeking to incorporate a training program or system to educate its' employees on pavement preservation strategies and techniques. It is critical to understand that experience is a key factor in adult learning (6). The objective of this research is to develop a learning management system that addresses four pavement preservation techniques (chip seals, fog seals, slurry systems, and crack filling/sealing) as they are dealt with during the project phases of selection, design, and construction. Existing similar systems from the Upper Great Plains Transportation Institute and the National Highway Institute along with the Instructional System Development model were used as templates and guides in order to develop a LMS. Through several meetings with the department specific needs for each treatment at each phase were identified and addressed throughout the development of training modules. The training modules have been completed and are ready to be implemented.

INTRODUCTION

A learning management system (LMS) is a network of information where groups of people can use a mode, such as the internet, to communicate and collaborate in order to build and share knowledge (1). LMS are commonly found in the education field and mostly at the collegiate level, but the principles on which academic LMS are built can also be applied to other fields. Industries with constantly changing technologies and techniques can benefit from a LMS focused on adult training.

At the Upper Great Plains Transportation Institute (UGPTI) Tim Horner and others have developed a learning management system with the same ending goals. They have used presentations, webinars, and other online learning techniques within their pavement preservation LMS. The National Highway Institute (NHI) also has an online pavement preservation LMS titled Pavement Preservation Treatment Construction Guide (PPTCG). Both UGPTI and NHI's structures were used as a LMS template for the development of the proposed pavement preservation training program. The developed LMS is based on the traditional instructional system development (ISD) model. The ISD model consists of 5 steps: needs analysis, design, development, implementation, and evaluation (2). The 5 step process will yield a very well rounded LMS for the implementation of pavement preservation techniques. The findings of this research will emulate other LMS throughout the country and, although it has been lightly personalized for the Iowa DOT, it can serve as a basis in other states.

Adult and Online Learning

In order to implement an online LMS to teach adults on pavement preservation it is essential to first understand how adults learn and how online learning can be used as an adult teaching tool. Adults are self-directed, goal-oriented, relevancy oriented, and practical learners (3). This type of information was used as an outline for how the content was developed within the pavement preservation presentations. Because the concentration of experience rather than age is the key factor in adult learning (4), information obtained directly from the prospective adult users is needed as the basis for the LMS design. An essential step in developing effective online training is to know the intended training audience (5). Face to face meetings with the future trainees will help form more accurate training modules and a more useful LMS.

OBJECTIVE

The objective of this research is to develop a learning management system that addresses four pavement preservation techniques (chip seals, fog seals, slurry systems, and crack filling/sealing) as they are dealt with during the project phases of selection, design, and construction. To accomplish this primary goal the current knowledge gap in regards to pavement preservation must be identified. Once this has been done through needs analysis, the development of training modules will focus on reiterating basic knowledge and addressing such gaps. In order to validate the effectiveness these modules, evaluations and feedbacks will be developed.

METHODOLOGY

Currently, the Iowa Department of Transportation (DOT) is seeking to incorporate a training program or system to educate its' employees on pavement preservation strategies and techniques. Pavement preservation includes a set of cost-effective surfacing techniques that can be used to extend the life of bituminous pavements (6). The Iowa DOT wishes to implement training focusing on the following four pavement preservation treatments: slurry systems, chip seals (seal coats), crack fill/seals, and fog seals. Due to retirements and personnel changes within the department throughout the past decade, the department lacks experienced staff in all phases of pavement preservation projects. In order to further the implementation of a strong pavement preservation program, the Iowa DOT, with the help of researchers, will begin to develop a LMS with a focus on pavement preservation.

A meeting held in October 18, 2011 became the starting point for developing a learning management system for pavement preservation. In this meeting, with personnel from the Iowa DOT, the three different staff groups to be trained on pavement preservation were identified. Staff from the maintenance group, design group, and construction group attended the meeting and pointed out what were their overall needs. From this meeting it was clear that each group needed to be trained individually on each of the treatments. **Table 21** shows a matrix developed to organize and identify the progress of the research on different stages: needs analysis, presentations, feedbacks, and evaluations. The example shown is the presentation matrix.

Presentation Development Matrix				
Presentation Category	Treatments			
	<i>Seal Coating</i>	<i>Fog Sealing</i>	<i>Slurry Systems</i>	<i>Crack Sealing/Filling</i>
<i>Introduction</i>	x	x	x	x
<i>Concepting (Selection)</i>	x			
<i>Design</i>	x	x	x	x
<i>Construction</i>	x	x	x	x

Table 21: Structure used for training development (x = completed)

RESULTS AND DISCUSSION

Introduction to Treatments

In the October meeting DOT staff members mentioned that there is an overall need for everyone within the department to know why it would be important to push forward with the pavement preservation approach. Taking into account this detail, it was decided to provide training modules that would determine the importance of applying pavement preservation treatments while also introducing each treatment (definition, benefits, distresses addressed, variations, and disadvantages). These first introductory modules would contain an overall point of view with nothing specific to any particular staff, in other words, something that would apply to each group (maintenance, design, and construction). These presentations

would also serve as a good starting point for any future staff member working for the first time with pavement preservation techniques.

Although each treatment (chip seals, fog seals, slurry systems, and crack filling/sealing) has its own introduction presentation, the opportunity to develop an extra presentation for chip seal introduction was realized. The reason behind it is that there exist numerous variations to chip seals application. Although the Iowa DOT only specifies single and double seals, a staff member may be interested in learning more about other variations.

Concepting

Concepting refers to the process by which a road and treatment is selected for pavement preservation. Because not every treatment can be applied on every road, it was decided to develop one training module to present the importance of matching each treatment with its appropriate road and all the factors that need to be consider. Only one module was needed since at this point the main objective is to select the right treatment for the right road at the right time (known as the 3R's of pavement preservation). In other words, having one presentation comparing treatments and demonstrating the appropriate and inappropriate occasion on which to apply each treatment was the best approach.

The maintenance staff is the group in charge of this selection process. To them it was critical to have an understanding of the importance of making the right selection. Specially, selecting the treatment at the right time as time is crucial in a pavements deterioration life.

Design

Developing design training modules was probably one of the biggest challenges faced. The reason is that some treatments are designed in-house while others are designed by the supplier. In this case it was difficult to determine what information to include. Nonetheless, chip seals and crack seals/fills were determined to be in-house design while slurry systems and fog seals were supplier designed. In general, for every design training module developed topics such as materials and binder-aggregate compatibility were included.

Chip seals are probably the most extensive designs among the pavement preservation treatments. The major reason for it is that an application rate needs to be determined for the aggregate application and then another application rate needs to be determined for the binder application, and finally some adjustments need to be made. Although Iowa DOT specification provide determined application rates for chip seals, on a meeting held in June 19, 2012 some of the design staff members mentioned the interest to adopt a chip seal design system similar to the one found in the Minnesota Seal Coat Handbook. For this reason, it was decided to develop an extra chip seal design training module that takes a step-by-step approach of a chip seal design example using the Minnesota Seal Coat Handbook design process, also known as the McLeod Method.

Crack fill and crack seal treatments are designed within the Iowa DOT as well. This treatment design is not overly complicated and this is reflected in the development of the

training module. The module focuses on the options the designer has for certain scenarios and how the options should be used.

The design of slurry system and fog seal treatments is not developed directly by the department. This is reflected in the design training module as it is developed to focus on understanding the overall design process and material properties. For slurry systems each step and test is explained so that a design engineer is able to inspect the process to assure it has been conducted correctly.

Construction

On a meeting held on December 15, 2011 construction staff members expressed the need for an on-demand training module. The reason behind this request is that whoever will be in charge of a pavement preservation project will have knowledge about it a few days prior to application. On that same meeting, they expressed the need to have visual best and worst practices examples. Providing a good amount of visual images will help construction inspectors retain and associate the information necessary in the field. Construction training modules were developed to provide inspection responsibilities, pre-application and post-application responsibilities, best practices images, troubleshooting solutions, and calibration procedures.

In the case of chip seals, special attention was given to equipment calibration since two pieces of equipment (chip spreader and asphalt distributor) need to be calibrated. Calibration of the machines helps assure that appropriate application rates of aggregate and binder are being applied. Also, it became eminent to portray the importance of the rollers on a chip seal application. Rollers are what some professionals in the field consider to be the most important piece of machinery as they are in charge of properly embedding the aggregate in the binder.

For fog sealing, most of the information included in the construction module was similar to the one provided in the chip seal construction module (asphalt distributor inspection, pre-application, and troubleshooting). The difference came from the best practices examples and a section on water testing added. Fog seals consist of an application of diluted asphalt which sometimes needs to be adjusted in the field by the addition of water.

The information presented in the slurry systems construction training module is designed to give an inspector sufficient, on-demand, information on what steps should be taken to ensure a successful project delivery. Similar to chip sealing, the calibration of the equipment is very important to ensure that aggregate, binder, and additives are being combined correctly. Also, surface preparation is critical to the success of a slurry application as it provides proper bonding to the existing pavement.

Since there is vast experience within the department on crack filling and crack sealing treatments this area was not one of concern for the construction phase. The information in the training module is designed to give a new employee general but sufficient information on the process for how to apply a successful crack fill or crack seal treatment.

CONCLUSION

Using existing LMS structures as model and following the ISD model, it has been found that an effective LMS can be developed specific to certain needs. This was completed by initial needs analysis conducted via face to face meetings. This aided in gaining a sense of who the recipients were and the training that was desired. The LMS was first designed around the information obtained in the initial meetings. By doing this, the LMS became specialized and reflected the specific needs of each group within the department. This is a very important step since it the basis for the training content included in the LMS. To determine whether the information compiled and training module design were accurate, relevant, and useful it was face validated via presentation to colleagues and, more importantly, professionals within the industry and department. The final product is a LMS containing information that meets the specific needs of the entity and that is ready for implementation.

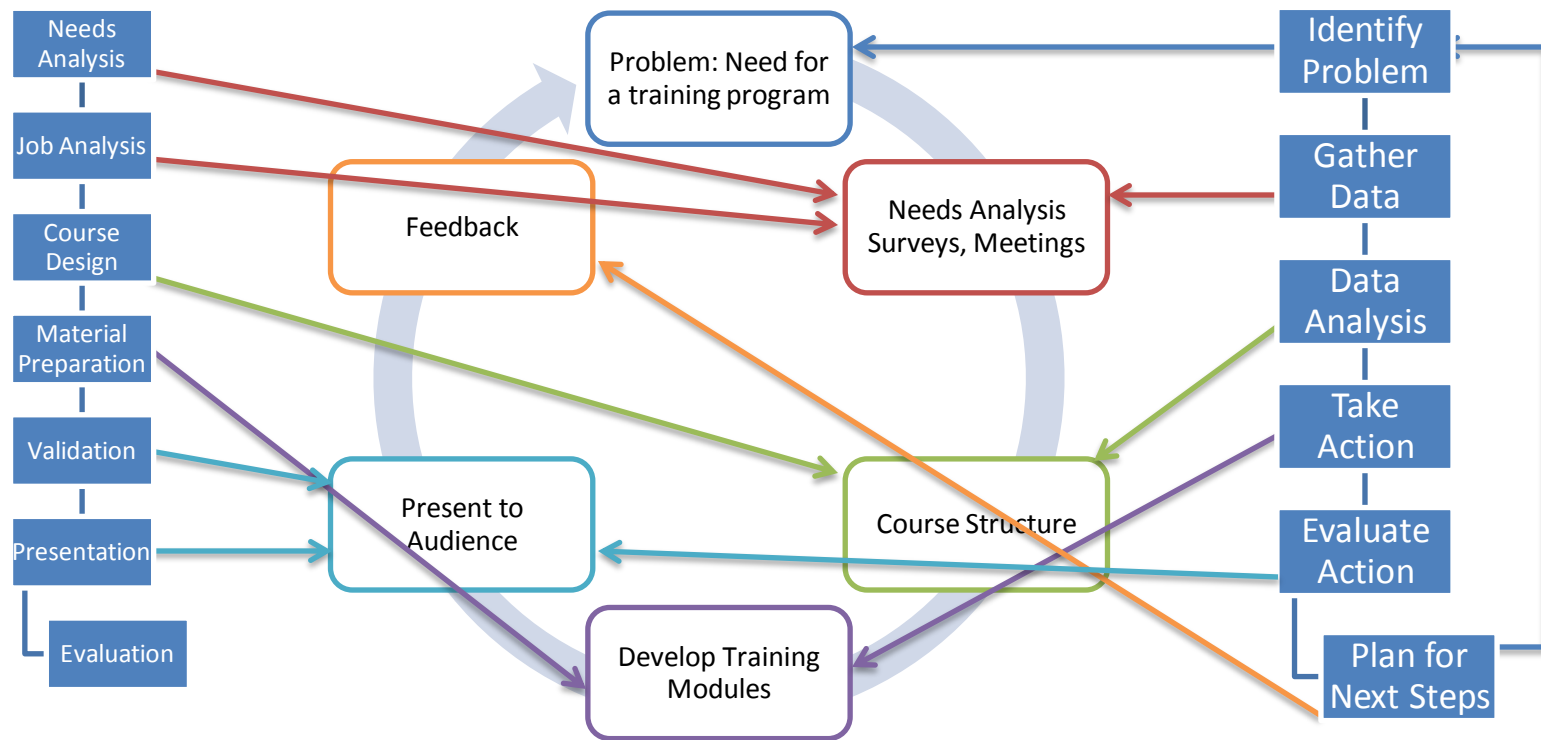
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APPENDIX C RESEARCH METHODOLOGY BASED ON JOB TRAINING STRUCTURE AND ACTION RESEARCH



APPENDIX D CONCEPTING NEEDS ANALYSIS QUESTIONNAIRE

PM Treatments: Concepting Questionnaire

The following is a questionnaire intended to recognize the current level of knowledge and experience within the Iowa DOT maintenance division employees on preventive maintenance techniques. Your responses will help researchers develop a proper approach for implementing a preventive maintenance treatment training program.

1. DOT District Number _____
2. Number of years worked in the maintenance division _____
3. Number of preventive maintenance projects Involved with _____
4. Date of last preventive maintenance project involved in (if applicable) _____

Questionnaire Definitions and Guidelines:

PM = Preventive Maintenance and includes these PM treatments: crack fill, crack seal, seal coat, micro-surface, slurry seal, and fog seal.

Comments – (if necessary) This is a designated area for you to explain, in more detail, the reasons for your rating or just some overall comments and/or concerns. Refer to the follow example:

Question	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Comments
I feel confident selecting or matching a road with its appropriate treatment according to the roads characteristics and conditions.			x			I know what conditions each treatment addresses but lack knowledge on how to take into account road's characteristics like volume and traffic speed.

Question	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Comments
----------	----------------	-------	---------	----------	-------------------	----------

1. I have a strong understanding of the importance and benefits of PM treatments.						
2. I have an extensive amount of experience and/or training on PM treatments						
3. I have a strong understanding of the road's behavior and deterioration through time.						
4. I have a clear understanding of the importance on selecting the right road at the right time with right treatment.						
5. I feel confident selecting or matching a road with its appropriate treatment according to the roads characteristics and conditions.						
6. I have a clear understating of the different distresses a road can experience and their causes.						
7. For each of the following treatments, I feel confident knowing where and when is the right time to apply them.						
a. Crack Fill/Seal						
b. Slurry Systems						
c. Seal Coating						
d. Fog Seal						
8. I have seen some decision matrices on regards to how to select the appropriate						

treatment and I feel they are helpful and effective. (If you haven't seen them, write it in the comments.)						
9. I understand the importance of right timing and the difference between preventive and corrective.						

Training Technique Section

1. On a scale from 1-5, 1 being most effective, rank the following training techniques on how EFFECTIVE you believe they would be as a possible training method for preventive maintenance treatments.

- A full day face to face training session with lectures/discussion and follow up quizzes.
- A shorter face to face training session with quick online reference videos available at any time.
- A basic online course followed up by a set date for a face to face or video conference meeting to discuss questions.
- A complete online course with online material, quizzes, and discussion boards to complete at the user's pace.
- A quick online video reference with online material.

2. On a scale from 1-5, 1 being most realistic and convenient, rank the same training techniques on how REALISTIC and CONVENIENT you believe they would be to possibly use as a training method within the IDOT for preventive maintenance treatments.

- A full day face to face training session with lectures/discussion and follow up quizzes.
- A shorter face to face training session with quick online reference videos available at any time.
- A basic online course followed up by a set date for a face to face or video conference meeting to discuss questions.
- A complete online course with online material, quizzes, and discussion boards to complete at the user's pace.
- A quick online video reference with online material.

Additional Overall Comments:

APPENDIX E DESIGN NEEDS ANALYSIS QUESTIONNAIRE

PM Treatments: Design Needs Analysis

The following is a questionnaire intended to recognize the current level of knowledge and experience within the Iowa DOT design division employees on preventive maintenance techniques. Your responses will help researchers develop a proper approach for implementing a preventive maintenance treatment training program. Take note some questions may not apply to all PM treatments.

5. DOT District Number _____
6. Number of years worked in the design division _____
7. Number of preventive maintenance projects Involved with _____
8. Date of last preventive maintenance project involved in (if applicable) _____

Questionnaire Definitions and Guidelines:

PM = Preventive Maintenance and includes these PM treatments: crack fill, crack seal, seal coat, micro-surface, slurry seal, and fog seal.

Comments – (if necessary) This is a designated area for you to explain, in more detail, the reasons for your rating or just some overall comments and/or concerns. Refer to the following example:

Question	Strongly Agree	Agree	Indifferent	Disagree	Strongly Disagree	Comments
For each of the following treatments, I feel comfortable reviewing treatment designs against the Iowa DOT specification.						
a. Crack Fill/Seal						
b. Slurry Systems			X			I know the process but I have not actually done a review myself, I would like to know more about it.
c. Seal Coating						
d. Fog Seal						

Question	Strongly Agree	Agree	Indifferent	Disagree	Strongly Disagree	Comments
10. I have a strong understanding of the importance and benefits of PM treatments.						
11. I have an extensive amount of experience and/or training on PM treatments.						
12. I have a strong understanding of the different types of emulsions such as cutbacks, asphalt emulsions, cationic and anionic emulsions.						
13. For each of the following treatments, I am familiar with the different types of aggregate gradation and properties.						
e. Slurry Systems						
f. Seal Coating						
14. For each of the following treatments, I have experience with the step by step design calculation process.						
g. Seal Coating						
15. For each of the following treatments, I feel comfortable reviewing treatment designs against the Iowa DOT specification.						
h. Crack Fill/Seal						
i. Slurry Systems						
j. Seal Coating						
k. Fog Seal						
16. For each of the following treatments, I understand the importance of aggregate and binder compatibility.						
l. Slurry Systems						
m. Seal Coating						
17. For each of the following treatments, I						

understand the aggregate and/or binder selection process.						
n. Slurry Systems						
o. Seal Coating						
Fog Seal						

Training Technique Section

3. On a scale from 1-5, 1 being most effective, rank the following training techniques on how EFFECTIVE you believe they would be as a possible training method for preventive maintenance treatments.

- A full day face to face training session with lectures/discussion and follow up quizzes.
- A shorter face to face training session with quick online reference videos available at any time.
- A basic online course followed up by a set date for a face to face or video conference meeting to discuss questions.
- A complete online course with online material, quizzes, and discussion boards to complete at user's pace (no meetings required).
- A quick online video reference with online material.

4. On a scale from 1-5, 1 being most realistic and convenient, rank the same training techniques on how REALISTIC and CONVENIENT you believe they would be to possibly use as a training method within the IDOT for preventive maintenance treatments.

- A full day face to face training session with lectures/discussion and follow up quizzes.
- A shorter face to face training session with quick online reference videos available at any time.
- A basic online course followed up by a set date for a face to face or video conference meeting to discuss questions.
- A complete online course with online material, quizzes, and discussion boards to complete at user's pace (no meetings required).
- A quick online video reference with online material.

Additional Overall Comments:

APPENDIX F CONSTRUCTION NEEDS ANALYSIS QUESTIONNAIRE

PM Treatments: Construction Questionnaire

The following is a questionnaire intended to recognize the current level of knowledge and experience within the Iowa DOT construction division employees on preventive maintenance techniques. Your responses will help researchers develop a proper approach for implementing a preventive maintenance treatment training program.

DOT District Number _____
 Number of years worked in the construction division _____
 Number of preventive maintenance projects Involved with _____
 Date of last preventive maintenance project involved in (if applicable) _____

Questionnaire Definitions and Guidelines:

PM = Preventive Maintenance and includes these PM treatments: crack fill, crack seal, seal coat, micro-surface, slurry seal, and fog seal.

Comments – (if necessary) This is a designated area for you to explain, in more detail, the reasons for your rating or just some overall comments and/or concerns. Refer to the follow example:

Question	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Comments
For each of the following treatments, I am very familiar with the equipment controls and settings.						
p. Crack Fill/Seal			X			I know a lot about the saw cutting machine but I lack knowledge with a router machine
q. Micro-surfacing	x					
r. Seal Coating					x	I have no familiarity with equipment settings for seal coating.
s. Fog Seal		x				

Question	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Comments
18. I have a strong understanding of the importance and benefits of PM treatments.						
19. I have an extensive amount of experience and/or training on PM treatments						
20. I have a strong understanding of the pre-application procedures for preparing a road for PM treatments.						
21. When I am in the field, I have confidence in being able to solve problems regarding the aggregate and binders of PM treatments						
22. For each of the following treatments, I am very familiar with the equipment controls and settings.						
a. Crack Fill/Seal						
b. Micro-surfacing						
c. Seal Coating						
d. Fog Seal						
23. For each of the following treatments, I feel comfortable with the calibration of the machinery.						
e. Crack Fill/Seal						
f. Micro-surfacing						
g. Seal Coating						
h. Fog Seal						
24. For each of the following treatments, I feel comfortable with the application process and am confident inspecting it.						
i. Crack Fill/Seal						
j. Micro-surfacing						

k. Seal Coating						
l. Fog Seal						
25. For each of the following treatments, I can visually identify when a treatment has been applied correctly.						
m. Crack Fill/Seal						
n. Micro-surfacing						
o. Seal Coating						
p. Fog Seal						
26. For each of the following treatments, I feel prepared to identify and solve problems in the field during application						
q. Crack Fill/Seal						
r. Micro-surfacing						
s. Seal Coating						
t. Fog Seal						
27. For each of the following treatments, I feel confident with the post-application procedures.						
u. Crack Fill/Seal						
v. Micro-surfacing						
w. Seal Coating						
x. Fog Seal						
28. For each of the following treatments, I am able to visually identify when a road is ready to be opened to traffic.						
y. Crack Fill/Seal						
z. Micro-surfacing						
aa. Seal Coating						
bb. Fog Seal						
29. For the following treatments, I feel confident inspecting special situations						

such as round-a-bouts and cul-de-sacs.						
cc. Crack Fill/Seal						
dd. Micro-surfacing						
ee. Seal Coating						
ff. Fog Seal						

Training Technique Section

5. On a scale from 1-5, 1 being most effective, rank the following training techniques on how EFFECTIVE you believe they would be as a possible training method for preventive maintenance treatments.

- ___ A full day face to face training session with lectures/discussion and follow up quizzes.
- ___ A shorter face to face training session with quick online reference videos available at any time.
- ___ A basic online course followed up by a set date for a face to face or video conference meeting to discuss questions.
- ___ A complete online course with online material, quizzes, and discussion boards to complete at the user's pace.
- ___ A quick online video reference with online material.

6. On a scale from 1-5, 1 being most realistic and convenient, rank the same training techniques on how REALISTIC and CONVENIENT you believe they would be to possibly use as a training method within the IDOT for preventive maintenance treatments.

- ___ A full day face to face training session with lectures/discussion and follow up quizzes.
- ___ A shorter face to face training session with quick online reference videos available at any time.
- ___ A basic online course followed up by a set date for a face to face or video conference meeting to discuss questions.
- ___ A complete online course with online material, quizzes, and discussion boards to complete at the user's pace.
- ___ A quick online video reference with online material.

Additional Overall Comments:

APPENDIX G-1 CONCEPTING TRAINING PRESENTATION

Slide 1



Slide 2



Let's remember that preventive maintenance does not add structural value to the road, it simply keeps the road in good condition for an extended period of time.

If we were to skip preventive maintenance and let the road deteriorate over time, a point will be reached where the approach necessary to deal with the road is a corrective treatment. A corrective treatment can be compared to building a new road.

As users we want to get from point A to point B in the most convenient way possible. Preventive maintenance could provide users with a smooth ride and less car/tire deterioration.

Slide 3

IMPORTANCE OF CONCEPTING TRAINING

- Training should help you:
 - Understand the overall road selection process
 - Identify road deteriorations and/or conditions that make a road a good candidate for preventive maintenance
 - Explore the different alternatives or treatments for road maintenance depending on such conditions
 - Value the importance of selecting the right treatment for the right road at the right time

Slide 4

PREVENTIVE MAINTENANCE

What is it?

- Timely use of alternative treatments to prolong the life of the road

Why do

-
-




Photo by Angel M. 2017 Cal Pymesser

Photo by CalTrans

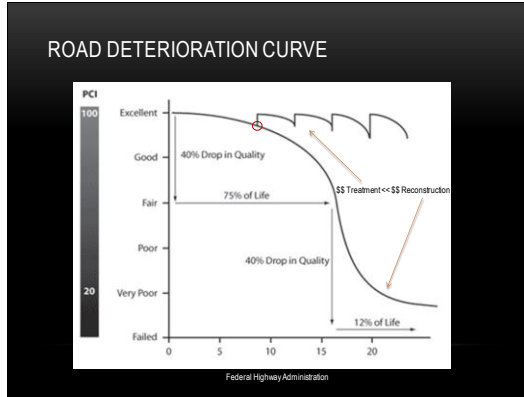
What is it

- Preventive Maintenance is like painting your house. It doesn't add any structural integrity but it gives the house a better surface and helps prevent major deterioration. In the same way, if you paint a house that is near falling down, the paint won't stop it from doing so.

Why use it

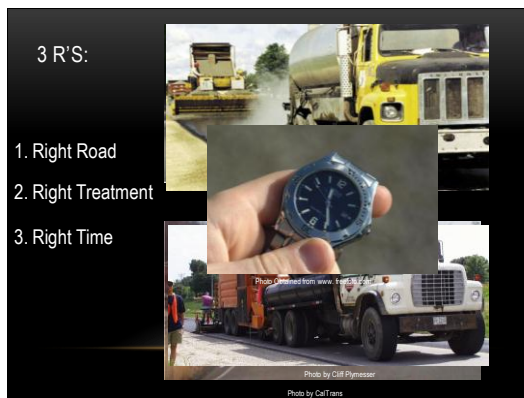
- Remember that the reasons we want to use preventive maintenance is because of the added benefits, but if preventive maintenance is not properly done the benefits are non-existent. Using preventive maintenance in the wrong way can actually be worse than doing nothing at all.
- With that said, when done correctly, a preventive maintenance adds many benefits to the users. The two most important are prolonging the lives of good roads and cutting down costs. There are also other benefits such as public satisfaction, public convenience, and, in some ways, sustainability.

Slide 5



- This illustration is a typical road deterioration curve. Each road is different in terms of the increments of time it takes to deteriorate, but all roads follow this characteristic curve.
- You can see the benefits I mentioned early. The road's life can be prolonged using treatments while saving money in the long run.
- As we will talk about later, the hardest part is finding the right time to apply the treatment before the road drops off.
- If a treatment is applied after the road has substantially deteriorated then the treatment application is considered more of a corrective maintenance than a preventive maintenance. (i.e. a slurry system will usually hold for 5-7 years but it could be placed on a very poor road and only hold it together for 1-2 years, giving the department time to find funding for reconstruction)

Slide 6



- As discussed earlier, in order to achieve the maximum benefits of preventive maintenance it must be incorporated properly.
- Finding the Right road, applying the Right treatment at the Right time are the key ingredients to a successful preventive maintenance.
- Each of the 3R's goes hand in hand.
- Throughout the rest of this presentation best practices for selecting roads will be discussed.

Slide 7

Asset Management

- You already be using it, but it may not be called asset management. Each and every agency has its own method of asset management.
- We are calling it asset management because you are allocating resources and funds to correct and/or maintain roads, which are a majority of an agencies assets (other assets are signs and bridges)
- When selecting a road the following characteristics are commonly considered in asset management programs:
 - Pavement Condition Index (PCI)
 - Traffic Volume (AADT)
 - Traffic Velocity
 - Road Classification (Primary, residential)
 - Proximity (# of business, # of residencies)
 - Budget (how much do you have to spend?)

Windshield Survey

Driving around roads for which the agency is responsible for Document the conditions of roads

From survey information they determine which roads will require a preventive maintenance treatment

Life Cycle Cost Analysis

It is important to consider the cost of the possible applications.

More than that, it is recommended to consider the life cost of such treatments. Treatments have different lifespans, so considering the equivalent annual cost of available treatments is a better interpretation of the real cost-benefit ratio.

Slide 8

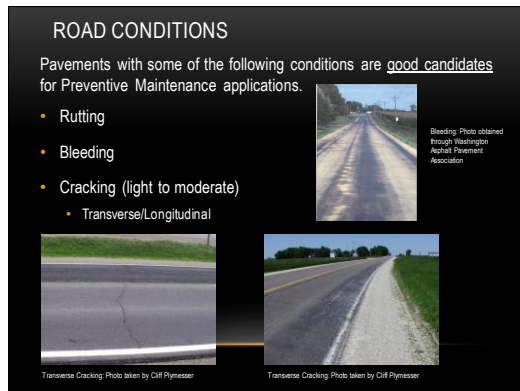


Oxidation – caused by exposure to sun and water, binder becomes brittle and aggregate can be easily removed. Surface of pavement is light gray.

Raveling – also known as weathering, aggregate or binder has worn away due to oxidation, traffic, snow plow (picture)

Pocking – individual pieces of aggregate have dislodged from the surface leaving small voids.

Slide 9



Rutting – a surface depression that runs parallel to traffic and is commonly located in the wheel path. Rutting can be caused by unstable mix, structural failure or insufficient compaction during construction. (picture)

Bleeding – occurs when asphalt binder is pushed to the surface providing a shiny black appearance. Mix was too rich in binder.

Longitudinal cracks – run parallel to traffic and indicate structural failure. Transverse cracks – perpendicular to traffic and indicate thermal shrinkage. (picture)

Alligator cracking – interconnected cracks that resemble alligator scales,

Slide 10



usually forms in areas of high volume loads.

Seal coats – also called chip seal. Seal coat is an application of binder followed by an application of single sized aggregate chips. Seal coats are typically used in low volume roads. They provide surface waterproof and seal existing cracks while adding friction for traction. Disadvantages - They may cause dust, flyrock and noise.

Fog seals – this treatment consists of a light application of binder to the pavement. They serve to seal the surface and prevent distresses as oxidation and raveling. Disadvantages - Fog seal takes time to cure (6-8 hours) and provide low friction. Fog seals are commonly paired with seal coats to provide stability and minimize the amount of dust and flyrock.

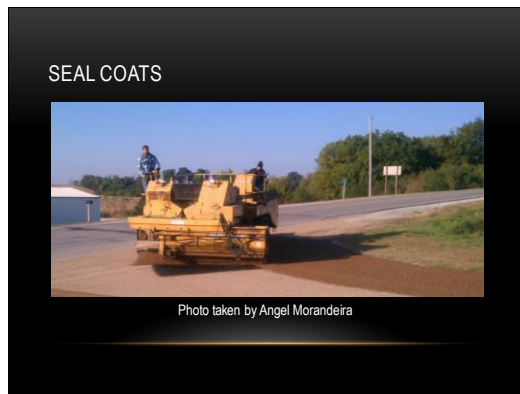
Slurry Seals/Micro-surfacing – Slurry seals and micro-surfacing are very closely related. They only differ in how they cure; slurry seal cures via evaporation while micro-surfacing cures through a chemical reaction known as breaking. Micro-surfacing and slurry seals can be used to seal surfaces, restore texture, fill cracks and ruts, and level a surface. Disadvantages – There is a longer wait time until driving is permitted when compared to seal coats. Also micro-surfacing is one of the most expensive preventive maintenance treatments.

Crack seals/fills – Crack Filling and Sealing prevents water and incompressible intrusions, improves

ride quality, slows down pavement deterioration, is cost effective, and is essential in the preventive maintenance process. Roads need to have their cracks filled or seal before a seal coat or micro-surface can be applied.

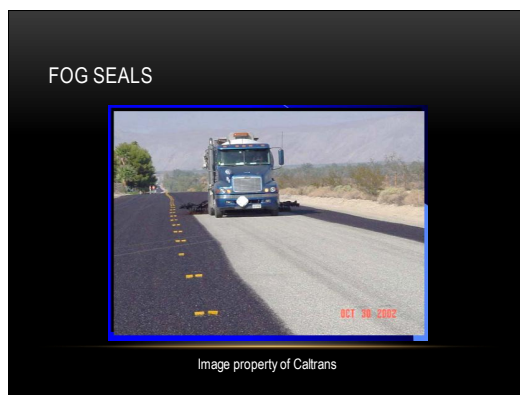
Disadvantages – Crack filling and sealing only affects a small part of the road and cannot be used to improve the entire surface. This is why other treatments need to be used with crack filling and sealing.

Slide 11



Seal coats – also called chip seal. Seal coat is an application of binder followed by an application of single sized aggregate chips. Seal coats are typically used in low volume roads. They provide surface waterproof and seal existing cracks while adding friction for traction. Disadvantages - They may cause dust, flyrock and noise.

Slide 12



Fog seals – this treatment consists of a light application of binder to the pavement. They serve to seal the surface and prevent distresses as oxidation and raveling. Disadvantages - Fog seal takes time to cure (6-8 hours) and provide low friction. Fog seals are commonly paired with seal coats to provide stability and minimize the amount of dust and flyrock.

Slide 13



Slurry Seals/Micro-surfacing – Slurry seals and micro-surfacing are very closely related. They only differ in how they cure; slurry seal cures via evaporation while micro-surfacing cures through a chemical reaction known as breaking. Micro-surfacing and slurry seals can be used to seal surfaces, restore texture, fill cracks and ruts, and level a surface. Disadvantages – There is a longer wait time until driving is permitted when compared to seal coats. Also micro-surfacing is one of the most expensive preventive maintenance treatments.

Slide 14



Crack seals/fills – Crack Filling and Sealing prevents water and incompressible intrusions, improves ride quality, slows down pavement deterioration, is cost effective, and is essential in the preventive maintenance process. Roads need to have their cracks filled or seal before a seal coat or micro-surface can be applied. Disadvantages – Crack filling and sealing only affects a small part of the road and cannot be used to improve the entire surface. This is why other treatments need to be used with crack filling and sealing.

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DECISION MATRICES

Decision Matrices on regards to which treatment to select based on the road's condition have been developed for reference.

Generalized decision matrix for selecting appropriate TMS solutions

Factor	Fog seal	Seal coat	Slurry seal	Micro-surfacing	This HMA overlay
Traffic	T	T	T	T	T
AADT < 2,000	T	T	T	T	T
2,000 < AADT < 5,000	T	←→	←→	T	T
AADT > 5,000	T	←→	←→	T	T
Bleeding	4	T	T	T	T
Raveling	4	4	T	T	T
Raveling	T	T	T	T	T
Few tight cracks	T	T	T	T	T
Cracks	4	T	4	4	T
Extensive cracking	4	T	4	4	T
Alignter cracking	4	←→	4	4	4
Low Friction	May improve ¹	May improve	May improve	May improve ²	May improve
Price (\$/SqF) ³	\$0.10-\$0.80	\$0.80	\$0.90	\$1.50	\$4.40

† Recommended 4 Not recommended ←→ Marginal
 ‡ There is a greater likelihood of success when used in lower speed traffic.
 § Not used as lower, but other states have some success.
 ¶ Fog seal will reduce friction for the first few months until traffic wears binder off of the top of aggregate.
 ** Micro-surfacing reportedly retains high friction for a longer period of time.
 †† Prices were obtained from interviews and secondary evidence from authors.
 Developed by Dr. Charles Jahren (2007)

Tendencies on regards to what treatments have been used depending on road conditions have been observed. Researches and professionals have developed decision matrices or decision trees that can be used as a reference on helping someone decide which treatment fits best. It should be noted that these are only for REFERENCE and do not have to be followed strictly. The decision should not only be based on road condition as cost, experienced labor availability and aggregate availability may also influence the decision.

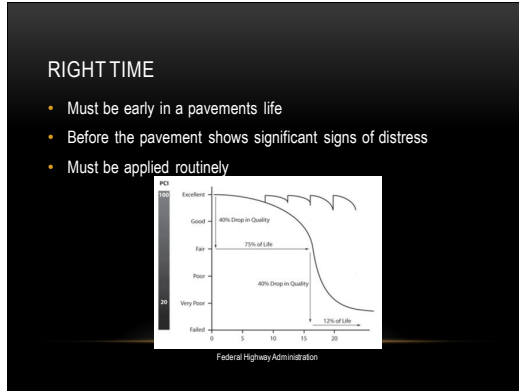
Say you had a road with 3,000 AADT, few tight cracks, and raveling. According to this matrix a fog seal and a micro are recommended.

Slide 16

Preparation Conditions	Parameters	Treatments									
		Thin Overlay	Slurry Seal	Crack Seal	Emul Seal ¹	Emul Seal ²	Chap Seal	Chap Seal	Micro-Surfacing	Micro-Surfacing	Price
Traffic	AADT Level ²	T	T	T	T	T	T	T	T	T	T
	100 - AADT < 4000	T	T	T	T	T	T	T	T	T	T
	> 4000	T	T	T	T	T	T	T	T	T	T
Rain ³	< 3 in.	T	T	T	T	T	T	T	T	T	T
	3 - 6 in.	T	T	T	T	T	T	T	T	T	T
Cracking	Low	T	T	T	T	T	T	T	T	T	T
	Medium	T	T	T	T	T	T	T	T	T	T
	High	T	T	T	T	T	T	T	T	T	T
Longitudinal	Low	T	T	T	T	T	T	T	T	T	T
	Medium	T	T	T	T	T	T	T	T	T	T
	High	T	T	T	T	T	T	T	T	T	T
Transverse	Low	T	T	T	T	T	T	T	T	T	T
	Medium	T	T	T	T	T	T	T	T	T	T
	High	T	T	T	T	T	T	T	T	T	T
Aliphatic Surface Appearance	OK	T	T	T	T	T	T	T	T	T	T
	Flicking	T	T	T	T	T	T	T	T	T	T
	Spalling	T	T	T	T	T	T	T	T	T	T
Raveling	Low	T	T	T	T	T	T	T	T	T	T
	Medium	T	T	T	T	T	T	T	T	T	T
	High	T	T	T	T	T	T	T	T	T	T
Potholes	Low	T	T	T	T	T	T	T	T	T	T
	Medium	T	T	T	T	T	T	T	T	T	T
	High	T	T	T	T	T	T	T	T	T	T
Sealing Treatment ⁴ within 24 Hours	Yes	T	T	T	T	T	T	T	T	T	T
	No	T	T	T	T	T	T	T	T	T	T
	Not Applicable	T	T	T	T	T	T	T	T	T	T
High Speed Area ⁵	Yes	T	T	T	T	T	T	T	T	T	T
	No	T	T	T	T	T	T	T	T	T	T
	Not Applicable	T	T	T	T	T	T	T	T	T	T

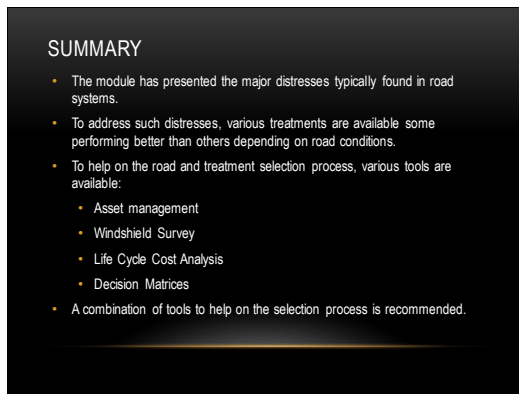
† The data pertains to specific conditions only and equipment, material and experience should be used to select the proper treatment.
 ‡ Rating list occurred over an extended period of time.
 § For AADT less than 10,000 (total) and/or traffic volume in excess of 20 percent this treatment can be effective, but is not recommended.
 ¶ Higher percentages of trucks have a significant effect on performance.
 †† Requires routine maintenance or new mix controls, typically.
 ††† Spot treatment on dry conditions only.
 †††† High Speed Area - 50 mph or greater.
 ††††† Low Friction/High Friction.
 Developed by Hicks, Seeds & Peshkin, (FPP, 2007)

Slide 17



- Figuring out the correct time is the most difficult part of preventive maintenance.
- Right time (preventive vs. Corrective)
 - Treatments done in the corrective or reconstruction phase are more of holding strategies
- One of the benefits of having a good asset management program is that it allows you to forecast the application of various treatments and give continuity to road maintenance.

Slide 18



APPENDIX G-2 SEAL COAT: OVERALL TRAINING PRESENTATION

Slide 1



Slide 2

IMPORTANCE OF OVERALL INFORMATION

This presentation should:

- Help you understand some overall information on Seal Coats as a pavement preservation technique.
- Help you identify cases where a seal coat application is appropriate and cases where it is not.
- Show some advantages and disadvantages of a seal coat application.
- Proper selection, design and construction of seal coats starts by understanding the basics of the technique, you need the background information.

Objectives of the presentation:

- Provide overall/background information on seal coats as a preventive maintenance technique.
- Show visual images of appropriate and inappropriate cases to apply seal coats.
- Identify advantages and disadvantages of seal coats.
- It all starts with background information.

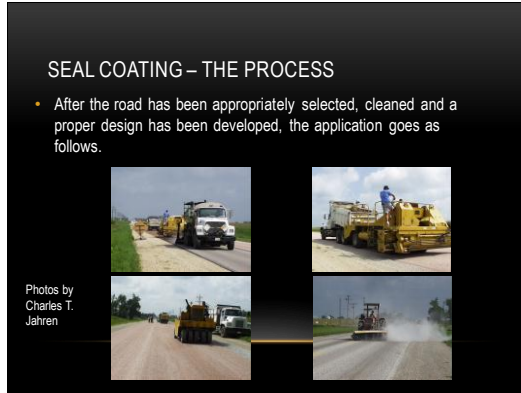
Slide 3

WHAT IS SEAL COATING?

- Seal Coating is a Preventive Maintenance Technique used in some states to keep a road in good condition at a low cost.
- Seal coats consist of a layer of binder over an structurally sound existing pavement followed by a layer of one-sized aggregate (variations exists).

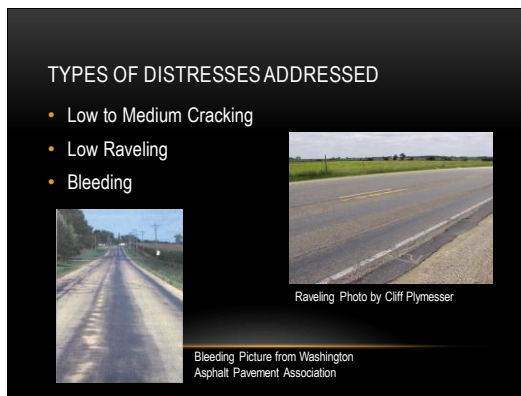
Seal coats do not add structural value to the road; it is a treatment to keep the road in good condition for a period of time at a low cost.

Slide 4



- Distributor applies a layer of binder to the road.
- As seen in the first picture, a spreader follows closely behind at the same speed as the distributor applying the aggregate to the surface.
- A couple of minutes later, rollers pass over the surface to embed the aggregate with the binder. (providing stability and skid resistance)
- Brooms go thru the surface later on to sweep away excess aggregate.
- Open to traffic.

Slide 5

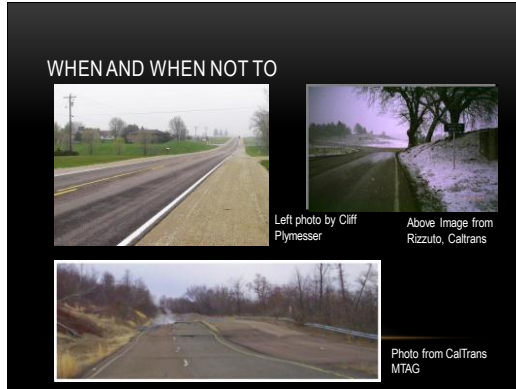


Cracks are usually transverse or longitudinal. Transverse cracks commonly represent thermal failure due to expansion/shrinkage. Longitudinal cracks commonly represent structural failure.

Raveling – also known as weathering, aggregate or binder has worn away due to oxidation, traffic, snow plow.

Bleeding – occurs when asphalt binder is pushed to the surface providing a shiny black appearance. Usually happens shortly after application and represents a mix too rich in binder.

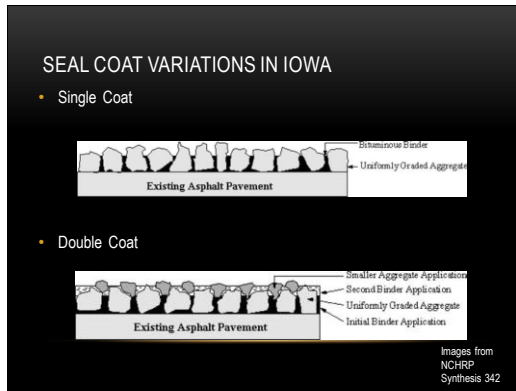
Slide 6



When – first picture shows some raveling but no major imperfections or unsound structure.

When not to – severe climate (snow, rain, high wind)
structurally unsound road,
Picture is extreme case

Slide 7



Single coats are commonly used when no special situations are present that would require the use of a double coat or any other variation.

Double coats provide less noise, additional waterproofing and are more robust than single coats, therefore they could be used when there is a high percentage of truck traffic or steep grades.

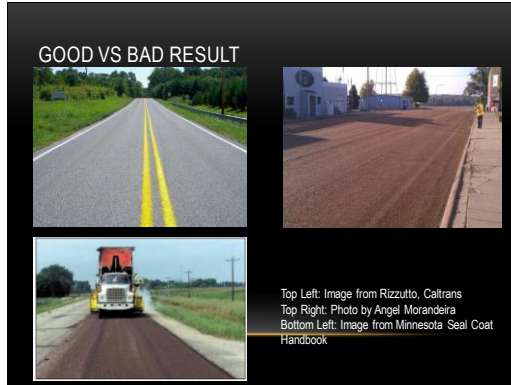
Although single and double layer coats are the two types of seal coats used in Iowa, other variations do exist and are covered in another training module called Seal Coat Variations.

Slide 8



Proper function and timed sequence of equipment is key to proper application. Checking for nozzle angles, nozzle height, and the possibility of nozzles getting clogged on the distributor are some of the inspection responsibilities.

Slide 9



Top Left photo shows the result of a proper seal coat application where it looks uniform and with no imperfections.

Top Right shows a uniform application but major distresses like rutting were not addressed correctly before application.

Bottom left picture shows an application either rich on binder or low on aggregate as the truck wheel path is exposed immediately after passing.

Slide 10

SUMMARY

- Seal coating provides many road preservation benefits but only with proper planning will these be achieved.
- It is critical to know the main distresses seal coating triggers in order to apply it properly after other distresses have been addressed.
- With many variations and options a seal coat project should be studied and analyzed by comparing all available alternatives in their different aspects.
- Due to the use of different equipment compared to other treatments, it is important to keep an eye on their proper function during application.
- Proper selection, design and construction of seal coats start by understanding the basics of the technique, you need the background information.

Conclusion:

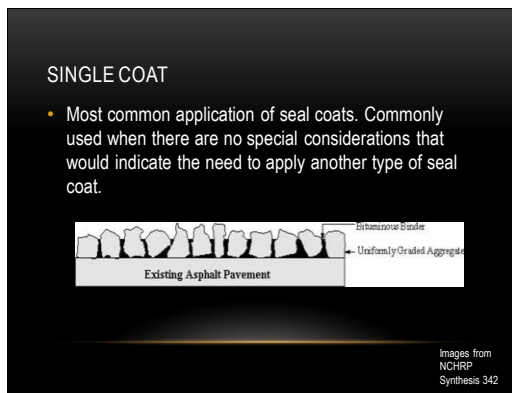
- Benefits can only be achieved with proper planning: selection, design and application.
- Major distresses like potholes and major cracks just to name a few should be addressed prior to application.
- Different types of seal coats and the availability of variations like pre-coated aggregates should be analyzed before decision.
- Careful and constant inspection is crucial for a proper application.

APPENDIX G-3 SEAL COAT: VARIATIONS TRAINING PRESENTATION

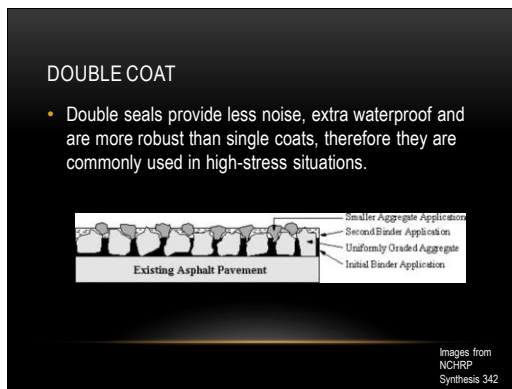
Slide 1



Slide 2



Slide 3




By high stress situations we mean roads that have high percentages of truck traffic or roads on steep grades.

Slide 4

RACKED-IN SEAL

- Racked-in seals can be used in areas where there are many turning movements as they provide an interlock between the aggregates.




Images from NCHRP Synthesis 342

Choke stone is applied to prevent the larger aggregates to dislodge before the binder is fully cured.

Slide 5

CAPE SEAL

- Cape seals are robust and provide a higher shear resistance when compared to asphalt.



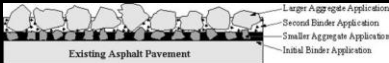
Images from NCHRP Synthesis 342

A slurry seal is a preventive maintenance technique that and is discussed in more details in other training modules.

Slide 6

INVERTED SEALS

- Called inverted due to the fact that it is a double seal upside down. Inverted seals are commonly used when needing to correct a bleeding surface.




Images from NCHRP Synthesis 342

Slide 7

SANDWICH SEAL

- Sandwich seals are commonly used to restore surfaces on raveled surfaces.




Images from NCHRP Synthesis 342

Slide 8

GEOTEXTILE-REINFORCED SEAL


- This type of seal coat is useful to treat surfaces experiencing extreme oxidation or high thermal cracking.



Images from NCHRP Synthesis 342

Geotextiles can enhance the performance of a conventional seal coat. A layer of geotextile material is placed over a layer of tack coat asphalt over the surface before applying the seal coat.

Slide 9



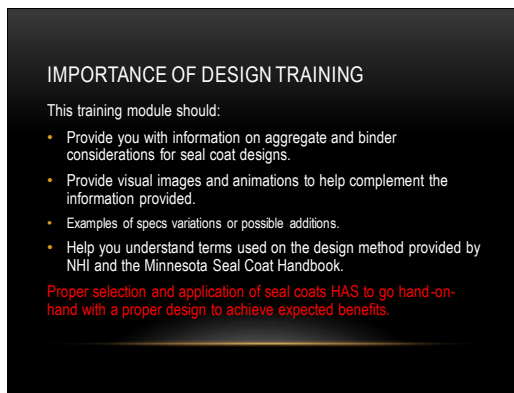
Geotextile Reinforced Seal
Photo from CalTrans MTAG

APPENDIX G-4 SEAL COAT: DESIGN TRAINING PRESENTATION

Slide 1



Slide 2



Slide 3

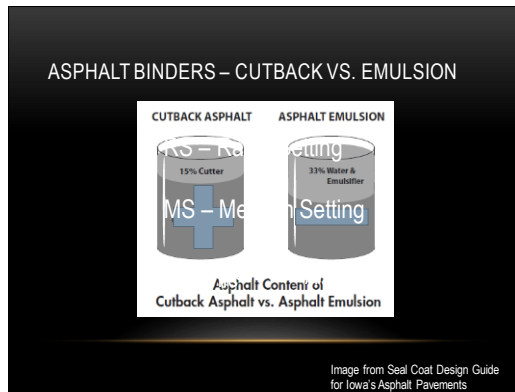


Let's remember that preventive maintenance does not add structural value to the road, it simply keeps the road in good condition for an extended period of time.

If we were to skip preventive maintenance and let the road deteriorate over time, a point will be reached where the approach necessary to deal with the road is a corrective treatment. A corrective treatment can be compared to building a new road.

As users we want to get from point A to point B in the most convenient way possible. Preventive maintenance could provide users with a smooth ride and less car/tire deterioration.

Slide 4



Cutback – asphalt cement dissolved in a solvent, typically kerosene or gasoline. Rapid curing cutbacks use gasoline while medium curing ones use kerosene. The amount of cutter affects the viscosity, thus more cutter less viscous or more fluid. The use of cutbacks has declined due to environmental and health risks.

Emulsions – consist of asphalt particles dispersed in water and chemically stabilized and suspended by emulsifiers. Emulsions are classified by their electrical charge, (+) cationic and (-) anionic, settling speed, high-float availability and viscosity.

Cationic vs anionic – cationic is used more often since aggregates used for seal coats are usually negatively charged. Cationics are less sensitive to weather, stabilize quicker. Anionics are less critical when handling, need no close attention when storing.

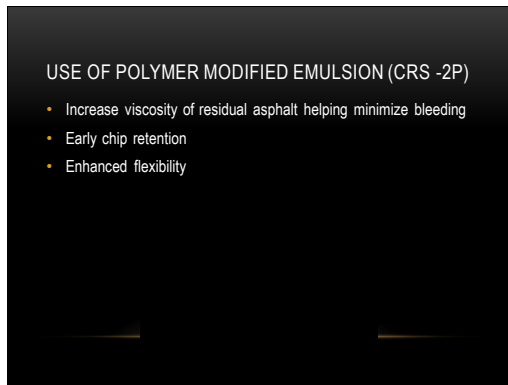
High-float contains chemicals that allow for a thicker asphalt layer and could be used with dusty aggregates.

Viscosity for emulsions is designated by numbers 1 and 2, 1 is lower viscosity thus more fluid.

Slide 5

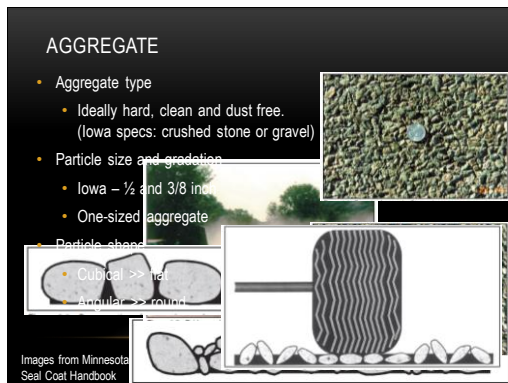


Slide 6



Example CRS-2P

Slide 7



Clean – we wouldn't want other material, like organic material, mixed with the aggregates that will later get between the aggregates and binder. Also we want to avoid an aggregate with clayey content since clay will keep the binder from adhering to the aggregate.

One-sized aggregate for a single coat so that we achieve a uniform surface and no loose aggregate is settled on top of other aggregates.

Having a distributed gradation will not only cause chips to be placed over

other chips without emulsion, but will also cause smaller chips to occupy the emulsion's space causing flushing.

Flat aggregates tend to lay on their flat side when traffic passes over it, think of it as a football

Angular aggregates help particles lock better between themselves provide more surface adherence and are less susceptible to rolling and displacement.

Slide 8

DESIGN GOAL

Binder should cover close to 70% of average chip height after trafficking.



Image from Seal Coat Design Guide for Iowa's Asphalt Pavements

50% before trafficking.

Slide 9

IOWA DOT SPECS RECOMMENDATIONS

Aggregate Size	Spreading Rate Gal./Sq. Yds. (L/m ²)	Basic Rate* Gal./Sq. Yds. (L/m ²)
Sand	0.15 - 0.20 (0.7 - 0.9)	0.15 (0.8)
3/8 inch (9.5 mm)	0.25 - 0.35 (1.1 - 1.6)	0.30 (1.4)
1/2 inch (12.5 mm)	0.35 - 0.45 (1.6 - 2.0)	0.40 (1.8)

* The basic rate will be used for design purposes.

Unless specified by the engineer:

- One Course:
 - Emulsion at 0.35 gal/yd²
 - Aggregate at 30 lb/yd²
- Two Course:
 - First layer same as One Course
 - Second layer of emulsion at 0.30 gal/yd²
 - Second layer of aggregate at 25 lb/yd²

Table from Iowa DOT Specification 2307

Slide 10

SEAL COAT DESIGN PROCESS (ACCORDING TO SEAL COAT DESIGN GUIDE FOR IOWA'S ASPHALT PAVEMENTS)

- Determine median particle size of the aggregate (MPS)
- Measure flakiness index of aggregate (FI)
- Calculate average least dimension of the seal coat (ALD)
- Determine bulk specific gravity of the aggregate (BSG)
- Calculate loose unit weight of aggregate (LUW)
- Calculate voids in the loose aggregate (VLA)
- Determine traffic waste factor (TWF)
- Determine aggregate application rate (AAR)
- Determine traffic volume factor (TVF)
- Determine pavement condition factor (PCF)
- Determine aggregate absorption factor (AAF)
- Determine asphalt content of binder (AC)
- Calculate binder application rate (BAR)
- Adjust binder application rate

Percent Waste Allowed and Traffic Waste Factor

Percent Waste Allowed	TWF
1%	1.00
2%	1.02
3%	1.03
4%	1.04
5%	1.05

Pavement

CUTBACK ASPHALT 1% Cutback, 85% Asphalt

ASPHALT EMULSION 3% Water & Emulsifier, 67% Asphalt

Asphalt Content of Cutback Asphalt vs. Asphalt Emulsion

Aggregate Type	Asphalt Content (%)
Coarse	10.00
Medium	10.00
Fine	10.00
Finest	10.00
Avg.	10.00

Images from Seal Coat Design Guide for Iowa's Asphalt Pavements

This presentation will not go through all calculations needed for designing seal coats; it will just go over the theory behind it. It shows a high-tech calculation process fairly acceptable for estimating quantities. For a design example with calculations please refer to video Seal Coat Design Example.

- We determine the gradation (particle size distribution) using the sieve test and then we plot % vs Opening size to determine the median particle size which will be the one corresponding to 50% passing.
- Flakiness is the measure of the percent, by weight, of flat particles. A small sample is taken as chips that fit through the slots are considered to be flat. Lower FI = higher % of cubical aggregate.
- ALD is a reduction of the MPS as it accounts for flakiness. ALD represents the seal coat thickness in the wheel path.
- The lower the specific gravity, the lighter the aggregate is so less pounds of aggregate will cover a specific area. The bulk specific Gravity is determined using the AASHTO T 84 test.
- LUW is needed to calculate the air voids expected between the aggregates, what will later become the space for the binder. Determined using the ASTM C29 test where 3 buckets of known volume and weight are filled with aggregate and the final weight is averaged.
- VLA is a percentage in decimal expressing the volume of the seal coat occupied by voids. It

commonly goes from 50% when placed to 30% when rolled and finally 20% when traffic has passed over it.

- Traffic waste factor addresses the aggregate that gets whipped off to the side of the road due to traffic on a fresh seal. 5% is commonly used for low-volume residential areas and 10% for higher-speed roads.

- It is a good practice to check your AAR by spreading the amount of aggregate in a one square yard box and seeing if the layer is one-stone thick.

- The higher the traffic volume the lower the binder application rate, this happens because with higher volume of traffic more aggregates are forced onto their flat side so less binder is needed to cover 70% embedment.

- Newer smoother roads with less voids require less binder and the other way around.

- Aggregates absorb some of the binder applied therefore the binder needs to be corrected for this factor. This factor can be computed using the AASHTO T84 test. As a general rule if the absorption is 1.5% or higher an AAF of 0.02gal/yd² is recommended, if less than 1.5% then these aggregates does not need correction.

- ACB depends on the binder to be used expresses as a percentage on decimal.

- This will determine how many gal/yd² will be needed for the seal coat.

- This rate may need adjustments due to the fact that roads are not

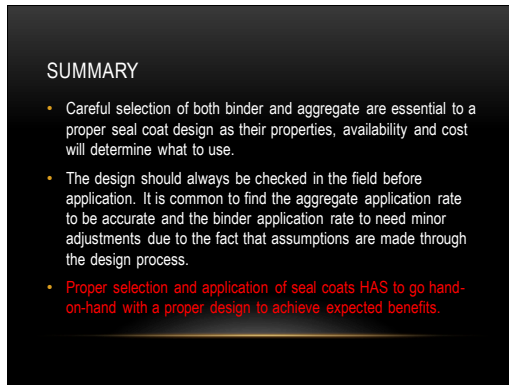
perfect and thus some areas may need less or more binder along the road.

Slide 11



The smaller the circle of sand spread is, the more binder will be needed. Sand fills the voids of the pavements, thus providing a good interpretation of the surface macrotexture.

Slide 12



APPENDIX G-5 SEAL COAT: DESIGN EXAMPLE TRAINING PRESENTATION

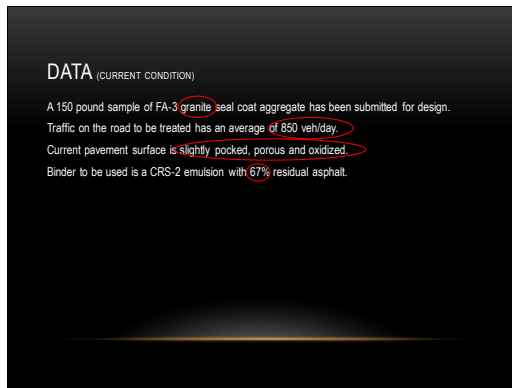
Slide 1



Slide 2



Slide 3



Slide 4

STEP #1: DETERMINE MEDIAN PARTICLE SIZE (MPS)

- MPS = 0.215 in
- FI =
- ALD =
- BSG =
- LWU =
- VLA =
- TWF =
- AAR =
- TVF =
- PCF =
- AAF =
- ACB =
- BAR =
- Adjust binder application rate

Sieve	U.S. Sieve	Openings, In.	U.S. Sieve	Percent Passing
100	2.0	0.075	100	100
20	0.85	0.150	95	95
40	0.425	0.300	85	85
60	0.250	0.475	75	75
80	0.1875	0.600	65	65
100	0.150	0.750	55	55
150	0.106	1.180	45	45
200	0.075	1.900	35	35
250	0.063	2.500	25	25

Slide 5

STEP #2: MEASURE FLAKINESS INDEX OF AGGREGATE

- MPS = 0.215 in
- FI = 28.6
- ALD =
- BSG =
- LWU =
- VLA =
- TWF =
- AAR =
- TVF =
- PCF =
- AAF =
- ACB =
- BAR =
- Adjust binder application rate

Weight of aggregate passing slots (flat particles)	Measured Weight (g)
145.3	145.3
Weight of total aggregate sample	507.2

$$FI = \frac{\text{flat particles weight}}{\text{total weight}} = \frac{145.3g}{507.2g} = 28.6$$

Slide 6

STEP #3: CALCULATE AVERAGE LEAST DIMENSION

- MPS = 0.215 in
- FI = 28.6
- ALD = 0.146 in
- BSG =
- LWU =
- VLA =
- TWF =
- AAR =
- TVF =
- PCF =
- AAF =
- ACB =
- BAR =
- Adjust binder application rate

$$ALD = \frac{MPS}{1.139285 + 0.011506 \cdot FI} = \frac{0.215in}{1.139285 + 0.011506 \cdot 28.6} = 0.146in$$

Slide 7

STEP #4: DETERMINE THE BULK SPECIFIC GRAVITY (AASHTO T84)

- MPS = 0.215 in
- FI = 28.6
- ALD = 0.146 in
- BSG = 2.71
- LWU =
- VLA =
- TWF =
- AAR =
- TVF =
- PCF =
- AAF =
- ACB =
- BAR =
- Adjust binder application rate

From an AASHTO T84 test it was determined that the BSG of the aggregate is 2.71

Aggregate Type	Density (lb/cu ft)	Class A			Class B			Class C		
		1 1/2" Thick	1 1/4" Thick	1 1/8" Thick	1 1/2" Thick	1 1/4" Thick	1 1/8" Thick	1 1/2" Thick	1 1/4" Thick	1 1/8" Thick
Bulk Specific Gravity	2.70	2.82	2.80	2.80	2.81	2.80	2.80	2.80	2.80	2.80
Unit Weight	120	120	120	120	120	120	120	120	120	120

Slide 8

STEP #5: CALCULATE THE LOOSE UNIT WEIGHT

- MPS = 0.215 in
- FI = 28.6
- ALD = 0.146 in
- BSG = 2.71
- L UW = 90.58 lb/ft³
- V LA =
- TWF =
- AAR =
- TVF =
- PCF =
- AAF =
- ACB =
- BAR =
- Adjust binder application rate

Test	Weight of Aggregate Filling the Cylinder	
	U.S. Units	S.I. Units
1	45.20 lb	20.57 kg
2	45.20 lb	20.60 kg
3	45.20 lb	20.59 kg
Average	45.20 lb	20.59 kg

$$L UW = \frac{\text{weight of aggregate in cylinder}}{\text{cylinder volume}} = \frac{45.29 \text{ lb}}{0.50 \text{ ft}^3} = 90.58 \text{ lb/ft}^3$$

Slide 9

STEP #6: CALCULATE VOIDS IN THE LOOSE AGGREGATE

- MPS = 0.215 in
- FI = 28.6
- ALD = 0.146 in
- BSG = 2.71
- L UW = 90.58 lb/ft³
- V LA = 0.46
- TWF =
- AAR =
- TVF =
- PCF =
- AAF =
- ACB =
- BAR =
- Adjust binder application rate

$$V LA = 1 - \frac{L UW}{62.4 + BSG} = 1 - \frac{90.58}{62.4 + 2.71} = 0.46$$

Slide 10

STEP #7: DETERMINE TRAFFIC WASTE FACTOR

- MPS = 0.215 in
- FI = 28.6
- ALD = 0.146 in
- BSG = 2.71
- L UW = 90.58 lb/ft³
- V LA = 0.46
- TWF = 1.05
- AAR =
- TVF =
- PCF =
- AAF =
- ACB =
- BAR =
- Adjust binder application rate

Percent Waste Allowed	TWF
1%	1.00
2%	1.00
3%	1.00
4%	1.00
5%	1.00
6%	1.00
7%	1.05
8%	1.06
9%	1.06
10%	1.10
11%	1.11
12%	1.12
13%	1.13
14%	1.14
15%	1.15

Slide 11

STEP #8: CALCULATE AGGREGATE APPLICATION RATE

- MPS = 0.215 in
- FI = 28.6
- ALD = 0.146 in
- BSG = 2.71
- L UW = 90.58 lb/ft³
- V LA = 0.46
- TWF = 1.05
- AAR = 15.8 lb/yd²
- TVF =
- PCF =
- AAF =
- ACB =
- BAR =
- Adjust binder application rate

$$AAR = 46.8(1 - 0.4 + V LA) + ALD + BSG + TWF$$

$$= 46.8(1 - 0.4 + 0.46) + 0.146 + 2.71 + 1.05$$

$$= 15.8 \text{ lb/yd}^2$$

Slide 12

STEP #9: DETERMINE TRAFFIC VOLUME FACTOR & STEP #10: DETERMINE PAVEMENT CONDITION FACTOR

- MPS = 0.215 in
- FI = 28.6
- ALD = 0.146 in
- BSG = 2.71
- LWW = 90.58 lb/ft²
- VLA = 0.46
- TWF = 1.05
- AAR = 15.8 lb/yd²
- TVF = 0.70
- PCF = +0.06 gal/yd²
- AAF =
- ACB =
- BAR =
- Adjust binder application rate

Traffic Volume (number of vehicles per day) under 1,000	TVF
100 to 500	0.85
500 to 1,000	0.75
1,000 to 2,000	0.65
over 2,000	0.60

Pavement Surface Condition	U.S. Units	SI Units
Black, hot-set asphalt	0.85 to 0.98 gal/yd ²	0.084 to 0.077 liter/m ²
Black, warm-mix asphalt	0.75 gal/yd ²	0.08 liter/m ²
Hot-applied porous, waterbound	0.65 gal/yd ²	0.08 liter/m ²
Hot-applied porous, waterbound	0.55 gal/yd ²	0.07 liter/m ²
Hot-applied porous, waterbound	0.45 gal/yd ²	0.06 liter/m ²

Slide 13

STEP #11: DETERMINE AGGREGATE ABSORPTION FACTOR (AASHTO T84)

- MPS = 0.215 in
- FI = 28.6
- ALD = 0.146 in
- BSG = 2.71
- LWW = 90.58 lb/ft²
- VLA = 0.46
- TWF = 1.05
- AAR = 15.8 lb/yd²
- TVF = 0.70
- PCF = +0.06 gal/yd²
- AAF = 0
- ACB =
- BAR =
- Adjust binder application rate

From an AASHTO T84 test it was determined that the AAF of the aggregate is 0.3%, which is less than 1.5% so the AAF for this case can be ignored or stated as 0.

Slide 14

STEP #12: DETERMINE ASPHALT CONTENT ON BINDER

- MPS = 0.215 in
- FI = 28.6
- ALD = 0.146 in
- BSG = 2.71
- LWW = 90.58 lb/ft²
- VLA = 0.46
- TWF = 1.05
- AAR = 15.8 lb/yd²
- TVF = 0.70
- PCF = +0.06 gal/yd²
- AAF = 0
- ACB = 0.67
- BAR =
- Adjust binder application rate

CUTBACK ASPHALT

ASPHALT EMULSION

Asphalt Content of Cutback Asphalt vs. Asphalt Emulsion

Slide 15

STEP #13: CALCULATE BINDER APPLICATION RATE

- MPS = 0.215 in
- FI = 28.6
- ALD = 0.146 in
- BSG = 2.71
- LWW = 90.58 lb/ft²
- VLA = 0.46
- TWF = 1.05
- AAR = 15.8 lb/yd²
- TVF = 0.70
- PCF = +0.06 gal/yd²
- AAF = 0
- ACB = 0.67
- BAR = 0.25 gal/yd²
- Adjust binder application rate

$$BAR = \frac{2.244 \cdot ALD \cdot VLA \cdot TVF + PCF + AAF}{ACB} = \frac{2.244 \cdot 0.146 \cdot 0.46 + 0.06 + 0.06}{0.67} = 0.25 \text{ gal/yd}^2$$

APPENDIX G-6 SEAL COAT: CONSTRUCTION TRAINING PRESENTATION

Slide 1



Slide 2

IMPORTANCE OF CONSTRUCTION TRAINING

This training presentation should:

- Help you understand the standard procedure for seal coats application.
- Allow you to identify a proper application from a bad application.
- Prepare you to identify common problems during application and possible solutions.
- Proper selection and design of seal coats HAS to be complemented with proper application to achieve expected benefits.

Why would you need this training??

- We hope this presentation gives you some basic information on the construction process of seal coats.
- You may have heard of this before, or worked on a similar project, so this might just help you refresh your mind.
- Red bullet point is KEY.

Slide 3

PREVENTIVE MAINTENANCE BENEFITS

- Extends life of the road
- Costs less when compared to a corrective treatment
- Convenience and public satisfaction
- Less waste generation

*These benefits can only be achieved by properly selecting, designing and applying the right treatment on the right road at the right time.

Let's remember that preventive maintenance does not add structural value to the road, it simply keeps the road in good condition for an extended period of time.

If we were to skip preventive maintenance and let the road deteriorate over time, a point will be reached where the approach necessary to deal with the road is a corrective treatment. A corrective treatment can be compared to building a new road.

As users we want to get from point A to point B in the most convenient way possible. Preventive maintenance could provide users with a smooth ride and less car/tire deterioration.

Slide 4

WHAT IS SEAL COATING?

- Seal coats consist of an application of binder followed by an application of single sized aggregate chips.
- Seal coats are typically used in low volume roads.
- They provide surface waterproof, seal existing cracks and corrects raveling problems while adding friction for traction.
- Disadvantages - They may cause dust, flyrock and noise.




Photo by Cliff Plymsser

Basically seal coats consist of a layer of asphalt binder followed by a layer of aggregate to provide skid resistance.

Let's keep in mind that seal coats are not recommended for fixing major distresses like large cracks, pot holes or rutting problems.

Although they are typically used in low volume roads, there are cases where they have been used for average to high volume roads with low speeds.

To address some of the disadvantages of seal coats, some measures could be taken like:

- Using precoated aggregates that helps reduce dust
- Applying a layer of fog seal to keep the aggregates in place

More examples can be found in other modules.

Slide 5

ROAD CONDITIONS PRIOR TO TREATMENT

- Surface should be clean and dry (no organic material growing from small cracks, etc.).
- Major pavement distresses should be repaired in advance. (potholes, large cracks, rutting, etc.)
- High winds or the probability of rain can create problems.
- 40°F is commonly the lower limit for accepted air and surface temperature.




Photo by Cliff Plymsser

Prior to treatment the road should be prepared and the team should be conscious of their setting.

It could be a good idea to broom the surface before application to clear the surface from any loose material loose aggregates.

As said before, major distresses need to be repaired beforehand, since the seal coat application will not fix them.

The team should be alert of some no-go condition as for example:

- High winds that may alter the binder spray angle and coverage
- Probability of rain
- temperature

Slide 6

PRE-APPLICATION

- Check for aggregate size uniformity and cleanness.
- An appropriate Traffic Control Plan has been setup according to MUTCD.
- Cover existing utilities (cut roofing felt, sand, plastic, etc.)
- There is no drainage problems present and major distresses have been addressed.
- All equipment is functioning properly.

According to the Minnesota Seal Coat Handbook using sand to cover manholes is the preferred method since the material has to be disposed properly.

We do not want water or humidity in the road. Drainage problems will also cause binder to concentrate in some areas.

Slide 7

WHAT IF MAJOR DISTRESSES ARE NOT ADDRESSED PRIOR TO APPLICATION?

Video shows major cracks that were not corrected prior to treatment. Although application appears to be uniform at the beginning, binder will slowly fill cracks leaving un-embedded and exposed chips.

This could cause all kinds of problems to users as aggregate is loose and aggregates being dislodged by traffic (flyrock) can cause windshield damage.

Slide 8

PRE-APPLICATION (CONT.)

- Equipment Inspection
 - Distributor:
 - Spray bar height
 - Nozzles free of clogs
 - Nozzles at proper angle
 - Pressure
 - Chip Spreader
 - Gate control and settings
 - Truck hookup hitches
 - Trucks
 - Truck box is clean
 - Enough trucks
 - Rollers
 - Same tire pressure in all tires
 - Tires have smooth surfaces
 - Brooms
 - Bristles at proper length

Refer to picture 1 to show the importance of proper nozzle angles.

Slide 9


EQUIPMENT CALIBRATION

- Calibrate the Chip Spreader
 1. 1yd² rubber mats are laid on the roadway.
 2. Chip spreader drives over mat while dropping chips at application rate.

Slide 10

EQUIPMENT CALIBRATION

- Calibrate the Chip Spreader
 3. Aggregates on mats are emptied into plastic bags.
 4. Each bag is weighed and converted to lbs/yd²
 5. Each gate is adjusted so that it drops the same amount of aggregate.




Both images from Minnesota Seal Coat Handbook

Slide 11

EQUIPMENT CALIBRATION

- Binder Distributor (adjusting application rate)
 1. Spray approximately 50 feet at the design application rate.
 2. Apply a single layer of aggregate.
 3. Check height of the binder in relation to height of chips (binder should rise almost to the top).
 4. Adjust binder application as necessary.



Both images from Minnesota Seal Coat Handbook

Low Binder Correct Amount


Trial and error approach.

We try to get to a point where the binder covers close to 50% of aggregate height, for a future 70% after embedment.

Slide 12

DURING APPLICATION

- Application should look uniform (longitudinally and transversely).
- Constant checks for plugged nozzles.
- Distributor and Spreader match speed.
- Enough trucks are on hand to keep up constant production.
- No asphalt is on top of aggregates or excess aggregate is being placed.
- Stops and turns are made gradually to keep aggregate in place.
- Enough rollers (suggestion of 3) follow closely behind spreader at 5mph max.



Rizzuto, CalTrans

3 rollers would cover the width of the lane.

Slide 13

POST-APPLICATION

- Sweeping begins after sufficient bond has been formed between binder and aggregates.
- All loose aggregate from sweeping should be removed.
- Pavement markings are placed before opening to traffic (if weather allows it).
- Construction related signs are replaced by reduced speed limit signs.
- Traffic opening timing is of high importance.

We want to keep the traffic at slow speed at the beginning to minimize the chances of aggregate getting dislodged.

A fog seal may be applied after a seal coat to keep chips in place, although this will cause low friction and delay the opening time.

I believe that here in Iowa it is common to apply a seal coat with a fog seal by alternating days. For example if a project starts on Monday then a seal coat is applied on a section on that day, then on Tuesday a fog seal is applied over the recently applied seal coat. Then on Wednesday seal coat continues on the next section, then Thursday fog seal, and so on.

Slide 14

BEST PRACTICES VS. BAD PRACTICES

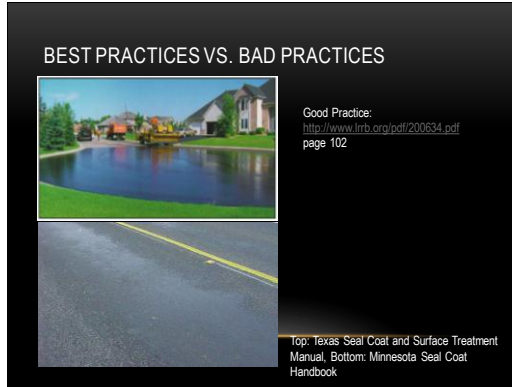
Rizzuto, CalTrans

Both left images from Minnesota Seal Coat Handbook

Proper application – top right, uniform with no imperfections

Improper – top left, use of dusty aggregate with what appears to be low to no sweeping before opening. Also, it could be argued that the aggregates didn't pass the gradation test, too many fines. Or storage area was over fines, and during the scoop and dump some dusty aggregates or fines got mixed. Bottom left, mix was too rich in binder or low in aggregate as binder is showing over the aggregate in the truck wheel path.

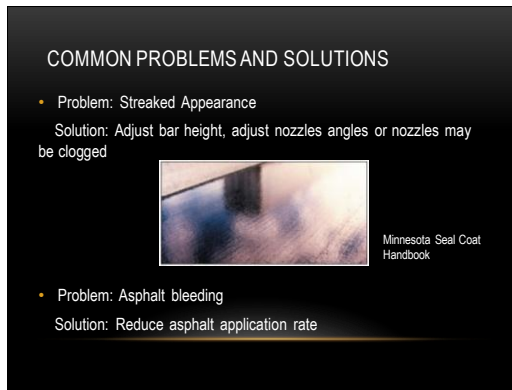
Slide 15



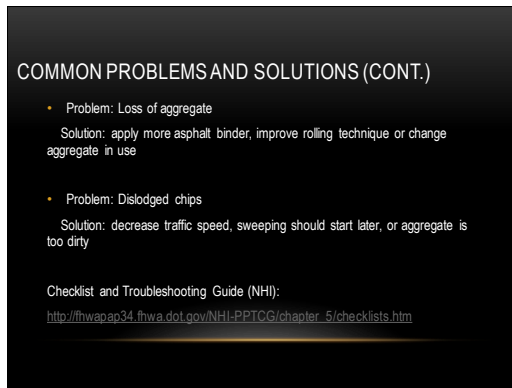
Roundabout incorrectly applied with seal coat since binder will start to cure before aggregate has been placed entirely.

High binder content caused quick bleeding.

Slide 16



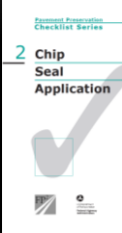
Slide 17



Slide 18

SUMMARY

- Proper application starts when the road is being prepared prior to application and ends when traffic is controlled at opening.
- Constant checking application and equipment is crucial for achieving best performance.
- It could be recommended to have a checklist to carry around to minimize the chances of letting things go by.
- Proper selection and design of seal coats HAS to be complemented with proper application to achieve expected benefits.



FHWA - FP²

Application of seal coats start as soon as the road is being cleaned. With improper cleaning come bad results.

Constant inspection for equipment malfunction, visual uniformity, and overall process is crucial for success.

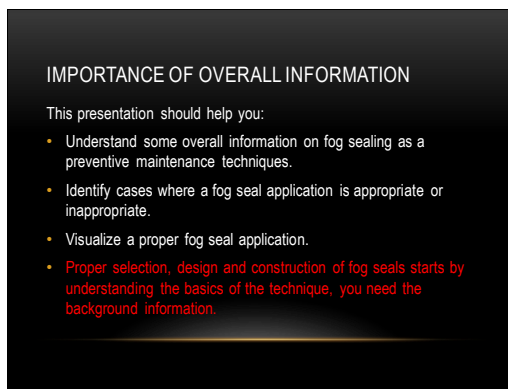
Pavement Preservation checklists are available to help guide you through the process.

APPENDIX G-7 FOG SEAL: OVERALL TRAINING PRESENTATION

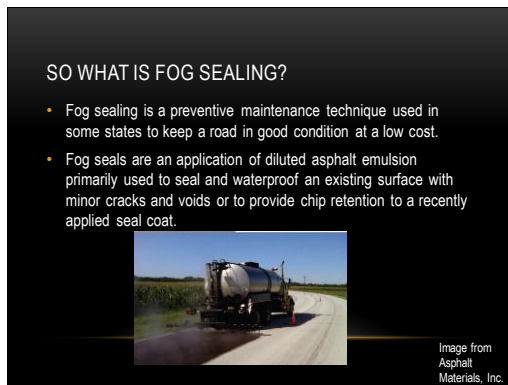
Slide 1



Slide 2



Slide 3



Fog seals are more commonly used after a chip seal has been applied to provide chip retention.

Fog seals are also used to keep a road in its present condition for a short period of time before applying another treatment.

They will not repair any major distresses and, as said before, it could be used in roads with minor cracks. In this presentation we refer to minor cracks as really small cracks that not necessarily need crack filling/sealing.

In general the fog seal emulsion should be of sufficient low viscosity to penetrate the voids.

Slide 4

FOG SEALING – THE PROCESS

- After the road has been appropriately selected, a design has been developed, and the road has been cleared and cleaned the design is checked and adjusted for road conditions and then applied using an asphalt distributor.

Image from Rizzutto, Caltrans



A design is performed beforehand by the manufacturer but it **NEEDS** to be checked on-site since the actual road conditions determine the application rate.

This is commonly determined by applying a layer of diluted asphalt on a 1sy2 area and observing the degree of absorption, then adjusting.

For more information on regards to designing and adjusting for application rates and dilution please refer to the fog seal design presentation.


In some cases a sand application follows a fog seal, and that will be covered later on this presentation.

Slide 5

TYPES OF DISTRESSES ADDRESSED

- Few Tight Cracks
- Low Raveling
- Low loss of aggregates
- Oxidation

Photo by Cliff Plymmer



NHI Pavement Preservation Modules

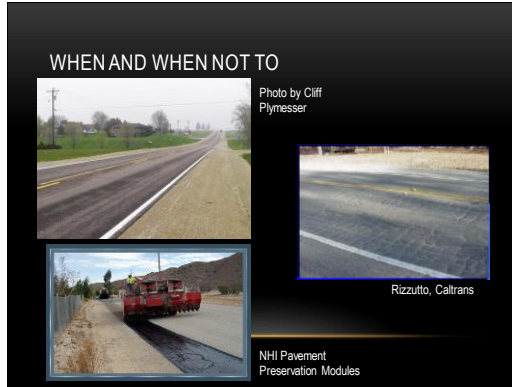
Few tight cracks – again, this are cracks that are extremely small as we can see in the low left picture.

Raveling - also known as weathering, aggregate or binder has worn away due to oxidation, traffic, snow plow.

Oxidation – this is the effect of weather and can be observed on roads with a light grey appearance.

As seen, fog seal will not repair any kind of major distresses like rutting, medium to large cracks, potholes, etc.

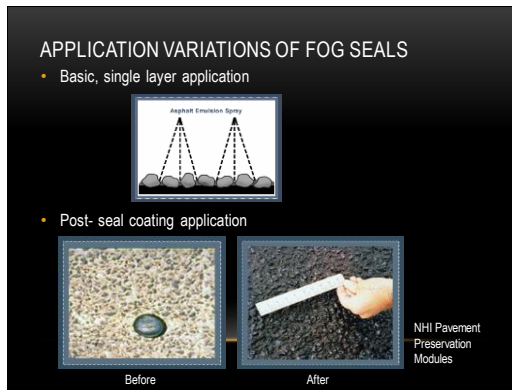
Slide 6



When to: if a road is experiencing some of the minor distresses mentioned before, then a fog seal could be a good application to keep the road in good condition. Also, after a seal coat has been applied and we want to provide some type of chip retention to avoid flyrock or chips getting dislodged, then fog seal can be helpful.

When not to: roads with major distresses as seen in both of this pictures. Also, when weather conditions are not favorable.

Slide 7



As mentioned before, fog seals are commonly used in two cases:

- A single layer of emulsion used to weatherproof a surface.
- After a chip seal to provide chip retention.

Slide 8



Reclamite: oil emulsion
 PASS: asphalt, oil and additives
 Topien C: asphalt, oil and additives.

So the rejuvenator seal penetrates the existing oxidized asphalt and they chemically combine to create a strong, durable, and flexible surface, from there rejuvenate.


From my understanding, here in Iowa the use of rejuvenators is not common but anyways I'm putting it out there so that you know that they could be applied, it is an option.

Slide 9

USE OF SAND

Sand may be applied with a fog seal to:

1. Provide skid resistance to a newly fog seal treated pavement.
2. Correct a fog seal with extra emulsion as it reduces it's slippery property.
3. Help interlock chips in a seal coat.
4. Allow for earlier traffic.



Brownridge & Fox,
California Pavement
Preservation Center




It is my understanding that a sand application following a fog seal is extremely common in Iowa, maybe it is always done.

According to the literature it is an option in other states, some of them use it, some don't.

Slide 10

EQUIPMENT

The equipment needed for a fog seal is a distributor truck. A sand spreader, trucks and brooms are used when a sand application is involved.

Photos by
Cliff
Plymesser

In the case sand will be used, rollers can also be used depending on the aggregate size.

Slide 11

GOOD VS BAD RESULT



CalTrans Division of
Maintenance

a) Before Treatment b) After Treatment




Image from Rizzutto, Caltrans

First picture shows a proper application of a fog seal, as the appearance looks uniform.

Second picture shows an improper application of a fog seal, as the emulsion was either diluted incorrectly or applied incorrectly. In this case the emulsion did not penetrate the surface properly leaving excess asphalt over the surface. This could be a problem as it leaves a slippery surface vulnerable to accidents.

Slide 12

SUMMARY

- Fog seals can provide many benefits to keep roads in good condition but this will only be achieved if a proper plan is executed.
- It is critical to understand that fog seals do not correct distresses on the road, it simply keeps them as they are for some time.
- With the possibility of applying a fog seal after a seal coat or adding rejuvenators and/or sand, it is important to know the variations and their primary functions and benefits.
- Proper selection, design and construction of fog seals starts by understanding the basics of the technique, you need the background information.

Some of the benefits:

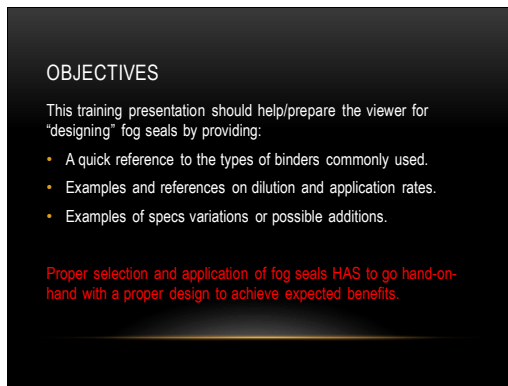
- Provides chip retention for chip seals
- It gives the appearance of a new HMA layer
- With a darker appearance after a seal coat, the temperature rises allowing a chip seal to cure quicker (good for late season chip seals).
- With a darker appearance, the amount of paint for pavement markings is lower.

APPENDIX G-8 FOG SEAL: DESIGN TRAINING PRESENTATION

Slide 1



Slide 2



I have "designing" within "" (quotations mark) because, when compared to seal coating for example, there is not really a design behind a fog seal. Dilution and application rates have already been established and the DOT specs state what to use. Nonetheless a proper selection needs to be made and verified.

Slide 3



Let's remember that preventive maintenance does not add structural value to the road, it simply keeps the road in good condition for an extended period of time.

If we were to skip preventive maintenance and let the road deteriorate over time, a point will be reached where the approach necessary to deal with the road is a corrective treatment. A corrective treatment can be compared to building a new road.

As users we want to get from point A to point B in the most convenient way possible. Preventive maintenance could provide users with a smooth ride and less car/tire deterioration.


Slide 4

MATERIALS

- Emulsions
 - CSS - 1
 - SS - 1
 - GSB - 88
- Potable water
- Sand
- Rejuvenators (not used in Iowa)
 - Reclamite®
 - PASS®
 - Topien O®

Iowa Specs

- CSS - 1h
- SS - 1h



Brownridge & Fox, California Pavement Preservation Center

Emulsions:

- CSS – cationic emulsion, positively charged
- SS – anionic, negatively charged, they tend to take longer to stabilize than CSS
- GSB – natural asphalt ore with high resin content (gilsonite – found in Utah mines and Saudi Arabia), combined with oils and plasticizers creating a cationic emulsion. GSB advantage is that it significantly retards deterioration when compared to conventional fog seals but its initial cost is higher.
- CSS – 1h and SS – 1h are not in the Iowa specs, but states like California commonly use them to create a thicker layer.

Water – needs to be potable to minimize the risk of adding pollutant or contaminants to the diluted emulsion that would alter the chemical composition.

Sand – a sand cover usually follows a fog seal to compensate for the loss of road friction that occurs from a fresh fog seal. (required in Iowa)

Rejuvenators – oily additives that soften the binder, reduce their viscosity, thus providing deeper surface penetration to restore AC components and characteristics.

- Reclamite – oil based emulsion with a surfactant
- Pass – polymer modified asphalt surface sealer
- Topien – oil based asphalt with chemical additives

Slide 5

DILUTION & APPLICATION RATES

Iowa Specs: "The dilution rate is one part of asphalt emulsion to four parts of water ... The diluted asphalt emulsion shall be applied at the rate of 0.12 gal/yd² (0.5L/m²) of pavement surface" (Iowa DOT Specification 2306).

% Original Emulsion	Dilution Rate	Tight Surface*		Open Surface**	
		(l/m ²)	(gal/yd ²)	(l/m ²)	(gal/yd ²)
50	1:1	0.15-0.5	0.03-0.11	0.4-1.0	0.09-0.22

Dilution (all in l/m ²) residual	Tight Surface	Open Surface
50	0.04-0.15	0.13-0.22
40	0.15-0.5	0.4-1
25	0.2-0.55	0.5-1.3
25	0.25-0.9	0.8-2
20	0.3-0.15	1-2.6



NHI Pavement Preservation Treatment Construction Guide
Table Referenced from VSS Emultech (Valley Slurry Seal Co.)

Although the recommended dilution rate nationwide is a 1:1 dilution rate, here in Iowa a dilution rate of 1:4 is used.

Note that the dilution and, specially, the application rates need to be checked and adjusted in the field to compensate for the actual environmental and road conditions.

Slide 6

SAND COVER

Brownridge & Fox, California Pavement Preservation Center

As mentioned before, a sand cover usually follows a fog seal to compensate for the loss of road friction that occurs from a fresh fog seal.

Slide 7

SUMMARY

As a conclusion:

- Binder selection should be carefully examined to meet DOT needs and road characteristics.
- Although the Iowa DOT specs state an exact dilution and application rate, other variations are available and could be examined for possible future adoption.
- Field verification should always be conducted to make sure the road surface is being uniformly treated.

Proper selection and application of fog seals HAS to go hand-on-hand with a proper design to achieve expected benefits.

Know the difference between a CSS, SS and GSB and what the DOT objectives for a specific road are. Although GSB is more expensive, it may be the proper choice according to what the DOT expects.

APPENDIX G-9 FOG SEAL: CONSTRUCTION TRAINING PRESENTATION

Slide 1



Slide 2

IMPORTANCE OF CONSTRUCTION TRAINING

This training should help the viewer:

- Understand the standard procedure for fog seal application.
- Prepare for design adjustments on site.
- Identify a proper application from a bad application.
- Identify common problems during application and possible solutions.
- Proper selection and design of fog seals HAS to be complemented with proper application to achieve expected benefits.

Slide 3

PREVENTIVE MAINTENANCE BENEFITS

- Extends life of the road
- Costs less when compared to a corrective treatment
- Convenience and public satisfaction
- Less waste generation

*These benefits can only be achieved by properly selecting, designing and applying the right treatment on the right road at the right time.

Let's remember that preventive maintenance does not add structural value to the road, it simply keeps the road in good condition for an extended period of time.

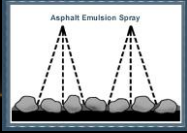
If we were to skip preventive maintenance and let the road deteriorate over time, a point will be reached where the approach necessary to deal with the road is a corrective treatment. A corrective treatment can be compared to building a new road.

As users we want to get from point A to point B in the most convenient way possible. Preventive maintenance could provide users with a smooth ride and less car/tire deterioration.

Slide 4

WHAT IS FOG SEALING?

- Fog seals are an application of diluted binder to an existing pavement or seal coat that serves to seal and weatherproof a pavement and/or keep chips in place.
- Some of the problems they correct include small tight cracks, very light raveling and oxidation.
- Disadvantages – Long time for curing and ability to be opened to traffic.



NHI Pavement Preservation Treatment Construction Guide

Another disadvantage goes along with the 2nd bullet; fog seals do not correct any major distresses.

If you are one of the construction guys in charge of applying or inspecting a fog seal, bullets 2 and 3 are important for you.

Slide 5

ROAD CONDITIONS PRIOR TO TREATMENT

- Surface should be clean and completely dry.
- Major pavement distresses should be repaired (potholes, cracks, rutting, etc.)
- High winds or the probability of rain can create problems.
- 60°F is commonly the accepted lower limit for air and surface temperature

Clean since we want the binder to stick to the surface.

Dry since we want our mix to have a certain amount of water.

As said before a fog seal will not correct major distresses so these need to be repaired beforehand.

Temperatures below 60 will cause the emulsion to take longer to cure.

Slide 6

PRE-APPLICATION

- An appropriate Traffic Control Plan has been setup according to MUTCD.
- Cover existing utilities.
- There is no drainage problems present.
- All equipment is functioning properly.
- In case water will be used in the field for dilution, it should be potable and free from solids.
- In case sand will be used as a cover, material should be clean and uniform.



Photo by Cliff Plymesser

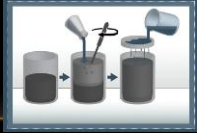
Drainage problems will cause the emulsion to concentrate in some areas, providing an uneven application.

We want to use potable water; the use of contaminated or dirty water will cause the affect the mix. The manufacturer usually dilutes the emulsion and tests for water-emulsion compatibility.

Slide 7

TESTING FOR WATER COMPATIBILITY

"Water can be checked for compatibility with the emulsion by mixing a small amount of the emulsion in a can (approximately 1 liter). The materials are mixed for 2 to 3 minutes with a stirrer and the resulting mixture is poured through a pre-wetted 150 mm sieve. If more than 1% by weight of material is retained on the sieve, the water is not compatible and clogging in spray jets may result." (NHI Pavement Preservation)




NHI Pavement Preservation Treatment Construction Guide

If water is not compatible then it needs to be treated with an emulsifier solution. The manufacturer will probably provide more information and recommendations on this regard.

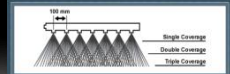
Slide 8

PRE-APPLICATION (CONT.)

- Equipment Inspection
 - Brooms
 - Bristles at proper length
 - Distributor:
 - Spray bar height
 - Nozzles free of clogs
 - Nozzles at proper angle
 - Pressure
 - Water has been added properly without creating foam
 - Sand Spreader (if used)
 - Gate control and settings checked
 - Truck hookup hitches
 - Trucks (if used)
 - Truck box is clean
 - Hookup hitch and apron are available
 - Enough trucks



Minnesota Seal Coat Handbook



NHI Pavement Preservation Treatment Construction Guide

In order to achieve a uniform application, all the settings and features of the distributor need to be carefully checked before application.

Slide 9

EQUIPMENT CALIBRATION

- Binder Distributor (pre-application + specs field verification)
 - Record the weight of a 1yd² pan.
 - Place the pan on the road and apply the emulsion over it.
 - Record the weight of the pan with the applied emulsion.
 - Subtract the two weights to determine the weight per area.
 - Convert to gal/yd², check with predetermined application rate range, and adjust according to design and conditions.
- During Application (random checks for quality control)
 - Record the volume of emulsion on the distributor.
 - Apply emulsion to a test section of known area.
 - Remeasure the volume of emulsion on the distributor.
 - Subtract both measures and determine the application rate, adjust if necessary.

Trial and error approach.

An equipment calibration during application, or recalibration, is highly recommended as we want to have the same application rate at all times. A little bit less can cause over-absorption; a little bit more can cause "bleeding".

Some literatures suggest calibrating and adjusting for application rates using the second options. That way you adjust the application rate according to the surface conditions and absorption.

Slide 10

COMMON APPLICATION RATES
Iowa Specs: one part emulsion to four parts water at 0.12gal/yd² (0.5 L/m²)

Table 1: AEMA Recommendations for Application Rates (5)

% Original Emulsion	Dilution Rate	Tight Surface*		Open Surface**	
		(l/m ²)	(gal/yd ²)	(l/m ²)	(gal/yd ²)
50	1:1	0.15-0.5	0.03-0.11	0.4-1.0	0.09-0.22

NHI Pavement Preservation Treatment Construction Guide

Dilution (all in l/m ²)	Tight Surface	Open Surface
residual	0.04-0.15	0.13-0.22
50	0.15-0.5	0.4-1
40	0.2-0.55	0.5-1.3
25	0.25-0.9	0.8-2
20	0.3-0.1.15	1-2.6

Table Referenced from VSS Emultech (Valley Slurry Seal Co.)

Tight surface: of low absorbance and relatively smooth
Open surface: relatively porous and absorbent with open voids.

Slide 11

DURING APPLICATION

Responsibilities of the inspector:

- Application should look uniform
- Application starts and stops on building paper.
- Constant checks for plugged nozzles.
- Constant checks for drilling and streaking.
- Random application rate checks are made.
- In case sand is used, no emulsion is on top of sand.
- Enough trucks are on hand to keep a steady supply of sand, if used.

Slide 12

POST-APPLICATION

- In case sand is used, sweeping begins after sufficient bond has been formed between binder and sand.
- Pavement markings are placed before opening to traffic.
- Construction related signs are replaced by reduced speed limit signs.
- Traffic opening timing is of high importance and should not exceed 25mph.

Unfortunately fog seals take their time to cure, so the timing of when the road is opened to traffic is critical. If opened too early, tires will tear up the seal.

At the beginning traffic speed should be controlled, but unlike seal coats, fog seals can be used in high speed roads.

Slide 13

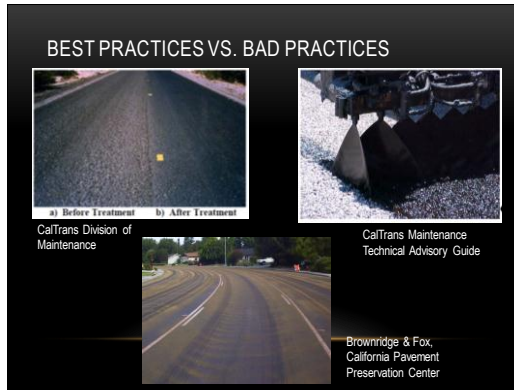
BEST PRACTICES VS. BAD PRACTICES

All three images from NHI Pavement Preservation Treatment Construction Guide

First two images are examples of best practices, as a fog seal is properly applied after a seal coat in the top image and in the lower image the fog seal looks uniform over a road with no major distress.

Bad practice in this other image where major distresses, like the pothole in this case, were not addressed before applying the seal coat.

Slide 14



Again, good practice is the top image where after treatment is applied the appearance looks uniform with no signs of bleeding.

If sand will be used, the bottom picture shows what the application should look like BEFORE sweeping.

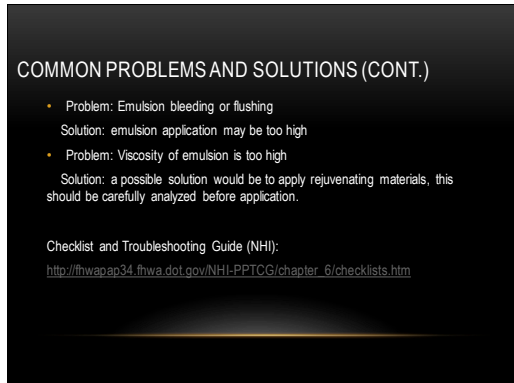
Bad practice is not inspecting nozzle angles during application; this will cause application not to be uniform.

Slide 15



Some of this also applies to seal coats or any treatment that uses the same equipment.

Slide 16



This troubleshooting guide may come in handy, so it wouldn't be a bad idea to have a hard copy of it around during application.

Slide 17

DOS AND DON'TS (CALTRANS DIVISION OF MAINTENANCE)	
Do	check water compatibility before dilution.
Do	check dilution - has it been done, by whom, and when?
Do	ensure that there is no contamination of the base emulsion by water, oils, or other liquids.
Do	prevent contamination by other emulsions.
Do	protect emulsions from freezing or localized boiling due to the application of direct heat.
Do	heat emulsion gently and ensure heating coils are under the liquid level (max 50°C (122°F)).
Do	load from the bottom of tankers or sprayers to avoid foaming.
Do	check equipment and nozzles.
Do	check application rates.
Do	exercise proper traffic control.
Do	ensure the know-how is available on the job.
Do	add water to emulsion, not emulsion to water.
Don't	store diluted emulsion longer than 24 hours.
Don't	continuously stir or circulate emulsion.
Don't	apply emulsion if air temperature is <10°C (50°F) and pavement temperature <15°C (59°F).
Don't	apply emulsion if rain or cool temperatures are imminent.
Don't	continue application if adequate breaking period is not available.
Don't	open treated surface to traffic until coefficient of friction is at least 0.30 as determined by CT 142.

Slide 18

SUMMARY

- Proper application starts when the road is being prepared prior to application and ends when traffic is controlled at opening.
- Constant checking of the application and equipment is crucial for achieving best performance.
- It could be recommended to have a checklist to carry around to minimize the chances of letting things go by.
- Proper selection and design of fog seals and any other preventive maintenance **HAS** to be complemented with proper application to achieve expected benefits.

Pavement Preservation
Checklist Series

4 Fog
Seal
Application

Application goes from getting prepared to traffic control after opening. If the road is not cleaned before applying the fog seal you will not achieve the benefits of fog sealing, the same thing happens if you don't control traffic speed when opening the road.

The inspector has many responsibilities and it's hard to keep an eye on everything.