IMPLEMENTATION PHASE OF SPR 777 STUDY AND GUIDANCE FOR A CHIP SEAL PERFORMANCE SPECIFICATION

Final Report

PROJECT STIC

Oregon Department of Transportation

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16. Abstract: This report outlines the development and implementation phase of chip seal performance specification for Oregon. Two chip seal workshops were held to involve chip seal stakeholders including a variety of Oregon Department of Transportation (ODOT) personnel and contractors. A voluntary survey about the potential specification changes was developed and results are presented. A series of specification meetings were held with ODOT and industry to re-evaluate the specification and potential changes line-by-line. The specifications developed as a result of the specification meetings are presented and specification guidance is provided. Flow charts were developed aid in specification processes and action items. This report also contains follow-up work from research in SPR 777 (https://www.oregon.gov/ODOT/Programs/ResearchDocuments/SPR777_ChipSeal.pdf). Chip seal design and a design spreadsheet are discussed. Finally, the Oregon DOT conducted a demonstration project under the new specification. The details and results of the demonstration project are presented.		
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APPROXIMATE CONVERSIONS TO SI UNITS					APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	When You Know	Multiply By	To Find	Symbol	Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH					**LENGTH**		
in	inches	25.4	millimeters	mm	mm	millimeters	0.039	inches	in
ft	feet	0.305	meters	m	m	meters	3.28	feet	ft
yd	yards	0.914	meters	m	m	meters	1.09	yards	yd
mi	miles	1.61	kilometers	km	km	kilometers	0.621	miles	mi
		AREA					**AREA**		
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ft^2	square feet	0.093	meters squared	m^2	m^2	meters squared	10.764	square feet	ft^2
yd^2	square yards	0.836	meters squared	m^2	m^2	meters squared	1.196	square yards	yd^2
ac	acres	0.405	hectares	ha	ha	hectares	2.47	acres	ac
mi^2	square miles	2.59	kilometers squared	km^2	km^2	kilometers squared	0.386	square miles	mi^2
		VOLUME					**VOLUME**		
fl oz	fluid ounces	29.57	milliliters	ml	ml	milliliters	0.034	fluid ounces	fl oz
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ft^3	cubic feet	0.028	meters cubed	m^3	m^3	meters cubed	35.315	cubic feet	ft^3
yd^3	cubic yards	0.765	meters cubed	m^3	m^3	meters cubed	1.308	cubic yards	yd^3
~NOTE: Volumes greater than 1000 L shall be shown in m^3.									
		MASS					**MASS**		
oz	ounces	28.35	grams	g	g	grams	0.035	ounces	oz
lb	pounds	0.454	kilograms	kg	kg	kilograms	2.205	pounds	lb
T	short tons (2000 lb)	0.907	megagrams	Mg	Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)					**TEMPERATURE (exact)**		
°F	Fahrenheit	(F-32)/1.8	Celsius	°C	°C	Celsius	1.8C+32	Fahrenheit	°F

*SI is the symbol for the International System of Measurement

ACKNOWLEDGEMENTS

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DISCLAIMER

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EXECUTIVE SUMMARY

This research focused on improving the quality of chip seal construction practices in Oregon and as a result improve the performance of chip seal surfaces during their service life. The primary objectives of this study were to perform the following:

- Initial implementation workshop for agency experts and invited guests for preliminary review of findings and recommendations
- Update and finalize chip seal design and specifications
- Survey with feedback
- Demonstration of chip seal best practices
- Data analysis using old methods and new methods
- Follow-up study of laboratory chip seal design and field application rates
- Follow-up performance testing on demonstration chip seal
- Final implementation workshop/conference for agency experts and invited guests
- Follow-up to combine research and demonstration chip seal results

A chip seal and performance-based specification workshop and planning meeting was held in Salem, Oregon in November 2017. The main purpose of the first chip seal workshop was to present the research findings and results of SPR 777 (Buss et al. 2016) and to discuss the performance specification with agency experts, stakeholders for the Oregon chip seal community, and prime contractors who regularly are involved in chip sealing state-owned roadways. As result of this workshop, there was a consensus that implementation of a performance specification was a major shift to work toward in this research.

A survey was distributed to contractors and suppliers to gather feedback and concerns related to the new research recommendations for chip seal data collection and reporting from the updated chip seal design specifications. The survey results indicated that there are three major alterations required to move to a performance-based specification. The survey questions and additional updates to the performance-based specification can be found in Chapters 3 and 4 of this report, respectively.

The research generated three flow charts for the performance specification of chip seal in Oregon. The first covered the overall process, the second addressed a refusal at initial inspection, and the third addressed refusal at final inspection. The charts along with discussion can be found in Chapter 5 of this report.

A second chip seal workshop was held in Salem, Oregon on February 7, 2018. The purpose of the second chip seal workshop was to discuss the proposed specifications with the chip sealing community in Oregon. Specifications were updated based on survey results and a series of meetings. A summary of all presentations, group discussions, feedback from participants, and takeaways are presented in Chapter 6 of this report.

One of the tasks in this research was to utilize the data from Buss et al. (2016) to study the macrotexture deterioration of 14 test sections, which were built in 2014 and 2015. It was observed that all 14 sections performed well during the four-year and five-year performance evaluation. An update on the performance of all of the chip seal test sections' macrotexture is documented in Chapter 7 of this report.

Chip seal can be designed by the McLeod or New Zealand method. Therefore, a spreadsheet that follows both the McLeod and the New Zealand methods was designed by the Iowa State University research team for contractors and engineers to utilize. The spreadsheet includes a conversion to English units, which makes it more user-friendly. The chip seal designs of both methods are detailed and presented in Chapter 8 of this report.

A demonstration site was selected by the Oregon Department of Transportation to introduce the new chip seal specifications. The chip seal was applied over 7.5 mi, and various application rates for aggregate and binder were utilized on 12 test locations throughout the road. The macrotexture was measured by the sand circle by following the test procedures and standards provided in ASTM E965-15. The project construction report and environmental consideration details are available in Chapter 9 of this report.

1.0 INTRODUCTION

Workmanship and high-quality materials are important for achieving long-lasting chip seals. This study investigated the implementation of a performance specification for Oregon chip seals based on previous research that demonstrated proof-of-concept for the specification. The goals of this project were to provide a pathway for implementation of a performance specification for chip seal projects in Oregon.

Two workshops and a series of meetings with ODOT representatives and industry stakeholders were held to develop a chip seal performance specification based on proof-of-concept research and feedback from previous workshops and meetings. The workshops helped the research team share why the performance specification is needed and foster discussions on what the new specification should look like. Agencies, contractors, and suppliers were involved in discussions to help develop a specification acceptable to all parties involved in quality chip sealing. During these meetings, discussions helped shape the language and framework for the potential performance specification. Flowcharts were also developed to assist with communicating the specification process. The proposed performance specification is largely based on chip seal specifications and chip seal research performed in New Zealand. A study in Oklahoma also showed that the New Zealand methodology could be developed for use in the US (Zaman et al. 2014).

Moving chip seal away from an "art" to a "science" by using a design framework helps to ensure that materials used in the chip seal process are adequately tested and inspectors are familiar with the materials before chip seal construction. A design framework is presented in this report and provides a more scientific approach to making field adjustments to application rates. The chip seal design is presented, and a chip seal design spreadsheet was developed to facilitate implementation of the design.

This report provides summaries from project workshops, chip seal design, performance specification developments, results from a survey collecting feedback for the potential performance specification, chip seal field evaluation, and a demonstration project.

1.1 SUMMARY OF SPR 777 CHIP SEAL PROJECT

The Oregon Department of Transportation (ODOT) report for SPR 777 research (Buss et al. 2016) is available at:
https://www.oregon.gov/ODOT/Programs/ResearchDocuments/SPR777_ChipSeal.pdf.

The literature review studied different types of chip seal design methods, specifications for chip seals, and important factors for chip seal success. In Buss et al. (2016), 14 chip seal sections were studied. Pre-construction roadway conditions were assessed, and macrotexture measurements were taken before construction, after construction, one year after construction, and two years after construction (for sections constructed in 2014). Project details can be found in

Buss et al. (2016). Laboratory tests were conducted on the chip seal aggregate, and performance in the field was also studied. Macrotexture depth based on New Zealand's chip seal performance specification was studied. Also, a back-analysis was performed to determine the differences between field chip seal application rates and laboratory design recommendations.

Overall, the field sections in Buss et al. (2016) were constructed and performed satisfactorily for the duration of the project. The intent for this implementation project was to document proof-of-concept for a chip seal performance specification based on macrotexture similar to the New Zealand specification. Buss et al. (2016) helped to set a benchmark for acceptable performance for chip seals. In Buss et al. (2016), all chip seal sections performed well over time and passed a one-year design criteria based on the New Zealand performance specification. The field study tracked performance of macrotextures and compared macrotexture performance with the macrotexture requirements of New Zealand's performance specification.

1.2 OBJECTIVES

The primary objectives of this study were to implement the findings and recommendations from the laboratory and field chip seal study. To do this, stakeholders were involved in the process to ensure that the proposed performance specifications developed in this study would be acceptable to all parties involved. Meetings included binder suppliers, contractors, and staff representatives of various ODOT offices. Other objectives of this work included the following:

- Encourage a more scientific approach to chip sealing by providing information about chip seal design and a chip seal design spreadsheet
- Involve stakeholders in chip seal workshops and a survey to gather feedback about a potential chip seal performance specification
- Work with stakeholders to develop a chip seal performance specification that could work for Oregon
- Review other chip seal performance specifications and discuss with vendor community
- Perform follow-up chip seal macrotexture measurements to validate recommended macrotexture requirements
- Work with ODOT to perform a demonstration project under the new performance specification

1.3 CHIP SEAL PERFORMANCE SPECIFICATION AND DEVELOPMENT PROCESS

The majority of the chip seal performance specification development involved discussions of how to best tailor existing performance specifications for Oregon. Example specifications included New Zealand's chip seal performance specification and language from Michigan's chip seal specification. The current ODOT specification requires the contractor to follow prescribed methods (e.g., apply the emulsion at certain application rates). True performance specifications generally do not provide prescribed methods, but performance criteria carry a significant financial impact. The meetings included line-by-line discussion of the current proposed chip seal performance specification.

A series of meetings were held to discuss each section in detail and to determine which sections were needed and which sections were not relevant under the new specification. In the meetings, there were discussions on whether to remove some of the prescriptive requirements in the specifications. Meeting participants agreed that many of the prescriptive requirements in the current specification represent ODOT best practices and, if removed, should remain as part of specification guidance for contractors and agency personnel working with the performance specification. The changes based on the group discussions and meetings are outlined in this report and if a section was removed, this report provides commentary for guidance and best practices based on discussions.

2.0 INITIAL CHIP SEAL WORKSHOP AND PERFORMANCE SPECIFICATION PLANNING

2.1 INTRODUCTION AND PURPOSE OF THE WORKSHOP

A chip seal and performance-based specification workshop and planning meeting was held in Salem, Oregon in November 2017. The workshop attendees included stakeholders for the Oregon chip seal community and prime contractors who regularly are involved in chip sealing state-owned roadways as a prime contractor or subcontractor. The workshop was well attended and included representatives from ODOT, Federal Highway Administration (FHWA), suppliers, contractors, and the research team from Iowa State University (ISU).

The purpose of the initial workshop was to engage both industry and academia in discussion to reach a common goal of improving chip seal specifications for Oregon and develop a performance specification that can be used as a tool for agencies to give contractors more freedom to choose application rates and innovative materials. At the workshop, research findings and results from Buss et al. (2016) were discussed. The workshop also began a conversation about what a chip seal performance specification would look like for the state of Oregon. The workshop helped in collecting feedback for the new specification. At the time of the workshop, the draft specification was tentative. There were concerns raised about the payment schedule if any significant delay in payment occurred as a result of this specification. A delayed payment was discussed, because the research required time after construction to verify performance. A delay in payment would likely increase costs of the chip sealing and be burdensome for contractors if a payment schedule under the new specification included a significant delay in full payment after construction to verify performance.

2.2 WORKSHOP AGENDA AND SUMMARY OF PRESENTATIONS

The initial workshop was held on November 2, 2017. Table 2.1 shows the workshop's agenda and schedule.

Table 2.1. Initial Chip Seal Performance Specification Workshop Agenda and Schedule

Time	Agenda
8:00–8:30 a.m.	Introduction: • Purpose and agenda of meeting • Introduce speakers
8:30–9:15 a.m.	R. Christopher Williams – **Performance Specifications.** *Types of specifications, performance specifications and types of warranties.*
9:15–10:00 a.m.	Doug Gransberg – **New Zealand Chip Seal Performance Specification.** *Chip seal best practices and research correlating performance with construction specifications.*
10:20–11:00 a.m.	Ashley Buss – **Oregon Chip Seal Research Results.** *Findings of the Oregon SPR 777 project and data supporting performance specifications.*
11:00–11:45 a.m.	Larry Ilg – **Chip Seal Proposed Specification ODOT's Perspective.** *Why the new specification is needed and what we hope it will do.*
1:00–2:15 p.m.	**Discussion:** Proposed chip seal specifications changes and chip seal design
2:15–3:00 p.m.	**Discussion:** Concerns/Challenges
3:20–4:00 p.m.	**Discussion of chip seal design and specifications** Recommend adjustment to the proposed specification and reason
4:00–5:00 p.m.	Summary and wrap-up

Dr. R. Christopher Williams spoke about types of specifications including: method specifications, end-result specifications, statistical acceptance specifications, performance specifications, and types of warranties. The New Zealand performance specification was briefly presented as well as Michigan's warranty period for chip seals (MDOT 2010).

Dr. Doug Gransberg presented validated best practices for chip seals and the correlation between chip seal performance and construction methods. He also presented the New Zealand chip seal performance specification and his research in Oklahoma (Zaman et al. 2014), showing that the specification could work for agencies in the US.

Dr. Ashley Buss presented a summary of the research performed during the Phase1 ODOT chip seal study (Buss et al. 2016). This research showed how macrotexture changed over time for the 14 roadways included in the study. The Oregon project found similar results to Dr. Gransberg's Oklahoma research (Zaman et al. 2014). Findings showed that the New Zealand performance specification helps provide a quantitative measure of performance for the chip seal. The Buss et al. (2016) findings provided an understanding of how typical Oregon chip seals perform under normal conditions in various regions of the state. Macrotexture measurements from the Phase 1 chip seal test sections showed that a performance specification based on macrotexture may work well for Oregon roads and could quantitatively identify a failed chip seal. A performance specification could also provide the contractor more freedom to set chip seal application rates and to implement new technologies. Finally, the research showed that using a chip seal design process could help bring "science" into the "art" of chip sealing. The design may be especially helpful for making field adjustments when chip sealing crews have limited experience.

Larry Ilg, quality assurance engineer (former pavement quality and materials engineer) with ODOT, presented on chip seal history in Oregon, project selection, construction responsibility, and recent research in the field and chip seal performance in various regions in Oregon.

2.3 SUMMARY OF TAKEAWAYS FROM THE WORKSHOP

The workshop identified that implementation of a performance specification was a major shift from the current method specification. Discussions from this workshop showed that a follow-up survey was needed to organize topic-by-topic feedback for the proposed specification changes and would help facilitate the future direction of the specification. In addition to the survey, it was determined that a series of specification web-conference meetings were needed to meet with stakeholders to go through the new specifications line-by-line, make updates, and identify best practices.

Another important part of the workshop was to discuss chip seal designs. Responsibility for chip sealing projects is shared between ODOT and contractors. Currently, ODOT sets the application rates, and contractors are responsible for construction at the selected rates. There was consensus that a new performance specification cannot prescribe application rates. In Buss et al. (2016), chip seal designs were back-calculated based on collected aggregate samples, binder information, and pre-construction data. Using the design framework requires knowledge of the roadway being chip sealed and testing of materials to be used in the chip seal construction. Some contractors already perform chip seal designs and are familiar with the chip seal design process. The benefits to the chip seal design process are that it provides a framework for the agency and contractor to test and become familiar with the material being used for the chip seal, the design methods require investigation of the roadway condition prior to chip seal construction, and a design framework can help identify potential issues before construction begins. The pre-seal roadway or pavement condition plays a crucial role in the performance of a chip seal; therefore, a pavement survey before construction is critical for optimal chip seal performance.

There was a consensus that implementing a performance-based specification could provide the contractors more freedom in choosing the most appropriate application rates for the emulsion and roadway condition. Other major differences between New Zealand's performance specification and ODOT's current specification include:

- Maintenance of the chip seal is the responsibility of the contractor for one year (unless otherwise specified)
- Traffic and aggregate properties determine design life and texture depth requirements
- 12-month post-construction inspection of macrotexture
- Proportional payment based on chip seal performance

Another topic of discussion was a pay item change. Minnesota research noted the benefits of paying for the chip seal based on the square yard and paying for the asphalt by the gallon/ton (Wood and Olson, 2007). The current ODOT specification pays for aggregate by the ton or cubic yard and the asphalt emulsion by the ton (ODOT Specifications 00705.80 and 00705.90). If the specification was changed, there would be no incentive to over-chip the seal. The research findings from Buss et al. (2016) found that emulsified asphalt chip seals may be over-chipped.

Figure 2.1 shows the details of the current ODOT specification on emulsified asphalt.

Measurement

00705.80 Measurement - The quantities of Emulsified Asphalt will be measured on the weight basis.

The quantities of Aggregate cover Material will be measured on the weight basis or on the volume basis in the hauling vehicle.

Payment

00705.90 Payment - The accepted quantities of Work performed under this Section will be paid for at the Contract unit price, per unit of measurement, for the following items:

	Pay Item	Unit of Measurement
(a)	Emulsified Asphalt in Prime Coat	Ton
(b)	Emulsified Asphalt in Fog Coat	Ton
(c)	Aggregate Cover Material	Ton or Cubic Yard

Item (b) includes water required to dilute the Emulsified Asphalt, according to 00705.11(c).

Payment will be payment in full for furnishing and placing all Materials, and for furnishing all Equipment, labor, and Incidentals necessary to complete the Work as specified.

No separate or additional payment will be made for materials used during the maintenance period.

Figure 2.1. ODOT emulsified asphalt specification

To summarize, the initial chip seal workshop provided an opportunity for participants to learn about the Oregon chip seal research and work together toward creating updates to the chip seal specification that will encourage high-quality construction and workmanship. The next steps after this workshop included the development of a survey to gather detailed feedback about the specification to date. A series of meetings were also planned to develop the new specification line-by-line, so the proposed specification developed in the project could be implemented and used by ODOT as a tool to enhance chip seal life and allow for more contractor innovation in chip sealing.

3.0 CHIP SEAL QUESTIONNAIRE RESULTS

The purpose of the survey was to gather feedback from stakeholders about the proposed performance specifications. An amended version of the draft specification was prepared as well as survey questions. At the time of the survey, only limited discussion on the specifications had occurred and the respondents' feedback provided further direction for the specification. The survey results helped identify concerns related to the new research recommendations for chip seal data collection and reporting from the updated chip seal design specifications. Additional updates to the specification based on the survey results are presented in Chapter 4.

The survey explained that there are three major changes required to move to a performance-based specification from ODOT's current method specification. These changes include having (1) an initial inspection after two weeks with partial payment for the completed job, (2) a one-year maintenance period, and (3) a final inspection with a macrotexture performance measurement at 12 months.

The draft performance specification provided with the survey included a 70% initial payment after passing the initial inspection and a 30% final payment after passing the final inspection. The specification was developed under the premise that a performance criteria of the chip seal would have significant financial implications.

3.1 GENERAL QUESTIONS AND QUESTIONS ABOUT IMPACT OF CHIP SEAL PERFORMANCE SPECIFICATION

Figure 3.1 displays the background/employment of survey respondents.

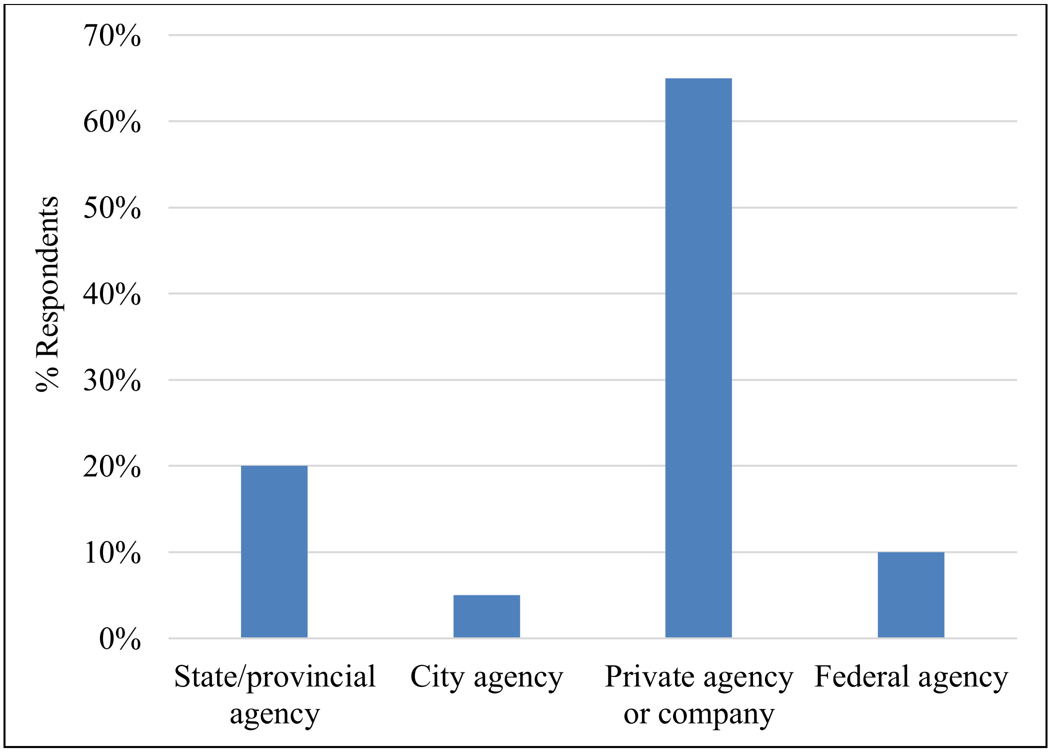


Figure 3.1. Type of organizations for respondents

The primary purpose of the survey was to involve contractor and binder supplier stakeholders in the development of a performance specification, and their feedback was helpful in further development of the specification. There were about 20 survey participants; however, responses were optional and provided on a voluntary basis and so not all questions have 20 respondents.

Survey question: *How involved is your organization in chip sealing?* For this question, a majority of respondents considered chip sealing their primary field, or their organization has major involvement in chip sealing projects. The results are shown in Figure 3.2.

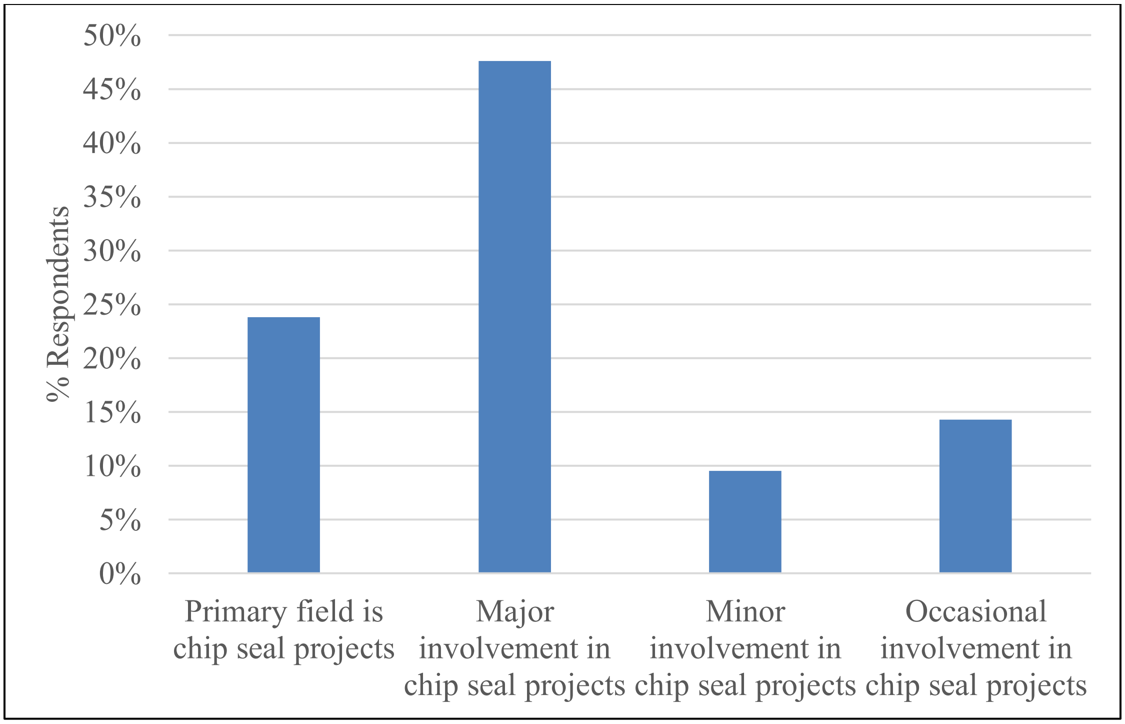


Figure 3.2. Involvement of respondent's organization in chip sealing

Survey question: *Based upon your own experience and opinion, which approach (contractor or agency constructed seals) seem to yield a better final chip seal product*? The answers showed that there was no consensus in which approach yields better performance: 35% of respondents chose agencies construct better chip seals, 35% of respondents chose contractors construct better chip seals, and 30% of respondents were undecided.

Survey question: *How do you rate your organization's overall experience with the performance of chip seals in Oregon?* The survey responses, Figure 3.3, show that the majority of responents responded that their organization had experienced excellent or good chip seal performance in Oregon.

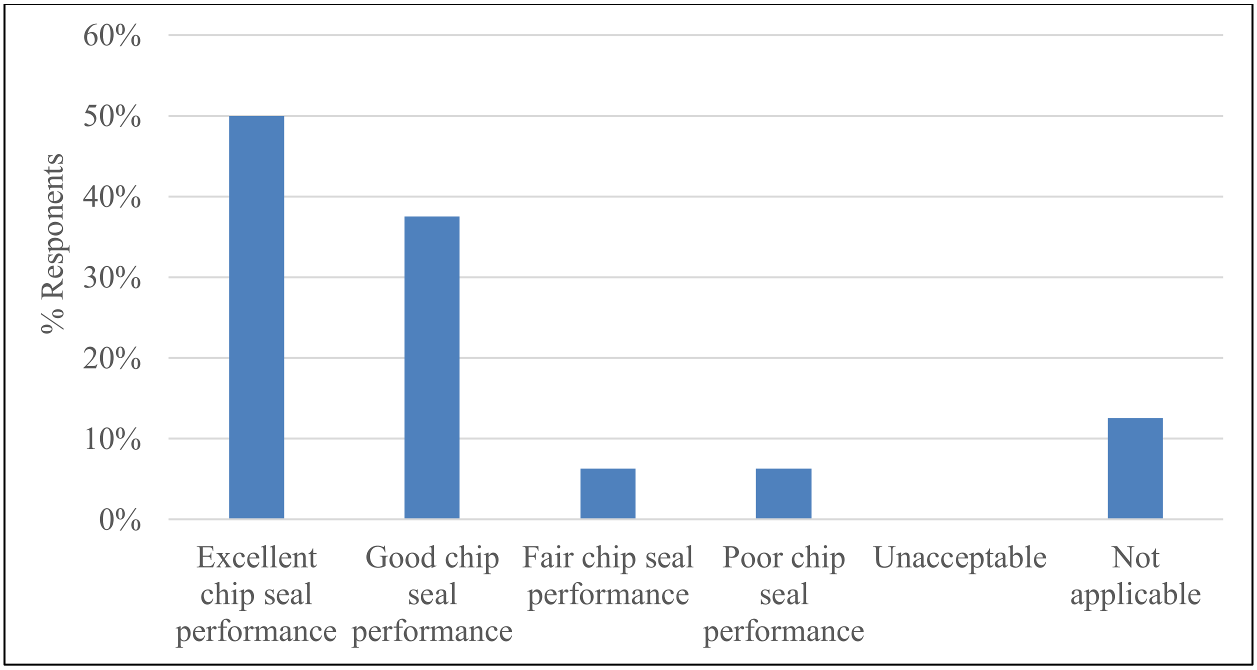


Figure 3.3. Respondent's overall experience with the performance of chip seals in Oregon

Additionally, respondents were asked what they believe influences chip seal performance. Many respondents emphasized that construction plays a significant role, and pride/ownership of the project is important to achieving high-quality results. Knowledge and experience in chip sealing were also deemed important. One respondent answered, "It [chip seal performance] is from selecting the right oil for the right environment, traffic loading, and putting down early season chip seals that have time to cure before winter. I also feel checking oil/rock compatibility is important. Having the ability to adjust oil and rock rates throughout the day on the project helps make a successful seal." Several respondents also mentioned the importance of quality control. As a side note, prior to the Buss et al. (2016) project being funded in 2014, ODOT had experienced several major chip seal failures.

Survey question: *Based upon your own experience and opinion, what are the primary and most common problems associated with chip sealazs in Oregon? (Check all that apply and indicate which is the most common.)* The results are shown in Figure 3.4, and note that the loss of aggregate is a major concern followed by flushing/bleeding at intersections/turns. The other problems mentioned are loss of aggregate in shaded areas, not rolling properly, and broad specifications.

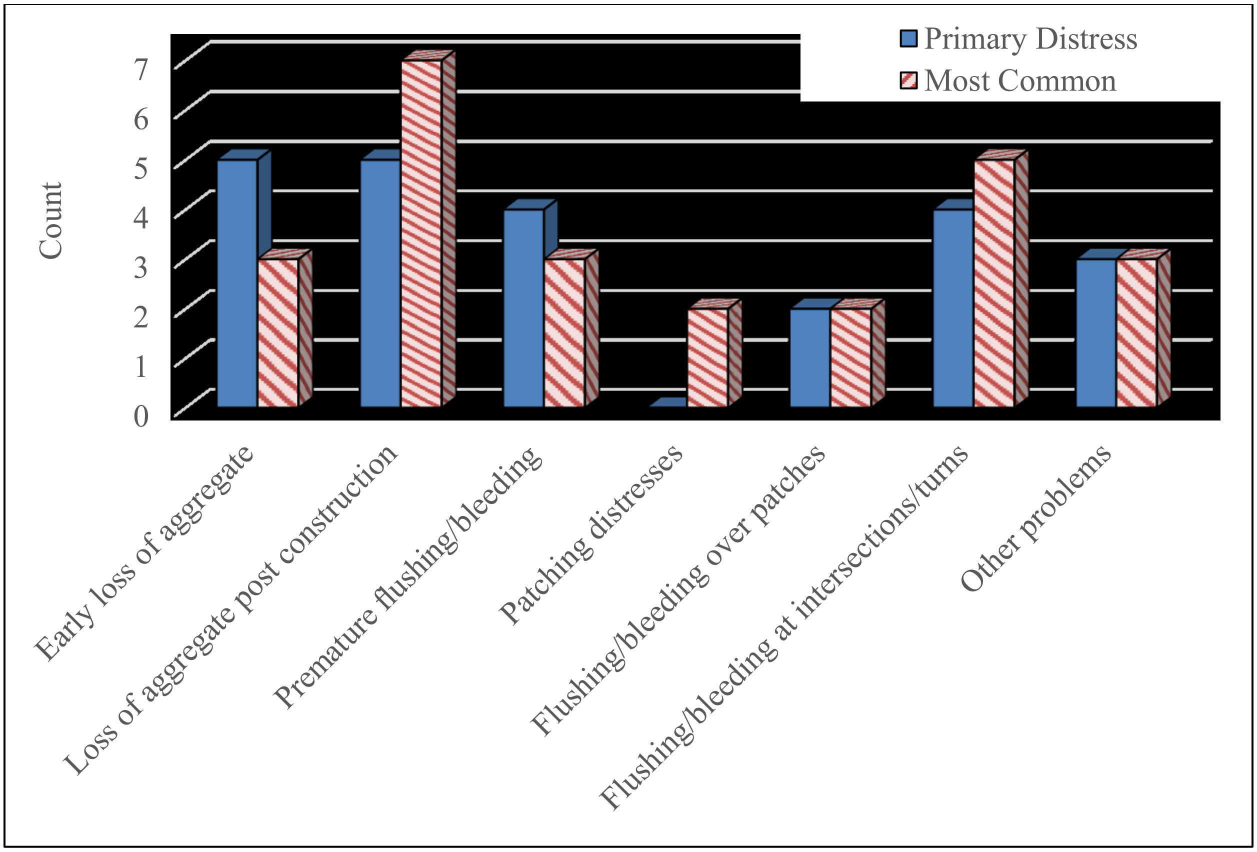


Figure 3.4. Primary and common chip seal distresses based on respondents' experience/opinion

Survey question: *What are the pavement parameters assessed that formulate the decision-making process to apply a chip seal?* The pavement condition, cracking, and age were major factors in the decision-making process for applying a chip seal based on the respondent's answers. Another factor for choosing a chip seal is that the customer cannot afford rehabilitation or to fully reconstruct the road at that time. Respondents selected the survey answers as follows (more than one pavement parameter could be chosen by respondents):

- 13% of respondents selected "Not involved in chip seal selection process"
- 21% of respondents selected "Pavement condition rating or index"
- 21% of respondents selected "Cracking severity/amount"
- 18% of respondents selected "Age of the surface"
- 10% of respondents selected "Amount of oxidation"
- 5% of respondents selected "Other"

Survey question: *Based upon your experience, rank the primary reasons that lead your organization to select chip seal application for a given pavement?* The respondents' rankings are shown in Figure 3.5. The "other" category includes respondents noting chip seals are chosen due to costs or to extend the life and seal the pavement surface.

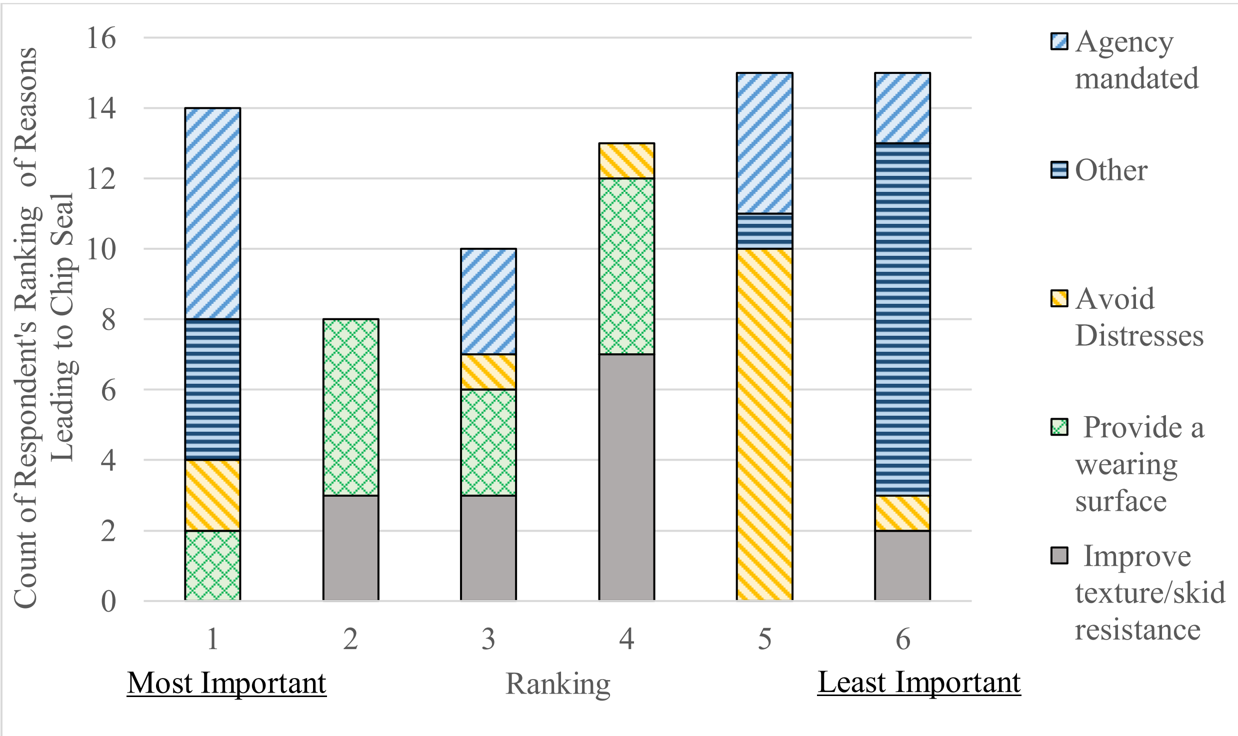


Figure 3.5. Ranking of reasons chip seal seals are chosen for a roadway

Part of the objective of the chip seal performance specification is to allow the contractor more freedom with application rates contingent upon performance criteria being met. Figure 3.6 shows the proposed change at the time the survey was distributed.

00710.44 Application Rates - ~~Apply the Emulsified Asphalt and spread the Aggregate within the following ranges of rates for the specified surface treatment design. The exact application and spread rate will be determined by the Engineer.~~ Use the Oregon Chip Seal Job Mix Formula Guide, available on the Oregon Department of Transportation website, for determining initial application rates but the design is not required when the performance acceptance criteria is used. Provide the following to the Engineer at least 2 weeks before beginning construction:

~~Chip Seal Design~~	~~Emulsified Asphalt Application Rate (gal./sq. yd.)~~	~~Aggregate Spread Rate (cu. yd./sq. yd.)~~
~~Fine~~	~~0.25 - 0.40~~	~~0.004 - 0.009~~
~~Single Size Medium~~	~~0.40 - 0.65~~	~~0.005 - 0.015~~
~~Graded Medium~~	~~0.40 - 0.65~~	~~0.005 - 0.015~~
~~Coarse~~	~~0.33 - 0.70~~	~~0.009 - 0.018~~

Gradation and all quality test results, as specified in 00710.10 [00711.10],
Designed application rate of seal coat aggregate design application rate,
Designed application rate of bituminous material design application rate

Figure 3.6. Possible changes to the Application Rates specification contingent upon addition of new performance requirements

Survey question: *Based upon your experience and practice, do you think the performance-based design specification will improve the construction of Oregon chip seals?* Sixty-one percent of respondents answered yes, while 38% responded no.

Survey question: *Based on your experience and practice, do you think that providing contractors more freedom with application rates will improve chip seal quality?* Seventy-seven percent of respondents answered yes, 23% of respondents answered "Unsure," and 0% of respondents answered no. Respondents who answered yes explained the following: costs need to be considered, follow design best practices/ODOT guidelines, and field adjustments need to be considered. One participant responded, "Yes, but make the contractor warranty their work."

As part of the new specification, there was a discussion about having a one-year maintenance period based on New Zealand's specification (Figure 3.7).

E. Maintenance

00710.61 Maintenance Period – It is the Contractor's responsibility to maintain the seal for one year unless otherwise specified. The maintenance period is one-year prior to the acceptance/performance testing date. The Contractor is required to submit a request for maintenance activities to the Engineer with proposed dates and sections to the ½ mile (e.g. rework MP 12.5 thru 13.0). No maintenance activities are to be started until a Notice to Proceed is received from the Engineer. A notification is required after maintenance activities are completed confirming the dates and locations of work.

Although repairs within the first few days can be made using the same size chip that was used initially, it is common practice to use the next smaller grade chip for later repairs. Make repairs with materials that meet or exceed 00710 Materials requirements. If at any time during the liability period repairs shall be performed using a chip with an ALD not exceeding 0.5 mm smaller than that of the original chip used for construction.

Figure 3.7. Possible maintenance period to be added to the specification

Survey question: *Have you bid on a preservation project that contained a maintenance requirement in the contract?* Respondents were mixed, with 35% saying yes, 35% saying no, and 30% responding not applicable. Respondents answering yes explained they've worked with Idaho's warranty specification (ITD 2015) and with cities in Washington and Oregon.

Survey question: *How will the updated maintenance specification impact your company or agency?* The results are shown in Figure 3.8.

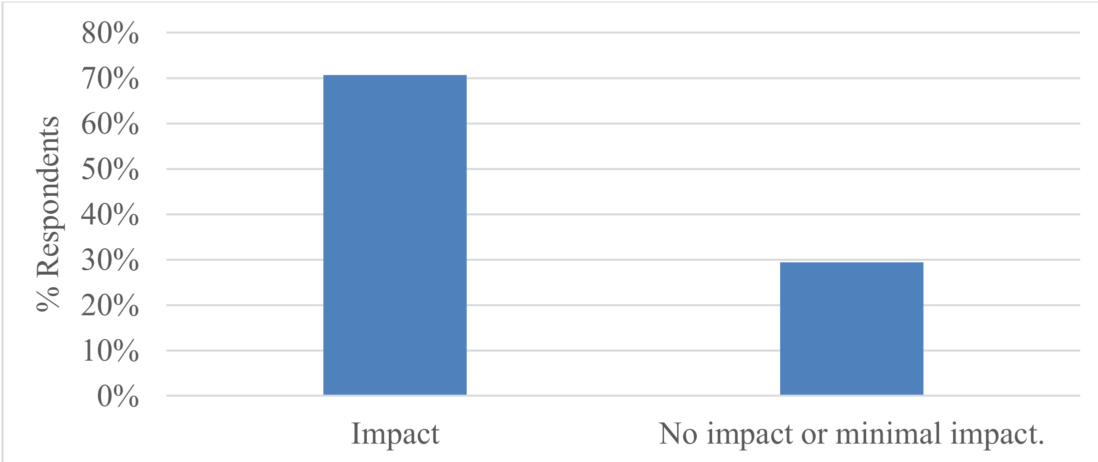


Figure 3.8. Respondents' answers to if an updated maintenance specification would impact their company or agency

The chip seal specification was still under development when the questionnaire was sent out. Specific impacts were unknown, but respondents listed several concerns with a maintenance period that included the following responses:

- "The need to commit resources for an extended time period after construction is complete."
- Concerns and questions about causes of damage to the chip seal. (e.g., "What would occur if the state caused damage with snowplows, etc…? Who would determine this?")
- If final payment wasn't made until after a period of time, how would contractors pay suppliers and/or subcontractors?
- "Increase in bid pricing will be reflected if the state uses a 30% retainage."
- Concern that a warranty fee structure doesn't improve quality of work and that the best way is to have multiple inspectors on-site during application to ensure seal is constructed properly.

Survey question: *Will the specification change impact Oregon DOT and contractor relations?* Fifty-three percent of respondents answered that the change will have an impact, and 47% responded that there will be no impact or minimal impact. At the time of the survey, the specification language was still being discussed. Potential ways respondents noted the specification could impact the agency-contractor relations are as follows:

- ODOT wouldn't set the application rates, which changes the role of the inspector
- Changes to payments and payment schedules will impact prices
- The specification will be a learning process for both the agency and the contractors

- There were also concerns about the definition of failure based on a performance specification

Survey question: *Based on your experience and practice, will a one-year maintenance requirement contribute to prolonging a chip seal's life span?* Most respondents answered yes at 58%, with 23% not sure, and 17% answering no.

Survey question*: Is the specification's one-year maintenance requirement straightforward?* Answers were mixed for this question and are shown in Figure 3.9.

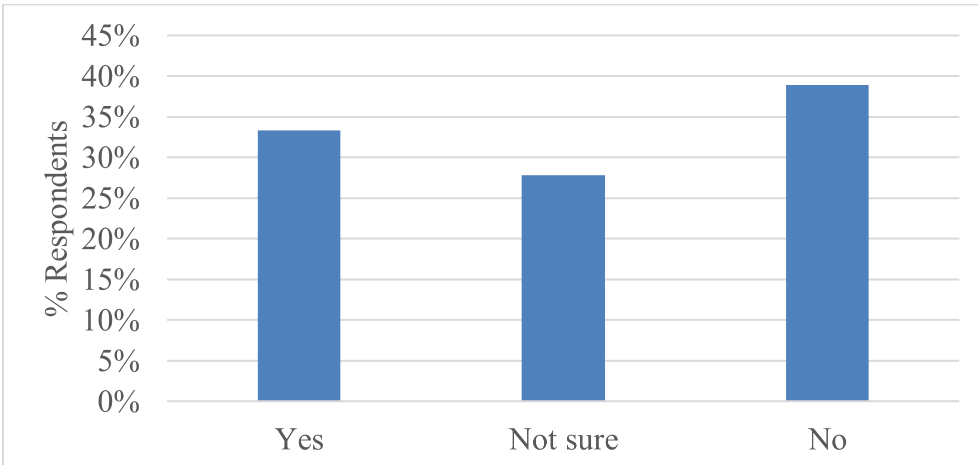


Figure 3.9. Respondents' answers to whether the specification's proposed one-year maintenance requirement was straightforward

Comments about reasons the specification remains unclear are due to a lack of clarity of when maintenance would be required, what acceptable maintenance is, and who makes the determination. This was also one of the issues for chip seal warranties discussed at the first chip seal workshop.

Survey question: *Based on your experience and practice, is the one-year maintenance requirement enforceable by Oregon DOT?* Respondents' answers are shown in Figure 3.10.

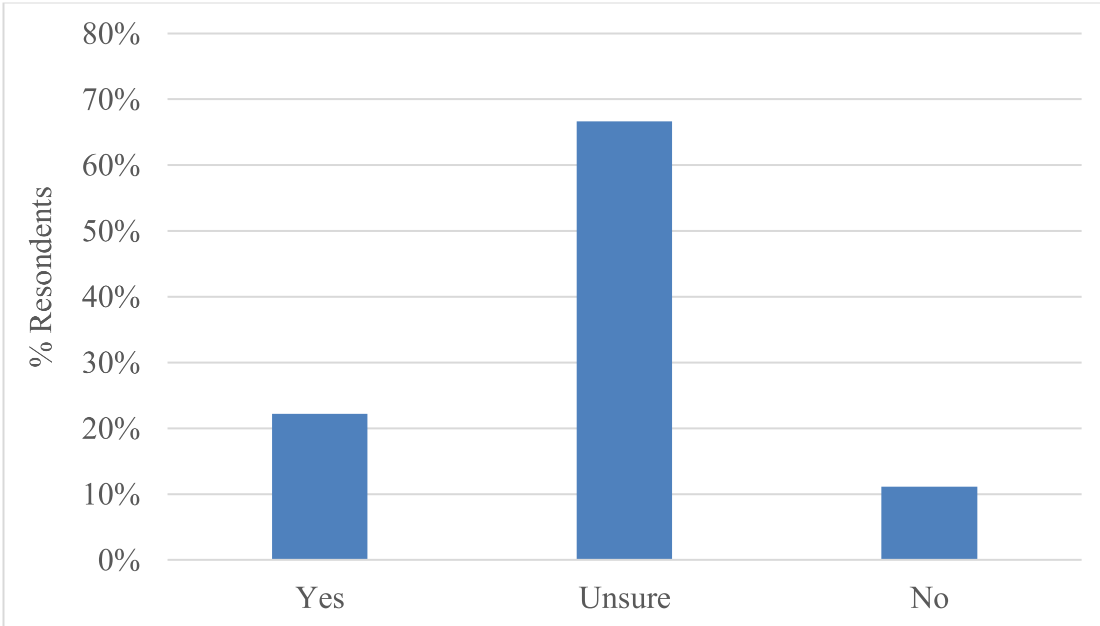


Figure 3.10. Respondents' answers to if the proposed new specification is enforceable

At the time of the survey, more developments were needed for clarifying the one-year maintenance requirements. The respondents explained that the specification may not be enforceable because there may be too many variables of potential damage or failure. For another question, a respondent uploaded Idaho's chip seal warranty guide (ITD 2015), which addresses some of the situations that are out of the contractor's control. Some examples of these types of concerns include snow plow damage, studded tires, marks in the wheel path from sudden stops, and damage from sharp-turning traffic.

Survey question: *Based on your experience and practice, how necessary is a one-year maintenance period in the context of the performance specification?* There was no consensus on whether a maintenance period is necessary for the performance specification (Figure 3.11).

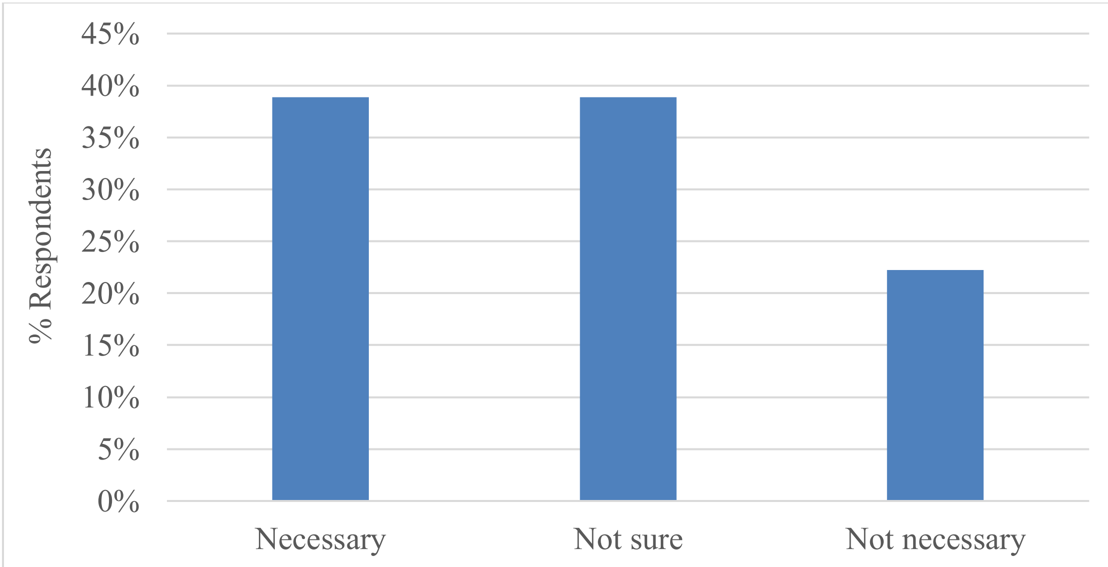


Figure 3.11. Respondents' answers to whether a maintenance period is needed for the performance specification

Previously mentioned challenges to requiring a maintenance period were that many factors can influence performance, with one example being snowplowing. One respondent indicated the requirement was not necessary but suggested having a warranty instead. However, there have been discussions about state of Oregon policies that may make the enforcement of warranties more challenging than what is done in other states. Another respondent indicated the maintenance period is not necessary and emphasized consistently good/excellent chip seals are obtained when more inspectors are on the job, ensuring all specifications are being met at the time of construction.

Survey question: *Based upon your experience and practice, do you think adding a performance specification for payment will improve the quality and performance of chip seals?* The answers to this were no, yes, or "Other reflections," with almost equal responses between participants. At the time of the survey, the possibility of a retainer agreement was being explored. Respondents noted the challenge a retainage would cause contractors, and the state would pay more for chip sealing services if the contractor had to take on higher risk and estimated the extra cost would be approximately equal to the price of the retainage.

Survey question: *Based upon your experience and practice, will the specification change requiring a one-year maintenance period impact a contractor's approach to chip sealing?* An overwhelming majority of 94% noted that the change would impact a contractor's approach to chip sealing. The respondents were asked to explain the impact. One respondent explained that the level of change would vary depending on the contractor. For instance, if the specification would put contractors in charge of the application rates, it would be a major change from current specifications. Several respondents mentioned that a performance specification requiring maintenance would result in contractors being more careful at construction. Another potential change mentioned was higher prices due to the additional risk to the contractor, or the project may not receive any bids. Other comments indicated the contractor would be more careful during chip seal construction and follow chip seal best practices if responsible for maintenance.

3.2 QUESTIONS ABOUT ACCEPTANCE UNDER A PERFORMANCE SPECIFICATION

This section presents survey questions and responses about acceptance testing under the performance specification. Figure 3.12 presents the proposed language at the time the survey was sent to stakeholders.

Acceptance

00710.92 Where the existing (pre-chip seal) conditions make achieving a uniform texture difficult, or there is a high risk for failure, then an alternative acceptance criteria can be agreed upon. This may entail identifying areas where some chip loss may occur on high stress sites and agreeing on the area involved. The alternative acceptance criteria must be site-specific, written and agreed on prior to construction.

00710.92 Initial Acceptance –
Initial acceptance: Initial acceptance of the chip seal is based on the contractor providing the specified materials. This inspection is scheduled a minimum of two weeks after construction is completed.

Payment of 70% is made at this stage. Visual inspection to ODOT approval. Sand circle measurements will be taken at any areas of concern. Visual inspection requirements are as follows:

Surface Cracking. Each individual driving lane will be reviewed for measuring and quantifying surface cracking. All open cracks will be logged within the chosen segments by crack type. The total length of longitudinal cracks will be logged for each segment. The transverse cracks will be logged by those between 6 inches and 6 feet in length and those equal or exceeding 6 feet in length. Transverse cracks and longitudinal cracks will be converted to defective cracks by the following:

A. One transverse crack 6 feet or greater, in length = one defective crack.
B. Five transverse cracks between 6 inches and 6 feet in length = one defective crack.
C. A total of 125 feet of longitudinal crack(s) = one defective crack.

If the number of defective cracks equal or exceed the values in Table 2, the segment is considered defective. Repair/maintenance work is required when the average of all segments reviewed exceed the following values in Table 2.

Table 2: Repair Requirements for Surface Cracking

Chip Seal Treatment	Pavement Type	Number of Defective Cracks
Single Chip Seal	Flexible	25

Corrective action for this parameter requires the Contractor to overband crack fill all cracks on the entire site, including shoulders if part of the chip seal work.

Loss of Cover Aggregate. The allowable threshold limit for loss of cover aggregate must not exceed 40 percent of the segment length. All segments in the driving lane or shoulder (528 feet in length) will be measured where the aggregate loss is evident. This measurement is linear and not dependent on area of aggregate loss. Corrective action, full-width across the driving lane or shoulder, will be required for each defective segment.

Bleeding/Flushing. The allowable threshold limit for bleeding or flushing must not exceed 40 percent of the segment length. All segments in the driving lane or shoulder (528 feet in length) will be measured where the bleeding or flushing is evident. This measurement is linear and not dependent on area of bleeding or flushing. Corrective action, full-width across the driving lane or shoulder, will be required for each defective segment.

A length of 528 ft. is used for testing and the performance of five sand circle tests to determine texture depth. Five sand circles are to be taken across the width of the seal. The specified locations are: between the outer wheel path and the pavement edge, in the outer wheelpath, between wheel paths, in the inner wheelpath between the center line. The five readings are to be alternated across the road every 500 ft. to ensure a mean reading is obtained for the complete road width, thus avoiding bias to one lane. Where pavement has edge marking, this is regarded as the pavement edge. To ensure that the texture of the seal is above the required minimum, the mean of the five tests is reduced by a factor dependent on the standard deviation. The texture measurements are taken by the sand circle method. The minimum value of the average texture depth calculated from the sand circle measurements shall be:

$$X - 0.519S > 0.07\ ALD\ \log_{10} Y_d + 0.9$$

Where:

- X = average of the 5 texture depth measurements
- S = sample standard deviation calculated for the 5 tests

Note: X - 0.519S is commonly termed the 'texture depth criterion'

Figure 3.12. Potential acceptance criteria based on New Zealand specifications and guidelines

Survey question: *Is the modified acceptance specifications clear and easy to understand?* For this question, 44% of respondents answered no and 56% of respondents answered yes. Individuals answering no recommended providing more information about the sand circle test, texture calculation, clarity on surface cracking, and clarifying segment length for surface cracking. Buss et al. (2016) showed that cracking is related to the pre-seal condition of the roadway.

Survey question: *Based upon your experience and practice, do you think acceptance criteria will improve the quality and performance of chip seals?* The respondents' answers were evenly split between yes and no for this question. The respondents explained there is a concern about cracking and visual inspection criteria for a performance specification. These criteria were improved in updated versions of the specification.

Survey question: *Based upon your experience and practice, do you think acceptance criteria will enhance chip seal construction practices?* The respondents' answers to this question are shown in Figure 3.13.

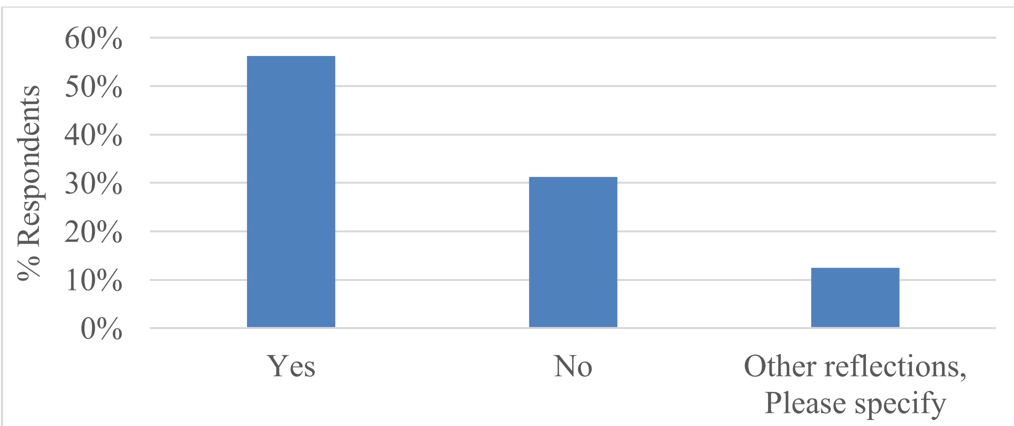


Figure 3.13. Respondents' answers to whether new acceptance criteria will enhance chip seal construction practices

A majority answered yes, while about 30% selected no and a few "Other reflections." Comments for "Other reflections" mentioned more enforcement of current specifications, and another questioned using the sand circle test method two weeks after chip seal construction.

Survey question: *How will the added acceptance specification impact your company or agency?* Two-thirds of respondents noted the specification change would affect their job or business, with the remaining noting no or minimal impact. The respondents who indicated the specification would affect their company explained bid prices would likely increase under a specification similar to the New Zealand specification. The new specification would shift risk and could influence the payment schedule, and either of those would affect the bid price. One respondent mentioned that shifting risk might ultimately have a negative impact between the state and contractors.

Survey question: *Based on your experience and practice, do you think that adding acceptance criteria will increase or incentivize the use of a rational design approach rather than experience-*

based methods? The answers for this question were 50% yes and 50% no. Respondents answering yes noted that quality always follows expectations, and another mentioned the criteria would only incentivize a rational design approach if contractors have control of the application rates. Respondents answering no explained that chip seal is a visually accepted method that requires experience and were skeptical whether the performance specification would work as desired.

A similar survey question was asked: *Based upon your experience and practice, do you think that adding a performance specification will increase the use of a rational design approach rather than experience-based methods?* For this question, 46% answered yes, while 23% of respondents answered no, and 23% answered "Unsure." Other recommendations about the acceptance criteria suggested allowing the initial acceptance to occur upon completion of construction, because if there is a one-year maintenance period, there is no need to wait two weeks for initial acceptance. Another recommendation was to have one party take responsibility of the project and have control of all the rates and quality of work.

The next two questions addressed chip retention and repairs within the Acceptance section. The proposed specification language at the time the survey was sent is shown in Figure 3.14.

[Section Heading #] Chip Retention: A visual assessment of the surface shall be performed to assess the level of chip coverage and retention. Chip retention shall be assessed by determining the chip coverage on any 1 square foot area. The segment shall be rejected if any three locations assessed have less than 95% chip coverage in the wheelpath location or less than 90% chip coverage on areas outside the wheelpath. All areas of chip loss greater than above must be repaired within the timeframe specified in the contract document.

Retesting: A provision is made to allow the contractor (or consultant) to retest the wheelpaths. In retesting, the lot is divided into individual lanes and these are assessed separately. In the case of an outlier that causes "S" to increase substantially, the sand circle measurements may be taken a second time. If the texture depth is below the minimum to achieve the design life Y_d, then the expected life Y_f can be calculated from equation 4 above. Payment is then reduced by a factor based on Uniform Series Present Worth Factor (USPWF) up to a reduction in life of 25%. If the reduction in life is greater than 25% then the payment reduces proportionally until no payment is given for a loss in life greater than 60%. In the case of one outlier that causes "S" to increase substantially, the sand circle measurements may be taken a second time."

Section Heading #] Repairs: Unless an exception is approved by the engineer, any repairs shall be performed using a chip with an ALD not exceeding **0.5 mm** smaller than that of the original chip used for construction.

If at any time during the defects liability period repairs are required over an area greater than 10% of the area of the section then the proposed repair technique and acceptance criteria shall be agreed with the Engineer.

Any areas repaired during the defects liability period more than nine months after construction will, at the discretion of the Engineer, be subjected to a further 12 month defects liability period. If the area of repairs at the end of 12 months are greater than 10% of the section and revised acceptance criteria has not been agreed with the Engineer, then the section will be subject to a further 12 month defects liability period.

The contractor will submit a chip seal design for all repairs to ensure that the risk of a reduced seal design life is minimized.

Figure 3.14. Potential chip retention and repairs addition to the specification

Survey question: *Is chip retention adequately addressed in the Acceptance section?* Most respondents answered yes or "Probably yes." No respondents answered, "Probably not" or "Definitely not." Results are shown in Figure 3.15.

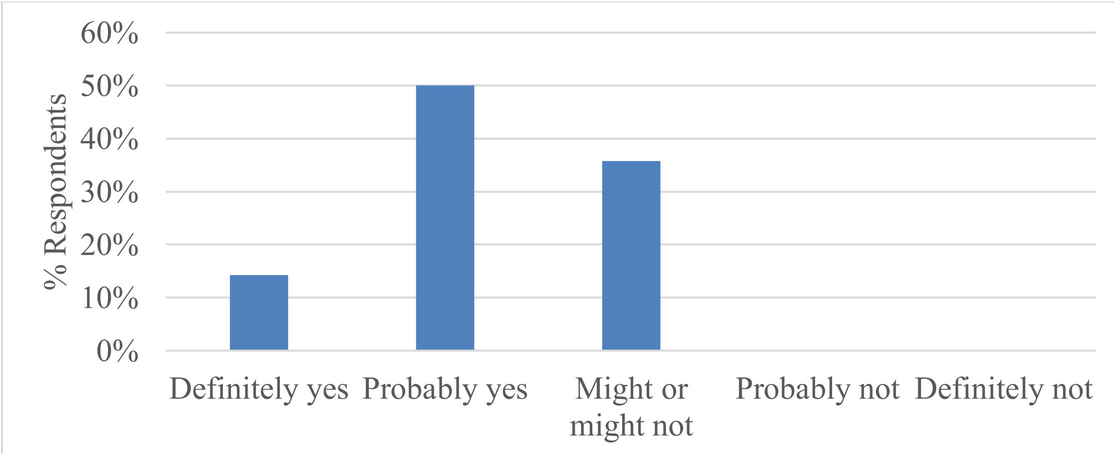


Figure 3.15. Respondents' answers to whether chip retention is adequately addressed in the acceptance section

Survey Question: *Is the requirement for repairs clearly defined in the new specification?* Respondent answers to this question are shown in Figure 3.16. The majority of respondents answered, "Probably yes."

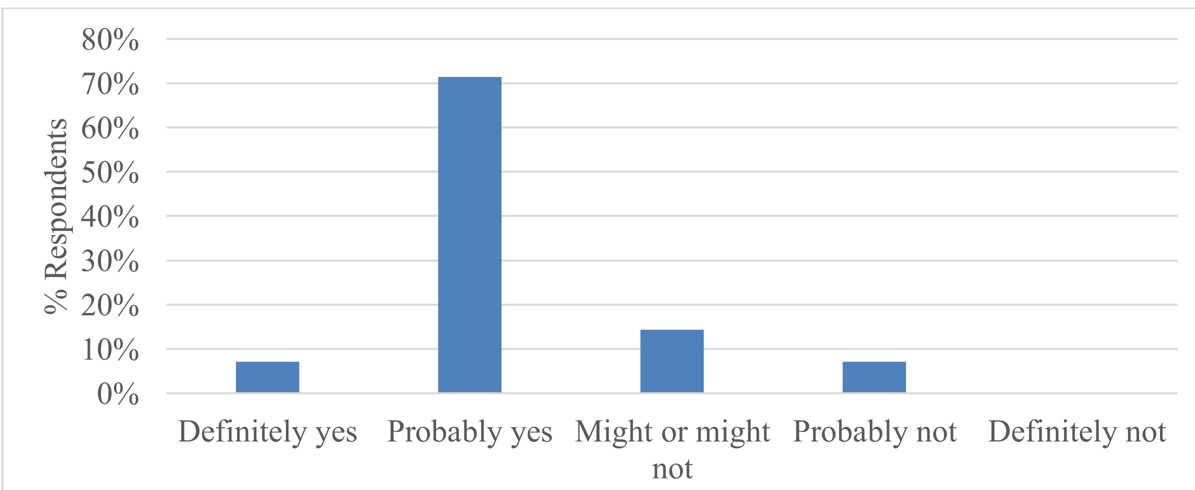


Figure 3.16. Respondents' answers to whether the requirement for repairs is clearly defined in the new specification

3.3 QUESTIONS ABOUT PAYMENT UNDER A PERFORMANCE SPECIFICATION

The proposed changes to payment under a performance specification at the time the survey was sent out are shown in Figure 3.17.

00710.90 Payment - ~~The accepted quantities of Work performed under this Section will be paid for at the Contract unit price, per unit of measurement, for the following items:~~

~~Pay Item~~ ~~Unit of Measurement~~

~~(a) Aggregate in Emulsified Asphalt Surface Treatment.................Ton or Cubic Yard~~
~~(b) Asphalt in Emulsified Asphalt Surface Treatment.................................Ton~~
~~(c) Extra for Emulsified Asphalt Surface Treatment Approaches...............Each~~

~~Item (c) applies to the extra costs of placing the Aggregates and asphalt in single application Emulsified Asphalt surface treatments only on street connections and road approaches. Payment will be in addition to payment made for the Materials used in the Work.~~

~~Payment will be payment in full for furnishing and placing all Materials, and for furnishing all Equipment, labor, and Incidentals necessary to complete the Work as specified.~~

~~No separate or additional payment will be made for preparing the road surface, placing Materials in final position, or brooming.~~

Upon passing initial acceptance, 70 percent will be paid. Payment is for furnishing and placing all materials, and for furnishing all Equipment, labor, and incidentals necessary to complete the Work as specified. The remaining 30 percent will be paid after passing the final acceptance inspection.

Figure 3.17. Potential payment plan for completed chip seal application

Survey question: *Based upon your experience and practice, is it better to have payment for materials or for square yard of chip seal?* Explain your answer. The respondents' answers are shown in Figure 3.18.

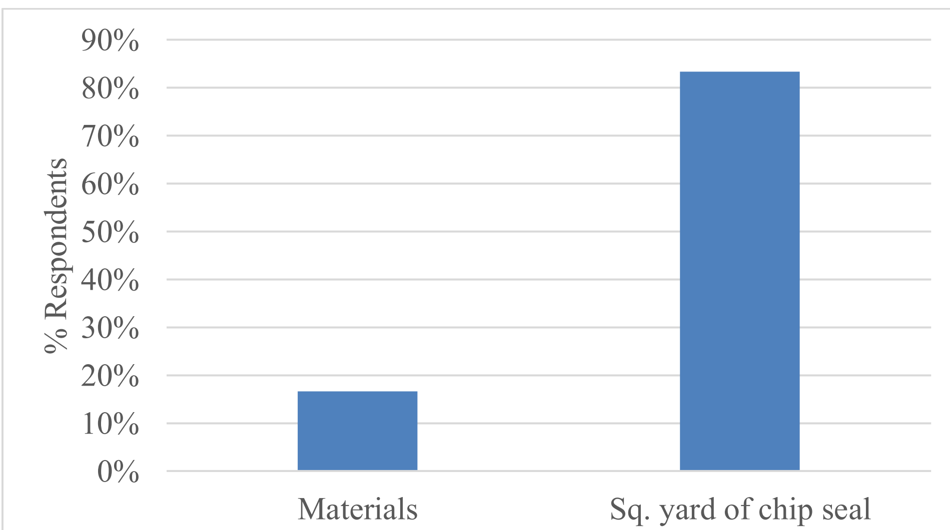


Figure 3.18. Respondents' answers to whether the requirement should base payment on materials or square yard

The respondents choosing "Materials" indicated the contractor would use more emulsion to hold the chips, and another respondent noted a roadway surface would dictate the amount of oil needed. A few respondents who selected "Payment based on square yard" mentioned square yards is easy to measure and track. Another respondent mentioned that payment by square yards does not allow for manipulation of design requirements to achieve more payment. The square yards payment would allow the contractors to have equal bids, and if a contractor's design has a variable rate, the risk would be on the contractor under a performance specification. Another respondent mentioned that payment should be based on the square yard if the contractor has control of application rates and other design and placement aspects of the seal.

Survey question: *Based on your experience, would the 70% payment after initial acceptance and the remaining 30% payment after final acceptance be acceptable?* The majority of respondents answered no, as shown in Figure 3.19.

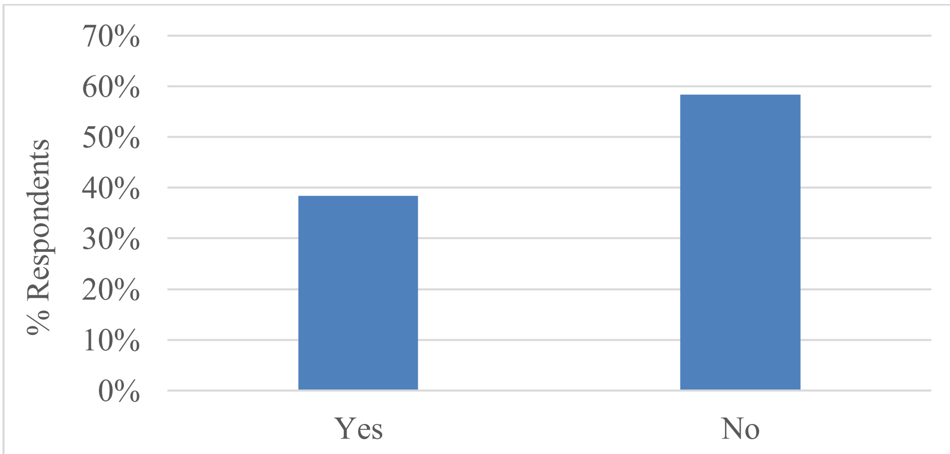


Figure 3.19. Respondents' answers to whether 30% payment after a one-year acceptance period is acceptable

A respondent who answered yes was concerned that the price increase would cause the chip seal treatment to be cost-prohibitive if a high retainage was implemented. On the other hand, other respondents were concerned that 30% retainage would be too low if a very poor-quality chip seal job was performed. Other concerns with a 30% retainage were a one-year acceptance criteria would be too long for contractors to make payment to the suppliers. Thus, it is likely that bids would be adjusted so all work is paid up front, and the one-year retainage would be treated as a bonus.

Survey question: *Based upon your experience and practice, do you think the specification is enforceable by Oregon DOT?* Respondent's answers are shown in Figure 3.20, and overall results are mixed.

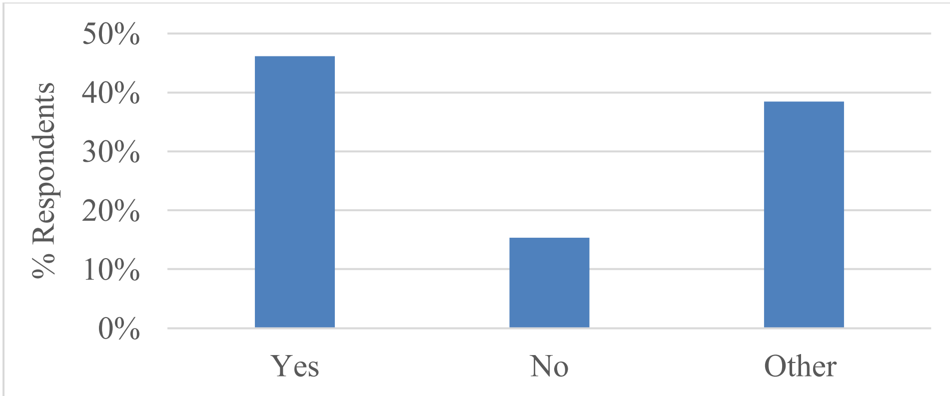


Figure 3.20. Respondents' answers to whether the specification is enforceable

The comments emphasized that under the new specification, contractors should have the ability to apply best practices and innovation, but also, if any direction is given (or required) from ODOT to the contractor, it would expose ODOT to liability, and then their answer to this question would be no.

Survey question: *Based upon your experience and practice, do you think retaining 30% from the contractor until final acceptance will improve chip seal performance?* Half of the respondents answered no, while the other 50% were equally split between yes and "Other," as shown in Figure 3.21.

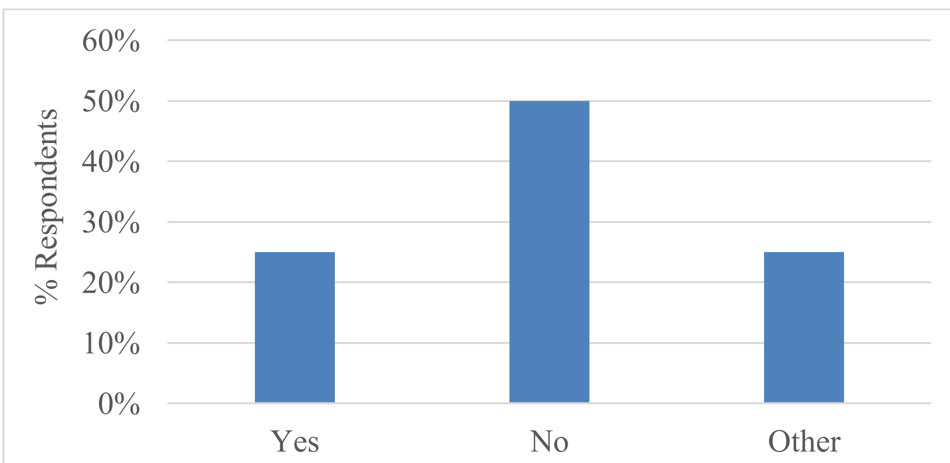


Figure 3.21. Respondents' answers to whether retaining 30% from the contractor until final acceptance would improve chip seal performance

Respondent comments noted the state would be paying more for the same product. A respondent who answered yes emphasized that the answer was conditional upon the contractor remaining in control of the design.

Survey question: *Based upon your experience and practice, do you think adding this part [payment retainage] will motivate a rational chip seal design approach rather than experience-*

based methods? Respondents answers are shown in Figure 3.22, and half of the respondents answered no. The remaining votes were evenly split between yes and "Unsure."

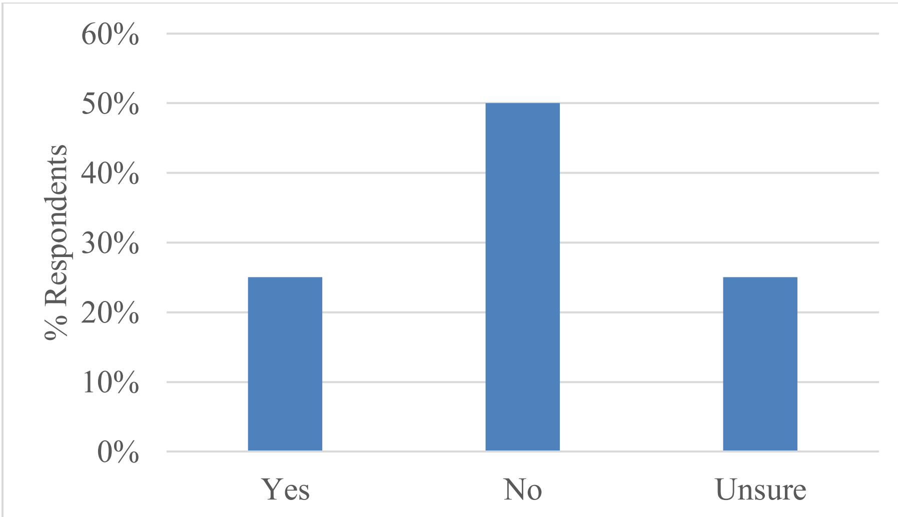


Figure 3.22. Respondents' answers to whether a payment retainage will motivate a rational chip seal design approach over experience-based methods

3.4 QUESTIONS ABOUT POTENTIAL IMPACT OF CHIP SEAL PERFORMANCE AFTER IMPLEMENTATION OF PERFORMANCE SPECIFICATIONS

The proposed performance criteria at 12 months is presented in Figure 3.23 and is based on the New Zealand specification.

Performance criteria at 12 months

00710.91 Performance – The chip seal performance measure is macrotexture. After one year of traffic, the pavement macrotexture must meet the required mean texture depth.

For single-coat seals the required mean texture depth as measured by ODOT provisional test method [XXXX] at one year is calculated as follows:

$$TD1 = 0.07\ ALD\ \log_{10} Y_d + 0.9$$

Where:

- TD_1 = Texture depth after one year in mm
- Y_d = design life in years
- ALD = average least dimension of the sealing chip in mm

For single-coat seals the design life is calculated as follows:

$$Y_d = 4.916 + 1.68\ (ALD) - (1.03 + 0.219\ ALD)\ \log_{10}\ (elv)$$

Where:

- Y_d = design life in years
- elv = equivalent light vehicles
- ALD = average least dimension of the sealing chip in mm

Equivalent light vehicles/lane/day is calculated as:

$$elv = \frac{AADT}{Number\ of\ lanes}\left(1 + \frac{9(HCV)}{100}\right)$$

AADT = annual average daily traffic on the road section
HCV = percentage of Trucks. Trucks are defined as a Class 4-13 Vehicle.

The estimated life, Yf, is found by the following equation:

$$Yf = \text{antilog}\ [(TD_1-0.9)/(0.07*ALD)]$$

Where Yf is the expected life in years before the seal will flush.

If the expected life is less than the design life, then the section is considered to be outside the specification, no additional payment will be made without corrective action.

Figure 3.23. Proposed performance criteria to be added to the specification

Research results from Buss et al. (2016) showed that ODOT chip seals regularly exceed this performance criteria.

Survey question: *Have you bid on or been involved with a chip seal project that used a performance specification?* Respondents' answers are shown in Figure 3.24, and the majority of respondents have not worked with chip seal projects requiring a performance specification. Respondents who answered yes explained the state of Idaho's warranty bond for chip seals requires chip seal performance.

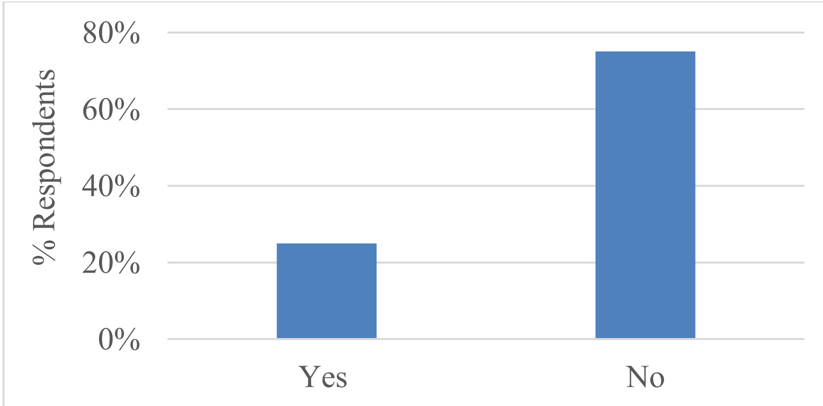


Figure 3.24. Respondents' answers to whether they have been involved with a chip seal project that uses a performance specification

Survey question: *Based on your experience, do you think the proposed performance specification will improve the quality and performance of chip seals?* Respondents' answers are shown in Figure 3.25.

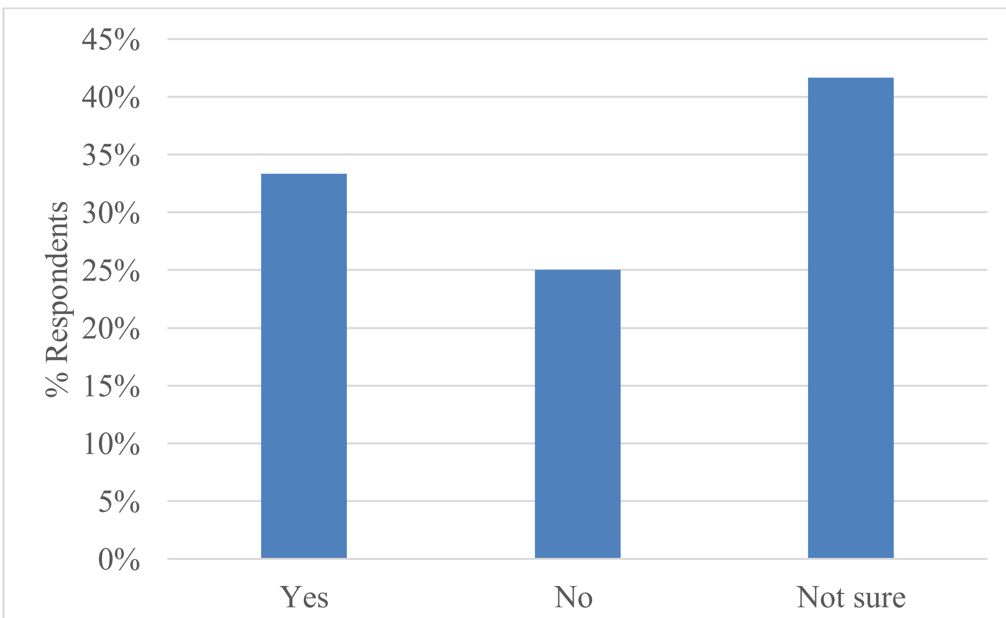


Figure 3.25. Respondents' answers to whether the proposed performance specification will improve the quality and performance of chip seals

Respondents who answered no explained why, and the reasons included that the current specifications are adequate and that the performance specification as proposed has the potential to cause more disputes between the state and contractors, which may lead to avoiding such projects. Another respondent emphasized that contractors need control over the chip seal design.

Survey question: *Based upon your experience and practice, do you think the specification is easily adopted by contractors?* Respondents' answers are shown in Figure 3.26.

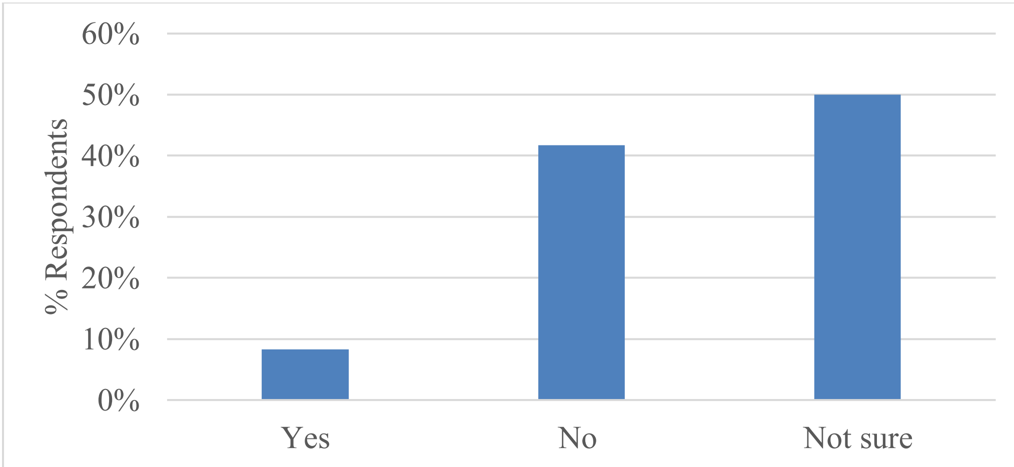


Figure 3.26. Respondents' answers to whether the specification is easily adopted by contractors

At the time of the survey, the proposed specification followed New Zealand's specification and had a large payment retainage, 30%, until final acceptance was approved one year after construction. The respondents who answered no explained that this specification adds a whole new element of risk. Another answered that the specification as written would not be easily adopted currently.

Survey question: *Based on your experience, will a performance specification encourage rational chip seal design approaches rather than experience-based methods?* Respondents' answers are presented in Figure 3.27, and there is no consensus as to whether a rational chip seal design would be further adopted based on this specification.

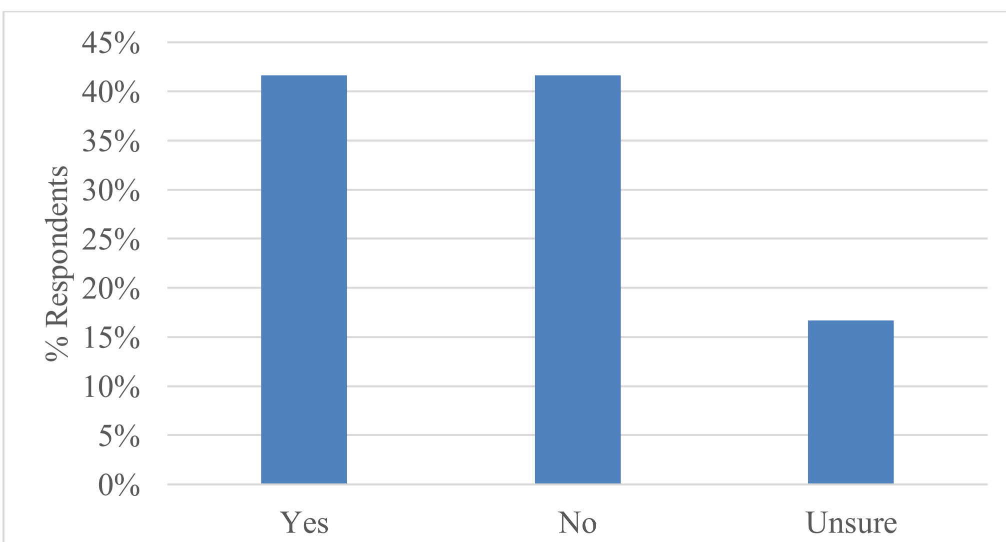


Figure 3.27. Respondents' answers to whether a performance specification will encourage rational chip seal design approaches rather than experience-based methods

Survey question: *Based on your experience, is a chip seal performance specification necessary for Oregon to provide high-quality chip seals to the traveling public?* Respondents' answers are shown in Figure 3.28, and the answers reflect there is not a consensus as to whether the specifications are necessary.

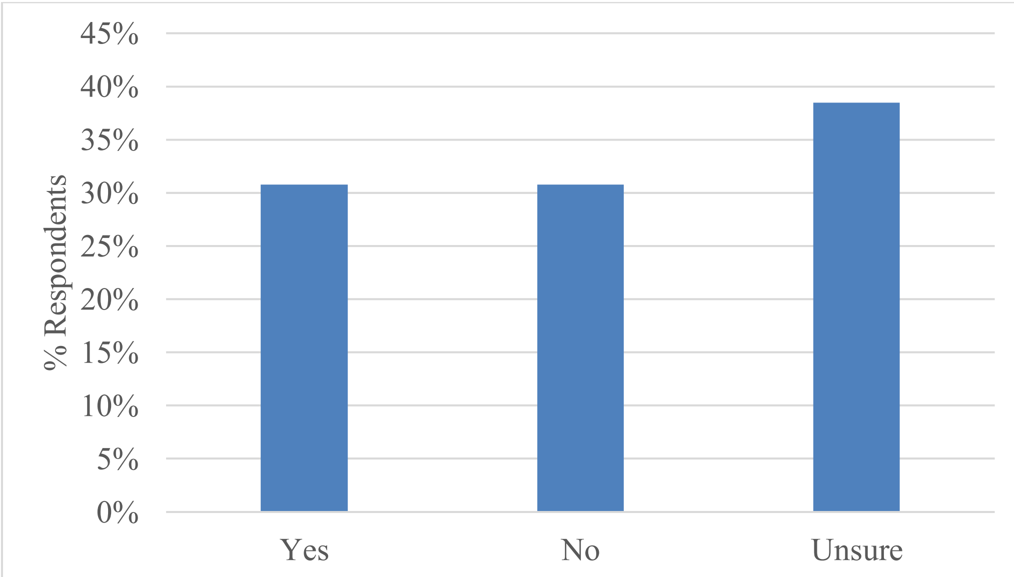


Figure 3.28. Respondents' answers to whether a chip seal performance specification is necessary for Oregon to provide high-quality chip seals

Respondents answering "Unsure" explained that a warranty guide is the best, because it would let the contractor design, build, and warranty the job and allocates all risk for the project to one party. Another respondent explained that the current specification can be fixed (i.e., improved) and that a performance specification could provide high-quality chip seals, if written correctly and gives design control to the contractor.

Survey question: *Based upon your experience and practice, do you think the performance-based design specification will improve the construction of Oregon chip seals?* A small majority of respondents answered yes, as shown in Figure 3.29.

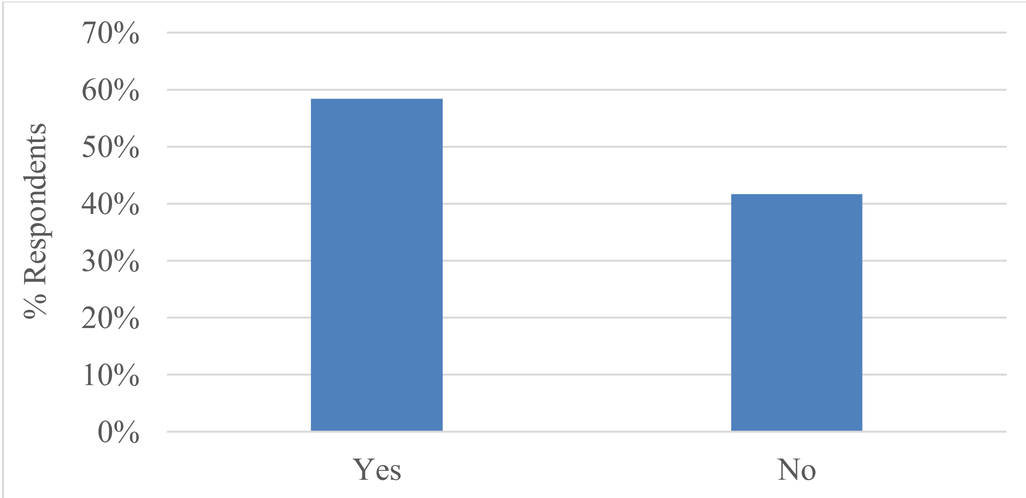


Figure 3.29. Respondents' answers to whether the performance-based design specification will improve construction of Oregon chip seals

Survey question: *Based on your experience and practice, do you think that providing contractors more freedom with application rates will improve chip seal quality?* Respondents' answers are shown in Figure 3.30, and most respondents answered yes.

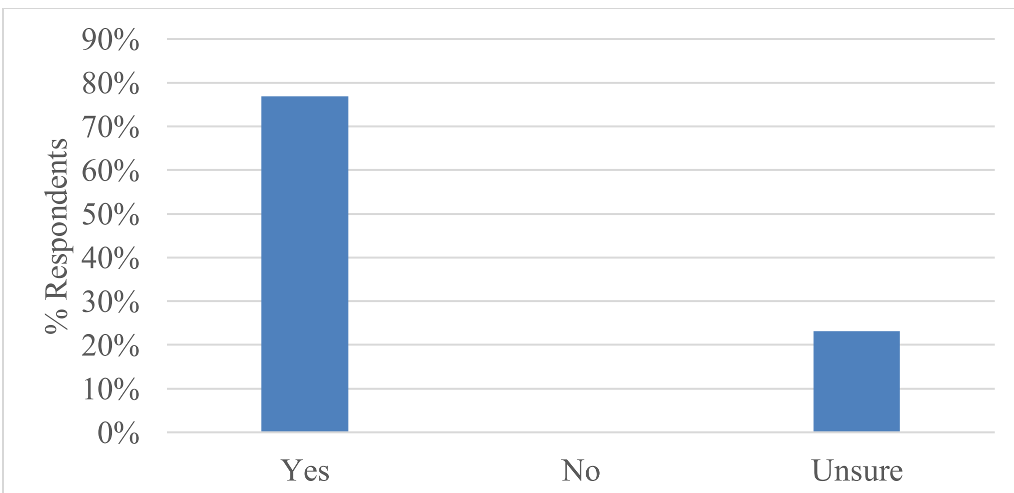


Figure 3.30. Respondents' answers to whether providing contractors more freedom with application rates would improve chip seal quality

Respondents answering yes further explained their reasons. One respondent emphasized the consideration of costs. Another recommended following ODOT guidelines and adjusting in the field as needed. Finally, respondents mentioned that design best practices must be followed, and another explained that the contractor should warranty their work.

3.5 SURVEY QUESTIONS ABOUT CHANGES TO SPECIFICATION DUE TO PERFORMANCE SPECIFICATION IMPLEMENTATION AND SURVEY WRAP-UP QUESTIONS

The purpose of some of these questions was to gain respondents' feedback about keeping other aspects of the specification that would fall under a more "method-based" specification. These questions were asked and answered based on the understanding that a large payment retainage was contingent upon meeting one-year performance criteria.

Survey question: *As ODOT shifts from a method- to performance-based chip seal specification, should we keep the following weather restriction, "The placing of single application Emulsified Asphalt surface treatments will not be allowed before July 1 or after August 31"?* Respondents' answers are shown in Figure 3.31, and a majority of respondents answered that the specification should focus on performance and not have the weather restriction.

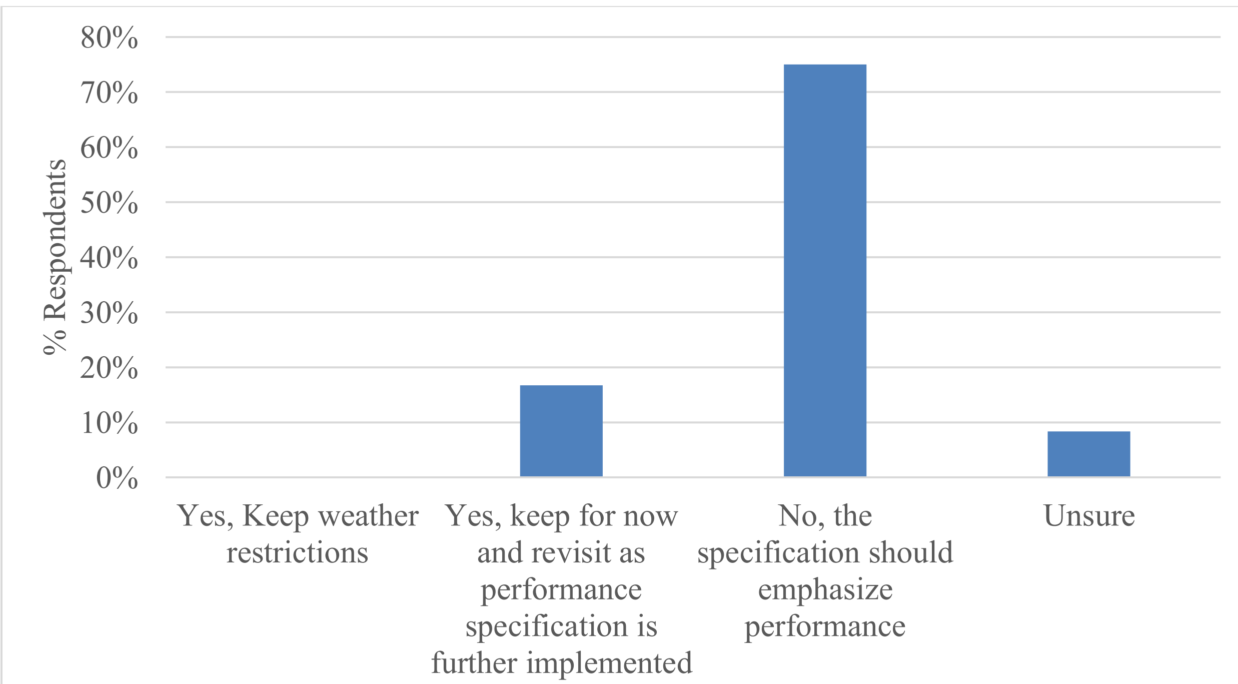


Figure 3.31. Respondents' answers to "Should we keep the following weather restriction, 'The placing of single application emulsified asphalt surface treatments will not be allowed before July 1 or after August 31'?"

Figure 3.32 shows the proposed updates and changes to the Equipment section of the chip seal specification at the time the survey was sent to survey participants.

Equipment

00710.20 Equipment - Provide a pressure distributor, hauling vehicles, chip spreader, compactors, power brooms and other necessary Equipment to ensure ~~efficient~~ operation and construction to meet specified results. Provide Equipment in sufficient number and capacities that will provide coordinated and uniform progress of the Work. Provide communication for the operation.

~~Provide two-way radio communication between the asphalt distributor and chip spreader.~~

00710.21 Asphalt Distributor - Provide ~~an~~field verification that the asphalt distributor is calibrated to maintain a variation of 0.015 gallons/SY for each load. designed, equipped, maintained and operated so the Emulsified Asphalt material may be applied uniformly at even heat. The distributor shall be capable of applying the asphalt on variable surface widths up to 16 feet~~, at readily determined and controlled rates from 0.05 - 2.0 gallons per square yard, and with uniform pressure. The variation allowed from any specified rate shall not exceed 0.02 gallons per square yard.~~ . Provide distributor Equipment that includes a tachometer, pressure gauges, accurate volume measuring devices and a thermometer for measuring temperature of tank contents. Provide distributors equipped with a positive power unit for the asphalt pump, and full circulation spray bars adjustable both laterally and vertically. ~~Set the bar height for triple lap coverage.~~

00710.22 Chip Spreaders~~ - Provide~~ - Provide field verification that the chip spreader is calibrated to maintain application rate within 10% of the target rate. Provide a self-propelled chip spreaders equipped with a mechanical device that will spread the Aggregate at a uniform rate across the full width of the chip spreaders. ~~Provide chip spreaders equipped with an Aggregate segregator assembly. Chip spreaders without an Aggregate segregator assembly may be allowed if approved by the Engineer.~~ Provide chip spreaders of adequate width to provide full coverage of the specified Panel and without placing joints in the travel lanes.

00710.23 ~~Compactors~~Rollers - Provide self-propelled pneumatic-tired or steel-wheeled rollers ~~in good condition~~to provide uniform roller coverage and capable of operating at speeds compatible with the surface treatment operation. ~~A minimum of two pneumatic-tired rollers and one steel-wheeled roller is required.~~

(a) Pneumatic-tired Rollers ~~- Provide~~ - When pneumatic-tired rollers are used, provide self-propelled, tandem or multiple axle, multiple wheel type pneumatic-tired rollers with smooth-tread pneumatic tires of equal size. The tires shall be staggered on the axles at such spacings and overlaps that will provide uniform ~~compacting~~contact pressure for the full ~~compacting~~ width of the roller. The minimum load per tire shall be 2,800 pounds, with tire inflation pressures of 45 psi to 90 psi.

(b) Steel-wheeled Rollers - ~~**Provide**~~ When steel-wheeled rollers ~~**with**~~are used, steel-wheeled rollers require a gross static weight of at least 8 tons.

00710.24 Power Brooms - Provide pickup or non-pickup type power brooms equipped with a positive means to control vertical pressure.

Figure 3.32. Proposed updates to equipment section of chip seal specification

Survey question: *Based on your experience and practice, do you think to require more proof of equipment calibration will improve overall chip seal quality?* The majority of respondents answered yes, with another 25% answering "Not sure," and results are shown in Figure 3.33. The responses reflect the importance of calibration.

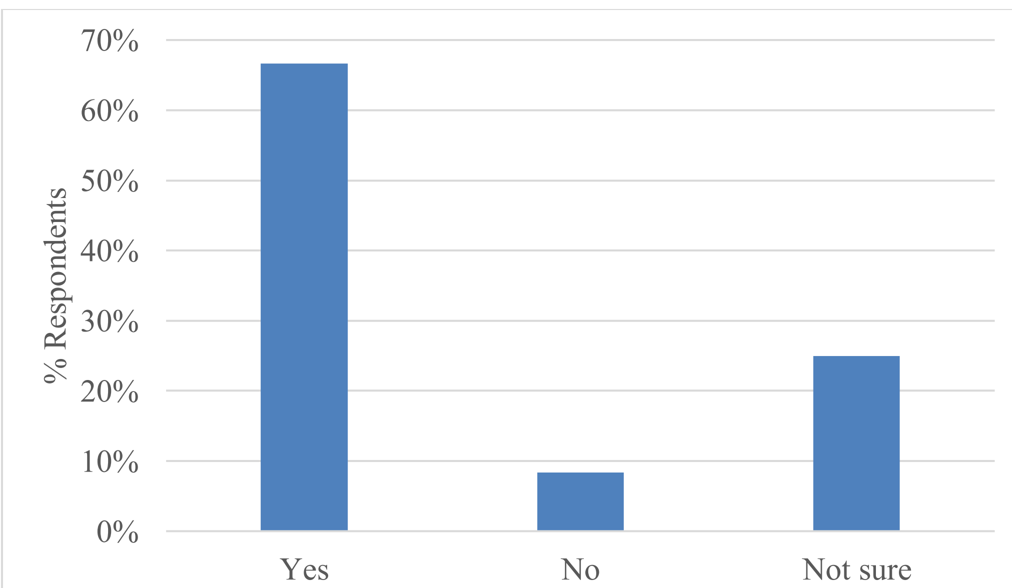


Figure 3.33. Respondents' answers to whether requiring more proof of equipment calibration will improve overall chip seal quality

Survey question: *Based on your experience and practice, do you think that adding this [equipment] part will lead contractors to enhance their on-site construction practices?* Most respondents answered yes, as shown in Figure 3.34.

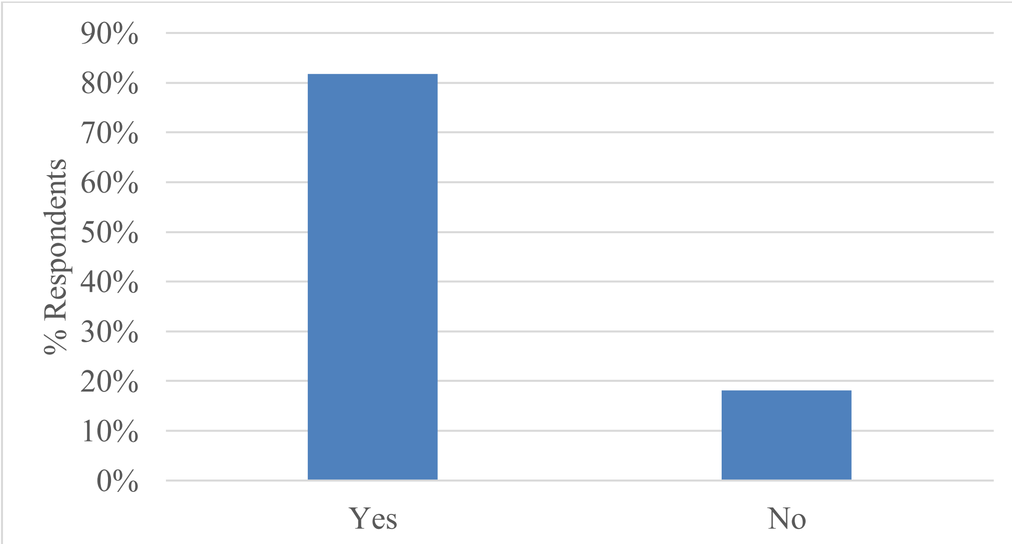


Figure 3.34. Respondents' answers to whether the updated equipment specification will lead contractors to enhance their on-site construction practices

Survey question: *How will the modified equipment specification impact your company or agency?* With the exception of calibration, the remaining proposed changes would give the contractor much needed flexibility (Figure 3.35).

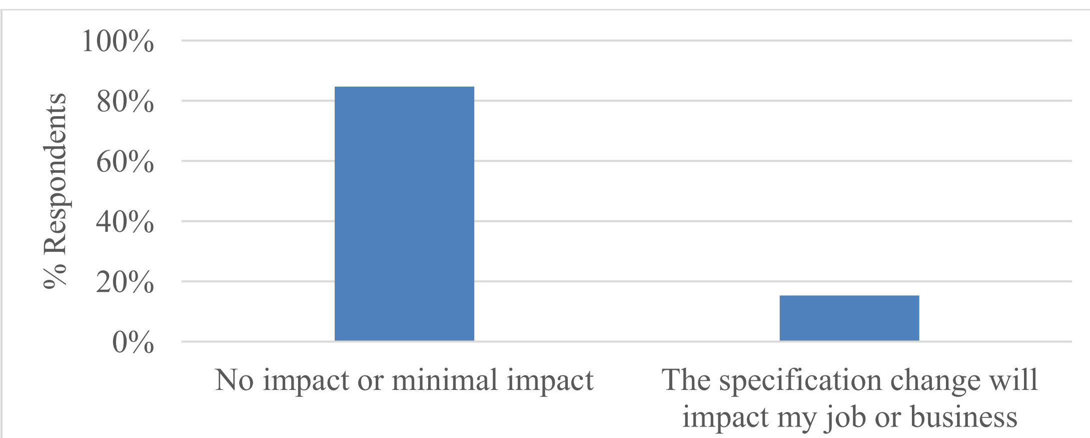


Figure 3.35. Respondents' answers to how the modified equipment specification will impact their company or agency

Survey question: *In your opinion, will the conflict resolution process adequately resolve any conflict?* The conflict resolution update is shown in Figure 3.36 and was based on a Michigan DOT specification (MDOT 2010).

Conflict Resolution Team. The sole responsibility of the Conflict Resolution Team (CRT) is to provide a decision on disputes between the Department and the Contractor regarding application or fulfillment of the warranty requirements. The CRT will consist of five members:

1. Two members selected and compensated by the Department.
2. Two members selected and compensated by the Contractor.
3. One member mutually selected by the Department and the Contractor. Compensation for the third party member will be equally shared by the Department and the Contractor.

If a dispute arises on the application or fulfillment of the terms of this warranty, either party may serve written notice that appointment of a CRT is required.

At least three members of the CRT must vote in favor of a motion to make a decision. If agreement cannot be reached, the CRT may decide to conduct a forensic investigation. The CRT will determine the scope of work and select the party to conduct the investigation. All costs related to the forensic investigation will be shared proportionally between the Contractor and the Department based on the determined cause of the condition.

Figure 3.36. Conflict resolution team addition to the specification

Although there are no publications or data to show how well this conflict resolution specification is working, chip seal research remains active in the state of Michigan (Boz et al. 2018, Kutay and Ozdemir 2016). The respondents' answers are shown in Figure 3.37. A majority of respondents answered "Maybe," while just over 20% answered yes.

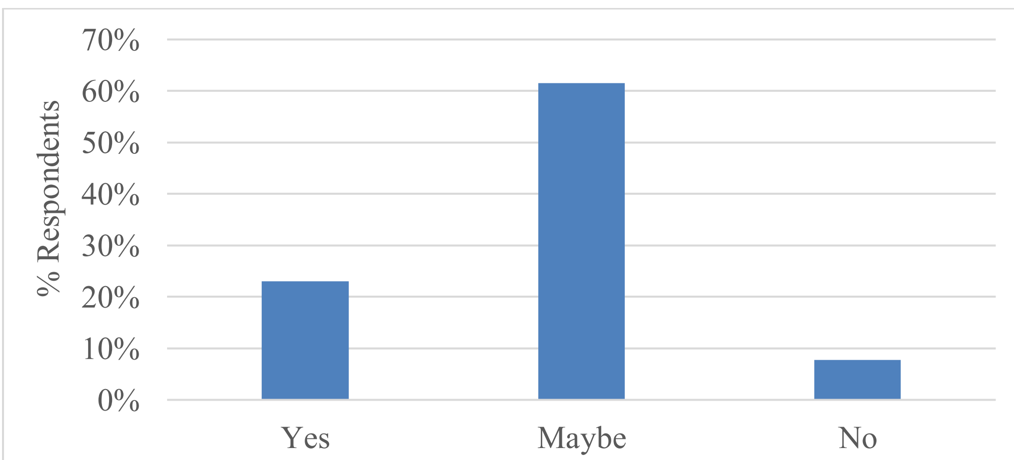


Figure 3.37. Respondents' answers to whether the conflict resolution process will adequately resolve any conflict

Survey question: *Based upon your experience and opinion, is the specification [conflict resolution team] easily adopted by agencies and contractors?* Respondents' answers are shown in Figure 3.38. The majority of respondents answered "Maybe," with just over 20% answering yes.

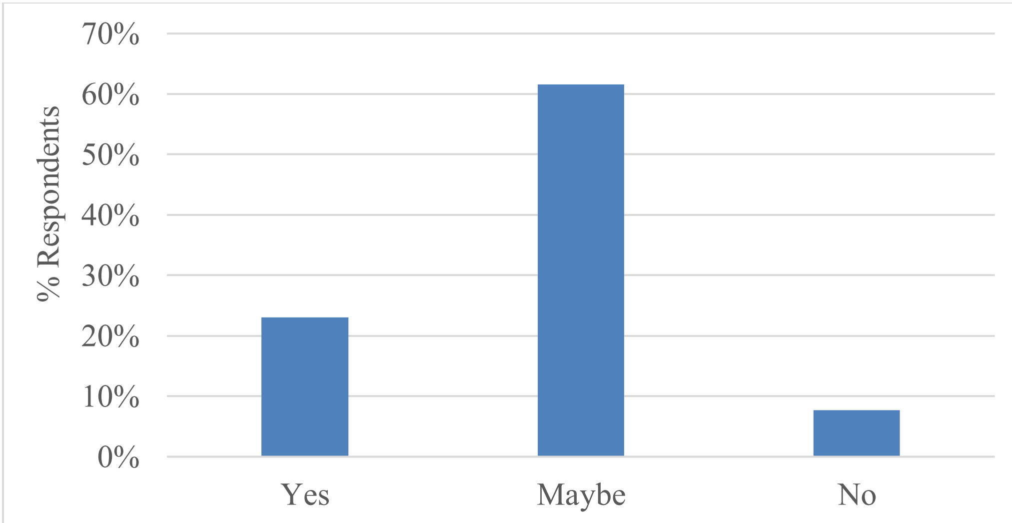


Figure 3.38. Respondents' answers to whether the conflict resolution team is easily adopted by agencies and contractors

Survey question: *Based upon your experience and opinion, is the specification easily adopted by agencies and contractors?* The respondents' answers are shown in Figure 3.39 with the majority responding no and approximately 25% responding "Maybe." A respondent who answered no mentioned that the current version of the specification is still based on experience and opinion.

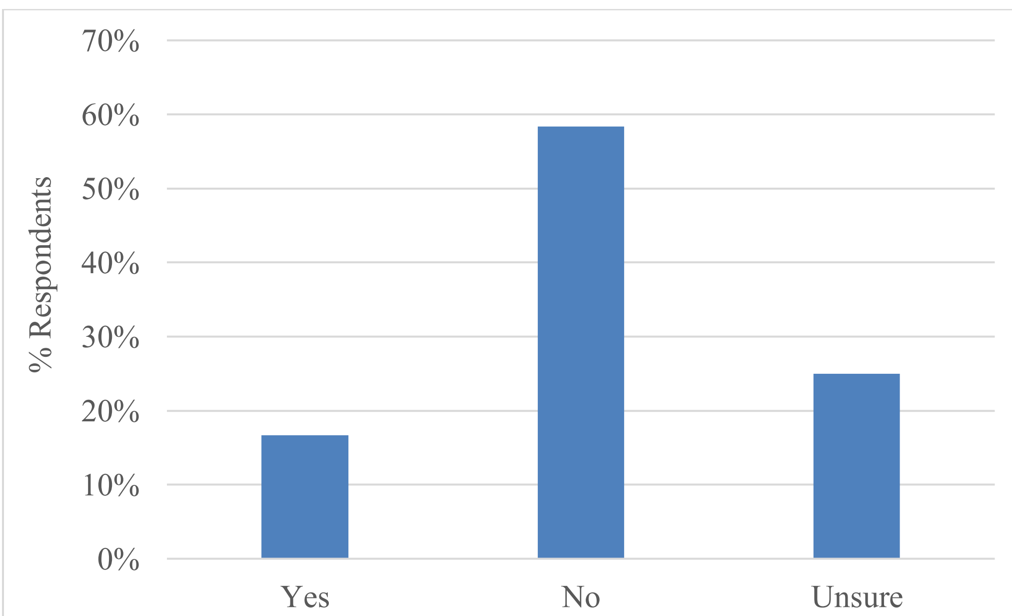


Figure 3.39. Respondents' answers to the specification on whether a conflict resolution team is easily adopted by agencies and contractors

Survey question: *Do you think that these modifications would contribute positively to chip sealing quality?* Respondents' answers are shown in Figure 3.40, and about 55% of respondents answered yes, with another 35% answering "Yes, but the following should be improved."

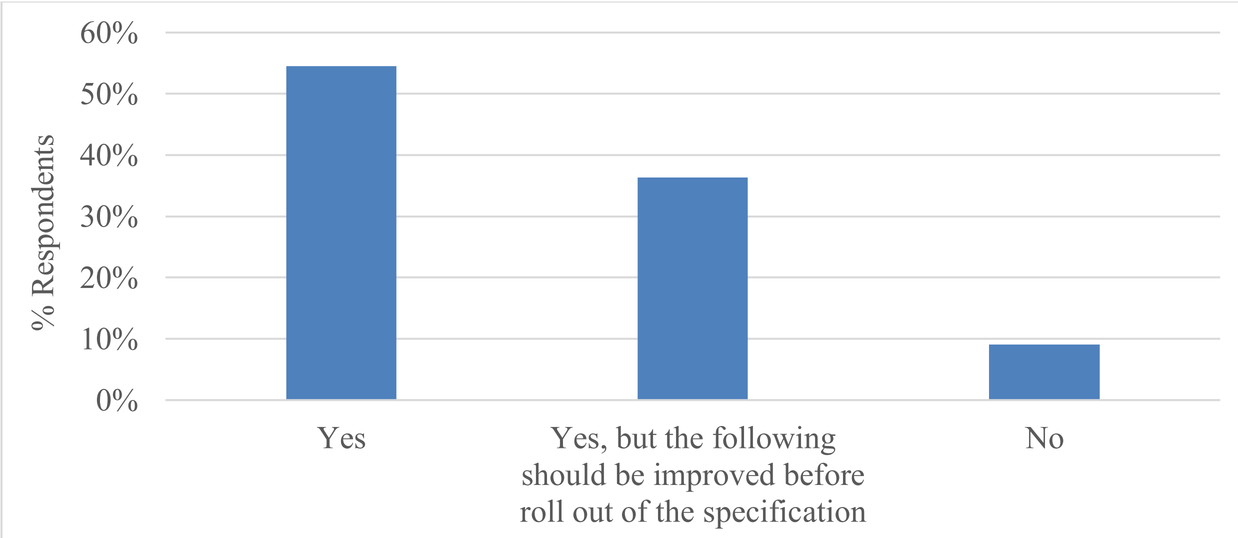


Figure 3.40. Respondents' answers to whether these modifications would contribute positively to chip sealing quality

The items to be improved included revisiting payment percentages and removing complex formulas. Several respondents suggested improving the specification by making the specification more of a warranty method. A respondent who answered no suggested more enforcement of the current specifications and that the current specifications can provide high-quality chip seals.

Final notes from the survey included the following comments:

- It should be noted this is a "living document" that can be modified as ODOT gains more experience in performance-based chip seals
- This needs to be more of a warranty guide
- The contractor needs to have the design power and assume all risks
- The current version may lead to large disputes and potential failures

3.6 FUTURE DIRECTION BASED ON SURVEY RESULTS

The findings of the survey showed that a payment retainage is likely not feasible for contractors and suppliers. The extra financing would likely add unnecessary cost to the chip seal program where most chip seal roads are performing well. There were discussions of replacing the one-year acceptance criteria with a one-year criteria for a bonus award. In Buss et al. (2016), all 14 chip seals met the 1-year acceptance criteria, and 13 of the 14 exceeded the criteria 2 years after chip seal construction. Warranty bond programs, such as ones in Idaho and Michigan, are another option but would require a careful outline of ODOT performance expectations for the chip seals. The Idaho Chip Seal Warranty manual provides some guidance (ITD 2015); however, it is visual-based, whereas performance criteria aim to define quantifiable failure thresholds.

4.0 DETAILS ABOUT PROPOSED SPECIFICATION UPDATES AND SUPPORTING SPECIFICATION GUIDANCE

This chapter outlines the proposed updates and potential changes to the ODOT Specification 00710, Single Application Emulsified Asphalt Surface Treatment. The proposed updates were based on a series of meetings held to review, discuss, and provide guidance for the development of a chip seal performance specification. Each section of the proposed chip seal specification was discussed by stakeholders during these meetings. Research showed that measuring macrotexture performance would likely be able to predict long-term performance when macrotexture is measured at 12 months. However, this did not seem practical, and the approach was difficult to match to an amicable payment schedule; therefore, the proposed changes were a hybrid of changes to enhance the existing method specifications and to incorporate more quantifiable performance metrics and acceptance criteria. In this chapter, the specification changes based on discussions throughout the meetings are outlined, and supporting guidance and processes are documented. Some specification updates are taken directly from other agency specifications, other updates are ideas from other specifications adapted for Oregon, and others are based on specification meeting discussions.

The intention of the proposed changes is to set quantifiable performance metrics to encourage quality workmanship and incentivize innovation. The intention for encouraging adoption of the chip seal design specification is to enhance the science behind which application rates are chosen for chip seals in the field.

Each specification section is outlined with proposed changes and updates as well as supporting guidance for the specification. Supporting guidance includes discussion, flow charts and diagrams to outline the new specification procedures. The organization for this chapter follows the specification organization. Changes are based on the 2017 version of the specification. The document should be considered as a living document, and allocation of risk was in flux throughout discussions. For example, some items in the specification were proposed for removal (e.g., required application rates).

4.1 DESCRIPTION

The title of the specification is Single Application Emulsified Asphalt Surface Treatment and only applies to chip seals one layer in thickness. The performance specifications were developed only for single-layer chip seals. For each part of the specification included in text boxes, the original language is included in black; the proposed additions are underlined in red, and the proposed cuts are in red and signified by a strikethrough.

Scope of specification

00710.00 Scope - This Work consists of applying Emulsified Asphalt and graded Aggregates as shown or directed.

The surface treatment design will be designated on the Plans or in the Special Provisions. Provide a chip seal design according to the "Oregon's Chip Seal Job Mix Formula Guide" available on the ODOT Pavement Services website.

The addition of "*Provide a chip seal design according to the Oregon's Chip Seal Job Mix Formula Guide available on the ODOT Pavement Services website*" should be carefully considered. The benefit of inclusion is ODOT can provide guidance for the job mix formula process, but the disadvantage is that this may be too prescriptive for a performance specification. The job mix formula guide is not meant to mandate application rates but to provide guidance to improve chip sealing practices, evaluation of materials, evaluation of the roadway, and guide field adjustments based on knowledge of material properties and roadway surface characteristics. The proposed chip seal design spreadsheet presented in the chip seal design section can be used to help develop ODOT's official chip seal job mix formula.

4.2 MATERIALS

Although not the prime objective, there were discussions about changing chip seal gradations for materials. For the following section of the specification, there was a suggestion to delete "Graded Medium." Cyclists prefer chip seals with smaller aggregate size.

Aggregate including size designation and fractured faces

00710.10 Aggregates - Furnish Aggregates meeting the following requirements:**(a) Size Designation** - Provide the size of Aggregate for the single application Emulsified Asphalt surface treatment design designated in the Plans or Special Provisions according to the following:

Chip Seal Design	**Size of Screenings**
Fine	3/8"–No. 8
Single Size Medium	3/8"–¼"
Graded Medium	3/8"–No. 4
Coarse	½"–¼"

(b) Fractured Faces - Provide Aggregates consisting of broken stone, crushed gravel or a combination of both. Crush Aggregate such that at least 90 percent by weight of the total Aggregate retained on the No. 8 and larger sieves is fractured on two faces, as determined according to AASHTO T 335.

The next sections show several options for changing the gradations of the specification. There are three possible options. Option A is the current specification and includes no changes.

Option B is based on proposed ODOT changes from December 2017. These changes make the gradation more uniform, adds No. 10 sieve requirements for fine aggregates, and reduces the material passing a No. 200 sieve. Finally, Option C is to adjust gradations based on the draft American Association of State Highway and Transportation Officials (AASHTO) Designation PP 82-16 Emulsified Asphalt Chip Seal Design.

Aggregate - Grading Option A: Original and current specification (as of 2018)

(c) Grading - Perform sieve analysis according to AASHTO T 27 and AASHTO T 11. Provide grading for the designated single application Emulsified Asphalt surface treatment design according to the following:

Sieve Size	**Coarse ½"–¼"**	**Single Size Medium 3/8"–No. 4**	**Graded Medium 3/8"–No. 4**	**Fine No. 4–0**
		Percent Passing (by Weight)		
¾"	100			
½"	85–100	100	100	
3/8"	–	85–100	80–100	100
¼"	0–15	0–15	10–40	–
No. 4	–	–	–	45–65
No. 8	0–4	–	0–6	0–10
No. 30	–	0–2	0–2	–
No. 200 (wet)	0.0–2.0	0.0–2.0	0.0–2.0	0.0–2.0
No. 200 (wet)*	0.0–1.0	0.0–1.0	0.0–1.0	0.0–1.0

*in gravels

(d) Unit Weight of Aggregate - Provide Aggregate with a minimum unit weight of 90 pounds per cubic foot according to AASHTO T 19.

The Unit Weight of Aggregate section of the specification was discussed. The research team in discussions with ODOT recommends keeping the minimum unit weight in the specification, because it may have long-term consequences (past one year) if aggregates do not have sufficient density. In chip seal design, the shoveling method is recommended, because it best estimates the "free-falling" of a single layer of aggregate. AASHTO T 19 contains several different methods. It would be beneficial for clarity to specify whether the specification is referring to the shoveling procedure or a rodded unit weight. The loose unit weights (shoveling method) of the aggregates from the Phase 1 study (Buss et al. 2016) were slightly below 90 lb/ft^3 but would have exceeded the 90 lb/ft^3 specification if rodding had been done.

Option B was developed based on discussions from December 2017. In this section, "Graded Medium" is deleted. A No. 10 sieve is added for fine gradations, and most changes make the gradation more uniform.

Aggregate - Grading Option B: Based on discussions from December 2017

(c) Grading - Perform sieve analysis according to AASHTO T 27 and AASHTO T 11. Provide grading for the designated single application Emulsified Asphalt surface treatment design according to the following:

Sieve Size	Coarse ½"–¼"	Single Size Medium 3/8"–No. 4	Fine No. 4–0
		Percent Passing (by Weight)	
¾"	100		
½"	~~85~~ 90–100	100	
3/8"	60–85	85–100	100
¼"	0–15	~~0–15~~	85–100
No. 4	0–3	0–15	45–65
No. 8	~~0–4~~ –	0–5	~~0–10~~ –
No. 10	–	–	0–15
No. 30	–	0–2	–
No. 200 (wet)	0.0–1.5 ~~2.0~~	0.0–1.5 ~~2.0~~	0.0–1.5 ~~2.0~~
~~No. 200 (wet)*~~	~~0.0–1.0~~	~~0.0–1.0~~	~~0.0–1.0~~

~~*in gravels~~

(d) Unit Weight of Aggregate - Provide Aggregate with a minimum unit weight of 90 pounds per cubic foot according to AASHTO T 19.

Updating the requirements for the section (g), Harmful Substances, was discussed. The proposed changes are to replace the flat and elongated coarse aggregate at a ratio of 5:1 requirement with the flakiness index text, because the flakiness index is a part of the chip seal design process.

Aggregate - Harmful Substances

(g) Harmful Substances - Provide Aggregates meeting the following harmful substances requirements:

Test	Test Method ODOT	Test Method AASHTO	Limits
Lightweight Pieces		T 113	1.0% maximum
Wood Particles	TM 225		0.1% maximum
~~Elongated Pieces (coarse Aggregate at a ratio of 5:1)~~	~~TM 229~~		~~10.0% maximum~~
Flakiness Index*	TM*		25.0% maximum
Cleanness Value	TM 227		75 minimum

*Test aggregate retained on each sieve, if weight of retained aggregate comprises at least 4 percent of the total sample weight.

The language in section (h), Taking Aggregates from Agency Stockpiles, may want to be revisited for a performance specification, because under a performance specification, the agency would not specify the aggregates be taken from agency-controlled stockpiles. If the agency specified the aggregates, then the risk of the chip seal meeting performance expectations should shift to the agency.

Aggregate - Taking Aggregates from Agency Stockpiles

(h) Taking Aggregates from Agency Stockpiles - When it is specified that Aggregates are to be taken from Agency-controlled stockpiles, take the material in an orderly manner. Do not contaminate the materials. Salvage all material possible from the area which the material is taken. Shape unused portions of a stockpile to Neat Lines. The Contractor will be charged for materials wasted through negligence or used without authority.

For other material requirements within section 00710.10, there were no other changes discussed. This includes the following sections:

- (e) Soundness
- (f) Durability
- (i) Stockpiling Contractor Furnished Aggregates on Agency Property

Next, section 00710.11, Emulsified Asphalt, was discussed to determine which, if any, changes may be needed for a performance specification. Typical emulsified asphalt types are included in the current specification. The proposed language is added to support contractor innovation by allowing the contractor to use an "approved equal" asphalt emulsion product. Even under a performance specification, approval of the asphalt emulsion type would need to be maintained by the agency, because asphalt quality will affect performance longer than the one-year acceptance/incentive criteria. The New Zealand performance specification states, "The binder grade to be used is specified, because this input has long-term performance ramifications that extend well beyond the set maintenance period [one year]."

Emulsified Asphalt specifications

00710.11 Emulsified Asphalt - Furnish polymer-modified Emulsified Asphalt or non-polymer-modified Emulsified Asphalt as specified for the single application Emulsified Asphalt surface treatment design designated in the Plans or Special Provisions. When non-polymer-modified Emulsified Asphalt is designated, the Contractor may elect to substitute a polymer-modified Emulsified Asphalt, however, selection of the polymer-modified Emulsified Asphalt will not be cause for additional compensation.**(a) Non-Polymer-Modified Emulsified Asphalt** - When non-polymer-modified Emulsified Asphalt is specified, use CRS-2 or HFRS-2 or approved equal Emulsified Asphalt as the Contractor elects.

(b) Polymer-Modified Emulsified Asphalt - When polymer-modified Emulsified Asphalt is specified, use CRS-2P or HFRS-P1 or approved equal as the Contractor elects.

(c) Acceptance of Emulsified Asphalt - Provide Emulsified Asphalt conforming to the requirements of ODOT's publication, "Standard Specifications for Asphalt Materials." Copies of the publication are available from the ODOT Pavement Services Engineer. The applicable Specifications are those contained in the current publication on the date the Project is advertised. The materials may be conditionally accepted at the source or point of loading for transport to the Project.

Excessive delay in the use of the Emulsified Asphalt or excessive pumping of the Emulsified Asphalt may significantly reduce the viscosity and may make the material unsuitable for surface treatment use. For this reason, limit pumping between the bulk storage tank, hauling transportation, field storage tanks and distributor to an absolute minimum to maintain proper viscosity. Final acceptance of Emulsified Asphalt will be at the point of application.

Obtain samples of Emulsified Asphalt according to AASHTO T 40 at the frequency indicated in the MFTP. Samples will be tested at the ODOT Materials Laboratory, or other laboratory as designated by the Agency. Non-polymer-modified Emulsified Asphalt will be tested within 30 Calendar Days from the date it is sampled. Polymer-modified Emulsified Asphalt will be tested within 14 Calendar Days from the date it is sampled.

Next, the proposed language for the chip seal design was discussed. In a true performance specification, a chip seal design would not be required, as more risk would be shifted to the contractor, but the decision was made to move forward with implementing a one-year performance benchmark as an incentive bonus in the ballpark of 5%–10% and has the agency still carrying considerable risk in the case of underperformance. The following language was proposed for developing the starting application rates.

Chip Seal Design Requirements

00710.13 Chip Seal Design Requirements - Do not start placing chip seal on the Project until the chip seal design is reviewed by the Engineer and written consent is provided to proceed. The chip seal design will be evaluated based on the criteria identified in the latest "Oregon's Chip Seal Job Mix Formula Guide." A new chip seal design is required if the Emulsified Asphalt supplier or the source of the Aggregate change during production.

Submit the chip seal design(s) to the Engineer at least 14 Calendar Days before the anticipated chip seal placement according to the latest copy of the "Oregon's Chip Seal Job Mix Formula Guide" and the following:

- Gradation and all quality test results, as specified in 00710.10
- Designed application rate of seal coat aggregate design application rate
- Designed application rate of bituminous material design application rate
- If requested, a 100 lb sample of aggregate from each proposed aggregate source and two quarts of Emulsified Asphalt from each supplier
- Graphs and plan for application rate adjustments in the field

In this proposed option, chip seal design is required. The benefits of requiring a chip seal design are that the contractor and agency are familiar with the proposed materials for chip sealing and with the roadway conditions for the project. It also allows for tailoring the design to the roadway conditions, and the design provides a framework for field adjustments. Preparation, planning, and ownership of the project ahead of construction increase the probability of successful chip seal construction.

The specification allows ODOT to request aggregate and emulsified asphalt samples if quality assurance testing is desired.

The bullet point of *"Graphs and plan for application rate adjustments in the field"* was added after discussions and analysis of survey results as a potential way to enhance communication between agency and contractor about how rate adjustments are made in the field. An Excel spreadsheet was designed and developed by the ISU research team as a tool for engineers and contractors to utilize. This design spreadsheet requires aggregate, binder, and road characteristics and generates the recommended application rates for chip sealing by the New Zealand and McLeod methods. The design spreadsheet provides graphs that adjust the application rate based on roadway conditions and traffic. Making a plan before the start of construction that outlines how adjustment rates may be modified to account for varying field conditions and changes in roadway's surface characteristics (hills, patched areas, shade, etc.) facilitates discussion between contractor and agency.

The next sections are 00710.15, Aggregate Production Quality Control, and 00710.16, Acceptance of Aggregate. No changes are being recommended to this part of the specification.

A question was raised about whether aggregate production quality control (QC) should be applicable in a performance specification. The purpose of this section is to provide guidance to the crushing operations of the aggregate source. This section outlines control for crushing operations and if removed, could negatively affect high-quality aggregate production.

Aggregate Production Quality Control

00710.15 Aggregate Production Quality Control Provide quality control during production of Aggregate according to Section 00165. Sampling and Testing shall be performed by a CAgT at the minimum frequency schedule indicated in the MFTP.

(a) Quality Control Compliance - Evaluate Aggregates for compliance according to the following:

(1) Gradation - Analyze gradation statistically according to Section 00165. A stockpile contains specification Aggregate when the Pay Factor (PF) for each sieve size calculated according to 00165.40 is equal to or greater than 1.00. Each required sample represents a sub-lot.

When the results from Table 00165-2 yield a Pay Factor of less than 1.00 for any sieve size, the material is non-specification. The Engineer will reject any stockpile of Aggregate containing non-specification material unless the non-specification material is removed from the stockpile. Do not add additional material to such a stockpile until enough non-specification material is removed so that the PF for each sieve size is equal to or greater than 1.00.

(2) Other Tests - Stop production, make appropriate operational adjustments, and remove all failing material from the stockpile whenever a quality control test result, other than sieve analysis, does not meet Specifications. Document operational adjustments made and notify the Engineer prior to resuming production.

(3) Preproduced Aggregate - Compliance of Aggregates produced and stockpiled before the Award of this Contract will be determined by either of the following:

- Continuing production records meeting the requirements of 00710.10 and 00710.15.
- Sampling according to AASHTO T 2 and testing the entire stockpile at the minimum frequency schedule indicated in the MFTP. The material shall meet the requirements of 00710.10 and 00710.15.

(b) Materials on Hand - Payment for stockpiled materials on hand may be allowed as described in 00195.60 subject to meeting the requirements of 00710.10 and 00710.15.

00710.16 Acceptance of Aggregate The Contractors quality control tests will be used for acceptance of Aggregates if verified by the Agency's quality assurance program. The Agency will perform Aggregate production quality assurance according to the following:

(a) ODOT Administered Projects - Quality assurance testing on ODOT administered projects will be performed according to Section 00165, the MFTP and the ODOT Quality Assurance Program.

(b) Projects Administered by Other Agencies - The quantity of quality assurance testing on projects administered by other Agencies will be at the discretion of the Agency or as designated in the Special Provisions.

4.3 EQUIPMENT AND LABOR

The proposed updates to the Equipment and Labor specifications are shown below.

Equipment and Labor

00710.20 Equipment Provide a pressure distributor, hauling vehicles, chip spreader, compactors, power brooms and other necessary Equipment to ensure efficient operation and construction to meet specified results. Provide Equipment in sufficient number and capacities that will provide coordinated and uniform progress of the Work. Provide communication for the operation.

~~Provide two-way radio communication between the asphalt distributor and chip spreader.~~

00710.21 Asphalt Distributor Provide an asphalt distributor designed, equipped, maintain~~ed~~ a variation of 0.015 gal/yd^2 for each load, designed, equipped, maintained and operated so the Emulsified Asphalt material may be applied uniformly at even heat. The distributor shall be capable of applying the asphalt on variable surface widths up to 16 feet.~~, at readily determined and controlled rates from 0.05- 2.0 gallons per square yard, and with uniform pressure. The variation allowed from any specified rate shall not exceed 0.02 gallons per square yard.~~ Provide distributor Equipment that includes a tachometer, pressure gauges, accurate volume measuring devices and a thermometer for measuring temperature of tank contents. Provide distributors equipped with a positive power unit for the asphalt pump, and full circulation spray bars adjustable both laterally and vertically. ~~Set the bar height for triple lap coverage.~~

00710.22 Chip Spreaders Provide field verification that the chip spreader is calibrated to maintain application rate within 10% of the target rate. Provide self-propelled chip spreaders equipped with a mechanical device that will spread the Aggregate at a uniform rate across the full width of the chip spreaders. ~~Provide chip spreaders equipped with an Aggregate segregator assembly. Chip spreaders without an Aggregate segregator assembly may be allowed if approved by the Engineer.~~ Provide chip spreaders of adequate width to provide full coverage of the specified Panel and without placing joints in the travel lanes.

00710.23 Compactors Provide self-propelled pneumatic-tired or steel-wheeled rollers in good condition and capable of operating at speeds compatible with the surface treatment operation. ~~A minimum of two pneumatic-tired rollers and one steel-wheeled roller is required.~~ A minimum of three rollers is required. Preferably, two pneumatic-tired rollers and one steel-wheeled roller.

(a) Pneumatic-tired Rollers - Provide self-propelled, tandem or multiple axle, multiple wheel type pneumatic-tired rollers with smooth-tread pneumatic tires of equal size. The tires shall be staggered on the axles at such spacings and overlaps that will provide uniform compacting pressure for the full compacting width of the roller. The minimum load per tire shall be 2,800 pounds, with tire inflation pressures of 45 psi to 90 psi.

(b) Steel-wheeled Rollers - ~~Provide~~ When steel-wheeled rollers are used, steel-wheeled rollers require ~~with~~ a gross static weight of at least 8 tons.

00710.24 Power Brooms Provide pickup or non-pickup type power brooms equipped with a positive means to control vertical pressure.

Labor

00710.30 Quality Control Personnel Provide a technician having a CAgT technical certification.

Potential updates were made to the Equipment section during discussions with chip seal contractors and with the ODOT. There was a discussion of how to balance detailed requirements for equipment for a performance specification. The term "specified results" in this section is vague, and the performance expectations provide a quantitative measure and process for better defining a chip seal's performance.

It was decided that specifying two-way radio communication was unnecessary and recommended to be replaced with *"Provide communication for the operation."* Communication needs to be compliant with Oregon's distracted driving law, House Bill 4116 (Oregon Legislative Assembly 2018), which states it is illegal to drive while holding or using an electronic device (e.g., cellphone, tablet, GPS, laptop) (ODOT 2019a).

For section 710.21, Asphalt Distributor, the specifications were condensed. The update of *"a variation of 0.015 gal/yd^2"* was added based on an emulsion task force draft specification, and the new language shortens this section slightly. ASTM D2995-14 is a commonly accepted method for determination of transverse and longitudinal application rate and residual application rate of asphalt distributors. The allowable variation from specified application rates was removed due to the nature of the performance specification giving contractors more freedom to adjust application rates; however, understanding the balance of risk in the final version of the specification is necessary. While the 5% to 10% bonus provides adequate incentive to provide quality workmanship for the chip seal, it may not be enough to cover maintenance costs if the chip seal underperforms. The balance of risk and reward and how specification language is shifting the risk should be carefully considered in the final version. Initially, the proposed changes were made under the assumption that performance specifications would carry a significant financial impact in terms of project payment if performance benchmarks were not met.

Specifying triple lap coverage was removed based on the group discussions; however, the recommendation to remove the language was made when the performance specification included language that significantly impacted payment when the performance criteria was not met. Triple lap coverage is still an ODOT recommended best practice but was removed, because the discussion noted that there are instances when triple lap coverage will not work as well. For example, triple lap coverage requires a higher bar height, and in windy conditions, the emulsion spreading may be more uniform with a lower bar height set at double coverage. Under the current limitations of being able to tie the payment to performance, the best option may be to keep the sentence of "Set the bar height for triple lap coverage," and add "unless approved by the engineer" to the end of this section.

For section 00710.22, Chip Spreaders, language for calibration was proposed. The proposed specification removes specification language requiring an aggregate segregator assembly.

Section 00710.23, Compactors, was updated based on discussions. It's still necessary to make sure that adequate equipment is being used for the project. Steel-wheeled rollers are not recommended in some situations, and the proposed specification language allows contractors more freedom to decide when steel-wheeled rollers are appropriate. This was updated based on contractor feedback. Steel-wheeled rollers are not applicable in all cases and may crush some aggregates or "bridge" full/complete compaction, especially if rutting is in the road. Discussions on this topic also noted that steel-wheeled rollers can be useful on the joint and for assuring aggregates lie as flat as possible, or orient to lay on the least great dimension, making the chip seal more resistant to aggregate loss when snowplowed.

There were discussions about the specifications for pneumatic-tired rollers and steel-wheeled roller sizes. Based on discussions in the group, a minimum contact pressure of 80 psi is recommended, and this reflects a recommendation in another states' bid document (New York State n.d.). The group's discussion pertaining to the sentence of "The minimum load per tire shall be 2,800 pounds, with tire inflation pressures of 45 psi to 90 psi" did not come to a firm recommendation but decided potential options for changes include the following:

- Keep as is while understanding the limitations of not specifying a contact pressure
- Remove and provide a minimum contact pressure recommendations in best practices
- Update the specification and require minimum contact pressures in the specification

The specifications for the steel-wheeled rollers were also discussed, because the current specification requires a gross static weight but does not specify size; therefore, contact pressure could vary significantly. This could be revised by specifying the width of the roller or contact pressure; for example, 4 ton, 4 ft. wide rollers may provide contact pressure equal to a wider and larger roller. Also, the discussion included a note that 6–8 ton rollers are used in chip sealing, and the gross weight of a roller does not necessarily correlate to the contact pressure. Contact pressure is a function of both the weight and the overall contact of the roller on the road (force over an area). The group's discussion pertaining to the revised sentence of *"Steel-wheeled Rollers - When steel-wheeled rollers are used, steel-wheeled rollers require with a gross static weight of at least 8 tons"* did not come to a firm recommendation but decided potential options for changes include the following:

- Remove gross static weight
- Change to a minimum of 6 tons of weight
- No change; keep the minimum at 8 tons of weight, and also add "unless approved by the engineer" to the specification
- Specify a contact pressure to enforce

The labor section requires a technician having technical certification. Certification and education related to chip seals is important for quality work.

4.4 CONSTRUCTION

The Construction specification section will be presented in several parts to facilitate better discussion about the various aspects of the specification. Section 00710.40, Season and Weather Limitations, were discussed and potential updates to the specification were made.

Construction specifications

Construction

00710.40 Season and Weather Limitations~~Do not~~ Apply Emulsified Asphalt when the Pavement temperature is ~~below~~ between 70°F and 125°F, ~~or if the~~ and when humidity is ~~higher~~ less than or equal to 75 percent. Complete the application of the Emulsified Asphalt and the Aggregate 3 hours before sunset. Remove by milling, or other methods approved by the Engineer, and replace all surface treatments damaged by weather during the first 24 hours after application at no additional cost to the Agency. When removing a chip seal by milling, the spacing between the cutting teeth is required to be no greater than 5/16 in. The placing of single application Emulsified Asphalt surface treatments will not be allowed ~~before July 1 or~~ after August 31.

00710.41 Rate of Progress and Scheduling Do not apply more surface treatment in any 1 Day than can be broomed the following morning, unless approved by the Engineer. Provide a traffic control plan for approval by the Engineer if operations exceed 3 centerline miles or 6 lane miles per Day.

00710.42 Preparation of Underlying Surfaces Immediately before applying the Emulsified Asphalt, clean and dry the surface to be treated in a manner approved by the Engineer.

00710.43 Sequence of Operations Construct the single application Emulsified Asphalt surface treatment with a single spread of Emulsified Asphalt followed immediately with a single spread of Aggregate and initial rolling, unless otherwise directed by the Engineer. Complete the initial rolling within 2 minutes after applying the aggregate at a speed no greater than 5 mph to prevent the turning over of the aggregate. Surface treatment is not required for guardrail flares, driveways, or other irregular areas as directed.

It was proposed to allow chip sealing when pavement temperatures are between 70°F and 125°F for Oregon; other research conducted showed that different ranges may be used for different climatic conditions, such as in Utah, where a range between 70°F and 136°F is recommended (Lee 2004). In Buss et al. (2016), the specified pavement temperatures for chip seals were studied and compared with other states, and the new recommendation aligns with other state specifications. The sentence on temperature and humidity was updated, but the language proposed ensures the humidity requirement, 75% maximum, remains the same. The specification requirement to complete the application three hours before sunset was discussed, and the group discussions ultimately led to the recommendation that this requirement remain in the specification based on the experience of chip seal practitioners participating in the meetings.

A question about roughness was raised for chip seals placed on a milled surface, so the following was proposed to be added to the specification, *"When removing a chip seal by milling, the spacing between the cutting teeth is required to be no greater than 5/16 in."* The current date restrictions were discussed, and it was decided to remove the July 1 requirement. The goal is to open up the time frame as long as the weather limitations are met.

No changes were made to sections 00710.41, Rate of Progress and Scheduling, and 00710.42, Preparation of Underlying Surfaces. The requirement of "clean and dry the surface to be treated in a manner approved by the Engineer" is an important part of the construction specification. Ensuring that a roadway is clean is critical to success. Although no direct changes were made to the section of the specification, this is an important part of best practices. There was also a discussion of whether the sentence of "Complete the initial rolling within 2 minutes after applying the aggregate at a speed no greater than 5 mph to prevent the turning over of the aggregate" is needed in a performance specification. Many chip seal specifications require initial rolling be "immediate."

Section 00710.44 shows changes to the Application Rates. A primary goal in this project was to bring more "science" into the "art" of chip sealing.

Application Rates

00710.44 Application Rates Refer to 00710.13 as a guideline for determining initial application rates. If the initial application rates are different from the design application rates, document and submit to the Engineer. Document and submit additional adjustments to the application rates during placement of the chip seal.

~~Apply the Emulsified Asphalt and spread the Aggregate within the following ranges of rates for the specified surface treatment design. The exact application and spread rate will be determined by the Engineer.~~

~~**Chip Seal Design**~~	~~**Emulsified Asphalt Application Rate (gal./sq. yd.)**~~	~~**Aggregate Spread Rate (cu. yd./sq. yd.)**~~
~~Fine~~	~~0.25 - 0.40~~	~~0.004 - 0.009~~
~~Single Size Medium~~	~~0.40 - 0.65~~	~~0.005 - 0.015~~
~~Graded Medium~~	~~0.40 - 0.65~~	~~0.005 - 0.015~~
~~Coarse~~	~~0.33 - 0.70~~	~~0.009 - 0.018~~

Chip seal design methods provide a framework for determining chip seal designs, how adjustments are made in the field, and documentation between design-and-actual field application rates can be tracked over time as "feedback" into making data-driven adjustments to the design equations. The updated specification does not require the contractor follow a prescribed application rate or a design application rate but does require documentation of adjustments of application rates during chip seal placement. When discussion for this section occurred, it was assumed that the performance criteria would have a significant financial implication if not met.

In a future version of the specification, if more risk is shifted to the contractor, the following addition to the specification may be necessary, "The design application rate is not required to be used if the performance acceptance criteria applies."

In general, the majority of chip seals placed in Oregon perform well, and many of these chip seals were placed under the original version of this specification. The recommended application rate ranges, based on the original version of this specification, are shown in Table 4.1, and are still considered to be ranges for good chip sealing practice for Oregon roadways.

Table 4.1. Required Chip Seal Application Rates from 2018 Specification

Chip seal design	Emulsified asphalt application rate (gal/yd^2)	Aggregate spread rate (yd^3/yd^2)
Fine	0.25–0.40	0.004–0.009
Single size medium	0.40–0.65	0.005–0.015
Graded medium	0.40–0.65	0.005–0.015
Coarse	0.33–0.70	0.009–0.018

Section 00710.45, Applying Emulsified Asphalt, was reviewed based on what should be included in a performance specification. In a true performance specification, much of this section could be removed; however, an incentive bonus shifts only a small portion of the risk. All items listed in the specification are considered best practices for Oregon roadways.

Applying Emulsified Asphalt

00710.45 Applying Emulsified Asphalt Apply Emulsified Asphalt at the rates ~~specified in~~ according to 00710.44 and ~~according to~~ the following:

- Apply the Emulsified Asphalt working toward the Aggregate stockpile at all times, unless otherwise approved by the Engineer.
- Leave a minimum of 200 gallons of Emulsified Asphalt in the distributor tank at all times.
- Do not apply Emulsified Asphalt to more than one-half the width of the travel way at one time with the remaining width remaining open to traffic. Do not close the open lane until traffic controlled by pilot car is operating on the new surface treatment. Apply the surface treatment, weather permitting, to both sides of the travel way so that the end of the Work is squared up 3 hours before sunset.
- Do not apply Emulsified Asphalt a greater distance than can be immediately covered by Aggregates before the emulsion breaks.
- Place building paper over the treated surface at the beginning of each spread to ensure that the nozzles are operating properly before the uncovered surface is reached. Remove and dispose of building paper in a manner satisfactory to the Engineer.
- If requested by the Engineer, demonstrate that the distribution of the Emulsified Asphalt does not vary between the individual nozzles by more than 15 percent transversely from the average, and no more than 10 percent longitudinally from the specified rate of application.
- Apply the Emulsified Asphalt at a temperature between 140°F and 185°F or as recommended by the manufacturer. If manufacturer recommended different, notice and corresponding paperwork must be given to engineer prior to construction

The sentence of “Do not apply Emulsified Asphalt a greater distance than can be immediately covered by Aggregates before the emulsion breaks” is highlighted in gray and could likely be removed in a performance specification. This statement is similar to the statement in 00710.43, Sequence of Operations, “Complete the initial rolling within 2 minutes after applying the aggregate at a speed no greater than 5 mph to prevent the turning over of the aggregate.” Options are to (1) remove both if a performance specification adequately shifts risk to the contractor, (2) remove one to reduce duplication of requirements in the specification, or (3) keep both but adjust so that the language is consistent (2 minutes versus immediately).

The sentences of “Place building paper over the treated surface at the beginning of each spread to ensure that the nozzles are operating properly before the uncovered surface is reached. Remove and dispose of building paper in a manner satisfactory to the Engineer” are recommended to be kept in the specification, because the performance specification does not directly evaluate the proper construction of transverse joints. Proper construction of transverse joints is important for quality workmanship of the chip seal.

Section 00710.46, Hauling and Spreading Aggregates, is another section reviewed based on what should be included in a performance specification. The areas of the specification highlighted in gray are items that were discussed or proposed for removal under a performance specification.

Hauling and Spreading Aggregates

00710.46 Hauling and Spreading Aggregates Spread Aggregates at the rates ~~specified in~~ according to 00710.44.

Do not operate hauling and spreading Equipment on uncovered Emulsified Asphalt. During the first hour after application of the Emulsified Asphalt and Aggregate, operate at speeds no more than 10 mph and after the first hour, not more than 15 mph until otherwise allowed by the Engineer. Carefully operate hauling Equipment at all times, at moderate speeds that will not damage the new surface treatment or create a hazard to the traveling public. Route hauling Equipment and pilot lines as uniformly as possible over the full width of the new surface in place.

Calibrate the gate opening, gear selection and engine RPM of the chip spreaders for the various sizes of Aggregate to be used. Following calibration, verify the rate of application by a method acceptable to the Engineer.

Immediately cover the Emulsified Asphalt surface with Aggregate unless otherwise authorized by the Engineer. Maintain the rate of spread of this Aggregate within 10 percent of specified rate. Using approved methods, remove or repair Emulsified Asphalt that has set or "broke" before being covered with Aggregate, at no additional cost to the Agency.

Aggregates shall be surface damp at the time of application. Excess free water (water not adhering to the Aggregate surface) on the Aggregate will not be allowed.

Do not operate the chip spreader at speeds which cause the chips to roll over after striking the emulsion covered surface.

Provide coverage without gaps or overlapping adjacent coverages. Do not construct longitudinal joints within the travel lanes.

Construct neat transverse cut off of Aggregates and remove any excess Aggregates from the surface prior to resuming operations.

The sentence of "During the first hour after application of the Emulsified Asphalt and Aggregate, operate at speeds no more than 10 mph and after the first hour, not more than 15 mph until otherwise allowed by the Engineer" would not be needed in a true performance specification. Also, the sentences of "Immediately cover the Emulsified Asphalt surface with Aggregate unless otherwise authorized by the Engineer. Maintain the rate of spread of this Aggregate within 10 percent of specified rate" were discussed. These sentences all impact the progression and operation of chip seal construction. The specification should be revised to ensure consistent messaging for chip seal construction operations and speeds. Other statements in the specification that need to align to improve clarity for chip seal construction operations, include the following:

- "Do not operate the chip spreader at speeds which cause the chips to roll over after striking the emulsion covered surface." (Also highlighted in gray).

- In section 00710.43, Sequence of Operations, the specification currently requires contractors to "Complete the initial rolling within 2 minutes after applying the aggregate at a speed no greater than 5 mph to prevent the turning over of the aggregate." If the compaction should be completed immediately to two minutes after placement, the distributor and the chip seal spreader should not operate at speeds two- to three-times as fast as the rollers.

The following sentences were discussed, "Calibrate the gate opening, gear selection, and engine RPM of the chip spreaders for the various sizes of Aggregate to be used. Following calibration, verify the rate of application by a method acceptable to the Engineer." A common method used for calibration is ASTM D5624-13: Standard Practice for Determining the Transverse-Aggregate Spread Rate for Surface Treatment Applications. In specification discussions, proof of field calibration of the chip seal spreader was added in the Equipment section of the specification. The addition states: *"Provide field verification that the chip spreader is calibrated to maintain application rate within 10% of the target rate.*" From survey findings, most survey respondents were in favor of additional proof of field calibration. It may help to simplify the specification by considering the following:

- Place all calibration discussions in the Equipment section of the specification

- Provide additional guidance for various methods that verify the rate of application

The sentences of "Aggregates shall be surface damp at the time of application. Excess free water (water not adhering to the Aggregate surface) on the Aggregate will not be allowed" were discussed. In a true performance specification, this requirement would not be necessary, but for an incentive bonus with minimal shift in risk, the specification should protect against excessive moisture in the aggregates. If it was decided that this portion of the specification needs to be more prescriptive, an aggregate moisture content (by dry weight) specification could be developed for Oregon aggregates. Ohio DOT's Specification states (Ohio DOT 2008) that "Aggregate moisture content (by dry weight) should be:

- 4.0% max. for agg. Absorption >2.0%

- 3.0% max. for agg. Absorption ≤2.0%"

The section 00710.47, Shaping and Compacting, was updated based on the changes in section 00710.23, Compactors. As previously discussed, steel-wheeled rollers are not appropriate in all situations.

Shaping and Compacting

00710.47 Shaping and Compacting After the Aggregates have been placed on the Emulsified Asphalt, spread or remove all piles, ridges, or uneven distribution to ensure against rough spots in the final surface.

~~Compact the surface with a minimum of two coverages with a pneumatic-tired roller and one coverage with a steel-wheeled roller. Continue compacting until the~~ Compaction should ensure that the material is interlocked, firm and partially bound with the underlying Emulsified Asphalt. The sequence of roller coverages may be adjusted at the discretion of the Engineer.

Operate rollers at speeds such that the rollers do not pick up Aggregates from the surface. Do not exceed rolling speeds of 5 mph.

In the event Aggregates begin to pick up under traffic or from the rolling operation, immediately cover and roll the area with additional quantities of Aggregate.

The sentence of “The sequence of roller coverages may be adjusted at the discretion of the Engineer” would need to be changed in a true performance specification, because the agency would need to be cautious about the sequence of roller coverage if the specification is based on performance and more risk was shifted to the contractor.

The sentence of “Do not exceed rolling speeds of 5 mph” should align with consistent messaging in the specification about the speed of operation. This concern was discussed in more depth in the section Hauling and Spreading Aggregates. The emulsion and chip spreader have higher allowable speeds compared to compactors, and the messaging in the specification needs to encourage chip seal operations that move along in a consistent progression, keeping the chip spreader close to the distributor and then getting initial compaction immediately after placement.

4.5 WEATHER LIMITATIONS ON CHIP SEAL CONSTRUCTION

This section summarizes the available literature reviews for weather limitation of chip seal construction and recommendations to avoid applying chip seal during undesirable weather conditions. The ODOT specifications limit chip sealing to two months, July and August. The preferred weather conditions should be clear, dry, and warm (Buss et al. 2016). Chip seal and other bituminous surface treatments are most sensitive to environmental conditions such as wind, moisture, and temperature.

4.5.1 Wind

Excessive wind can cause the emulsion spraying to be diverted and compromise uniformity of application rate (Buss et al. 2016). Uneven application of emulsion leads to loss of aggregate and unfavorable appearance of chip seal. To avoid such scenarios, early planning and coordinating between contractor and the agency to utilize shielding equipment or delay construction until more favorable gentle winds exist. Soft winds can assist in accelerating the curing time for emulsions.

4.5.2 Moisture

Chip seals are most sensitive to moisture environments in the form of rain, humidity, and extreme dry weather. Most chip seals deteriorate as a result of failure to meet the specification regarding the moisture conditions (NCDOT 2015). The destructive impacts of moisture on chip seal performance are bleeding, floating, and loss of aggregate; these can be catastrophic failures and cause the chip seal to be an undesirable surface treatment. Too much moisture during construction will cause the binding mechanism to erode between the aggregate and binder, which will cause bleeding; whereas, too much dryness and heat during construction will cause the emulsion to break before it bonds with the aggregate. Rain during the chip seal curing process will cause floating of the asphalt. To avoid the emulsion floating or breaking and setting before locking to the aggregate, it is ideal to apply chip seals under controlled traffic flow on a day without extreme conditions such as rain, fog, and dryness.

4.5.3 Temperature

The bond between the aggregate and emulsion is highly dependent on the temperature of the air and surface. In general, pavement surface temperatures should be 55°F (10°C) and rising, and the humidity should be 50% or lower (Buss et al. 2016). The Minnesota Department of Transportation (MnDOT) Seal Coat Handbook recommends applying chip seals early on a day when temperature is forecasted to increase afterward (Wood et al. 2006). MnDOT recommends the application of chip seals only when the temperature is rising in order to secure a proper environment for the bond to be formed between the aggregate and emulsion. When the temperature is above the maximum limit allowed, asphalt breaks before the bond with the aggregate is formed. Also, vice versa, when the temperature is too cold, the emulsion will not break to bond the aggregate. Appropriate atmospheric temperature during construction and following the agency specifications are crucial for successful chip seal.

Weather requirements for chip seals from the FHWA (2002) are as follows:

- Follow the range of dates established by the agency when chip sealing can be performed.
- Construct a chip seal only during daylight hours.
- Air and surface temperatures have been checked at the coolest location on the project.
- Air and surface temperatures are 50°F and rising, unless warranted by agency requirements.
- Suspend chip sealing if pavement temperatures exceed 140°F, unless warranted by agency requirements.
- Construct chip seal only when chance for precipitation is zero or very low.

- High winds can create problems with asphalt application. Work should be avoided when wind speeds exceed 20 mph.

- Air and pavement surface temperatures, humidity, and wind will affect how long the asphalt emulsion takes to break.

4.6 MAINTENANCE

Another major proposed change is a one-year maintenance period after chip seal placement. No major changes were proposed for the 00710.60, Power Brooming, section. There was a discussion of whether a minimum of two power brooms should be specified.

Another point of discussion was the definition of excess chips or when brooming is needed. Recommendations for this section originate from New Zealand guidance, which provides a quantifiable definition for "excess chips." The New Zealand guidance requires brooming if there are 50 loose chips/2 m^2. This equates to approximately 30 chips/yd^2.

Maintenance Specification – Power Brooming

Maintenance
00710.60 Power Brooming Following the application of the surface treatment, carefully broom the entire surface to remove loose Aggregate. Discontinue the operation if brooming damages the surface treatment. Use a minimum of two power brooms. Subsequent brooming the following 2 days may be directed by the Engineer to ensure that the surface is free of loose Aggregate that could cause vehicle damage. In curbed areas, use a pick-up type power broom. On Bridges, sidewalks and other areas off the roadway, remove all loose Aggregates to the satisfaction of the Engineer.

The following is a discussion about the proposed specification language for the maintenance period.

Maintenance - Maintenance Period, Removal of Loose Chips, and Repairs

00710.61 Maintenance Period – It is the Contractor's responsibility to maintain the seal for one year unless otherwise specified and agreed to by the agency. The maintenance period is one year prior to the acceptance/performance testing date. Notification of maintenance is required to the Engineer of rework with proposed dates of rework and sections be not smaller than ½ mi (e.g., rework mp 12.5 thru 13.0). A subsequent notification is required after rework to confirm date of work and sections where rework was completed.

Although repairs within the first few days can often be made using the same size chip that was used initially~~, use the next smaller grade chip for later repairs~~. Make repairs with materials that meet or exceed 710 Materials requirements. If at any time during the maintenance period repairs shall be performed using a chip with an ALD not exceeding 0.5 mm smaller than that of the original chip used for construction.

A provision in section 00710.63, Repairs, is made to the Engineer to extend the maintenance period if repairs were required.

00710.62 Removal of Loose Chips - Loose chips will be removed whenever the Engineer regards the loose chips as a traffic hazard continuously throughout the 12-month maintenance period. Chip "build up" of windrows will not be allowed on either the pavement or the shoulders.

00710.63 Repairs - For any repairs, the Contractor must provide ODOT with a minimum of 7 calendar days' notice prior to repairs. ~~Unless an exception is approved by the engineer, any repairs shall be performed using a chip with an ALD not exceeding 0.5 mm smaller than that of the original chip used for construction. Make repairs with materials that meet or exceed 710 Materials requirements.~~

If at any time during the defects liability period repairs are required over an area greater than 10% of the area of the section, then the proposed repair technique and acceptance criteria shall be agreed upon with the Engineer.

Any areas repaired during the defects liability period more than nine months after construction will, at the discretion of the Engineer, be subjected to a further 12-month defects liability period. If the area of repairs at the end of 12 months are greater than 10% of the section and revised acceptance criteria has not been agreed upon with the Engineer, then the section will be subject to a further 12-month defects liability period.

The Contractor will submit a chip seal design for all repairs to ensure that the risk of a reduced seal design life is minimized.

The proposed specification language was developed while discussing whether final payment based on a one-year acceptance criteria would be required. The one-year acceptance criteria was later decided to be implemented as a bonus. Based on implementing the one-year criteria as a bonus, it is unlikely any significant maintenance will occur by the contractor. The maintenance period section may be removed due to the change in the proposed specification from a final payment after a one-year period to an incentive bonus after one year. This section provides discussion for each potential addition to the specification as it relates to a maintenance period.

Proposed language: *"It is the Contractor's responsibility to maintain the seal for one year unless otherwise specified."* Under a performance specification modeled after New Zealand's, there is a maintenance period of one year under the responsibility of the contractor. It is anticipated that the areas identified as requiring maintenance will follow the framework under which lots and sub-lots are identified for quality testing. A maintenance period allows the contractor to elect to make repairs or maintain the chip seal during the year leading up to the one-year acceptance/performance testing date. Guidance will need to be formalized for situations where the contractor is not liable. The research team recommends using guidance developed in the Idaho Transportation Department Sealcoat Warranty Guide (ITD 2015), which provides examples of non-contractor obligation defects (NCODs). NCODs include "damage to the sealcoat beyond the control of the Contractor…. These defects may be caused from existing maintenance patches, plow damage, acts of God, for other reasons. Before sealcoating, these existing areas must be identified by both the Engineer and the Contractor by visual inspection and documented in writing and approved to be excluded from the Contractor obligation defects (by both parties). After sealcoating, they may be determined to be NCODs by the Engineer at the time of final review." Some examples of damage (by category) would include:

- Traffic: Various conditions that can be categorized as NCOD defects are
    - Skid marks
    - Fuel spill or fire
    - Tire chain damage
    - (Not included in the Idaho Warranty guide) Excessive traffic due to detours
- Chip loss from snowplows; however, Idaho's warranty guide shows examples where contractor obligation defects are exacerbated by snowplows. These examples show excessive chip loss in the seal.
- Maintenance Blade Patch Failures
    - Must be documented and approved to be exempt

Proposed language: "*The maintenance period is one year prior to the acceptance/performance testing date. Notification of maintenance is required to the engineer of rework with proposed dates of rework and sections to the ½ mi (e.g., rework mp 12.5 thru 13.0). A subsequent notification is required after rework to confirm date of work and sections where rework was completed."* During the one-year maintenance period, the contractor will notify the ODOT about the dates and locations for the proposed repairs. A Repair section (00710.63) was added to the performance specification to provide additional guidance about repairs. This section of the specification includes both a proposal of repairs, locations, and dates, and then, the contractor would follow up to notify ODOT what actual repairs were made and where the chip seal repairs were made.

Proposed language: "*Although repairs within the first few days can often be made using the same size chip that was used initially, it is common practice to use the next smaller grade chip for later repairs. Make repairs with materials that meet or exceed 710 Materials requirements. If at any time during the liability period, repairs shall be performed using a chip with an ALD not exceeding 0.5 mm smaller than that of the original chip used for construction*." This section is similar to language from New Zealand's specification guidance. New Zealand has different grades of chips, and the specification language is shown as a strike through. New Zealand's specification guidance recommends using the next smaller grade for later chip seal repairs and this is recommended as a best practice. The repairs are required to be made with materials that meet or exceed the 710 Materials requirements, and the new aggregate cannot be too small.

The recommended best practice is that prompt response to maintenance is expected. If the seal distress is left too long, more expensive repair techniques may be required. Specific procedures from the agency will have to be developed, but 14 days seems a reasonable recommendation. This provides the contractor 7 days to develop the proposed repair plan and notify ODOT about the repair method/design, the location, and date(s) for repairs. Then, ODOT has 7 days for plan review and approval.

Proposed language: "*A provision is made to the Engineer to extend the maintenance period if repairs were required.*"

Proposed language: "*00710.62 Removal of Loose Chip - Loose chips will be removed whenever the Engineer regards the loose chips as a traffic hazard continuously throughout the 12-month maintenance period. Chip "build up" of windrows will not be allowed on either the pavement or the shoulders*." The New Zealand guidance defines "excess chips." The guidance requires brooming if there are 50 loose chips/2 m^2. This can be approximated to 30 chips/yd^2. It is considered best practice for the contractor to include the cost of more than one sweeping in the bid. The following may need to be added to the specification, "As a general rule, exceedance of 30 chips/aggregate per square yard may be considered (build-up) but is at the engineer discretion."

Proposed language: "*00710.63 Repairs - For any repairs, the contractor must provide ODOT with a minimum of 7 calendar days' notice prior to repairs*." The repairs section briefly outlines repair notifications. This section needs to be in compliance with other ODOT specifications, namely 00220. For example, 00220.03, Work Zone Notifications, lane closure requires 7 calendar days' notice. If the roadway is closed, 14 days are needed and all emergency, school districts, and post offices require notification. References to other sections of the specification may be needed in a final version.

The following sentences were included in discussions but were highlighted in gray and were presented with a strikethrough in the specification box for Maintenance - Maintenance Period, Removal of Loose Chips, and Repairs: "*Unless an exception is approved by the engineer, any repairs shall be performed using a chip with an ALD not exceeding 0.5 mm smaller than that of* *the original chip used for construction. Make repairs with materials that meet or exceed 710 Materials requirements*." The reason for the strikethrough is that it is duplicative of similar sentences earlier in the proposed maintenance period specification language: "Make repairs with materials that meet or exceed 710 Materials requirements. If at any time during the maintenance period repairs shall be performed using a chip with an ALD not exceeding 0.5 mm smaller than that of the original chip used for construction."

The next section of the specification states, "*If at any time during the defects liability period repairs are required over an area greater than 10% of the area of the section, then the proposed repair technique and acceptance criteria shall be agreed upon with the Engineer*." Extensive repairs are indicative of problems with the chip seals, and this section requires the contractor to propose a repair technique, and the Engineer will revisit the duration of the maintenance period (discussed in the next section). It is anticipated that "10% of the area of the section" refers to 10% of the chip seal lot.

Proposed language: "*Any areas repaired during the defects liability period more than nine months after construction will, at the discretion of the Engineer, be subjected to a further 12-month defects liability period. If the area of repairs at the end of 12 months are greater than 10% of the section and revised acceptance criteria has not been agreed upon with the Engineer, then the section will be subject to a further 12-month defects liability period*." This section allows the agency to extend the maintenance period if repairs were required. This protects the agency from chip seals that require extensive maintenance work. This section in the specification describes two situations when an additional 12 months are added to the maintenance period as follows:

- When repairs are needed on the chip seal after 9 months
- When repairs are required on 10% of the chip seal

Nine months is highlighted in gray, because the ODOT may want to revisit this timeline. For instance, ODOT may want all repairs to pass the acceptance criteria after exposure to at least one winter.

Proposed language: "*The Contractor will submit a chip seal design for all repairs to ensure that the risk of a reduced seal design life is minimized*." All repairs should have a chip seal design as part of the proposed repairs.

During development of the proposed specification language, there were also discussions about snow/ice sanding material and the potential for this reduce macrotexture. The following sentences were not included in the final version of the proposed specification, but they are an important consideration prior to the finalization of language on the construction and use of a macrotexture acceptance criteria: "Snow/Ice Sanding Material - Prior to construction, meet with the Engineer regarding the possible application of sanding and indicate the expectations for areas that may require the application of sanding material during the maintenance period. In cooperation with the Engineer, document the performance criteria with considerations for the excess sanding material that may fill the interstices and thereby effectively reduce texture depth after 12 months."

4.7 MEASUREMENT

All updates to the measurement section should match the pay items. The proposed specification language changes the aggregate payment from materials to square yards.

Measurement

Measurement
00710.80 Measurement The area of the pavement to be covered by chip seal will be provided in the plans. ~~The quantities of Aggregate will be measured on the weight basis or on the volume basis in the hauling vehicle.~~ The quantities of Emulsified Asphalt will be measured on the weight basis. The quantities of asphalt surface treatment of approaches will be measured on the unit basis for each street connection and road approach.

4.8 PAYMENT

New pay items were discussed and are proposed in this section.

Payment and Pay Items

Payment

00710.90 Payment The final acceptance is based on achieving the required texture depth without significant chip loss based on the performance criteria referred to in Section 00710.91. The Engineer is responsible for inspecting the seal at the end of the maintenance period. The Engineer ~~may decide it appropriate to~~ will invite the Contractor to conduct the field inspection as a joint exercise. The accepted quantities of Work performed under this Section will be paid for at the Contract unit price, per unit of measurement, for the following items:

Pay Items	Unit of Measurement
~~(a)Aggregate in Emulsified Asphalt Surface Treatment~~	~~Ton or Cubic Yard~~
(a) Chip Seal	Square Yard
(b)Asphalt in Emulsified Asphalt Surface Treatment	Ton
~~(c)Extra for Emulsified Asphalt Surface Treatment Approaches~~	~~Each~~

~~Item (c) applies to the extra costs of placing the Aggregates and asphalt in single application Emulsified Asphalt surface treatments only on street connections and road approaches. Payment will be in addition to payment made for the Materials used in the Work.~~

Payment will be payment in full after initial acceptance. Payment is for furnishing and placing all Materials, and for furnishing all Equipment, labor, maintenance period, and Incidentals necessary to complete the Work as specified.

A bonus will be paid after final acceptance based on the performance criteria outlined in Section 00710.91 at 12 months.

No separate or additional payment will be made for preparing the road surface, placing Materials in final position, or brooming.

Literature has recommended paying for chip seal aggregate by the square yard and continuing to pay for the asphalt emulsion by the gallon per ton. Over-chipping is a common problem and paying for aggregate coverage by the square yard eliminates any incentives to over-chip. Keeping the asphalt binder as a separate bid item helps ensure that adequate binder will be placed to seal the roadway's surface. There were some concerns raised in the survey about the separate pay items if the binder was bid separately; however, there is also a risk of not enough binder being applied if the binder was included in a single square yard bid price.

During the development of the payment section, there were many discussions about how and when the payment would occur under a performance specification. Ultimately, it was decided that the one-year acceptance criteria would determine whether a bonus was paid. This version of the specification still requires the chip seal to pass a two-week visual acceptance inspection. If a true performance specification is adopted later with a significant proportion of payment tied to performance, then the pay item could be only square yards.

For the section that was revised to *"The Engineer will invite the Contractor to conduct the field inspection as a joint exercise,"* it is recommended that measurement of the performance criteria at 12 months be as transparent as possible and the agency conducts the testing while the contractor observes.

Highlighted in gray, in the box above, is "the maintenance period" and "the Work as specified," because it is not clear under an incentive/bonus specification how the maintenance period would be included in the incentive/bonus specification, and this language will likely need to be updated.

A proportional payment for low texture depths was developed based on New Zealand's specification but was ultimately omitted. It is not necessary for a bonus/incentive and would unnecessarily complicate the payment section of the specification.

The following sentence was added to the specification based on the decision to include a bonus payment: *"A bonus of X% will be paid after final acceptance based on the performance criteria at 12 months."* The final percentage was left undecided but 5% to 10% was discussed as a percentage that could be integrated into the current system. In contrast, New Zealand specifications have a much higher percentage of payment tied to the 12-month performance criteria. Initially, the performance specification was designed so that approximately 90% of the payment would be tied to the 12-month performance criteria to minimize the number of failing chip seals.

The chip seal 12-month performance inspection was written with the intention that ODOT would perform the inspection, while the contractor is given the option to be present. The option could be developed for the contractor to also collect the macrotexture data and compare between contractor and ODOT values to further evaluate the test repeatability.

4.9 PERFORMANCE CRITERIA AT 12 MONTHS

This section is based on New Zealand's specification and proposes language for the 12-month performance criteria based on macrotexture. Performance is based on achieving the required texture depth without significant chip loss. The equation for calculating the required mean texture depth (MTD) is shown. The required texture depth is a function of the design life that is based on traffic and the average least dimension (ALD) of the aggregate used.

Chip Seal Performance criteria based on New Zealand specification

00710.91 Performance – The chip seal performance measure is macrotexture. After one year of traffic, the pavement macrotexture must meet the required mean texture depth.

For single-coat seals the required mean texture depth as measured by ODOT provisional test method [XXXX] at one year is calculated as follows:

$$TD1 = 0.07\ ALD\ \log_{10} Y_d + 0.9$$

Where:

- TD_1 = Texture depth after one year in mm
- Y_d = design life in years
- ALD = average least dimension of the sealing chip in mm

For single-coat seals the design life is calculated as follows:

$$Y_d = 4.916 + 1.68\ (ALD) - (1.03 + 0.219\ ALD)\ \log_{10}(elv)$$

Where:

- Y_d = design life in years
- elv = equivalent light vehicles
- ALD = average least dimension of the sealing chip in mm

Equivalent light vehicles/lane/day is calculated as:

$$\boldsymbol{elv = \frac{AADT}{Number\ of\ lanes}\left(1 + \frac{9(HCV)}{100}\right)}$$

Where:
AADT = annual average daily traffic on the road section
HCV = percentage of trucks; trucks are defined as a Class 4-13 vehicle

The estimated life, Yf, is found by the following equation and only applies when a measured texture depth is less than the required mean texture depth:

$$Yf = \text{antilog}\ [(TD1-0.9)/(0.07*ALD)]$$

where, Yf is the expected life in years before the seal will flush.

If the expected life is less than the design life, then the section is considered to be outside the specification, and no additional payment will be made without corrective action.

In addition to the section shown, New Zealand also had a method for proportional payment based on whether the texture was failing based on calculating an estimated life remaining, Yf. Based on the nature of the equation, Yf will calculate an unrealistically long chip seal life if texture depth is higher than the one-year texture depth criteria. A clarification was added that, "*[Yf] only applies when a measured texture depth is less than the required mean texture depth*."

In this version of the specification, the ALD and the texture depths are shown in millimeters. The agency may decide if English units are preferable for day-to-day operations; however, macrotexture measurements are relatively small, and millimeters may work better operationally than fractions of inches.

4.10 ACCEPTANCE

The criteria for acceptance under a performance specification is presented in this section. The first proposed section, 00710.92, outlines a collaborative approach to address certain areas that will be higher risk. Some examples include snowplows, intersections, steep hills, and areas with a lot of agriculture loading, areas with heavy truck traffic (truck stops), and areas with high shear loading (intersections).

4.10.1 Initial Acceptance

After it was decided that the 12-month acceptance criteria (where a large portion of the final payment was withheld until the after passing the 12-month performance inspection) was going to be too costly, there was a need to develop a more formalized initial acceptance based on visual inspection. Much of the language was based on Michigan's chip seal specification (MDOT 2010). The initial acceptance is based on visual observation of surface cracking, loss of cover aggregate, and bleeding/flushing.

One concern regarding the specification is underlying pavement condition can dictate a seal's performance. A major benefit to performing an evaluation ahead of the chip seal construction is that contractor and agency are both aware of a pavement's pre-seal condition and distresses that could impact chip seal performance. These distresses can be addressed before chip seal construction.

Acceptance – Initial Acceptance and Surface Cracking

Acceptance

00710.92 - Where the existing (pre-chip seal) conditions make achieving a uniform texture difficult, or there is a high risk for failure, then an alternative acceptance criteria can be agreed upon. This may entail identifying areas where some chip loss may occur on high-stress sites and agreeing on the area involved. The alternative acceptance criteria must be site-specific, written, and agreed on prior to construction.

00710.93 Initial Acceptance – Initial acceptance of the chip seal is based on the Contractor providing the specified materials. This inspection is scheduled a minimum of two weeks after construction is completed.

Payment of 100% is made at this stage. Visual inspection to ODOT approval. Sand circle measurements will be taken at any areas of concern. Visual inspection requirements are as follows:

Surface Cracking. Each individual driving lane will be reviewed for measuring and quantifying surface cracking. All open cracks will be logged within the chosen segments by crack type. The total length of longitudinal cracks will be logged for each segment. The transverse cracks will be logged by those between 6 in. and 6 ft in length and those equal or exceeding 6 ft in length. Transverse cracks and longitudinal cracks will be converted to defective cracks by the following:

A. One transverse crack 6 ft or greater, in length = one defective crack
B. Five transverse cracks between 6 in. and 6 ft in length = one defective crack
C. A total of 125 ft of longitudinal crack(s) = one defective crack

If the number of defective cracks equals or exceeds the values in Table 2, the segment is considered defective. Repair/maintenance work is required when the average of all segments reviewed exceeds the following values in Table 2.

Table 2: Repair Requirements for Surface Cracking

Chip Seal Treatment	Pavement Type	Number of Defective Cracks per Segment
Single Chip Seal	Flexible	25

Corrective action for this parameter requires the Contractor to overband crack fill all cracks on the entire site, including shoulders if part of the chip seal work.

Acceptance - Initial Acceptance: Loss of Cover Aggregate and Bleeding/Flushing

Loss of Cover Aggregate. The allowable threshold limit for loss of cover aggregate must not exceed 40% of the segment length. All segments in the driving lane or shoulder (528 ft in length) will be measured where the aggregate loss is evident. This measurement is linear and not dependent on area of aggregate loss. Corrective action, full-width across the driving lane or shoulder, will be required for each defective segment.

Bleeding/Flushing. The allowable threshold limit for bleeding or flushing must not exceed 40% of the segment length. All segments in the driving lane or shoulder (528 ft in length) will be measured where the bleeding or flushing is evident. A segment length is defined as 528 ft and starts at the place where a defect is identified due to bleeding or flushing. This measurement is linear and not dependent on area of bleeding or flushing. If an area 40% or more within a mile is found to be defective due to bleeding/flushing, then corrective action must be taken. Corrective action is defined as full-width repair or resurfacing across the driving lane and shoulder for each defective segment.

4.10.2 Definitions for Lots, Sub-Lots, and Segments

Table 4.2 provides a summary of useful definitions related to the performance specification.

Table 4.2. Proposed Definitions for Lots, Sub-lots, Segments, and Related Testing

	Jobs 5 miles and less of continuous chip seal	Jobs more than 5 miles of continuous chip seal
Lot definition	A **lot** is the continuous lane of chip seal of a project; A project may have several lots.	A **lot** is the continuous lane of chip seal of a project; A project may have several lots.
Sub-lot definition	A sub-lot is 1 mi.	A sub-lot is 1 mi.
Segments	A segment is 1/10 mi or 528 ft.	A segment is 1/10 mi or 528 ft.
Minimum number of segments	Each sub-lot is divided into ten 528 ft. segments. ODOT will select **two** 528 ft. segments **per lane** at random for testing within each sub-lot for acceptance testing.	Each sub-lot is divided into ten 528 ft. segments. ODOT will select **one** 528 ft. segment **per lane** at random for testing within each sub-lot for acceptance testing.
Testing within segments	One testing location should be within the first 264 ft. of the segment and the other location should be in the second 264 ft. of the segment.	For each 528 ft. segment, the agency will select one testing location at random within the segment.
Testing location box within segments	The testing locations of sand circles should be within a 50 ft. distance from start to finish. The sand circle tests should not exceed 50 ft. from the extreme ends of all the sand circle testing locations. It is intended that the 50 ft. box of tests represents the condition of the chip seal for the segment.	The testing locations of sand circles should be within a 50 ft. distance from start to finish. The sand circle tests should not exceed 50 ft. from the extreme ends of all the sand circle testing locations. It is intended that the 50 ft. box of tests represents the condition of the chip seal for the segment.
Sand circle test box within segments	Five sand circle tests will be conducted within one 50 ft. box; 1 sand circle test must be in-between the wheel path, and no more than 2 tests can be done in-between the wheel path. The remaining tests are conducted along the wheel path (inner or outer wheel path).	Five sand circle tests will be conducted within one 50 ft. box; 1 sand circle test must be in-between the wheel path, and no more than 2 tests can be done in-between the wheel path. The remaining tests are conducted along the wheel path (inner or outer wheel path).
Determination of failure of a segment	If both testing locations pass the acceptance criteria, then the segment passes. If both testing locations fail the acceptance criteria, then the segment fails. If one location fails and the other location passes, then a third and fourth testing location is selected. The third and fourth testing locations are taken at 264 ft in either direction of the failed test or end of segment, whichever is closer. If both the third and fourth test pass, the segment passes. If one or both of the third and fourth test fail, the segment fails.	If the one testing location passes the acceptance criteria, then the segment passes. If the one location fails, then a second and third testing location is selected. The second and third testing locations are taken at 264 ft. in either direction of the failed test or end of segment, whichever is closer. If both the second and third test pass, the segment passes. If one or both of the second and third test fail, the segment fails.

The following example and figures help to illustrate the definitions.

Step 1. Break the project into lots (Figure 4.1).

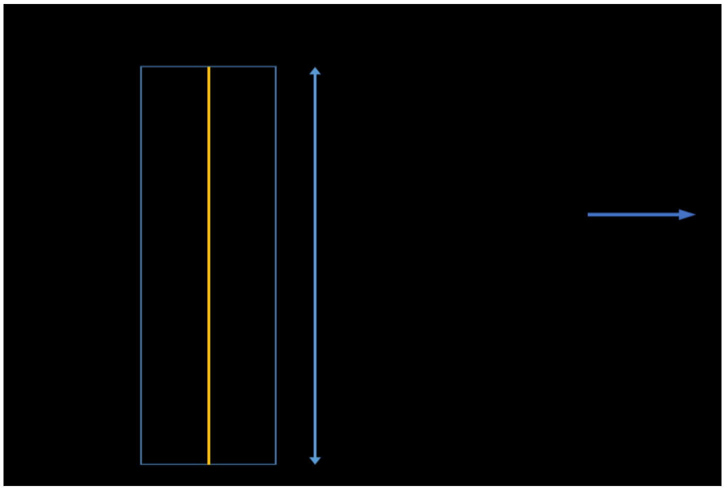


Figure 4.1. Diagram of a chip seal project lot

Step 2. Break the project into 1 mi sub-lots (Figure 4.2).

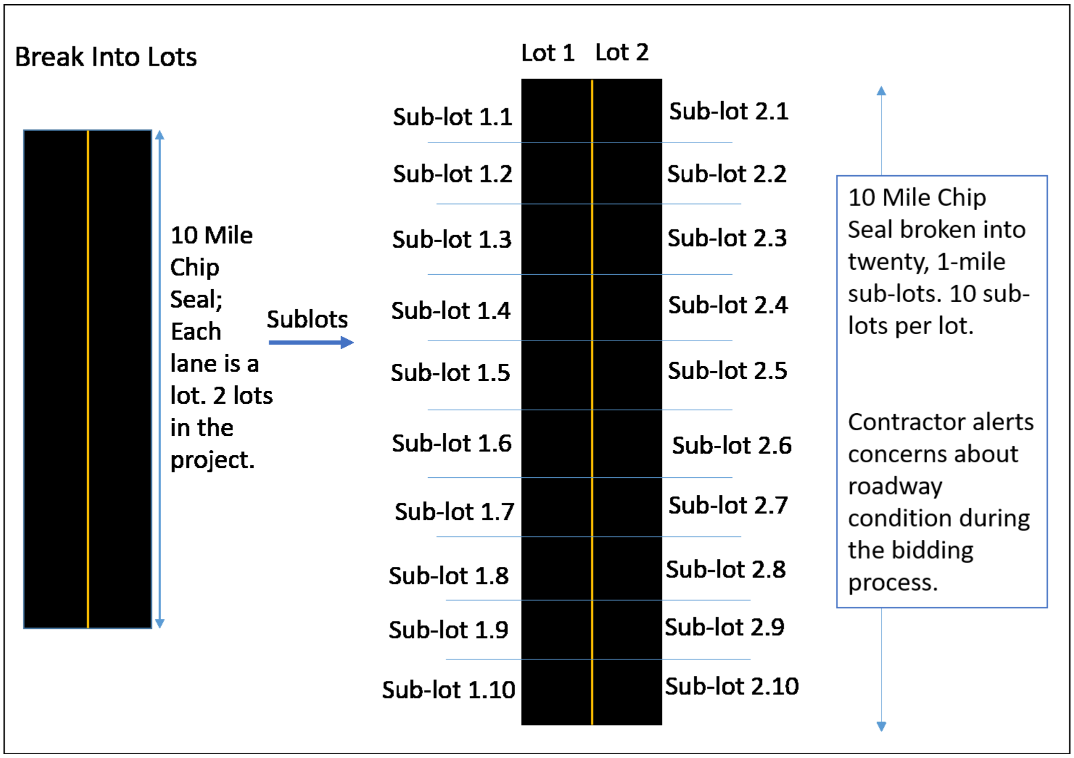


Figure 4.2. Diagram of sub-lots in an example chip seal project

Step 3. Break the sub-lots into segments. Segments are randomly selected for acceptance testing (Figure 4.3).

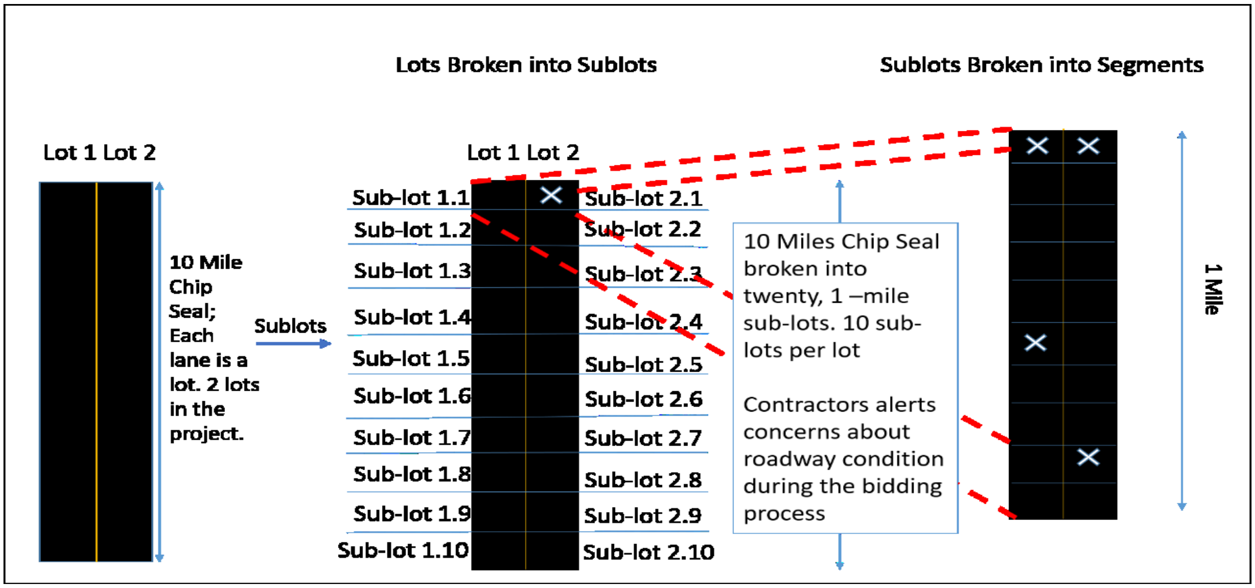


Figure 4.3. Creating segments in an example chip seal project

Step 4. Perform the sand circle testing on each randomly selected segment as shown in (Figure 4.4).

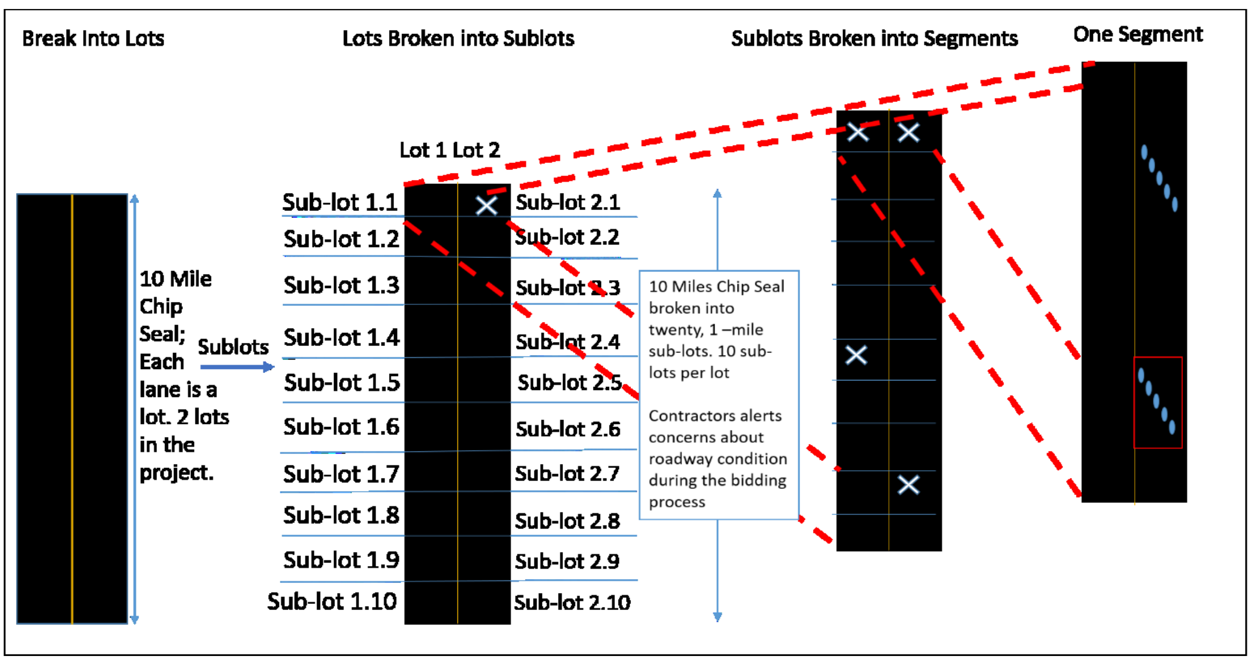


Figure 4.4. Sand circle testing in one segment

Step 5. Analyze results from the final inspection. The following proposed outcomes could occur:

- Both sand circle testing locations pass the failure criteria, and the section passes.
- Both sand circles testing locations fail the failure criteria, and the section fails.

- One sand circle testing location passes, and the other location fails. In this case, test a third and fourth location within the same segment.

Figure 4.5 provides an example performance test procedure.

Sand Circle Method (Based on TNZ T/3:1981)

The following items must be taken to the field:

- ☐ Method of recording data
- ☐ A soft brush or hand broom
- ☐ Tape Measure or ruler (at least 6 inches)
- ☐ Sand measuring cylinder 30 to 45 mm in diameter having an internal volume of 45 +/- 0.5 ml. The top of the cylinder shall be machined flat to assist striking off.
- ☐ A hockey puck fitted with handle for evenly spreading sand in a circle
- ☐ Clean dry sand with well rounded grains, 100% passing the 600 µm and 100% retained on 300 µm.

Sand Circle Procedure:

1 - Ensure that the area to be tested is try and free from debris. Brush any fine material from the surface.

2 - Fill the cylinder with sand and top lightly until the sand ceases to compact. Top off the cylinder with sand and strike off the surface with the straight edge.

3 - Pour out the sand in a conical heap in the center of the area to be tested. (In windy conditions the use of tire or screen to surround the sand is recommended.)

4 - Using the straight-edge, spread the sand into a circular patch so that the surface depressions are filled to the level of the tops of the stones (figure 1). The tops of the larger stones (see figure 1) should only just be visible through the sand layer.

5 - Measure the diameter of the patch twice, the direction of the second measure approximately at right angles to the first. Average the measurements to give "D", the sand circle diameter.

Sand Circle Calculation

The average texture depth may be calculated by dividing the volume of sand by the area of the sand patch. Report texture depth in mm.

$$\boxed{Average\ texture\ detph = \frac{57300}{D^2}\ mm \quad (D\ \boldsymbol{in\ mm})}$$

$$\boxed{Average\ texture\ detph = \frac{57300}{(D * 25.4)^2}\ mm \quad (D\ \boldsymbol{in\ inches})}$$

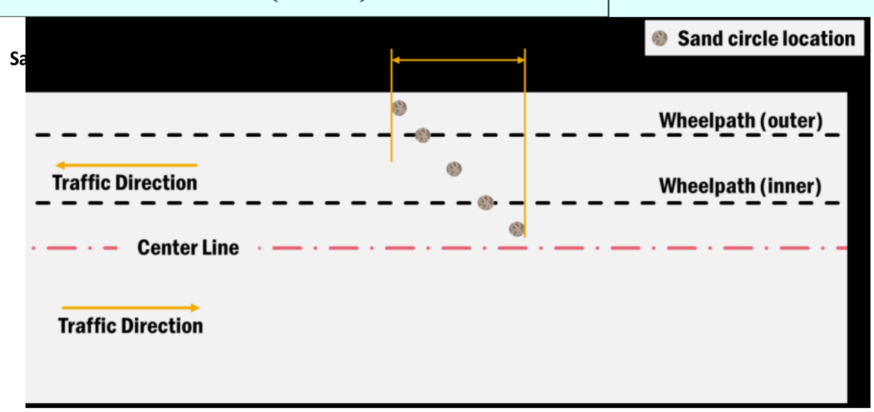


Figure 4.5. Sand circle test

In addition, Table 4.3 provides an example calculation of how to analyze sand circle performance results.

Table 4.3. Example of a Passing Sand Circle Test

Project	Segment test number	12-month sand circle testing				X = Ave.	S = Std. Dev.	X - 0.519S	Acceptance criteria*	P/F
		Diameter (OWP)	Diameter (BWP)	MTD (OWP)	MTD (BWP)					
Klamath Unit A	1	152.5	149	2.46	2.58	2.71	0.25	2.58	1.20	PASS
		151.5	140.5	2.50	2.90					
			136		3.10					
	2	143.5	143.5	2.78	2.78	2.76	0.03	2.75	1.20	PASS
		143.5	144	2.78	2.76					
			145.5		2.71					

*Acceptance criteria is a function of chip seal design life and ALD of the aggregate.

4.10.3 Final Acceptance

The proposed final acceptance is based on the macrotexture depth and a visual assessment of chip retention. This is the specification that will decide if the incentive/bonus is paid.

Final Acceptance

00710.94 Final Acceptance: A minimum texture depth has been specified. The final acceptance is based on achieving the required texture depth without significant chip loss. The Engineer is responsible for inspecting the seal at the end of the maintenance period, conducting the texture measurements, and compilation of the performance criteria report. This report details final texture measurements and individual lot assessment at the conclusion of the maintenance period. The Engineer will notify the Contractor when the final acceptance field inspection occurs. Final acceptance requires both a visual inspection and texture depth measurements. See Initial Acceptance for visual inspection guidance. If any of the following performance criteria are not met, repair work is required.

A length of 528 ft is used for testing, and the performance of five sand circle tests is used to determine texture depth. Five sand circles are to be taken across the width of the seal. The specified locations are: between the outer wheel path and the pavement edge, in the outer wheel path, between wheel paths, in the inner wheel path, and between the inner wheel path and the center line. The five readings are to be alternated across the road every 500 ft to ensure a mean reading is obtained for the complete road width, thus avoiding bias to one lane. Where pavement has edge marking, this is regarded as the pavement edge. No sand circle test shall be taken on pavement markings. To ensure that the texture of the seal is above the required minimum, the mean of the five tests is reduced by a factor dependent on the standard deviation. The texture measurements are taken by the sand circle method. The minimum value of the average texture depth calculated from the sand circle measurements shall be:

$$\mathbf{X - 0.519S > 0.07\ ALD\ \log_{10} Y_d + 0.9}$$

Where:

- X = average of the five texture depth measurements
- S = sample standard deviation calculated for the five tests
- Y_d = design life in years

Note: X - 0.519S is commonly termed the “texture depth criterion.”

The final acceptance criteria is based on New Zealand’s chip seal performance specification of 0.9 mm. This specification was studied during Phase 1 (Buss et al. 2016) of this chip seal project. Fourteen chip seal projects’ performance and macrotexture were tracked for several years. All 14 chip seal sections included in the study passed this performance criteria and were considered to be seals that performed adequately.

A section for retesting is added in the proposed specification. There was language for proportional payment based on New Zealand’s specification, but this was removed, because it was decided during the group discussions that the full payment should be made upon passing an initial inspection post-construction. However, the group wanted to have an optional bonus payment situation should a chip seal outperform its expected life span. The New Zealand language was modified for this purpose. Payment for the chip seal is made in full at the time of the initial acceptance, and passing the final acceptance awards a bonus/incentive pay. This is a shift away from a true performance specification, and therefore, careful ODOT requirements for construction and ODOT approval of application rates are still needed.

The chip retention is important for skid resistance and is addressed in the specification. Retesting is also addressed, because the standard deviation of the sand circles will influence whether the chip seal meets performance expectations.

The following equation 4.1 is used for calculating standard deviation:

$$\boldsymbol{\sigma} = \sqrt{\frac{\sum(\boldsymbol{x_i} - \boldsymbol{\mu})^2}{\boldsymbol{N}}} \tag{4-1}$$

Where:

σ = Population standard deviation

∑ = Sum of

x_i = Each value from the population

μ = The population mean

N = The size of the population

Chip Retention and Retesting

00710.95 Chip Retention - A visual assessment of the surface may be performed by the Engineer at any time before final acceptance to assess the level of chip coverage and retention. Chip retention shall be assessed by determining the chip coverage on any 1 ft^2 area. The segment shall be rejected if any three locations assessed have less than 95% chip coverage in the wheel path location or less than 90% chip coverage on areas outside the wheel path. All areas of chip loss greater than above must be repaired within the time frame specified in the contract document.

00710.96 Retesting - A provision is made to allow the Contractor (or consultant) to retest the wheel paths. In retesting, the lot is divided into individual lanes, and these are assessed separately. In the case of an outlier that causes standard deviation "S" to increase substantially, the sand circle measurements may be taken a second time.

The research team anticipates that the locations for retesting will be performed at the discretion of the ODOT engineer.

4.11 CONFLICT RESOLUTION TEAM

This section of the specification is based on wording from Michigan DOT's chip seal specification (MDOT 2010) and was included due to concerns that a performance specification may create future conflicts. This proposed performance specification is most likely to be implemented where the one-year performance criteria is an incentive bonus, likely 5%–10% of the project price, and under the incentive model, a conflict resolution team is not as necessary compared to if a payment retainage was being mediated.

The research team recommends this framework be further reviewed by ODOT to ensure it complies with all existing policies for conflict resolution and as it is not the prime focus of this current study.

Conflict Resolution Team

Conflict Resolution Team. The sole responsibility of the Conflict Resolution Team (CRT) is to provide a decision on disputes between the Department and the Contractor regarding application or fulfillment of the warranty requirements. The CRT will consist of five members:

1. Two members selected and compensated by the Department.
2. Two members selected and compensated by the Contractor.
3. One member mutually selected by the Department and the Contractor. Compensation for the third-party member will be equally shared by the Department and the Contractor.

If a dispute arises on the application or fulfillment of the terms of this warranty, either party may serve written notice that appointment of a CRT is required.

At least three members of the CRT must vote in favor of a motion to make a decision. If agreement cannot be reached, the CRT may decide to conduct a forensic investigation. The CRT will determine the scope of work and select the party to conduct the investigation. All costs related to the forensic investigation will be shared proportionally between the Contractor and the Department based on the determined cause of the condition.

4.12 PASSING AND FAILURE CATEGORIES

Overall, there was much discussion about how to proceed with a proposed performance specification. The performance metric, macrotexture as measured by the New Zealand sand circle test, has been proposed as a potential option for the agency, and the new specification is a hybrid of existing specifications with the performance criteria added. The performance specification serves as an additional contracting option. The ODOT has decided that bonus/incentive pay based on meeting or exceeding the performance criteria is the best option and avoids many of the issues involved with payment retainage but also provides an incentive for providing a quality chip seal product. The draft language proposes how to qualify for the bonus, but exact percentages for payment have not been determined. In the instance of failure at construction or after the one-year maintenance period, the agency will address those situations on a case-by-case basis with the option to pursue the contractor's bond for poor performance. The details regarding how and when the agency may file a claim on a bond are not addressed in this report.

Passing and Failure Categories and Definitions

Passing and Failure Categories and Definitions

There are five categories:

(Passing) Category A: The chip seal applied meets initial passing quality. The performance testing at one year indicates/forecasts higher macrotexture than expected based on formula (see Performance section). This category will likely result in full payment with incentive payments above expected contracted payments. Limit of 10%.

(Passing) Category B: The chip seal applied meets initial passing quality but required repairs during the one-year maintenance period. The performance testing at one year indicates/forecasts an adequate or higher macrotexture than expected based on the texture depth criterion (see Performance section). This category will likely result in full payment with a reduced incentive payment.

(Failure) Category C: The chip seal applied meets initial passing quality and did not require maintenance but has a reduced life span compared to expected baseline macrotexture goals based on formula (see Performance section). No incentive payment.

(Failure) Category D: The chip seal applied meets initial passing quality and required maintenance during the one-year maintenance period. The one-year inspection results showed reduced life span based on macrotexture goals based on the texture depth criterion (see Performance section). No incentive payment.

(Failure) Category F: The chip seal failed to meet initial passing quality. The Oregon Department of Transportation may decide how to proceed with payment.

Development of the performance criteria was based on many sand circle tests and studying 3 sections on 14 chip seals for 4 or 5 years (Buss et al. 2016). The duration for the study on these chip seals varied between four and five years depending on the seal's year of construction. All chip seals included in the study exceeded the one-year performance criteria and were considered as "passing" under this proposed specification. All of the chip seals would have qualified for the bonus pay in Category A as described above.

Table 4.4, acts as a quick reference list for all possible chip seal categories under the performance specification. The table outlines each major step of inspection, maintenance period, whether a performance incentive is paid, and hyperlinks to the required flow chart.

Table 4.4. Chip Seal Category Quick Reference

Chip seal category	Initial inspection	Was maintenance required during maintenance period? (Y/N)	Passes 1-year performance criteria? (Y/N)	Performance incentive	Flow charts needed
A	Pass	No	Yes	Yes	Overall Process Chart (Figure 5.1)
B	Pass	Yes	Yes	Case-by-case; likely reduced	Overall Process Chart (Figure 5.1)
C	Pass	No	No	No	Overall Process Chart (Figure 5.1) and Final Inspection Refusal Chart (Figure 5.4)
D	Pass	Yes	No	No	Overall Process Chart (Figure 5.1) and Final Inspection Refusal Chart (Figure 5.4)
F	Fail	Both Y & N apply for this category	Both Y & N Apply	No	Overall Process Chart (Figure 5.1 and Initial Inspection Refusal Chart (Figure 5.3)

Chip seals whose performance fall within categories C, D, and F are considered unacceptable and do not qualify for an incentive payment. Chip seals in category F would be at risk for non-payment due to unacceptable performance. In this instance, discussion between the ODOT and the contractor would take place to determine how to proceed in the event of a failed chip seal.

Initially, the performance specification was designed with the intent for the one-year performance criteria to have a significant financial impact on the project, so prescriptive methods could be reduced within the specification and risk shifted to the contractor. Some prescriptive methods, such as required application rates, were removed from the specification.

If the cost to build the chip seal to pass the one-year performance inspection is greater than the performance incentive (anticipated to be approximately 10% of the project at this time), then the ODOT risks having more chip seals falling within categories C and D. Chip seals falling within categories of C and D represent chip seals where initial performance is met, but the overall performance criteria predicts reduced life of the chip seal based on macrotexture.

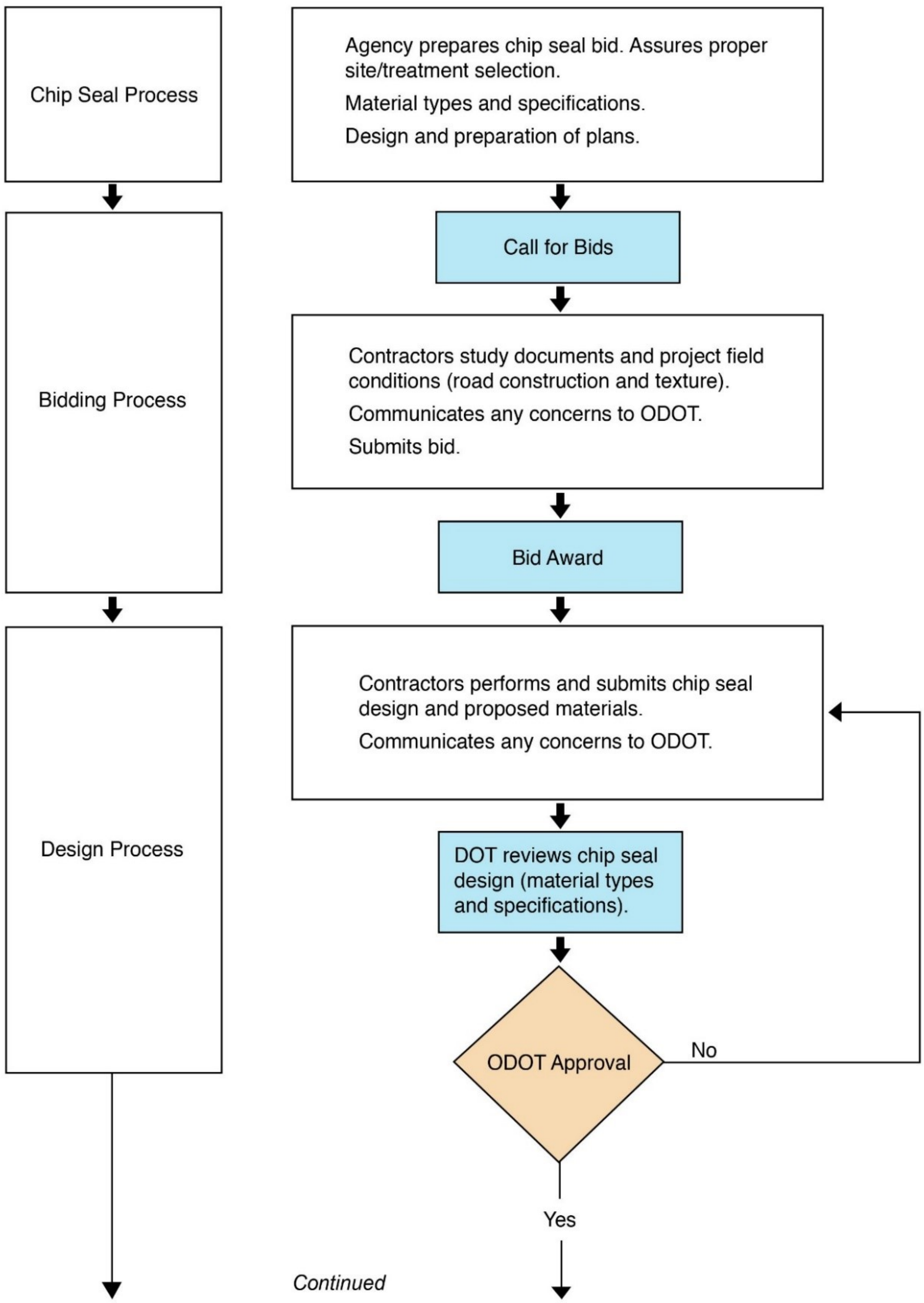
5.0 FLOW CHARTS AND DIAGRAMS FOR THE PERFORMANCE SPECIFICATION

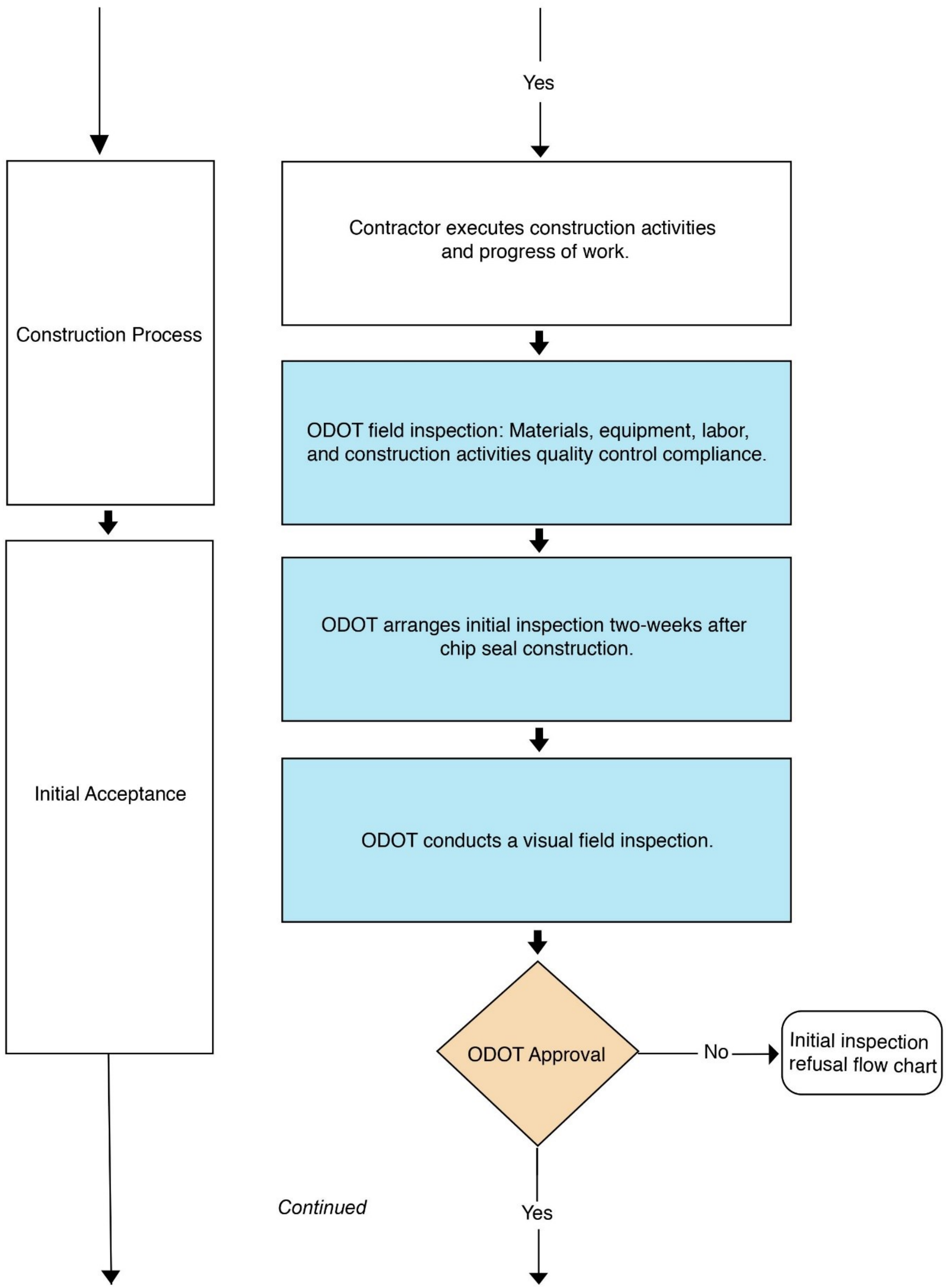
The three flow charts presented in this chapter can be used when working with the new specification. The first covers the overall process, the second addresses a refusal at initial inspection, and the third addresses refusal at final inspection. Refusal at initial inspection, as previously mentioned, would formally be addressed on a case-by-case basis. The refusal in final inspection would result in no incentive/bonus payment. When the final inspection flow chart was developed, the payment retainage was still being considered, so the chart was developed under that model; however, under an incentive/bonus payment, the chart may no longer be necessary. The chart is included in case a process for refusal at final inspection is needed for a special situation in the future.

5.1 FLOW CHART FOR THE OVERALL PROCESS FOR THE PERFORMANCE SPECIFICATION

This section provides a flow chart and guidance related to the overall process. The flow chart is presented in the next sub-section (Figure 5.1), and each subsequent sub-section discusses the activities related to the steps in the process.

5.1.1 Overall Flow Chart


Chip Seal Process
Agency prepares chip seal bid. Assures proper site/treatment selection.
Material types and specifications.
Design and preparation of plans.
Call for Bids
Bidding Process
Contractors study documents and project field conditions (road construction and texture).
Communicates any concerns to ODOT.
Submits bid.
Bid Award
Design Process
Contractors performs and submits chip seal design and proposed materials.
Communicates any concerns to ODOT.
DOT reviews chip seal design (material types and specifications).
ODOT Approval
No
Yes
Continued


Yes
Construction Process
Contractor executes construction activities and progress of work.
ODOT field inspection: Materials, equipment, labor, and construction activities quality control compliance.
Initial Acceptance
ODOT arranges initial inspection two-weeks after chip seal construction.
ODOT conducts a visual field inspection.
ODOT Approval
No
Initial inspection refusal flow chart
Yes
Continued

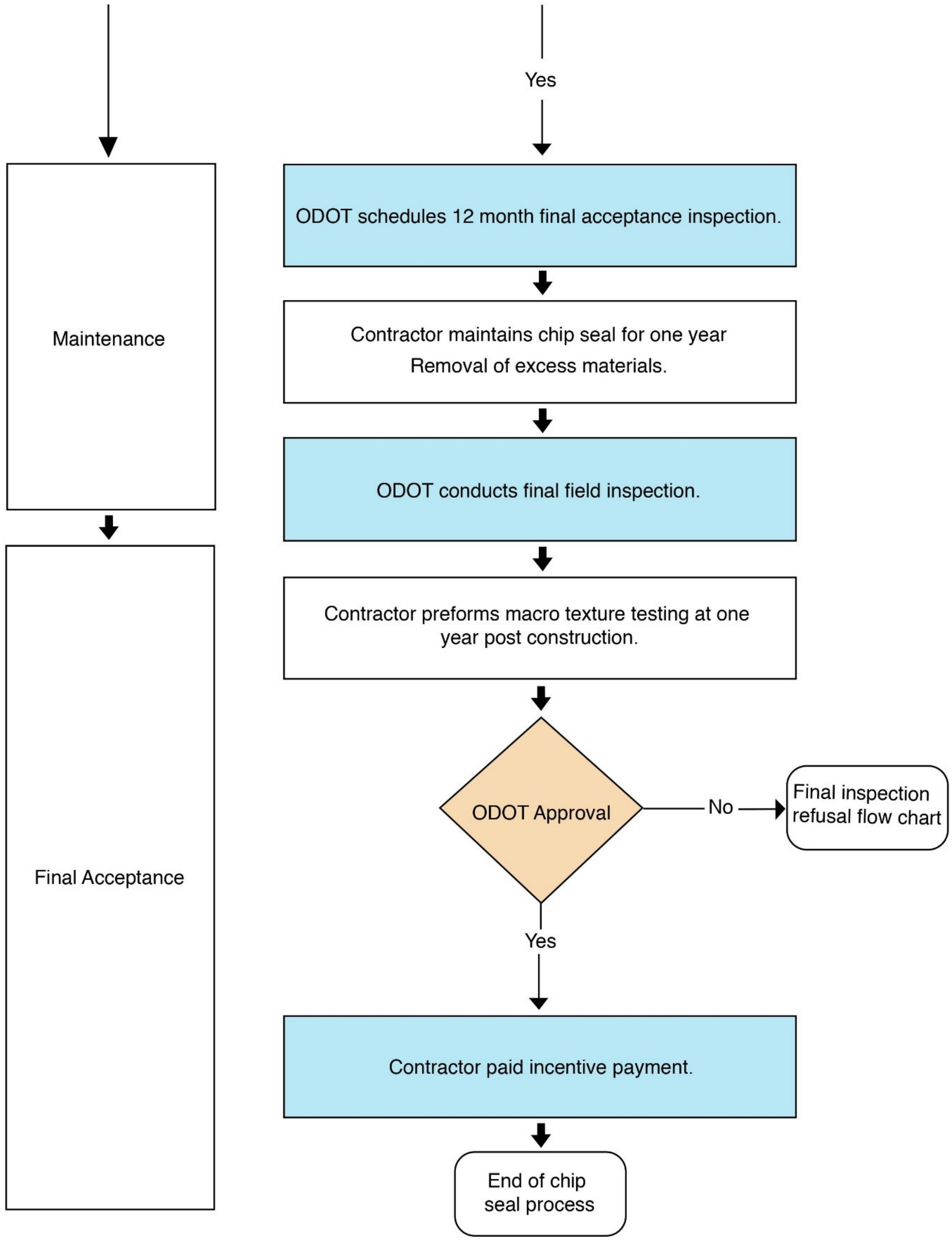


Figure 5.1. Overall chip seal process

5.1.2 Preparing the Chip Seal Bid and the Bidding Process

The proposed process begins with the agency selecting a roadway for chip sealing. The agency should determine if the project is a good fit for a chip seal and then if the performance specification is suitable. The following is a list of considerations:

- Existing pavement condition for chip seal, not too distressed, structural distresses.
- Overall drainage and cross-section shape (crown) of the roadway. Roads with multiple seals will lose their crown and good drainage will suffer.
- Areas subject to high shearing forces such as intersections, and sharp curves.
- Extensive heavy vehicle traffic and/or agriculture traffic.
- Steep hills will often wear prematurely.
- Large shaded areas that may present challenges during construction.
- Consider the potential for snowplow damage and whether sand application may dramatically affect macrotexture measurements at the 12-month performance evaluation.

The agency will specify a binder type, and the contractor can meet or exceed the binder specification. The agency will specify the aggregate size. To ensure that the macrotexture specification is appropriate, the pre-seal texture worksheet (Figure 5.2) should be completed by the agency before the project is bid using the macrotexture specification.

Pre-seal Pavement Texture Worksheet				
Location/ Measurement	Sand Circle Diameter in WHEELPATH (mm)	Sand Circle Diameter on CENTER LINE (mm)	Texture Depth Td (mm)	
			Wheelpath	Centerline
1.1	182.50	185.00	1.72	1.67
1.2	215.00	195.00	1.24	1.51
1.3	181.50	195.00	1.74	1.51
1.4	194.00	183.50	1.52	1.70
1.5	190.00	195.00	1.59	1.51
2.1	188.50	187.50	1.61	1.63
2.2	183.50	181.00	1.70	1.75
2.3	192.50	168.50	1.55	2.02
2.4	183.50	181.50	1.70	1.74
2.5	195.00	215.00	1.51	1.24
3.1	170.00	172.00	1.98	1.94
3.2	185.50	151.50	1.67	2.50
3.3	178.00	148.50	1.81	2.60
3.4	165.50	148.00	2.09	2.62
3.5	175.00	149.00	1.87	2.58

Average Texture Depth	1.79
Finest Texture (mm)	1.239589
Coarsest Texture (mm)	2.615961
Δ of Average to Finest (mm)	0.55
Δ of Average to Coarsest (mm)	0.82
Min Allowable ALD (inches)	0.51821

Figure 5.2. Pre-seal texture worksheet example

This worksheet is available in the chip seal design spreadsheet. The yellow cells are cells that the user needs to fill in, which includes the location or measurement, the sand circle diameter measured in the wheel path in millimeters, and sand circle diameter measured on the center line of the pavement. This exercise shows the minimum allowable ALD based on the variability in existing texture in the roadway. If there is high variability in the existing macrotexture, the chip seal will also have higher macrotexture variability, and it will be more difficult to pass the performance specification.

The agency will also prepare the plan set showing the area to be sealed. The agency specifies when they want a fog seal. The main advantage of fog seal application over chip seal surfaces are low cost, ease of construction, and desirable black appearance (Wood et al. 2006, Jahren et al. 2007). In terms of field performance, a study conducted by Im and Kim (2015) indicated that polymer modified emulsion (PME) showed better aggregate retention and resistance to bleeding. On the other hand, the main disadvantages for fog seals are delay in opening to traffic and reduction in skid resistance (Jahren et al. 2007).

The agency needs to provide the following information:

- Emulsion/Binder type, and outline the binder requirements that should be met or exceeded
- Aggregate gradation size per 00710.10
- Annual average daily traffic (AADT) and date of last AADT reading percent trucks
- Number of lanes to be sealed
- If a fog seal is needed
- Specify any maintenance needed (e.g., Before chip seal placement, a 2 ft by 6 ft hot-mixed asphalt [HMA] patch in the outside wheel path is needed to correct isolated longitudinal fatigue cracking at milepost 13.50)

Existing pavement conditions will influence pre-seal maintenance and will ultimately affect chip seal performance and may impact the chip seal during the initial acceptance if not adequately addressed before the chip seal construction. These include the following:

- Knowing the preexisting cracking condition of the roadway. Seal cracks well ahead of chip seal placement. (Practitioners experienced in chip sealing have recommended placing crack sealant between three months and one year before chip seal construction.)
- Percent patching in the roadway.
- Traffic levels per lane (vehicles/lane/day).
- Aggregate size (ALD).

In the proposed specification, the following is included to address these types of concerns:

"00710.92 - Where the existing (pre-chip seal) conditions make achieving a uniform texture difficult, or there is a high risk for failure, then an alternative acceptance criteria can be agreed upon. This may entail identifying areas where some chip loss may occur on high-stress sites and agreeing on the area involved. The alternative acceptance criteria must be site-specific, written, and agreed on prior to construction."

Any alternative acceptance criteria must specify the locations using the outlined lot and sub-lot framework with clear mile point ranges for each, which are covered under an alternative acceptance criteria. They must also specify the type of preexisting condition, which led to the need for an alternative acceptance criteria.

In conjunction with existing ODOT procurement practices, the next step is the call for bids. The contractor will review the documents and study the field conditions of the roadway. The following are recommended in preparing the bid:

- Know if the chip seal is being placed on an absorptive surface
- Understand if there are any pavement conditions that make chip seal construction difficult or negatively affect the chip seal performance
- Contractor should prepare a preliminary design to estimate the quantities, including:
    - Determine the surface condition for McLeod Design; perform ball penetration test for New Zealand design
    - Estimate the aggregate absorption factor based on aggregate absorption
    - Determine the loose unit weight of the aggregate and the percent of aggregate allowed for waste (typically 5% for low-volume and residential and 10% for higher speeds/county roads)
    - Estimate gradation, average greatest dimension (AGD), and flakiness of the aggregates

Any concerns should be communicated to the agency by the contractor. For example, concerns may include studded tire use, snowplow damage, intersections, steep curves, steep hills, and heavily shaded areas. These concerns should be addressed in determining if the roadway is a good candidate for the performance specification.

ODOT reviews the bids, and a bid is awarded.

5.1.3 Project Planning Process

After the bid award, the contractor performs and submits the material test results of proposed materials and the chip seal design. Any concerns regarding these should be communicated to ODOT. Initially, there was discussion about not requiring a chip seal design if the performance acceptance criteria is used but the performance at 12 months will only be implemented as an incentive payment. The contractor will provide the following:

- Gradation and all quality tests
- Application rate for chip seal coat aggregates (could use the chip seal design spreadsheet)
- Application rate for bituminous material

Major changes of the specification include the contractor setting the rates with agency approval, and there is an opportunity for innovation. The agency reviews the chip seal job mix formula and application rates. If there are concerns, the contractor re-submits materials and design documentation. If the materials and design meet expectations, the agency provides a Notice to Proceed.

5.1.4 Construction

The contractor executes the work as specified while the agency inspector is present. Under the original specification, the inspector recorded and observed the process but also actively directed the application rates. Under the new specification, the contractor will record and observe the contractor and the construction process. Best practice is to address any necessary repairs while the contractor is on site. Inspection notes will be used at the two-week initial acceptance and at final inspection. The inspector will discuss any concerns with the contractors. It is much easier to address repairs during construction. A construction report will be provided to ODOT.

5.1.5 Initial Acceptance

The agency arranges the initial inspection two weeks after chip seal construction and then conducts the visual field inspection. If approved, the full payment is released. If not approved, then the initial inspection refusal flow chart is followed (Figure 5.3).

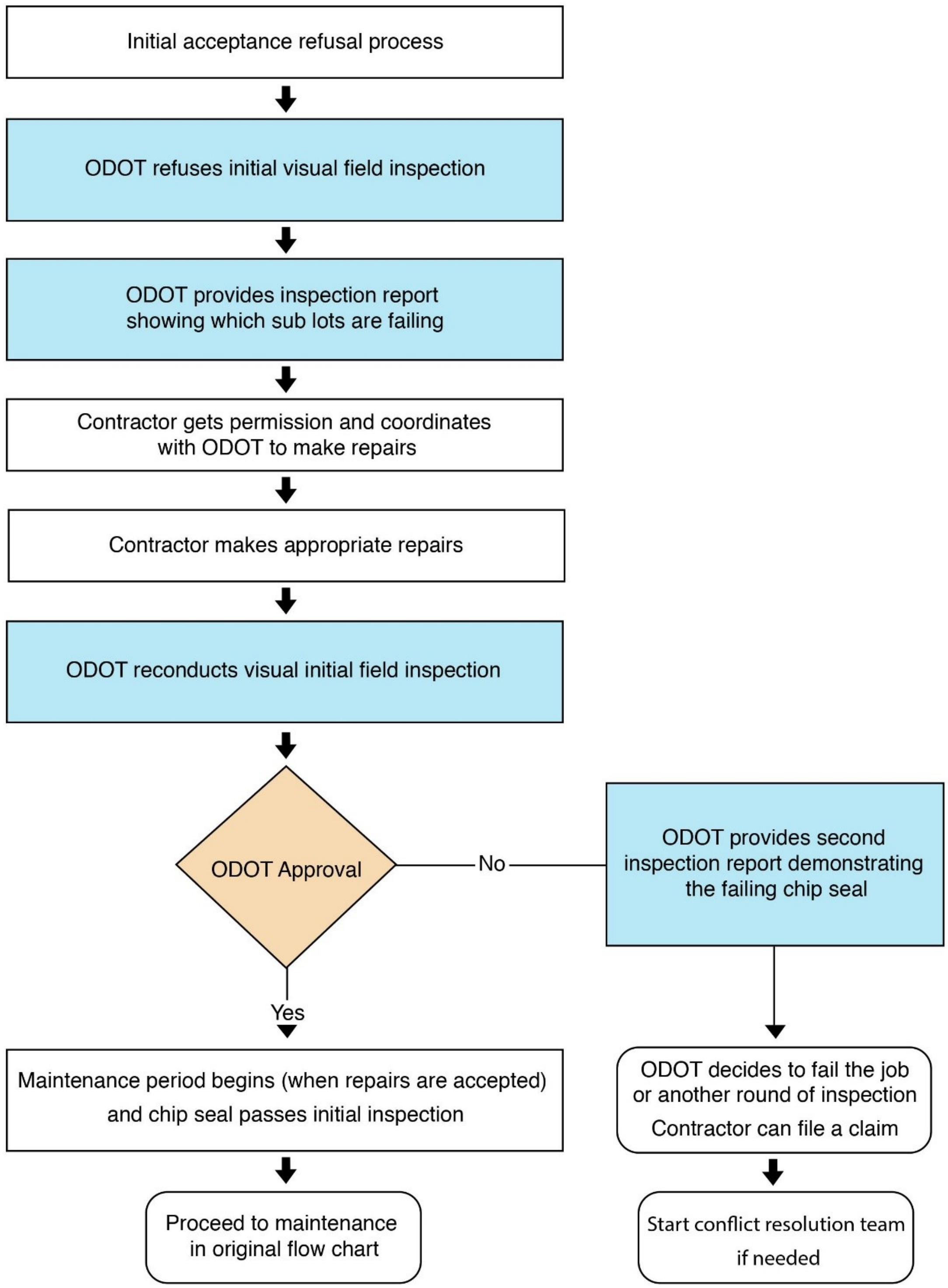


Figure 5.3. Initial acceptance refusal process

The initial acceptance process was described in the previous chapter and is section 710.93 in the proposed specification.

5.1.6 Maintenance Period

The decision to use the proposed 12-month performance specification as an incentive bonus makes it unlikely that significant maintenance will be performed by the contractor, and this section may no longer be necessary as part of the process. Under the original concept, the contractor maintains the seal for one year and removes excess loose aggregates as outlined in the specification, and full payment for the project is made after the chip seal passes a performance criteria based on macrotexture at 12 months. The maintenance period was described in the previous chapter, and the section is 710.61 in the proposed specification.

5.1.7 Final Acceptance

The agency and the contractor conduct the final field inspection and measure macrotexture. If the chip seal passes, the incentive payment is awarded as shown in Figure 5.4.

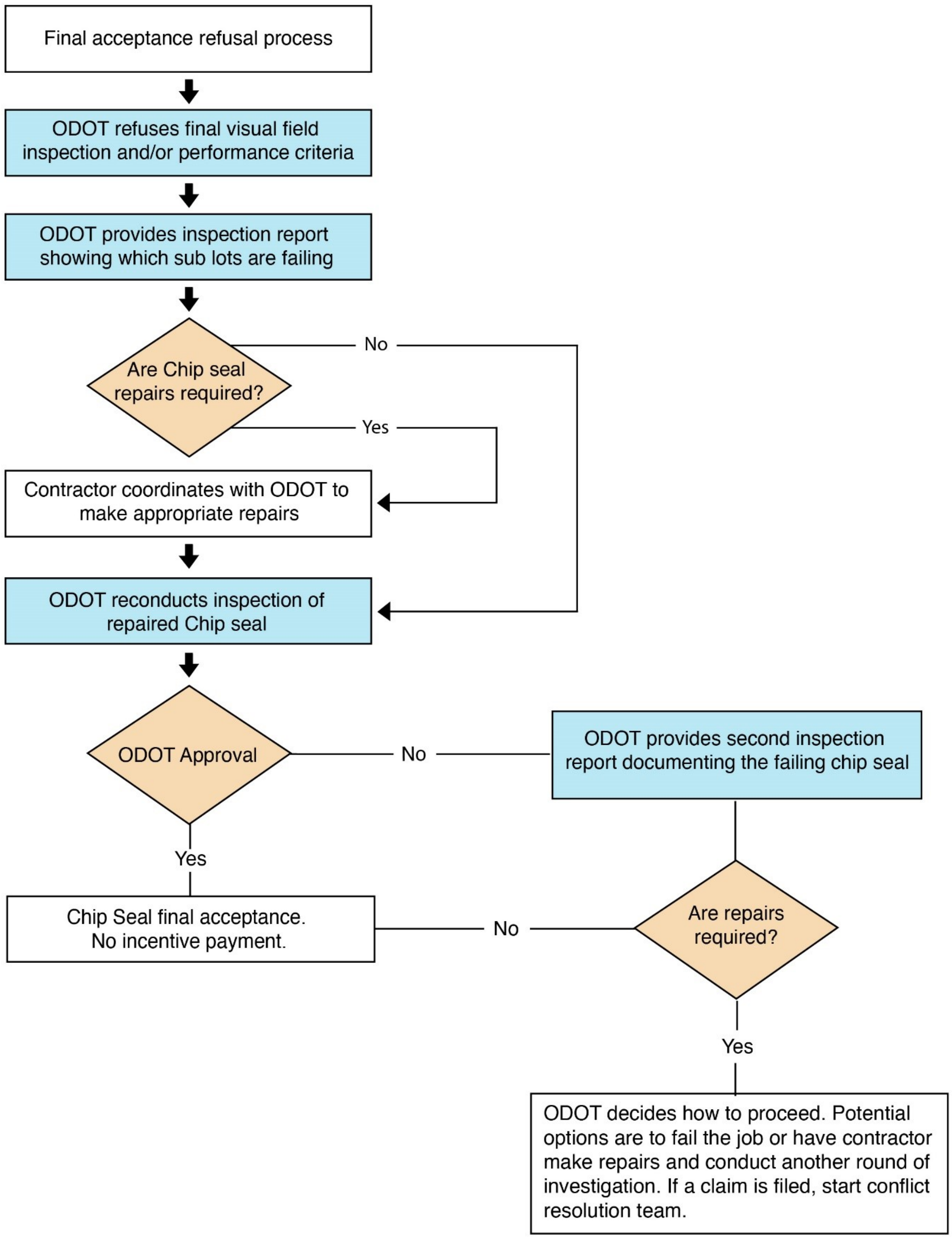


Figure 5.4. Final acceptance refusal process

The final acceptance was described in the previous chapter and is section 710.94. The performance criteria for the one-year post-construction inspection for final acceptance was detailed in the previous chapter and is section 710.91 in the proposed specification.

5.2 INSPECTION REFUSAL PROCESSES

The agency will work with the contractor on a case-by-case basis if there is a situation where the chip seal fails and does not pass the initial or final inspection. The previous flow chart in Figure 5.3 proposes a process if a chip seal does not meet expectations at the two-week inspection. In addition, the previous Figure 5.4 proposes a process if the chip seal does not pass the one-year inspection.

6.0 SECOND CHIP SEAL IMPLEMENTATION WORKSHOP

6.1 INTRODUCTION AND PURPOSE OF THE WORKSHOP

The second chip seal performance specification workshop was held in Salem, Oregon on February 7, 2018. The list of attendees included 20 participants: 2 from academia, 1 from FHWA, 5 from ODOT, 6 contractors, 5 asphalt suppliers, and 1 from a local agency.

The purpose of the second chip seal workshop was to discuss the proposed specifications with the chip sealing community in Oregon. The specifications were updated from the initial chip seal guidance based on the survey results and a series of meetings held with ODOT representatives from November 2018 through January 2018. In those meetings, each section of the specification was revisited and reviewed. Overall, the aim of the meetings was to develop a chip seal performance specification that will allow the contractor more freedom during the construction but also reduce the risk of failure, and thus, there's a greater likelihood that a higher quality chip seal is achieved.

The current ODOT chip seal specification is a method specification with chip seal application rates specified by the agency. The proposed specification removes the application rates requirement and allows the contractor more freedom in the applications; however, the new specification requires a visual inspection at two weeks, a one-year maintenance period at the responsibility of the contractor, and a final inspection at one year. The final inspection includes a visual inspection and a macrotexture performance requirement. This chapter contains the 2018 meeting agenda, summaries of the presentations, and a summary of the takeaways from the workshop.

6.2 WORKSHOP AGENDA AND SUMMARY OF PRESENTATIONS

Table 6.1 shows the workshop's agenda and schedule. Presentations from the workshop are shown in Appendix A.

Table 6.1. Second chip seal performance specification workshop agenda

Time	Agenda
8:00 to 8:20 A.M.	Introduction: • Purpose and Agenda of Meeting. • Jon Lazarus – Oregon DOT Research Coordinator.
8:20 to 9:00 A.M.	Larry Ilg – **ODOT Chip Seal Practices.** *History of Chip Seals in Oregon, Project Selection, Construction Responsibility, and Chip Seal Performance.*
9:00 to 10:00 A.M.	Doug Gransberg – **Oregon DOT Chip Seal Workshop Research.** *Validated Best Practices*.
10:20 to 12:00 P.M.	Ashley Buss – Oregon Chip Seal Research Results and Introduction to SPR 777 Implementation Project. • SPR 777 highlights. • MTD and its importance for the performance-based specifications. • Purpose and Scope of the SPR 777 project. • Introduction to the chip seal performance specification. • Q&A.
1:00 to 3:00 P.M.	Ashley Buss – Current Version of the Specification, Flow Charts, and Sand Circle Demonstration. • Walk through the flow charts and important sections in the specifications. • Payment schedule and acceptance. • Acceptance details. • Participants break into small groups to discuss write down feedback on forms to hand-in to research team. • Participants provide feedback on the overall process, ask questions are areas that are unclear. • Sand circle demonstration.
3:00 to 3:20 P.M.	Break/Hands-On Sand Circle Testing
3:20 to 4:30 P.M.	Action Items and Next Steps to Improve Performance Specification and Existing Guidance

Quality Assurance (QA) Engineer Larry Ilg presented Oregon's current chip seal practices. The main topics were history, project selection, construction responsibility, research, and chip seal. Funding for chip seal tends to go up and down from year to year, e.g., one year with approximately 800 lane miles, the next with approximately 200, and the following year having approximately 800 lane miles. Since 2012, there has been a shift from ODOT maintenance constructing the chip seals to contractors constructing the chip seals. Chip seals are used on rural highways with traffic volumes less than 5,000 average daily traffic (ADT) for emulsion seals or traffic volumes less than 10,000 ADT for hot seals. The pavement condition for chip seal candidates are fair to good with no structural issues. ODOT's Pavement Design Guide (ODOT 2019b) provides typical pavement selection guidelines for chip seals. Under the current specification, ODOT is responsible for setting rates, and the contractor is responsible for placing at those rates. Overall, most chip seals are performing well.

Dr. Doug Gransberg of ISU presented a summary of his chip seal research and experience with the New Zealand Chip Seal Performance Specification. The National Cooperative Highway Research Program (NCHRP) Synthesis 342 provides best practice recommendations for chip seals (Gransberg and James 2005). All states reporting excellent chip seal performance used chip seals as a preventative maintenance tool and were on a five-year preventative maintenance cycle (Gransberg, 2005). In addition, many of the states that have excellent performance use a formal design method (Gransberg 2005). Rolling on the chip seals is important and controlled in many specifications. For instance, in New Zealand, pneumatic-tired rollers are most common for rolling. New Zealand has had excellent experience with their sand circle performance specification requirement (Gransberg 2007). Testing in Oklahoma shows that this performance specification could be developed for use in the US. It provides a quantitative measure of performance and can be used to program roads for chip seals (Pittenger and Gransberg, 2012).

Dr. Ashley Buss of ISU presented the findings from the Phase1 of the Oregon Chip Seal research project (Buss et al. 2016). The main objectives were to document methods of chip sealing, report the performance of chip seals, apply chip seal design, and identify best practices for implementation. The ODOT helped identify chip seal locations for this project. Chip seal aggregates were collected, and general aggregate information was collected. Chip seal field application rates were obtained from the contractor or agency. The aggregate and roadway information was used to back-calculate design rates for the McLeod and New Zealand methods. The field performance was studied and compared with the New Zealand performance specification, and most chip seals performed well. The pre-seal conditions influenced the performance of the chip seal. For example, the section with most stresses before chip seal application showed the lowest MTD four years post-construction. Therefore, the New Zealand performance specification accurately reflected the performance of the chip seals in the Buss et al. (2016) project, and thus showed that a similar performance specification could be implemented in Oregon.

Buss also presented an in-depth look at the macrotexture performance of different seals and how the field sections performed in comparison to the proposed performance specification. Most of the chip seals performed well and were above the performance specification. The deterioration curve for chip seal macrotexture from Gransberg's Oklahoma research is very similar to the macrotexture deterioration curves from the Oregon research (Gransberg et al., 2010 and Buss et al., 2016). This confirms that the macrotexture measurements can be implemented as a performance specification. The tasks for the Phase 1 research were also presented (Buss et al. 2016). The project deliverables and schedule were presented. The purpose of this discussion was to present the project scope to workshop participants and clarify the current project's goals.

Buss also presented the challenges, based on previous group discussions and the surveys, with converting ODOT's current chip seal specification to a New Zealand-style performance specification. The presentation highlighted the main changes in the proposed specification and the main sections of the proposed ODOT chip seal specification. The largest proposed changes to the current specification are the removal of application rates and a revision of the specification from prescriptive- to a performance-based, thus changing the risk profile. The main sections of the proposed specification were listed, and each workshop attendee had a copy of the current version of the proposed chip seal specification changes.

Buss further presented the flow chart, as shown previously in Figure 5.1, developed for the chip seal performance specification and offered additional details about the proposed specification. In the bidding process in the proposed specification, the agency will provide information about the roadway to be chip sealed as well as the binder type and aggregate size. Further, there is a clause in the acceptance section that allows for the agency and contractor to come to a mutually agreed upon alternative acceptance criteria in site-specific locations with existing conditions that make achieving a uniform texture difficult. In leading up to the workshop, concerns had been voiced that certain areas are not appropriate for the performance specification and that the specification does not specifically address how snowplow-related damage may affect performance and final payment. Materials are still required to pass specifications. Under the proposed new specification, the role of the inspector changes from the person who is directing the application rates to an active observer who records the process and shares concerns with contractors. The visual inspection was developed based on the Michigan chip seal visual inspection specification (MDOT 2010), which provides a more quantitative way to conduct a visual inspection. New Zealand's reduction in payment example was presented and compared with the initial/final payment schedule proposed in the current version of the specification. The one-year maintenance period was discussed, and the maximum of 30 chips/yd^2 was noted as the general guide for required sweeping. The equations for the performance specifications were presented. Finally, the specification's inclusion of a conflict resolution team was presented. The conflict resolution team language is adopted from the Michigan Chip Seal Warranty Specification (MDOT 2010).

Participants used simulated roadway/chip seal surfaces with various textures to perform sand circle tests. The sand circle test provides the measurement of the chip seal macrotexture used in the performance specification and final acceptance.

6.3 SUMMARY OF TAKEAWAYS FROM THE WORKSHOP

During the meeting, participants expressed concerns about how traffic control is bid and paid for under the performance specification. However, the performance of the chip seal shouldn't influence traffic control payment. The bidding process and subsequent payment should reflect safety as the top priority. Lump sums of traffic control plans are commonly used. The traffic control plan is submitted and approved.

Another major concern from participants was the payment schedule. The initially proposed 70% payment after initial inspection and 30% payment after the final inspection was a major concern. Then, the proposed 90% payment after initial inspection and 10% payment after final inspection was also a concern. Participants anticipated that the contractor/supplier would increase the cost of their materials by the retainage percentage. Additional participant comments indicated that under a payment retention option, the cost would increase, or there wouldn't be bidders. Ultimately, from the discussions, a performance bond/warranty seemed to be the best alternative moving forward for the contractors. Funds from the project's bond would be used by ODOT to cover the cost to repair the failed chip seal. A bond helps to put everyone on a level playing field; contractors have to pay the suppliers and their workers. The bond language will not be written into the specification. The definition of various bonds needs to be investigated further so that ODOT has a payment schedule that can be reasonable for the contractor. These questions need to be discussed with ODOT's Contract Administration and with the Oregon Department of Justice (DOJ).

Attendees noted one of the challenges with the retainage option is that ODOT has removed some aspects of the method-based specification, giving the contractor more freedom during construction and changing the role of the ODOT inspector to an observer, but the proposed performance metric/criteria has only a small fraction of the payment tied to performance. If the cost to repair, maintain, or replace the chip seal is more than the payment retention, there would be no financial incentive for the contractor to return the project except if ODOT filed a claim on the company's bond.

Discussion on the payment retainage and conflict resolution team clauses in the specification led participants to note that an internal ODOT legal review should be performed to answer a couple of questions about the history of resolving problems that included financial resolutions pursuant to the terms of a bond. For example, on past chip seal failures, how were costs recovered? If costs were not recovered, how could bond terms and agreements be developed for ensuring quality work by the contractor? Based on workshop discussion, on a national scale, default rates on bonds are very low for state projects. It is expected that any payment retainage withheld by the state will have a relatively high carrying cost. A bond cost is about ~1.5% of construction, which would be much less than the overall cost of a retainage.

Incentives/disincentives and penalties were briefly discussed and had been part of the conversation in meetings leading up to the workshop. The bond route provides the financial disincentive to bring the contractor back to the project if there is a major failure on the chip seal project. The performance specification helps to define and quantify the failure.

There was a discussion about when the maintenance period should start relative to the time of repairs. There was a support that the maintenance period should start at the time of the repair; thus, the repair must last 12 months. This would avoid a situation where a contractor would only have to make the repair last for six months. Additionally, participants noted the sections, sub-lots, and lots need to be clearly defined in the specification, as shown previously in Table 4.2. The random selection process for testing needs to be clearly defined in the specification. From a statistical point of view, on a large chip seal project, there may be specific small areas that need to be repaired.

The performance metrics that the ODOT is trying to achieve must be spelled out clearly in the specification. If the metrics are clear, then the contractor can design the materials and construction methods that are appropriate for meeting the clearly defined acceptance thresholds. However, some decisions, like asphalt binder type, have implications beyond a 12-month performance specification.

Currently, the visual inspection includes cracking as a metric in the initial inspection. If cracking is showing through the chip seal, then those cracks need to be sealed. Chip seals are not meant to fix the cracking, but the Oregon research has shown that chip seals were effective in covering up some of the transverse cracking after one year; however, if a crack is too large, a chip seal will not bridge the crack. Cracks are not necessarily a chip seal workmanship defect but if cracking is occurring, proper pre-seal maintenance wasn't addressed and/or the wrong type of asphalt emulsion was used. For example, if an emulsion had too low viscosity, the emulsion may not bridge a crack needed in chip seal emulsions.

In the ODOT chip seal research (Buss et al. 2016), all chip seals were constructed with polymer-modified asphalt. Suppliers mentioned that a chip seal can be used to cover cracks by modifying the oil to seal and bridge the crack, but it would add cost. A question that arose during the workshop discussion was whether or not it is appropriate for the specification to include cracking in a visual inspection. If the crack specification is left in, is it reasonable, or will it cause prices to increase needlessly? The corrective action for addressing the cracks is that the crack should be sealed. The overall purpose of the seal is to keep water out. The agency should acknowledge cracks in the roadway that are too large for a chip seal to bridge at the beginning of a project. Larger cracks should be repaired before chip sealing. Contractors can also identify cracks of concern and negotiate a binder both parties agree may bridge the crack width. Roads with excessive cracking or large cracks are not good candidates for chip sealing. A performance specification is not going to be appropriate for roadways that are not good candidates for chip sealing.

There was a concern that traffic maybe higher than expected on the seal. The concern is that actual traffic count may indicate higher than expected amounts of traffic (over a short-term) for the year due to circumstances that are outside of the contractor's control. An example was provided about a situation when interstate traffic was diverted to a lower-volume road. Another similar concern was logging trucks or snowplows, which could potentially cause damage to the chip seal. These situations would fall under non-contractor obligation defects. Idaho's chip seal warranty manual (ITD 2015) provides guidance for these situations and will be modified to add to ODOT performance specifications.

There was a concern that the contractor would have to check on the performance of a chip seal during the one-year maintenance period to ensure the seal is performing well and that traffic has not caused damage to the seal. The discussion concluded with agreement that the most likely situation would be that a district maintenance engineer would notice that the chip seal wasn't performing and that the contractor would then need to perform maintenance. The district maintenance engineer would notify the project manager, who would notify the contractor. However, the group agreed the responsibility falls on the contractor even if ODOT provides feedback.

Chip seal selection is an important aspect of a project. Often, the timing of a chip seal project is pre-programmed into a road network's preservation plan. After the project completion, chip seals have been known to cause public complaints for various reasons. One reason is the loose stone that may damage or chip car windows, especially loose stone in urban areas. Another concern is that a rough surface texture is unpleasant for bicyclists. Smaller aggregate size has shown to help reduce complaints related to rough surface texture for cyclists. Chip seal selection is important. Measuring rutting or evidence of other structural distresses can help determine if the chip seal is a right candidate for the road surface. If a chip seal is being performed, the aggregate size, based on ALD, needs to be larger than the rutting. Also, the chip size will influence the cost, and larger aggregate requires more asphalt to be held in place.

Participants also discussed the specification requirements on rollers. Currently, Oregon's specification requires a steel-wheeled roller. Updates to the specification leave the roller type up to the contractor. Comments from the workshop in favor of using steel-wheeled rollers included that the steel wheel takes care of irregular aggregates that may be more prone to snowplow damage. Also, steel-wheel rollers are better for the longitudinal joints and for compaction where the joints meet. Inspectors and contractors should ensure that the steel-wheeled roller is not crushing the aggregate.

The Montana sweep test was discussed. This test is performed after construction. The aggregate material placed during chip seal construction is swept off from a pre-determined area and weighed. The reason for the test is so that the agency doesn't have to pay for aggregate that doesn't stick to the road. Changing the chip seal pay item from materials costs to cost per square yard will help the agency not have to pay for excess aggregate application.

Fog sealing chip seals was discussed, and fog seals help seal up microcracking, also "locks in" the chips on a new road, and provides a visually pleasing end result. Chip seal timing was also discussed; currently, chip seals are often placed at 5–10 years after a pavement's construction. Some agencies have reduced the timing and are applying chip seals sooner. One attendee mentioned that some states include a chip seal as part of the paving contract.

6.4 PARTICIPANT FEEDBACK

A crucial part of the workshop was to gather feedback from the workshop participants. Feedback forms were included in the packet of materials, and participants filled out the forms together to facilitate discussion. The questions and requests for feedback are presented below.

Q. From the specification changes and acceptance process presented, what seems to work well and/or can be easily implemented?

- A1. No comments written.
- A2. Contractor design will work. Acceptance process will be cumbersome.
- A3. Sand Circle Test is a good way to identify flushed pavement and a way to accept chip seals.
- A4. Understand you want to have a performance-based project.

Q. Based on your experience, what impacts do you see the specification changes having on the chip seal cost, construction practices, and overall performance?

- A1. Costs will rise and increase ODOT workload at the bid step. Contractors have to take more responsibility and performance should rise.
- A2. It appears to me to add costs to the project is the proposed 70/30 payment.
- A3. I think this will raise the prices to cover the unknowns of compensation if there is a failure. It should raise the quality and performance.
- A4. I think with 70/30 will raise costs 30%. I believe construction practices could improve with certain contractors.

Q. What areas of the specification need to be improved?

- A1. Bid process and payment. Be able to start in May.
- A2. Tighten up application rate parameters.
- A3. Cracks need to be removed as a deficiency.
- A4. I believe a warranty bond would be a better way to handle any failures. Make sure to add a contractor to the two-week visual inspection.

Q. Based on identified areas that need to be improved, what action items do you recommend?

- A1. Contracts need to be awarded by February and on a more equal work load per year.
- A2. Rethink the payment and acceptance process. Slow and not contractor friendly.
- A3. Remove the crack reference. I think keep specification payments by square yard and go with low bid.
- A4. I think we need to take a better look at what type of oil is used in certain areas. For example, using an AC-15P product on a heavily canopied area should not be used if it is late in the season with colder temperatures.

Q. What impact will specification changes have on the bidding process, your business, the chip sealing community, and ODOT's ability to use chip seals long-term?

- A1. Does not sound like 70/30 is an option for contractors. ODOT needs a better understanding of how bonds work.
- A2. The bidding process could be more involved and time consuming. Overall, chip seal costs will go up and be passed on.
- A3. Put this out as a pilot program with the understanding specifications will be adjusted as problems arise.
- A4. I believe after all the issues are ironed out, it will make for a better chip seal.

In addition, the respondent feedback is shown in italics, in Table 6.2 and Table 6.3.

Table 6.2. Workshop Recommendations for Specific Sections in the Specification

Specification section or section in the flow chart	Feedback
710.62	Needs to be quantified as to number of loose chips for additional brooming.
Bidding Process	Needs to be refined and more defined.
Initial Acceptance	Who will be involved in process and when does the two-week time start? End project or work zone completion?

Table 6.3. Workshop Recommendations about how to Develop Useful Guidance for the Updated Chip Seal Specification

Guidance document development topic or title	Feedback
General	Continue all party participation

7.0 SEAL PERFORMANCE UPDATE

7.1 MTD UPDATE

The primary focus of this chapter is to summarize the research on the macrotexture of various test sections from Phase 1 (Buss et al. 2016) to create a performance-based specification for the Oregon chip seal program. The use of New Zealand and McLeod methods has previously been discussed, and the results are published in Buss et al. (2016). This chapter covers a chip seal performance update for the various test sections in Oregon.

There are 14 test sections that were constructed in Oregon as part of the Phase 1 project; 10 of these sections were built in 2014, and 4 sections were built in 2015. Therefore, the updates for the performance are for four and five years of performance since they were constructed. The follow-up measurements were taken at one year, two years, and for some sections, four and five years post-construction. MTD values were taken on the 14 chip seal projects at 3 locations within each project to track the MTD over time using New Zealand's sand circle test (TNZ 1981), similar to ASTM E965-15, Standard Test Method for Measuring Pavement Macrotexture Depth Using a Volumetric Technique (ASTM 2015).

Figure 7.1 displays the MTD measurements over time in for test section Unit A before, after, and up to five years post-construction.

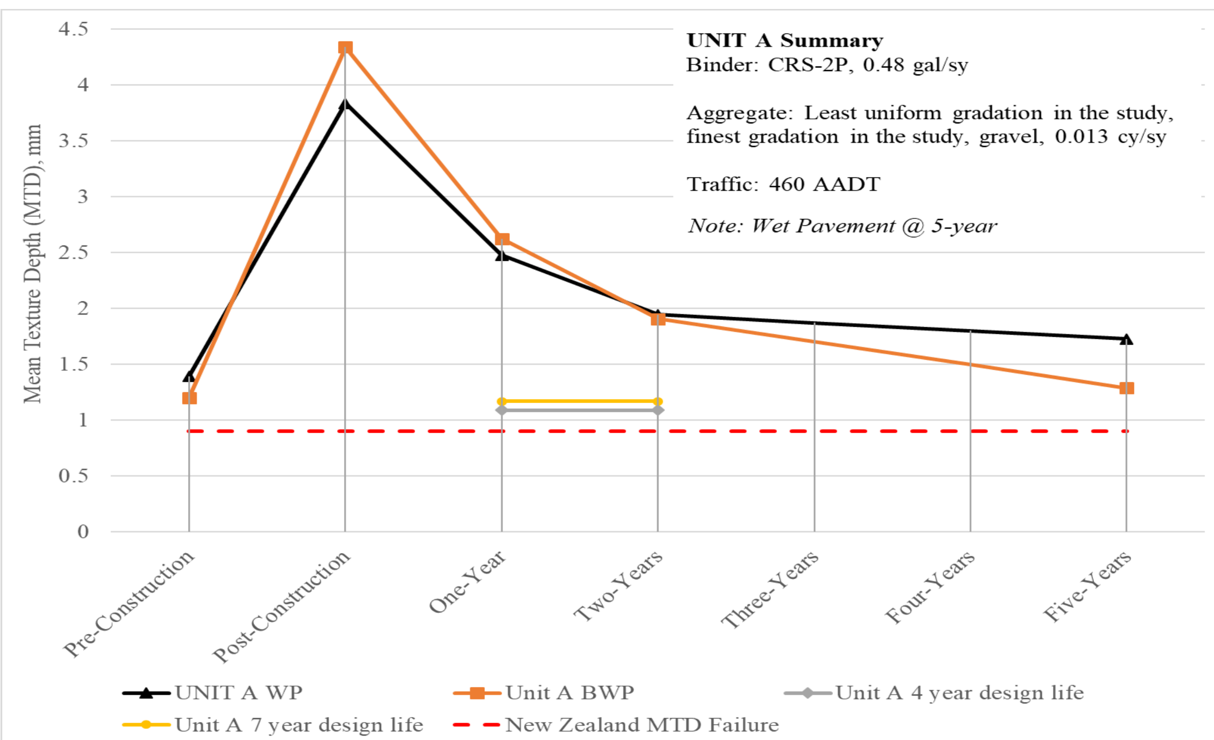


Figure 7.1. Unit A MTD measurements and performance criteria

An emulsified asphalt was used for this section. The exposed aggregate surface of the emulsion significantly increased the MTD right after construction. The MTD was reduced five years after construction, as expected. Unit A was above the New Zealand performance specification during the five-year inspection period. There was a difference between the measurements between the wheel paths (BWP) and measurements taken in the wheel paths (WP). The difference between the BWP and WP measurements was 0.44 mm. It is worth noting that the sand circle test was conducted on wet pavement, which may have affected the field measurements. From the MTD, Unit A appears to be performing well.

Figure 7.2 represents the MTD measurements for test section Units B and C.

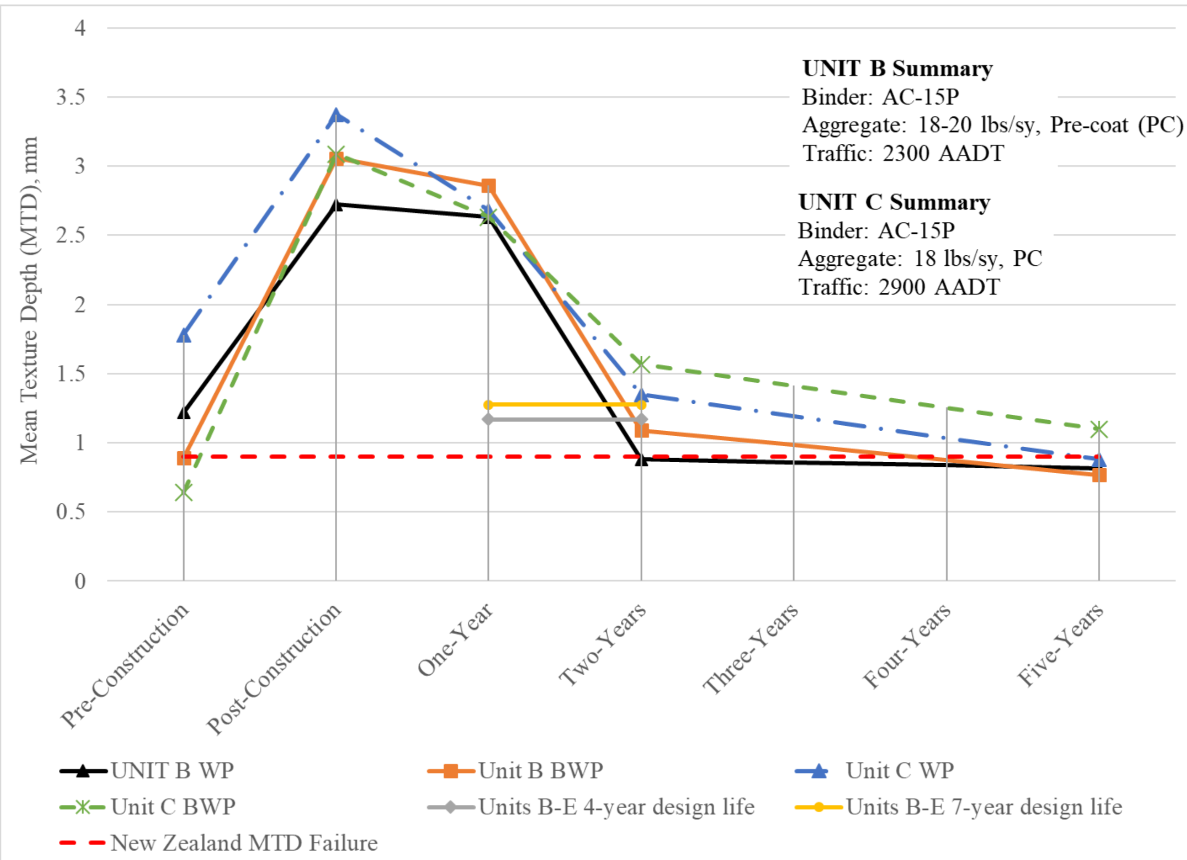


Figure 7.2. MTD for Units B and C with performance criteria

This section used a hot-applied seal. Both of these sections have an AADT of between 2,300 and 2,900, respectively. The initial improvement in MTD was recognized, and the decrease in MTD over the first year was relatively small, but the MTD in the two-year post-construction measurements show a significant decrease in MTD. The five-year MTD results were lower than the two-year results but insignificant compared from the difference from one year to two years. Unit B has fallen below the New Zealand criteria of 0.9 mm for the WP and BWP measurements. The Unit C BWP MTD was reported at 1.10 mm, which is higher than the New Zealand performance criteria, whereas the Unit C WP MTD was reported at 0.88 mm, which is slightly less than the New Zealand criteria, and thus, this would be considered a failure by 0.02 mm.

Figure 7.3 shows the MTD measurements for test section Units D and E, which used the same binder and aggregate as Units B and C with similar application rates.

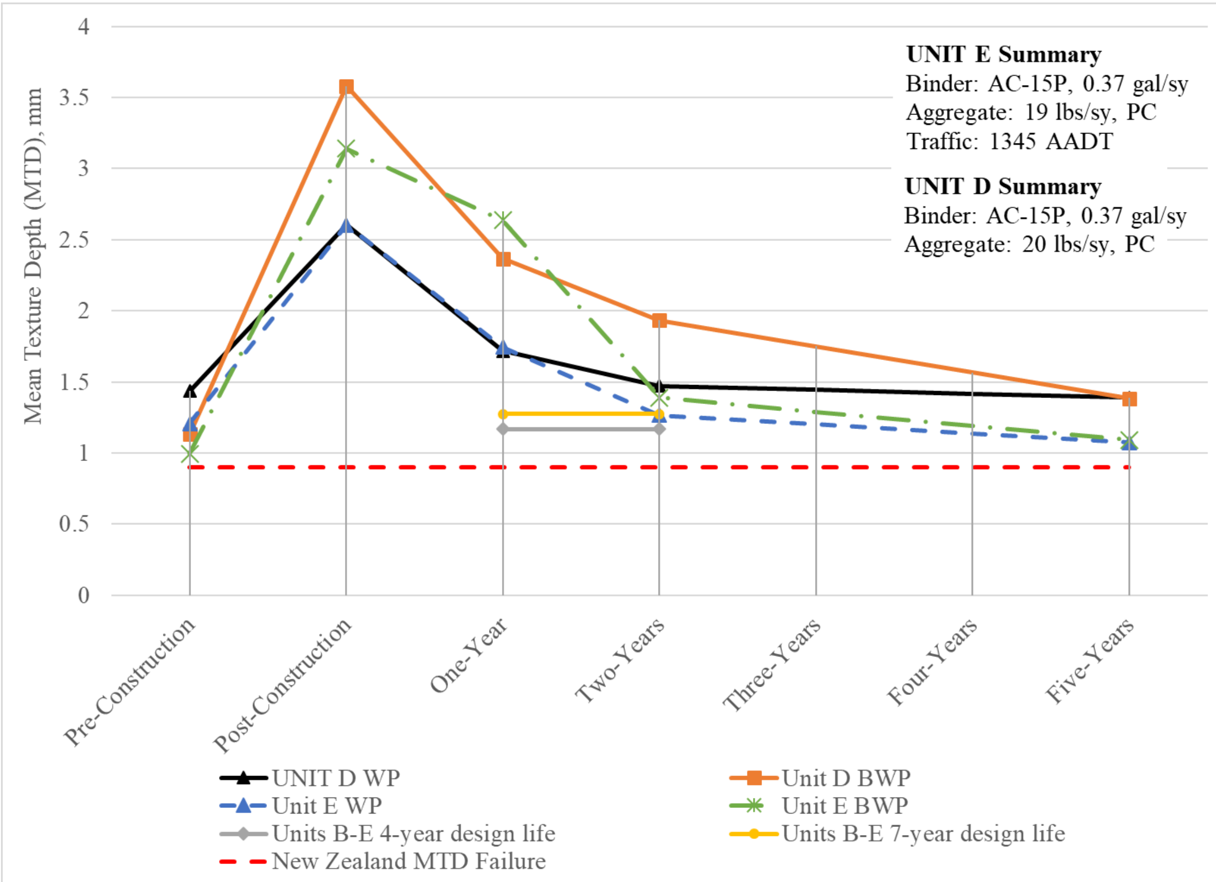


Figure 7.3. MTD for Units D and E with performance criteria

The AADT for Units D and E are 1,280 and 1,345, respectively. The five years of MTD performance data for Units D and E are above the New Zealand performance criteria of 0.9 mm. The measured five-year post-construction MTD values for the Unit D BWP was 1.38 mm and WP was 1.39 mm. These values are excellent and represent good MTD values as they are above the four-year and seven-year designs life thresholds. Moreover, the measured five-year post-construction MTD for the Unit E BWP was 1.09 mm and WP was 1.07 mm. These values are less than the four-year and seven-year designs life thresholds but higher than the New Zealand performance criteria. The reasons for lower values in Unit E than Unit D is due to the lower aggregate application rate and the higher AADT.

Figure 7.4 shows the MTD results for test section Units F and G.

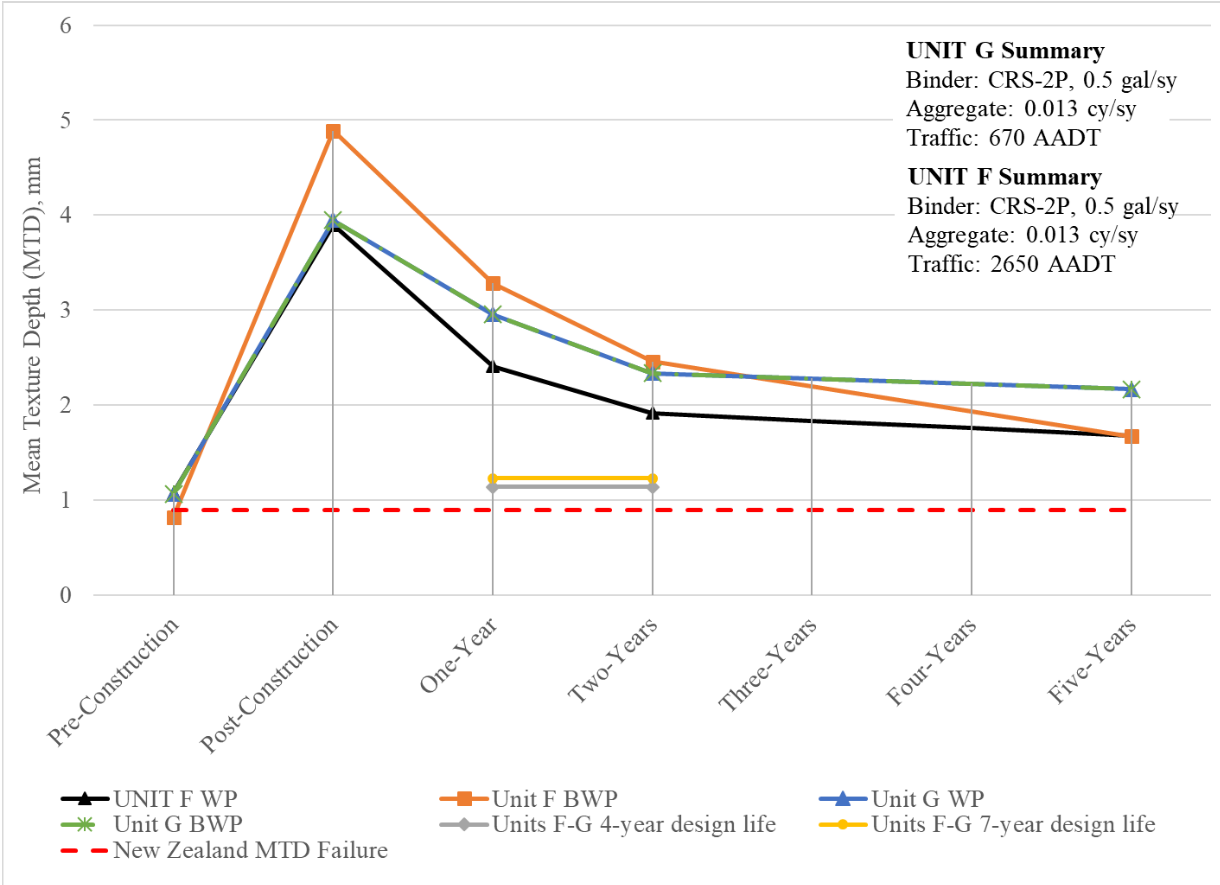


Figure 7.4. MTD for Units F and G with performance criteria

These sections were constructed with emulsified asphalt at a spraying rate of 0.50 gal/yd^2 and application of aggregate at the rate of 0.013 yd^3/yd^2 for both sections. The traffic levels between Units F and G are quite different, with Unit F having an AADT of 2,650 and Unit G having an AADT of 670. During the two-year post-construction evaluation, the MTD results did not exhibit a significant difference, but during the five-year post-construction evaluation, it was evident that the higher AADT decreased the MTD value on Unit F. Both Units F and G are performing well and exceeding the four-year and seven-year design life as shown in Figure 7.4.

Figure 7.5 displays the MTD measurements for test section Unit H.

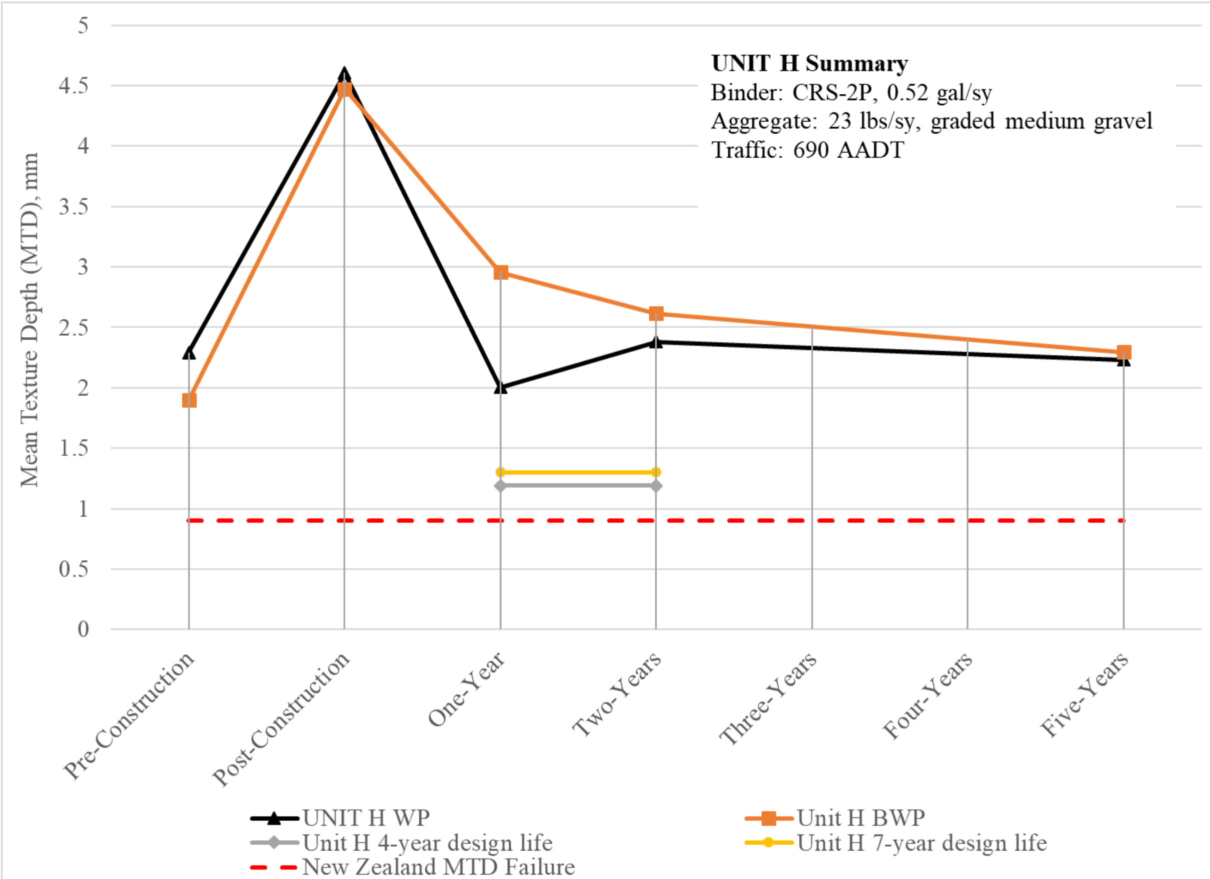


Figure 7.5. Unit H MTD measurements and performance criteria

This chip seal for this section was constructed using emulsified asphalt. The traffic level in this section is 690 AADT. The MTD decreased the most during the first year, and the rate of decrease in the MTD leveled off between one and five years post-construction. The MTD values passed the New Zealand performance criteria for the four-year and seven-year design life. The MTD for the BWP and WP measurements were similar at two years post-construction. The measured five-year post-construction for MTD values for the Unit H BWP was 2.30 mm and WP was 2.23 mm. It is worth noting in Figure 7.5 that the WP MTD measured value went up after the first year, which may have occurred because of variability in the roadway texture or may be due to human error during measurement.

Figure 7.6 shows the Parkway and Prairie roads chips seal MTD measurements.

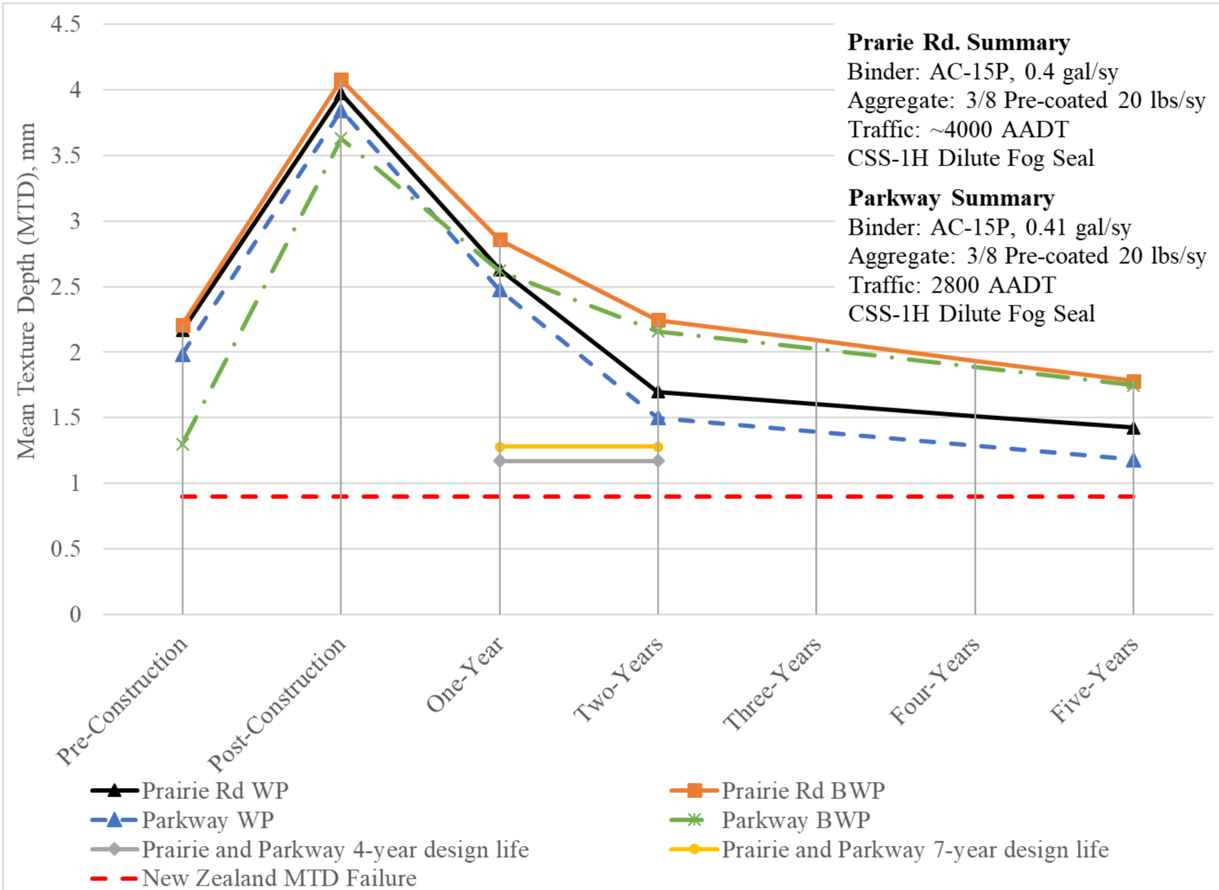


Figure 7.6. Prairie and Parkway MTD measurements and performance criteria

The seals on these test sections were hot-applied on roads with AADTs of 2,800 and approximately 4,000 for Parkway and Prairie, respectively. It is worth noting that these sections were fog sealed post-construction with CSS-1H Dilute fog seal and had the most uniformly graded aggregate used in construction. These sections exhibited a fairly steady decrease in MTD between one and two years post-construction. The measured five-year post-construction for MTD values for the Unit Prairie Road BWP was 1.78 mm and WP was 1.42 mm. In addition, the measured five-year post-construction for MTD values for the Unit Parkway Road BWP was 1.75 mm and WP was 1.18 mm. At the five-year post-construction evaluation, the Units Parkway and Prairie were still above the New Zealand performance specification.

Figure 7.7 represents the MTD values for Heppner and Condon roads, which were chip sealed in 2015.

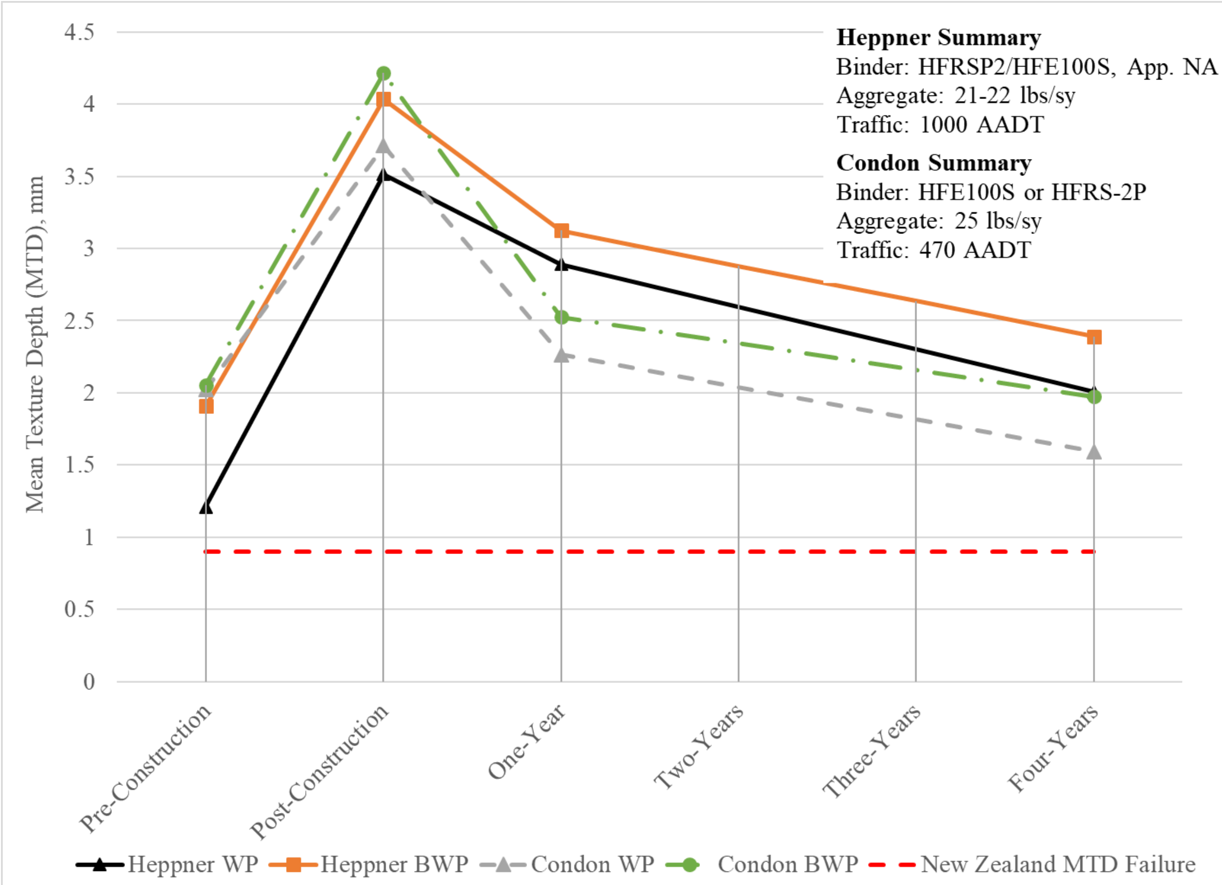


Figure 7.7. Heppner and Condon MTD

These sections were constructed in northeast Oregon. The AADT for Heppner and Condon are 1,000 and 470 AADT, respectively. The measured four-year post-construction MTD values for the Heppner Road BWP was 2.39 mm and WP was 2.01 mm. Furthermore, the measured five-year post-construction MTD values for the Condon Road BWP was 1.97 mm and WP was 1.59 mm. These roads are performing well and still above the New Zealand performance specification.

Figure 7.8 compares the MTD values for the Lewis and Clark section and the Sunset Beach Lane section over four years of their service life.

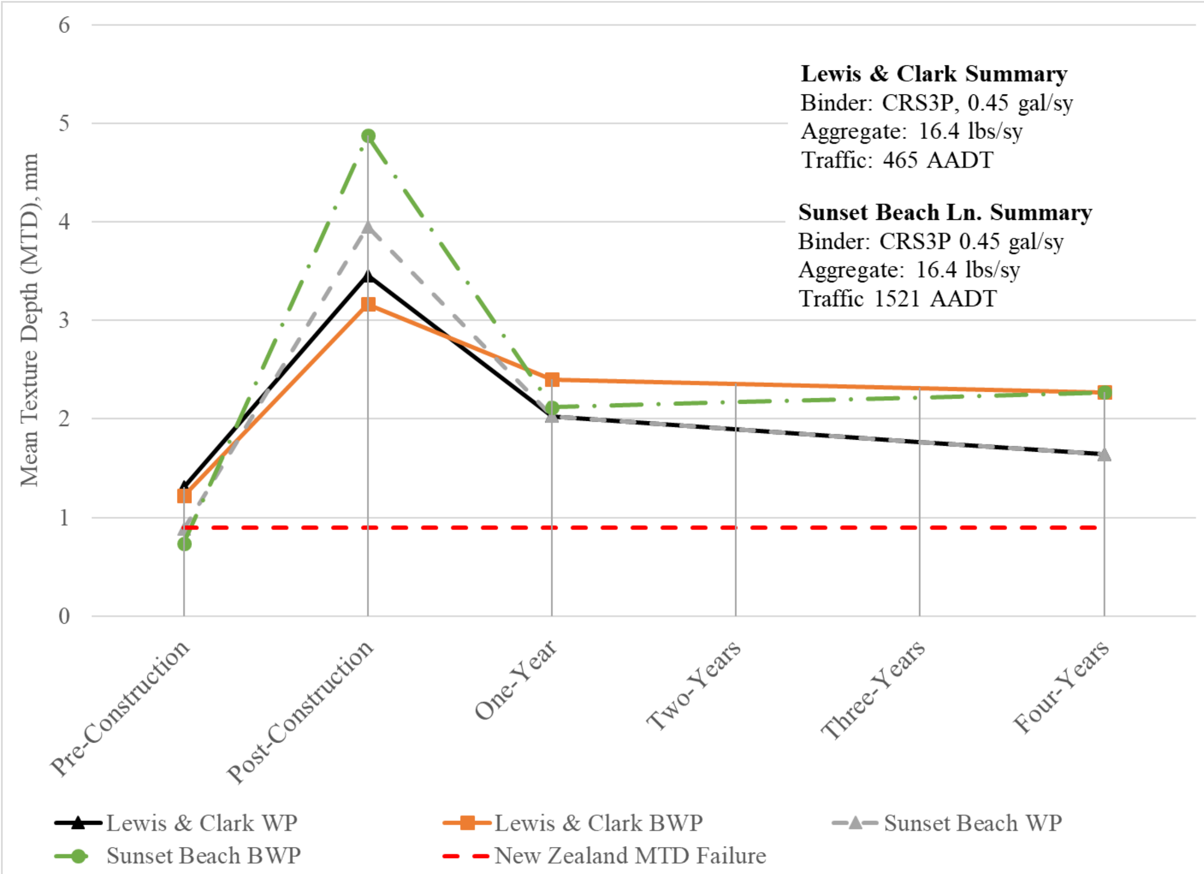


Figure 7.8. Lewis and Clark section and Sunset Beach section MTD

The emulsion utilized in these test sections was CRS-3P, and the AADT for the Lewis and Clark section and Sunset Beach section are 465 and 1,521, respectively. These sections were constructed in 2015. Therefore, the performance data includes the MTD values for up to four years post-construction. These sections performed well overall and followed a similar trend despite the difference in the AADT. The measured four-year post-construction MTD values for the Lewis and Clark section and the Sunset Beach Lane section BWP were 2.27 mm for both and WP were 1.64 mm and 1.63 mm, respectively, and they all passed the New Zealand performance specification.

7.2 DISCUSSION OF APPLYING NEW ZEALAND CHIP SEAL MTD PERFORMANCE SPECIFICATION

The five-year performance evaluation of all sections indicated that Unit G performed the best in terms of WP MTD and BWP MTD, as shown in Table 7.1.

Table 7.1. Five Years Post-Construction Percent Decrease in MTD Values

Units	WP MTD	BWP MTD
Unit A	-54.93	-70.27
Unit B	-70.07	-74.84
Unit C	-73.90	-64.35
Unit D	-52.22	-61.28
Unit E	-58.69	-65.21
Unit F	-56.71	-65.77
Unit G	-40.67	-44.96
Unit H	-51.50	-48.63
Prairie Rd.	-64.19	-56.38
Parkway	-69.16	-51.85

The percent decrease for the Unit G MTD values were 40.67% for the WP measurements and 44.96% for the BWP measurements after five years. These values represent the smallest decrease in MTD values over the five years since the road test sections were constructed in 2014. The greatest decrease in WP MTD values existed on Unit C, which lost 73.90% of its MTD value, and the greatest decrease in BWP MTD values existed on Unit B, which lost 74.84% of its MTD value.

Only three MTD measurements did not meet the New Zealand Transportation Authority's performance measure-based MTD criteria of 0.9 mm. These sections are both the WP and BWP measurements for Unit B and the WP measurement for Unit C. It is worth noting that Unit B exhibited the highest level of chip-seal related distresses at the two-year survey and the lowest MTD values. It is evident from this finding that the New Zealand chip seal performance specification can be implemented into the ODOT's chip seal program and its texture depth criteria can be used effectively as a performance metric to determine chip seal performance early during the chip seal service life.

All chip seal sections performed well during the four-year performance evaluation and compared to the New Zealand chip seal performance specification. The four-year performance evaluation indicated that Unit Heppner performed the best in terms of WP MTD values, and Lewis and Clark Road performed the best in terms of BWP MTD values, as shown in Table 7.2. Contrarily, Unit Sunset Beach Lane performed the worst overall in terms of MTD.

Table 7.2. Four Years Post-Construction Percent Decrease in MTD Values

Units	WP MTD	BWP MTD
Condon	-57.12	-53.17
Heppner	-42.88	-40.77
Lewis & Clark Rd.	-52.57	-28.31
Sunset Beach Ln	-58.67	-53.48

8.0 CHIP SEAL DESIGN AND CHIP SEAL DESIGN SPREADSHEET

This chapter explains each step involved in designing a single layer chip seal by following the McLeod and New Zealand methods. A demonstration chip seal construction project took place in The Dalles, Oregon in May 2019. The overall aim of the field experiment was to provide suppliers and contractors with a method to understand and practice chip seal as a science by utilizing available resources, e.g., the McLeod and New Zealand methods, for rational techniques. The construction process included the application of a single layer to monitor the newly placed chip seal surface over its service life.

The chip seal design spreadsheet described in this chapter follows the McLeod method and the New Zealand design method. In the spreadsheet, the equations for the New Zealand method include conversions to English units, which makes the new version more user-friendly for those who work in English units.

8.1 INTRODUCTION

Chip seal is considered one of the most cost-effective preventive maintenance techniques, and it is used worldwide by pavement engineers to extend the pavement service life and protect the underneath surface layer. In most chip seal projects, an empirical design method has been utilized, leading to a shorter service life of the chip seal and negatively affecting the reputation of chip seal amongst the public and stakeholders. Therefore, before construction, an interactive Excel spreadsheet was created to provide suppliers and contractors with a scientific approach to chip seal construction following the McLeod and New Zealand methods.

The newly placed chip seal will be evaluated by measuring the macrotexture in locations where any changes occurred during construction, and these changes include application rates and emulsion types. The McLeod and New Zealand methods are used in this study to compute the final application rates. The following descriptions of each step in the design process for both design methods can be used for future projects in Oregon to meet the stakeholders' goal of a more rational chip seal applications throughout the state.

8.2 MCLEOD DESIGN CRITICAL INPUTS

This section describes the design process based on the McLeod design criteria. The McLeod design method was established in 1960, and it was later updated to the currently practiced design method in 1969. The purpose of chip seal design is to select aggregate and asphalt emulsion application rates that will result in a durable pavement seal (Shuler et al. 2011). The following equations 8.1 and 8.2 are the recommended design application rates by McLeod.

$$\textbf{Aggregate Application Rate} = [46.8 \times (1 - 0.4V)] \times ALD \times G \times E$$

(8-1)

$$\textbf{Binder Application Rate} = [(2.244) \times (ALD) \times (T) \times (V) + S + A] \div R$$

(8-2)

Each variable in these equations will be discussed in more depth in the following paragraphs. The variables include the following:

- V = Voids in loose aggregate, %
- ALD = Average least dimension, in inches
- G = Bulk specific gravity of the aggregate
- E = Traffic whip-off factor
- T = Traffic correction factor
- S = Surface correction factor, gal/yd^2
- R= Residual asphalt content of the binder

V is the voids in loose aggregate, %. The voids in loose aggregate represent the percent of voids when the chip spreader applies the aggregate. It is important to test the aggregate for the unit weight and specific gravity to determine the voids in loose aggregate. The following equation can calculate voids in loose aggregate:

$$\textbf{Voids in Loose Aggregate } (V) = 1 - [W \div (62.4 \times G)] \times 100$$

(8-3)

W is the loose unit weight of the aggregate in lbs./ft^3, and *G* is the bulk specific gravity of the aggregate. Therefore, in this project, the voids in loose aggregate is 46.38%.

ALD is the average least dimension in inches. The ALD can be calculated from the following equation:

$$ALD = M \div (1.139285 + (0.011506 \times F))$$

(8-4)

M is the median size of the aggregate; it is the theoretical sieve size through which 50% of the material passes, as shown in Figure 8.1, and *F* is the flakiness index percentage, which can be measured in the laboratory by a slotted plate.

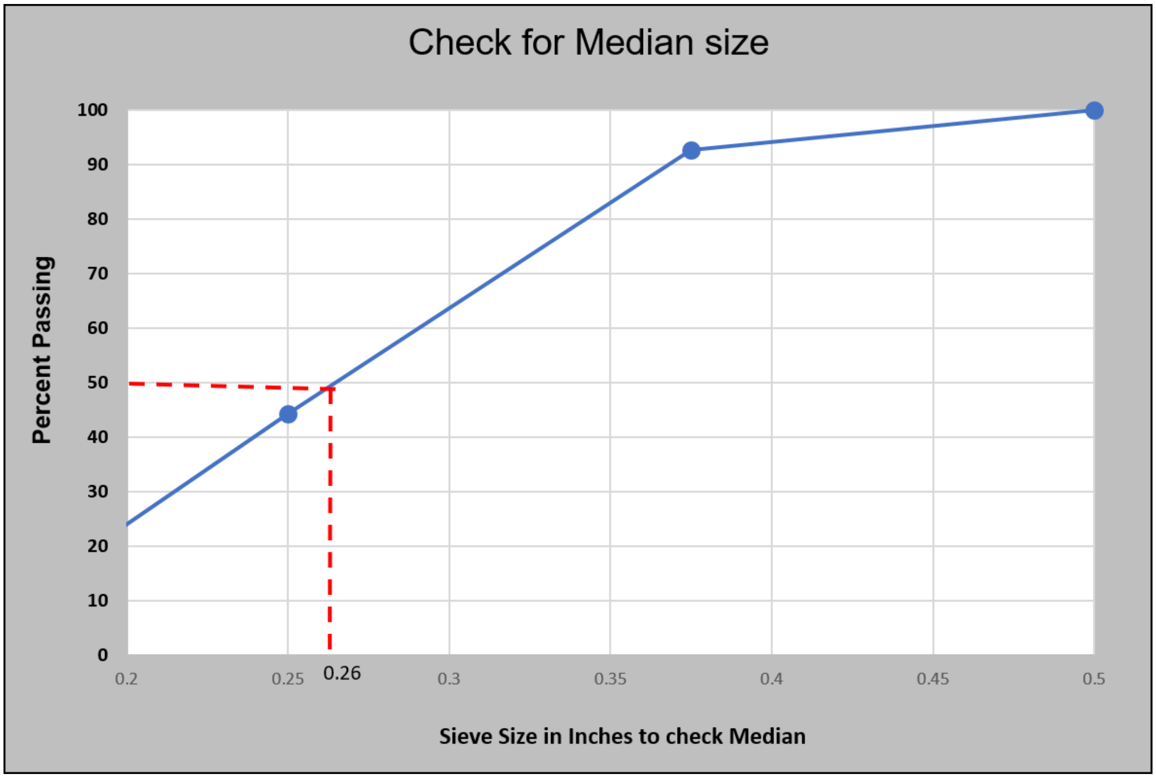


Figure 8.1. Check for median aggregate size

The flakiness index represents the percentage of flat particles in terms of their weight. Table 8.1 represents the results for total weight passing and retained.

Table 8.1. Flakiness Index Laboratory Calculations

Size fraction	Weight retained on slot (g)	Weight passing slot (g)
1 in to 3/4	0	0
3/4 in to 1/2	0	0
1/2 in to 3/8	136.9	14.8
3/8 in to 1/4	859	108.28
1/4 in to No. 4	445.65	62.35
Total	1441.55	185.43

A lower flakiness index percent indicates a more cubical aggregate, which are more suitable for chip seal. In the demonstration project, the median size (M) is 0.26, and the flakiness index (F) is 11.40%, as determined from the difference between the weight passing and the total weight.

The bulk specific gravity of the aggregate is measured to find G, and E is the traffic whip-off factor. The McLeod method considers the effect of traffic on a newly placed chip seal, and it accounts for removed aggregate from the road to the shoulders. Based on the road type, it recommends a percent wastage factor and whip-off factor. The higher the ADT, the higher the whip-off factor. The Asphalt Institute (1979) recommends utilizing Table 8.2 to select the appropriate percent waste allowed and traffic whip-off factor.

Table 8.2. Percent Waste Allowed and Traffic Wastage Factor

Percent waste allowed	Traffic wastage factor (E)
1%	1.01
2%	1.02
3%	1.03
4%	1.04
5%	1.05
6%	1.06
7%	1.07
8%	1.08
9%	1.09
10%	1.10
11%	1.11
12%	1.12
13%	1.13
14%	1.14
15%	1.15

Consequently, in this project, the percent waste is 5% and the traffic whip-off factor is 1.05.

The traffic correction factor (T) is needed to achieve the recommended 70%–80% embedment of aggregate; the traffic correction factor is an important element to determine the accurate binder application rate for the given number of vehicles per day, as shown in Table 8.3.

Table 8.3. AADT and Traffic Correction Factors

AADT	Traffic correction factors
Under 100	0.85
100–500	0.75
500–1,000	0.70
1,000–2,000	0.65
Over 2,000	0.60

Sources: Jannisch and Gaillard, 1998 and McLeod 1969

If too little binder is used, it will cause raveling, and if too much binder is used, it will cause bleeding.

The surface correction factor (S) in gal/yd^2 is important for determining the initial binder application rate. It is critical to evaluate and survey the road surface before any chip seal construction. Older and more badly pocked surfaces require a higher surface condition factor to account for binder being absorbed by the surface as shown in Table 8.4.

Table 8.4. Recommended Surface Condition Factors Based on Pavement Conditions

Pavement condition	Surface condition factor, *S* (gal/yd^2)
Black, flushed asphalt	-0.01 to 0.06
Smooth, non-porous or smooth	0
Slightly porous and oxidized or matte	0.03
Slightly pocked, porous, and oxidized	0.06
Badly pocked, porous and oxidized	0.09

The newer the surface and the more non-porous it is, the less likely it will absorb the freshly sprayed binder. In this project, the surface prior to construction was slightly porous and oxidized. Therefore, the surface condition factor is 0.03 gal/yd^2.

The aggregate absorption factor (*A*) in gallons per square yard accounts for the binder lost in aggregate absorption. In this project, granite aggregate was utilized for the chip seal. Before construction, the laboratory investigation revealed that the granite aggregate water absorption percentage is 2.52%. Therefore, based on the design, a 0.023 gal/yd^2 aggregate absorption factor is included. Table 8.5 contains other absorption cases and correction factors to control the binder application rate under different circumstances.

Table 8.5. Aggregate Absorption Conditions and Correction Factors

Aggregate absorption conditions	Aggregate absorption factor (gal/yd^2)
Absorption less than 1%	0
Absorption is between 1% and 1.25%	0.01
Absorption is between 1.25% and 1.8%	0.02
Absorption is More than 1.8%	0.023

The absorption factors have not been fully studied for Oregon aggregates, and more investigation to validate these values would be beneficial.

The percent residual asphalt binder in the emulsion (*R*), %, is typically between 68% and 69% of residual asphalt content. In the demonstration project, three different emulsions were utilized and based on their final residual content, and the emulsion application rate was set by the suppliers.

8.3 NEW ZEALAND DESIGN CRITICAL INPUTS

The changes to Oregon chip sealing design approach is advantageous to stakeholders and contractors as it paves the way for a rational method to construct a chip seal. For contractors to be more familiar with this approach, this section describes each step involved in the chip seal design process to construct a single layer chip seal with design criteria and input followed by agencies and contractors in New Zealand.

The aggregate application rate in the New Zealand method can be determined by aggregate characteristics such as ALD and loose unit weight. In contrast, the binder application can be accurately calculated by aggregate, road surface, and vehicle characteristics. It is worth noting that the New Zealand method requires the pre-construction macrotexture for the surface to calculate the binder application rate. Moreover, the method accounts for any binder that may penetrate the substrate or the lower surface, e.g., open-graded porous asphalt (OGPA), an open-graded emulsion mix (OGEM), or a grader-laid asphalt. The binder application rate can be adjusted and increased in the order of 0.022 to 0.044 gal/yd^2 if needed. Special consideration in New Zealand is given to soft substrates. Engineering judgment is recommended by the New Zealand method to increase the binder rate in order to hold the aggregate and not lose any during the winter but also not to apply too much to cause bleeding.

Heavier traffic on steep grades can cause early bleeding on the surface. To avoid this early sign of failure, a reduction of 0.022 to 0.033 gal/yd^2 is recommended by the New Zealand method. The aggregate shape is controlled in the New Zealand method, and the maximum cubical aggregate is controlled by a ratio of ALD:AGD of 1:2.25. For instance, if the ALD:AGD is 1:20, and the gradation consists of more cubical aggregate, the binder should be increased by 10%. Due to the concern of stakeholders and contractors in New Zealand, it was a common concern to increase the application rates for lower volume roads to reduce the loose aggregate on the center line and street parking spots.

The following equation can be used to calculate the aggregate application rate.

$$\textbf{Aggregate Application Rate} = \frac{\mathbf{750}}{\mathbf{ALD}}\ \mathbf{m^2/m^3} \tag{8-1}$$

The equation was developed by the New Zealand Transport Agency (NZTA) for local agencies and contractors to use mainly in New Zealand. For contractors and agencies in the US to use them, the following unit conversions can be used, and the final application rate will be in pounds per square yard.

$$\frac{\mathbf{1}}{\frac{\mathbf{750}}{\mathbf{ALD \times 25.4}}} \times (\boldsymbol{Loose\ Unit\ Weight} \times \mathbf{16.0185}) \times \mathbf{1.84335}\ \textbf{(lb/yd2)} \tag{8-2}$$

Where:

Loose unit weight, in lb/ft^3

ALD, in inches

The New Zealand method utilizes the following equation to calculate the binder application rate. Based on the site criteria, some of the variables in the equation might be adjusted.

$$\mathbf{BA = Vb + As + Ss + Gs + Cs + Us\ (gal/yd^2)} \tag{8-3}$$

Where:

BA = binder application rate, in gal/yd^2

$Vb = (\mathrm{ALD} + 0.7\ \mathrm{Td}) \times [0.291 - 0.025 \log10((2) \times \mathrm{v/l/d} \times 100)] \times 0.220881$

- Td: Texture depth and it is measured in the field from the sand circle test, in mm
- ALD: Average least dimension
- v/l/d: Vehicles per lane per day
- 0.220881 is a conversion factor from l/m^2 to gal/yd^2

As = Absorptive surface allowance, in gal/yd^2

Ss = Soft substrate allowance, in gal/yd^2

Gs = Steep grades allowance, in gal/yd^2

Cs = Chip shape allowance, % adjustment

Us = Allowance for urban and/or low-traffic volumes, in gal/yd^2

8.4 OREGON CHIP SEAL SPREADSHEET GUIDE

The chip seal designs are meant to be used as a guide and assist with starting application rates. Many other factors influence the ultimate chip seal performance. The spreadsheet and the guide provide a step-by-step overview of the chip seal design process. The data collected will provide a McLeod Design and a New Zealand Design that will provide initial application rates, which can then be adjusted as necessary in the field. The chip seal design charts may be used as a guide to make informed adjustments to the application rates during construction. Field test sections on the day of construction are also encouraged. The contractor should anticipate sharing the test section results with ODOT and explain justifications for changing application rates to achieve optimal performance on the day of construction.

The New Zealand and McLeod methods make adjustments based on roadway conditions. In the New Zealand design method, it is common to have multiple application rates based on changes in the roadway conditions. The spreadsheet only calculates one binder and one aggregate application rate. The user needs to be aware of the adjustments and also understand that binder adjustment recommendations have not been studied for Oregon aggregates.

8.4.1 Spreadsheet Cell Coloring and Project Information

The spreadsheet uses different colored cells to show headings, fill-in values, and calculated values, as shown in Figure 8.2.

Color Key:	
Heading	McLeod Application Rate
Fill in value	New Zealand Application Rate
Calculated Value	

Figure 8.2. Color key for the chip seal design spreadsheet

All cells are clearly labeled with text, and the color alone is not relied on to convey information. The McLeod and New Zealand application rates are shown in different colors as well; however, these cells are also labeled with text.

Figure 8.3 shows the section of the spreadsheet that requires project information.

Project and Asphalt Binder Information			
Project	Demonstration Project	Letting Date	4/23/2019
Date Reported	3/21/2019	District	?
County	Lane	Route	Hwy 30
Contractor	Great Contractors, Inc.	From Milepost	0.0
AC Source	Great Asphalt Supplier, Inc.	To Milepost	7.0
Emulsion Grade	HFRS	Chip Seal Design Life (Years)	7
Emulsion Sp.Gr.		Additional Information	
% Polymer, %	3	Near the Dalles with quarry near by.	
Residual Asphalt Content, % *	68		
AADT	690		
Percent Trucks (%) **	13		
Number of lanes to be sealed	2		
Is the seal being placed on an absorptive surface? (No or Yes)	No		
Will there be slow moving trucks on a steep grade or crawling lane? (Yes or No)	No		
*Use 100 if hot-applied			
**McLeod Method does not consider trucks while New Zealand does			

Figure 8.3. Chip seal project information for design spreadsheet

The residual asphalt content influences the binder application rate. The amount of traffic needs to be considered in the design as well. The New Zealand method uses percent trucks and vehicles/lane/day, and the McLeod method uses the AADT.

8.4.2 Pavement Surface Characteristics

The agency and contractor should ensure that the site is appropriate for a chip seal and determine whether all necessary pre-seal repairs have been completed and are satisfactory. The pre-seal repairs and maintenance required by the ODOT Pavement Design Guide 2019 (ODOT 2019b) are as follows:

- Repair localized and structural failures
- Seal cracks
- Level rutting

8.4.2.1 Surface Condition Factor (McLeod Design Input)

The McLeod method uses a surface condition factor to adjust the binder rate based on the surface condition of the roadway. Photographs from the Minnesota Seal Coat Handbook (Wood et al. 2006) are shown in Figure 8.4 and give examples of different types of roadway surfaces with corresponding values that range from 0.00 to 0.09.

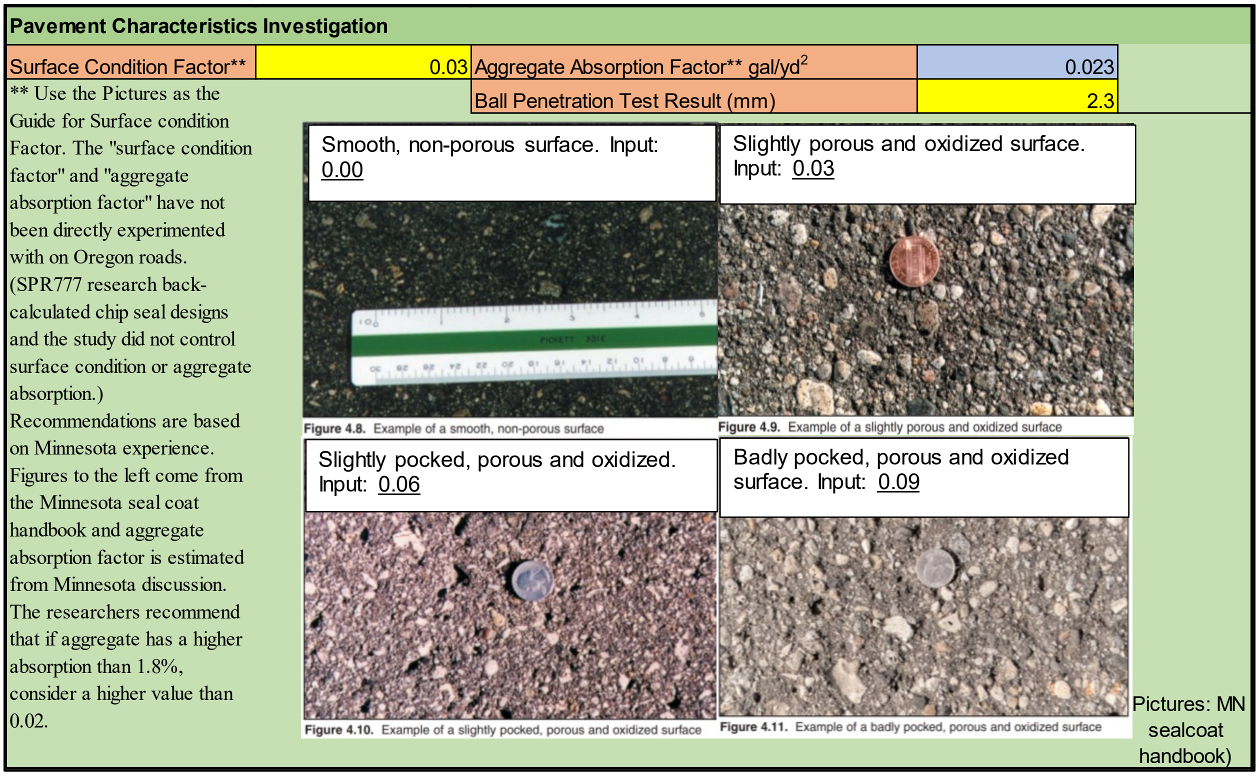


Figure 8.4. Pavement characteristics for chip seal design

Pocked surfaces have more surface area and will generally require more binder. These values apply to the average condition of the roadway surface. Often, patches tend to have high absorption, and the binder application rate will need to be temporarily increased to account for drain down into a patch with high porosity. A test strip at the beginning of the project is a useful strategy for validating design application rates.

8.4.2.2 Ball Penetration Test (New Zealand Design Input)

The ball penetration test measures the surface hardness. This is especially important for resealing projects. The ball penetration test is performed on five randomly selected locations or more as recommended by the Australian Department of Planning, Transport, and Infrastructure in TP 349. The test consists of measuring the penetration that a 19 mm (3/4 in.) ball bearing makes in a sample of the substrate when it is struck by one blow of a Marshall hot-mix compaction hammer (Asphalt Institute 1997). Typical ball penetration values for resealing surfaces in New Zealand are in the range of 2 to 3 mm. The final test result should be typed in millimeters in the spreadsheet's designated cell as shown in Figure 8.4.

The pavement surface characteristics are needed for scientifically estimating binder application rate calculations. The McLeod method requires a visual assessment, while the New Zealand method requires sand circle tests on the wheel path and on the center line.

8.4.2.3 Sand Circle Testing for Pavement Texture based on New Zealand's T/3 Standard (New Zealand Design Inputs)

The texture depth of the pavement may differ along the length of the project to be resealed. The results of sand circle tests are studied to determine how the surface should be divided up to achieve the optimum matching of application rate to the surface texture, without requiring an excessive number of adjustments. The spreadsheet contains a pre-seal texture worksheet for the input of the sand circle tests. The test can be performed by following the steps recommended in New Zealand's T/3 standard (TNZ 1981), similar to ASTM E965-15 (ASTM 2015). This tab is located next to the primary design input tab, design for graded medium, as shown in Figure 8.5.

Pre-seal Pavement Texture Worksheet				
Location/Measurement	Sand Circle Diameter in WHEELPATH (mm)	Sand Circle Diameter on CENTER LINE (mm)	Texture Depth Td (mm) Wheelpath	Texture Depth Td (mm) Centerline
1.1	182.50	185.00	1.72	1.67
1.2	215.00	195.00	1.24	1.51
1.3	181.50	195.00	1.74	1.51
1.4	194.00	183.50	1.52	1.70
1.5	190.00	195.00	1.59	1.51
2.1	188.50	187.50	1.61	1.63
2.2	183.50	181.00	1.70	1.75
2.3	192.50	168.50	1.55	2.02
2.4	183.50	181.50	1.70	1.74
2.5	195.00	215.00	1.51	1.24
3.1	170.00	172.00	1.98	1.94
3.2	185.50	151.50	1.67	2.50
3.3	178.00	148.50	1.81	2.60
3.4	165.50	148.00	2.09	2.62
3.5	175.00	149.00	1.87	2.58

Average Texture Depth	1.79
Finest Texture (mm)	1.239589
Coarsest Texture (mm)	2.615961
Δ of Average to Finest (mm)	0.55
Δ of Average to Coarsest (mm	0.82
Min Allowable ALD (inches)	0.51821

Figure 8.5. Pre-seal pavement texture worksheet

In New Zealand, the sand circle measurements are taken at 100 m (328 ft) intervals along the project. The ISU research team is concerned this interval will be viewed as excessive and therefore recommend one sand circle measurement be taken in the wheel path and one in the center line at 0.1 mi (528 ft) intervals. The spreadsheet is designed so that additional sand circle measurements can be added, and the calculations of average texture, fines texture, and coarsest texture will include the additional values. The sand circle diameter for the wheel path and the center line should be inputted to the spreadsheets. The texture depth will be automatically calculated for each respective sand circle.

If the section has more than 10% of its area with a coarser texture than 2 mm (estimated by sand circle), a void filling seal is the desirable seal type to select rather than a conventional reseal. To decide whether the difference between wheel path and center line textures is excessive, the following equations are calculated in the spreadsheet.

$$(coarse) - (average) \text{ shall be } < \text{Min ALD/16} \tag{8-8}$$

$$(average) - (fine) \text{ shall be } < \text{Min ALD/16} \tag{8-9}$$

Where:

$Td\ (average)$ = average texture depth (mm) from all the sand circle measurements taken

$Td\ (coarse)$ = largest texture depth (mm) from sand circle measurements

$Td\ (fine)$ = smallest texture depth (mm) from sand circle measurements

The spreadsheet also calculates the minimum allowable ALD in inches.

8.4.2.4 Aggregate Percent Allowed for Waste (McLeod Design Input)

The McLeod chip seal design accounts for the amount of aggregate that is allowed for waste depending on the roadway characteristics. For low-volume roads and residential streets, 5% waste is recommended. For high-speed or county roads 10% is recommended. (Note: On higher-speed roads with more waste, there may be more potential for flying chips to hit windshields, motorcyclists, or bicyclists).

Input the number 5, 10, or the desired percentage waste into the yellow cell as shown in Figure 8.6.

Aggregate Percent Allowed for Waste, %
5% recommended for low volume & residential and 10% recommended for higher speed/county roads
5

Figure 8.6. Aggregate percent allowed for waste

8.4.3 Aggregate Testing

A representative aggregate sample needs to be obtained to complete the design. In addition to the aggregate tests required in the design, the ODOT specifications require testing for the following:

- Percent fractured
- Soundness
- Durability
- Lightweight particles
- Wood particles
- Percent elongated (5:1)
- Cleanliness

There are cells in the spreadsheet to input these test results, but they are not used to calculate any design parameters. However, these tests provide valuable information about the aggregate quality and whether the aggregates are appropriate for use in chip seals. Table 8.6 shows aggregate requirements in the ODOT specification that are not used in the design equations.

Table 8.6. Aggregate Requirements in Specification not needed for Chip Seal Design

Aggregate requirements in specification that are not direct design parameters			
% Fractured	**Soundness**	**Durability**	
		Abrasion	**Coarse aggregate degradation passing No. 20 sieve (TM 208)**
Min. 90% two faces	Max 12% weight loss	Max 30%	Max 30%
100	2	20	20
Harmful substances			
Lightweight pieces (AASHTO T113)	Wood particles TM225	Percent elongated pieces (5:1 ratio)	Cleanness value
Max 1%	0.1% maximum	10.0% maximum	75 minimum
0	0.00	1	90

8.4.3.1 Bulk Specific Gravity and Aggregate Absorption (McLeod Design Input)

The bulk specific gravity of the aggregate as well as the aggregate absorption values need to be calculated according to ODOT specifications.

8.4.3.2 Loose Unit Weight (McLeod and New Zealand Design)

The loose unit weight should be conducted in accordance with AASHTO T 19. Loose unit weights should be greater than 90 lb./ft^3. The shoveling method was used in the development of this specification. The loose unit weight test and placement in the spreadsheet is shown in Table 8.7.

Table 8.7. Loose Unit Weight

Loose unit weight (AASHTO T19)
Minimum 90 lbs.
92.02

8.4.3.3 Aggregate Gradation (McLeod and New Zealand Design)

The sample size should conform to AASHTO T 27 Sieve Analysis of Fine and Coarse Aggregate. Perform AASHTO T 11, Materials Finer than No. 200 Sieve in Mineral Aggregate by Washing, in conjunction with AASHTO T 27. Separate aggregates into specified individual size fractions. The aggregate gradations should match the requirements of the chip seal specification. The sieve size, tolerance, and the percent passing should be determined. A wet and dry sieve analysis should be performed to determine the percent passing a No. 200 sieve accurately. Also, note the ¼ in. sieve requirement. Figure 8.7 shows aggregate information, the gradation tolerances, and results for the chip seal aggregate gradation; the asterisk in the final column of the tolerance row is meant to represent the tolerance for gravel aggregate.

Aggregate and Chip Seal Design Information

Aggregate Name	Description	Aggregate Source/Operator	Beds	Absorption (%)	G_{sb}	Flakiness Index++	Loose Unit Weight (AASHTO T19)	Aggregate Percent Allowed for Waste, %	Average Greatest Dimension (inches)
							Minimum 90 lbs.	5% recommended for low volume & residential and 10% recommended for higher speed/county roads	
Agg. for Chip Seal 1	Dalles Project	Quarry	-	2.52	2.75	28.65	92.02	5	0.342

	% Passing									
Aggregate Sieve Size	**1 1/2"**	**1"**	**3/4"**	**1/2"**	**3/8"**	**1/4"**	**#4**	**#8**	**#30**	**#200**
Tolerance	100	100	100	100	(100-80)	(40-10)	-	(6-0)	(2-0)	(2.0-0.0) (1.0-0.0)*
Agg. for Chip Seal 1	100	100	100	100	94.44	45.34	16.68	0.88	0.86	0.81

Figure 8.7. Aggregate information, the gradation tolerances, and results for the chip seal aggregate gradation

The gradation data automatically fills in the graph shown in Figure 8.8.

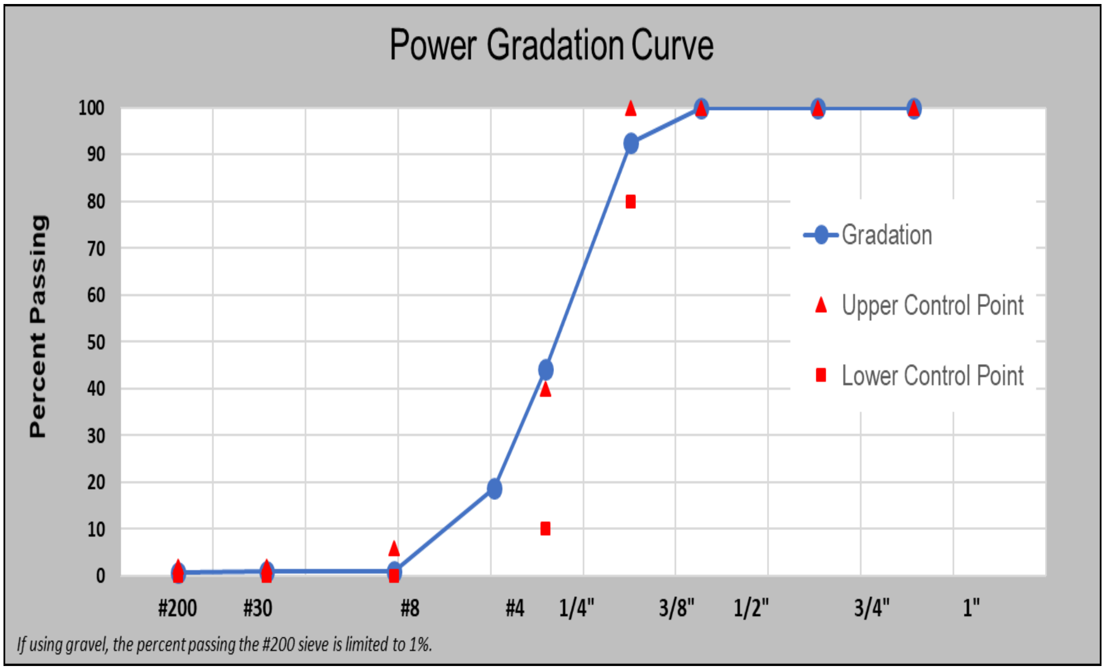


Figure 8.8. Gradation curve for chip seal aggregate

Keep the aggregates separated by sieve size to perform the flakiness index test. The median aggregate size is calculated from this gradation data. The median size, based on requirements from the gradation, must fall between 3/8 in. and ¼ in. The spreadsheet automatically graphs the gradation to provide a quick visual comparison between the gradation and tolerance points, and designers should also double check if the median aggregate size appears reasonable with this chart.

8.4.3.4 Flakiness Index Testing (McLeod Design and New Zealand Design)

The aggregate used to determine the gradation is then broken down into the following fractions:

1. Passing the 1 in. sieve but retained on the ¾ in. sieve
2. Passing the ¾ in. sieve but retained on the ½ in. sieve
3. Passing the ½ in. sieve but retained on the 3/8 in. sieve
4. Passing the 3/8 in. sieve but retained on the ¼ in. sieve
5. Passing the ¼ in. sieve but retained on the No. 4. sieve

The aggregate particles in each fraction are tested to see if they fit through the slotted plate shown in Figure 8.9.

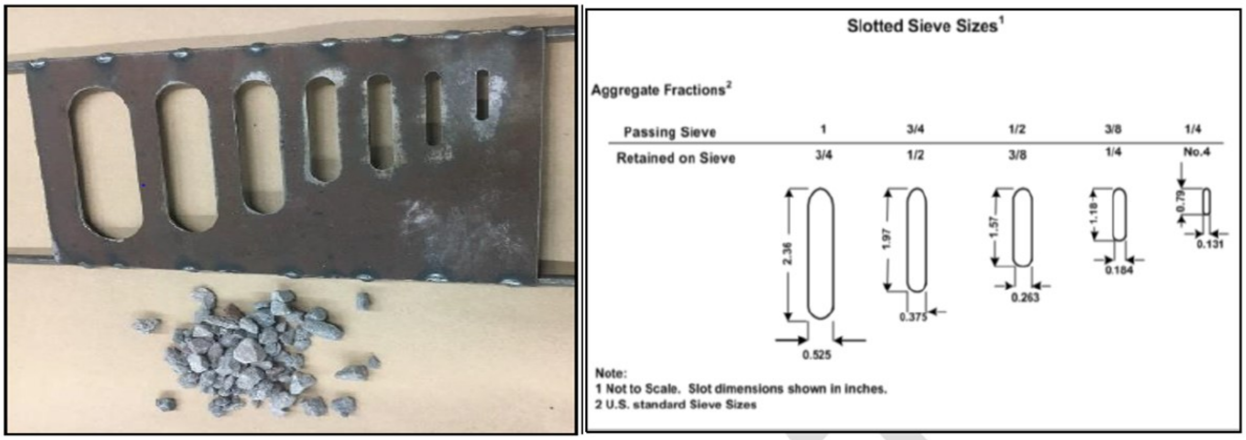


Figure 8.9. Flakiness index test equipment

For Table 8.8, fill in the yellow cells, and the flakiness index is automatically calculated.

Table 8.8. Flakiness Index Test Results

Size fraction	Weight retained on slot (g)	Weight passing slot (g)
1 in to 3/4	0	0
3/4 in to 1/2	0	0
1/2 in to 3/8 in	136.9	14.8
3/8 in to 1/4 in	859	108.28
1/4 in to No. 4	445.65	62.35
Total	1441.55	185.43
Flakiness Index	11.40%	

The totals are sums of their respective columns. The flakiness index is calculated as shown in the following equation (based on Minnesota DOT's equation):

$$\%\ \textbf{Flakiness Index} = \frac{\textbf{Total Passing Slots}}{\textbf{Total Passing Slots} + \textbf{Total Retained on Slots}} \tag{8-10}$$

(8-10)

8.4.3.5 Average Least Dimension

The ALD can be physically measured for individual aggregate particles, but it can also be estimated based on the flakiness index and the median aggregate size. Research has shown the equation given in equation 8.4 works well, and Minnesota has implemented it.

8.4.3.6 Average Greatest Dimension

The AGD is needed for the New Zealand chip seal design and is used to limit excessive flakiness. A maximum ratio of the AGD to the ALD is specified. A maximum ratio of AGD:ALD of 1:2.25 has been found to give an acceptable performance in New Zealand.

The AGD is obtained by placing a representative sample of the chip (retained on a No. 4 sieve or larger) end-to-end in a graduated trough, aligned in their greatest dimension. The AGD is the total length of the aggregate particles in the trough divided by the number of aggregate particles. The Excel sheet is programmed to calculate the AGD as shown in Table 8.9.

Table 8.9. AGD Test Results for Chip Seal Design Spreadsheet

Dimension test	Results
End-to-end length (in.)	23.622
Number of chips	69
AGD (in.)	0.342347826

8.4.4 Summary of Design and Design Graphs

The following graphs are developed automatically in the spreadsheet to assist with rational binder rate adjustments in the field based on the design. Figure 8.10 shows the McLeod binder adjustment chart, and Figure 8.11 shows the New Zealand binder adjustment chart.

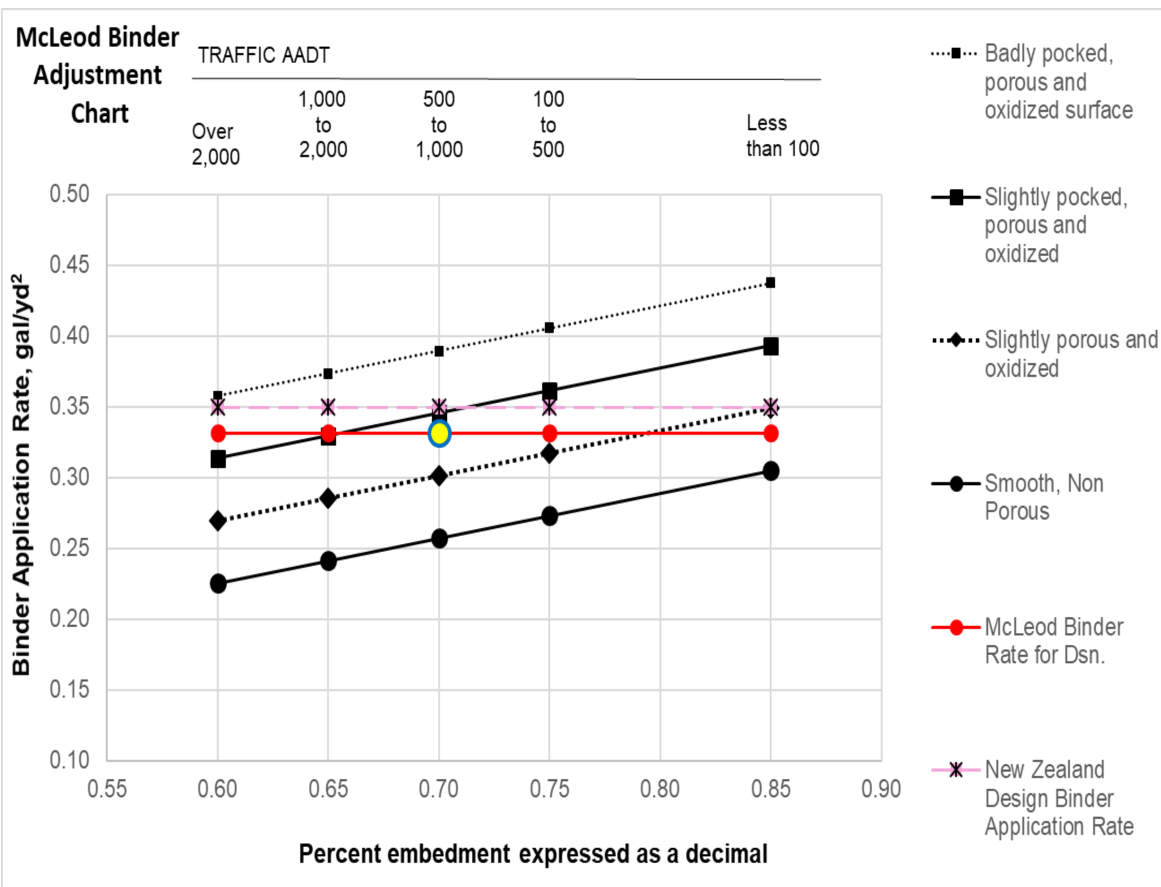


Figure 8.10. McLeod Binder adjustment chart

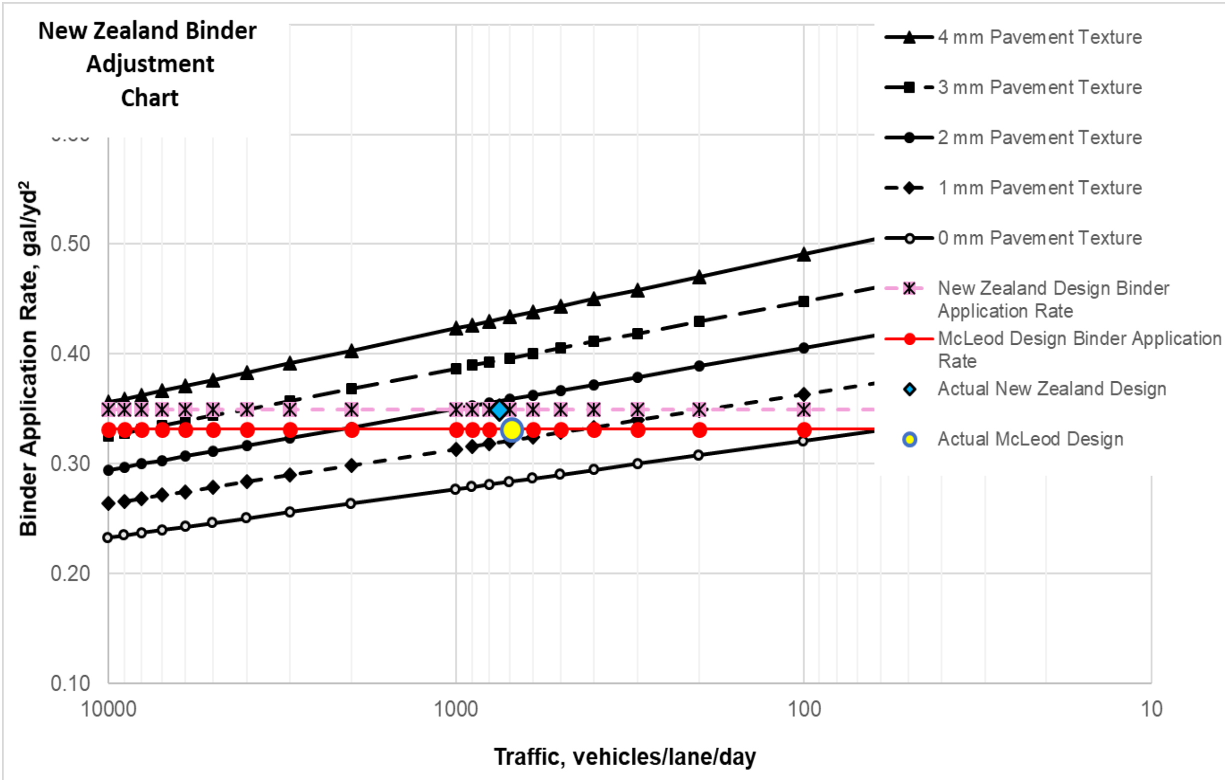


Figure 8.11. New Zealand Design Binder adjustment chart

The yellow dot in both figures represents the actual McLeod design and the blue diamond in Figure 8.11 represents the actual New Zealand Design. There may be differences due to traffic, percent trucks, pavement texture, or other influencing factors. Over time and with feedback, the design rates will be compared to determine which method is more accurately predicting the actual binder application rates.

8.4.5 Other Values Automatically Calculated in the Spreadsheet

8.4.5.1 Median Size

The median size of the aggregate is calculated by finding the slope between the two points that intersect 50% passing. This is illustrated in Figure 8.12.

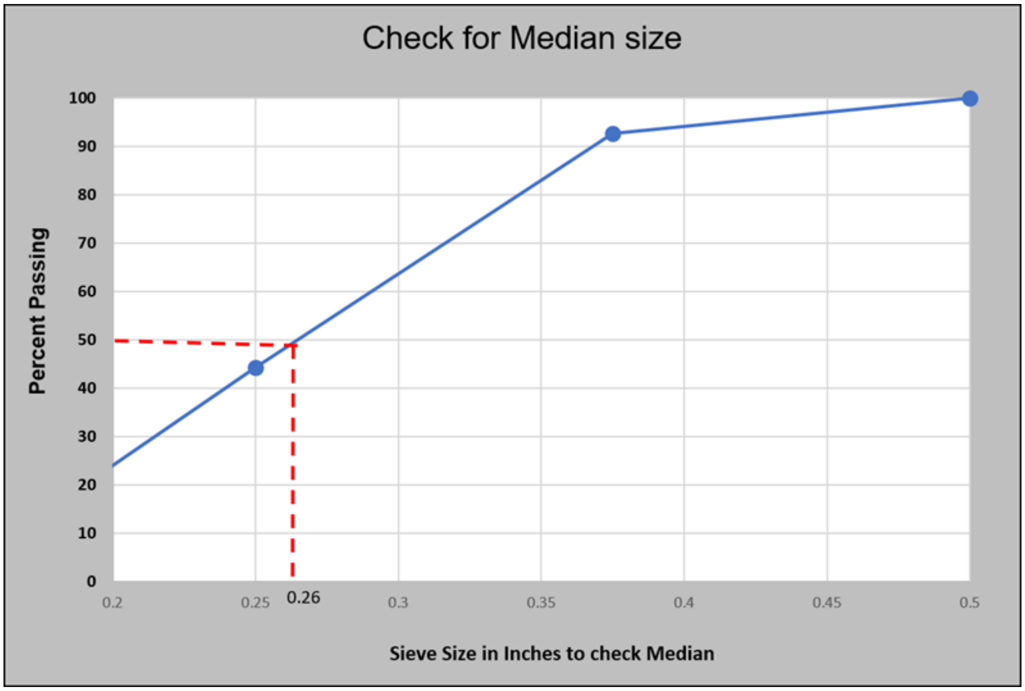


Figure 8.12. Check for median size aggregate

8.4.5.2 Voids in Loose Aggregate

The voids in loose aggregates are expressed as a percentage, and the total is calculated from the loose unit weight and the bulk specific gravity of the aggregate as shown previously in equation 8.3.

The Excel spreadsheet is programmed to calculate the voids in loose aggregate as shown in Figure 8.13.

Voids in Loose Aggregate (%)
46.38

Figure 8.13. Voids in loose aggregate as calculated

8.4.5.3 Traffic Whip-Off for Waste (Wastage Factor)

The spreadsheet uses the aggregate percent allowed for waste input (cell J29) to calculate the traffic whip-off for waste (also called the wastage factor) for the McLeod aggregate application rate equation, as shown in Figure 8.14.

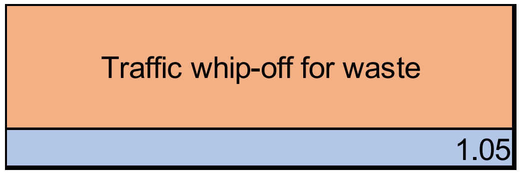


Figure 8.14. Traffic whip-off for waste as calculated

The McLeod procedure recognizes that some of the cover aggregate will get thrown to the side of the roadway by passing vehicles as the fresh seal coat is curing. The amount of allotted waste is related to the speed and the number of vehicles on the new seal coat. The recommended values in the Minnesota Seal Coat Handbook (Wood et al. 2006) are 5% for low-volume, residential type traffic and 10% for higher-speed roadways. If the percent allowed for waste is 10%, the wastage factor is 1.10.

8.4.5.4 Traffic Factor

The traffic factor adjusts the aggregates' percent embedment into the binder based on the amount of traffic on the roadway as shown in Figure 8.15; a higher embedment, 60%, is required for higher-traffic roadways.

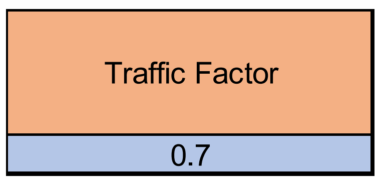


Figure 8.15. Traffic factor as calculated

8.4.5.5 Aggregate Absorption Factor

The aggregate absorption factor for the McLeod design has not been fully studied for Oregon aggregate. The Minnesota Seal Coat Handbook states that Class A aggregates generally do not require a correction for absorption, whereas Class B and C aggregates generally do (Wood et al. 2006). McLeod suggests an absorption correction factor of 0.02 gal/yd^2 if the aggregate absorption is around 1%. Wood et al. (2006) recommends using this correction if the absorption is 1.5% or higher. The Oregon chip seal design spreadsheet uses Table 8.10 to automatically calculate the aggregate absorption factor, as shown in Figure 8.16, until more experience is gained or further recommendations are provided with Oregon materials.

Table 8.10. Aggregate Absorption Adjustment Factors

Aggregate absorption	Aggregate absorption factor (gal/yd^2)
<1.0%	0.00
Equal to 1.0% but less than 1.25%	0.01
Equal to 1.25% but less than 1.8%	0.02
Greater than or equal to 1.8%	Experience or investigation needed (Spreadsheet returns an "Error")

Aggregate Absorption Factor, gal/yd^2
0.023

Figure 8.16. Aggregate absorption factor as calculated

8.4.5.6 McLeod Non-Wheel Path and Wheel Path Binder Application Rate, gal/yd^2

The McLeod method considers the non-wheel path and wheel path binder application rates in the calculation of the final binder application rate. The final application rate consists of the average of non-wheel path and wheel path binder application rates, in gallons per square yard, as shown in Figure 8.17.

Wheelpath Binder Application Rate, gal/yd^2	Non-Wheelpath Binder Application Rate, gal/yd^2
0.301234936	0.361618273

Figure 8.17. Wheel path and non-wheel path binder application rate for McLeod Design

8.4.5.7 McLeod Recommended Starting Binder Application Rate, gal/yd^2

The starting application rate value is the average of the wheel path binder application rate and the non-wheel path binder application rate, as shown in Figure 8.18.

McLeod Recommended Starting Binder Application Rate, gal/yd^2
0.33

Figure 8.18. McLeod recommended starting binder application rate

8.4.5.8 McLeod Recommended Starting Aggregate Application Rate, gal/yd^2

The value in Figure 8.19 is the recommended aggregate application rate by the McLeod method and uses the equation given in equation 8.1.

McLeod Recommended Starting Aggregate Application Rate, lbs./yd^2
22.9

Figure 8.19. McLeod recommended starting aggregate application rate

8.4.5.9 Absorptive Surface Allowance, gal/yd²

Absorptive surface examples include OGPA, OGEM, grader-laid asphalt, patches, and unbound granular base. If the surface is absorptive, increase the application rate by 0.02–0.04 gal/yd². The spreadsheet uses 0.03, but the value could be overwritten (at this time), as shown in Figure 8.20. This has not been fully studied for Oregon roadways.

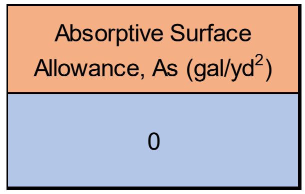


Figure 8.20. Adjustment for absorptive surface based on New Zealand Design

8.4.5.10 Allowance for a Steep Grade, gal/yd²

In New Zealand and other areas, chip seals do not perform well on steep grades with slow-moving trucks or where crawling lanes are needed. The spreadsheet, as shown in Figure 8.21, signals a warning of "Reconsider chip seal treatment, flushing likely to occur" if the spreadsheet user indicates that this situation occurs on the roadway.

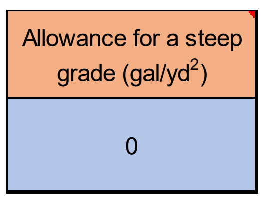


Figure 8.21. Binder adjustments for a steep grade based on New Zealand Design

8.4.5.11 Allowance for Urban and/or Low Traffic Volumes, gal/yd²

In New Zealand, a substantial number of urban streets sealed with typical application rates suffer from chip loss along center lines, in parking lanes, and roads with less than 100 vehicles/lane/day. To reduce chip loss, the New Zealand method recommends using their 1993 algorithm as explained in equation 8.10, which ultimately increases the application rate if the number of vehicles/lane/day is less than 100. This is currently programmed into the spreadsheet in (cell JK56) as shown in Figure 8.22, and it can be selected if the road criteria and conditions require.

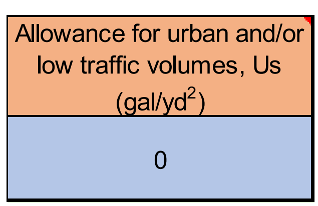


Figure 8.22. Adjustment for urban or low traffic volumes

8.4.5.12 New Zealand ALD Adjustment for Soft Surface, inches

This value uses the ball penetration test results. The adjustment is calculated as if the aggregates are being embedded into a soft surface, thus reducing their ALD. This value impacts the binder application rate. The spreadsheet uses the following Table 8.11.

Table 8.11. Ball Penetration Values and ALD Adjustments

Ball penetration values	ALD adjustment
1 mm or lower	Increase ALD by 1 mm
Greater than 1 mm and less than or equal to 3 mm	No adjustment
Greater than 3 mm and less than or equal to 5 mm	Decrease ALD by 1 mm
Greater than 5 mm	Substrate is too soft for a normal chip seal (Spreadsheet returns: "SURFACE TOO SOFT")

The spreadsheet converts the measurement to English units, and displays the New Zealand ALD adjustment for soft surface in inches, as shown in Figure 8.23.

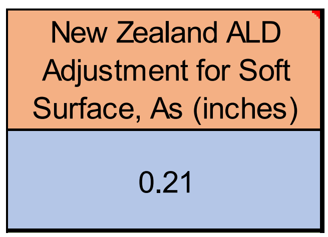


Figure 8.23. ALD-adjustment based on ball penetration values as calculated

8.4.5.13 Allowance for Chip Shape, % Adjustment

In the New Zealand Design, chip shape is controlled by a maximum ratio of ALD:AGD of 1:2.25, although typical ratios of 1:2 have been found in practice. These shapes are preferred as they pack in with maximum shoulder-to-shoulder contact.

Some aggregate crushing systems can result in more cubical chips with ratios less than 1:2.0. The volume of voids, with this more cubical shape of chip, is higher than the voids between chips having a 1:2.0 cubical shape. Subsequently, the binder application rate needs to be increased. Typically, the application requires up to 10% extra binder for chips with a more cubical shape.

Purely cubical aggregates would have a 1:1 ratio. Thus, if the 1:1 ratio required 10% extra binder, and a typical 1:2 ratio required no adjustment, the following adjustment from Figure 8.24 was developed and programmed into the spreadsheet as shown in Figure 8.25.

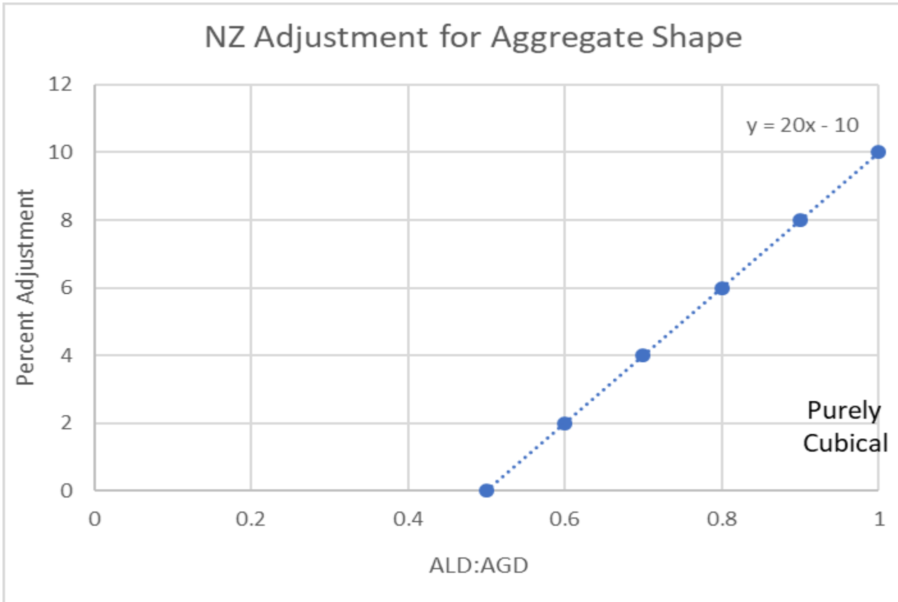


Figure 8.24. New Zealand adjustment for aggregate shape

Allowance for Chip Shape (% Adjustment)
2.2

Figure 8.25. Percent adjustment based on aggregate shape

The equation y = 20x – 10 satisfies the relationship where x is the ALD:AGD expressed as a decimal, and y is the percent adjustment. This equation is programmed into the spreadsheet and calculates the ALD:AGD ratio and the adjustment factor automatically. If the ratio of ALD:AGD is larger than 1:2.25, the spreadsheet recommends checking the flakiness.

8.4.5.14 New Zealand Traffic Factor and Equivalent Lane Vehicles (Includes Trucks)

The New Zealand Design incorporates percent trucks and increases the traffic load for trucks. This is done by calculating equivalent light vehicles (elv) in the following equation 8.9.

$$elv = v/l/d \times (1 + 0.09 \times \%Trucks) \tag{8-11}$$

Where:

v/l/d is vehicles per lane per day and percentage of trucks is New Zealand's equivalent to heavy commercial vehicles. For New Zealand, 11% trucks is typical; thus, the factor is generally 2.

The spreadsheet uses the equation $1 + 0.09 \times \%Trucks$ to calculate the truck factor and is shown in Figure 8.26.

New Zealand Traffic Factor	Equivalent Lane Vehicles (Includes Trucks)
2.17	749

Figure 8.26. New Zealand traffic factor and equivalent lane vehicles as calculated

8.4.5.15 Average Pre-Seal Pavement Texture and Excessive Differences in Texture

The pre-seal pavement texture (cell G56) is calculated from the pre-seal texture worksheet tab. The texture of the existing surface road may absorb some of the binder. Therefore, it is essential to account for the pre-seal pavement texture as shown in Figure 8.27.

Average Pre-Seal Pavement Texture (mm)
1.79

Figure 8.27. Pre-seal pavement texture average

The New Zealand design requires the pre-seal sand circle test data to measure the average pre-seal texture depth to calculate the final binder application rate.

The next cell (H56) checks if pre-seal texture variations may cause problems with meeting the texture specification. Excessive texture is described earlier in the Section 8.4.2.3, Sand Circle Testing for Pavement Texture based on New Zealand's T/3 Standard. This cell determines if the texture differences on the pavement will be excessive for the ALD of the aggregate used for the project, as shown in Figure 8.28.

Check for excessive differences in texture
Excessive Texture

Figure 8.28. Pre-seal pavement texture check

The Excel sheet provides two options to calculate traffic factor, Vb. The first option is the updated New Zealand 2004 chip seal design algorithm, given previously as part of equation 8.7, and as shown on the left in Figure 8.29.

2004 NZ Traffic Factor, Vb Eqn 9-11	1993 NZ Traffic Factor, Vb (Eqn 9-12)
0.232529205	0.382330867

Figure 8.29. New Zealand traffic factors using 2004 and 1993 equations

The second option is in a situation when existing traffic is less than 100 vehicles/lane/day. Then, the equation is modified based on the 1993 New Zealand traffic factor, Vb, which can be calculated as shown in the following equation 8.10 and shown on the right in Figure 8.29.

$$\mathbf{Vb = (ALD + 0.7\ Td) \times [0.42 - 0.0485\ log10\ ((2) \times v/l/d \times 100)] \times 0.220881} \qquad \textbf{(8-12)}$$

8.4.5.16 Initial Application Rates Based on New Zealand Design

The final application rates for aggregate and binder by the New Zealand methods are shown in Figure 8.30 and Figure 8.31.

New Zealand Recommended Starting Aggregate Application Rate, lbs./yd^2
19.2

Figure 8.30. Initial aggregate application rate based on New Zealand Design

New Zealand Recommended Starting Binder Application Rate (Yields a minimum), gal/yd^2
0.35

Figure 8.31. Initial binder application rate based on New Zealand Design

9.0 DEMONSTRATION PROJECT AND PLANS FOR ANTICIPATED FOLLOW UP

The ODOT selected a demonstration project location as a good candidate to introduce the new specification adopted from the New Zealand method and the McLeod design method. The chip seal design was performed, and various application rates were placed at 12 locations throughout the project. The design life for the demonstration project is set at years and uses the same standard design life from the Buss et al. (2016) research results. The chip seal design spreadsheet helped to streamline design calculations, especially for the New Zealand method, where many metric-to-English unit conversions were required. This chapter summarizes the construction materials, equipment, and construction process involved to perform the chip seal demonstration project on Oregon 206. It also provides a construction report and follow-up chip seal results at six months and one year post-construction in terms of MTD performance.

9.1 PRIOR TO CONSTRUCTION

A site visit was arranged to gather information from the road, Oregon 206, before the test section construction. The road length is 7.5 mi, and the width is 23 ft. approximately. The road is located in The Dalles, Oregon, as shown in Figure 9.1.

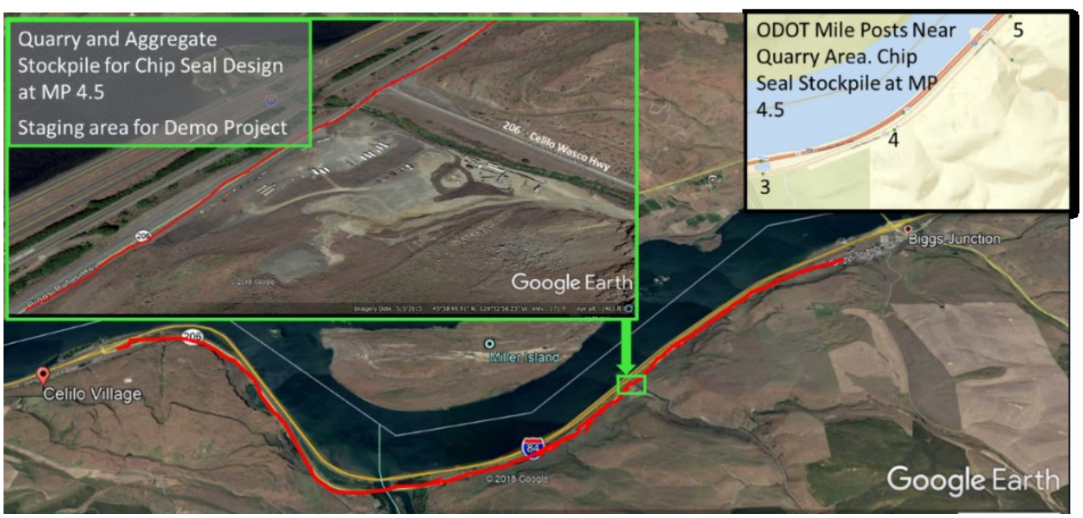


Figure 9.1. Location of the chip seal project

The AADT on the road is approximately 670 vehicles per day. The road was selected for a chip seal research project to extend its service life and to demonstrate newly placed chip seal surfaces with the participation of the multiple suppliers from the emulsion industry. Three different companies participated in the project, and they tested out four different emulsions with a variety of application rates. Figure 9.2 shows some sections of the road before construction.

Figure 9.2. Road condition before chip sealing on Oregon 206

9.2 ENVIRONMENTAL CONSIDERATIONS

Due to some weather constraints, the construction of the demonstration project had to be delayed for drier and warmer weather. Previous research indicates that the most ideal environmental condition for chip seal construction is hot, dry weather with no rain expected for the next several days after construction is completed (Epps et al. 1981). In addition, the research recommended to apply chip seal early in the season, because the temperature during the day continues to rise, and as result of that, asphalt can be less viscous. Therefore, a good adhesion and bond can be formed between the aggregate and asphalt emulsion.

9.3 MATERIALS

The demonstration construction was an experiment to examine different application rates in terms of emulsions and aggregate to identify the ideal application rates for chip sealing in Oregon. Sand circle tests were performed before construction, the second day after construction, six months post-construction, and one year post construction to measure the MTD of the road for 12 sections.

The three companies in this report are designated as supplier 1, supplier 2, and supplier 3. They were involved in this research study and during the construction processes. The research team provided the companies with the interactive Excel spreadsheet described in Chapter 8 to input the emulsion properties, road conditions, and aggregate criteria to compute the final application rates. The final aggregate and emulsion application rates were calculated in the McLeod and New Zealand methods. Each asphalt company picked the application rates based on their objectives to test their material in order to find the appropriate application rate for each emulsion. As a result, emulsion application rates varied from 0.38 gal/yd^2 up to 0.48 gal/yd^2, and aggregate application rates varied from 14.5 lb/yd^2 up to 22 lb/yd^2. The aggregate used throughout the project was 100% crushed basalt aggregate from Oregon.

The following are descriptions for emulsions used during the construction of the test sections on 7 mi on Oregon 206 for the demonstration project in The Dalles, Oregon.

1. [Supplier 1] – HFE-100S/HFRS-P2: HFE-100S/HFRS-P2 is a polymer-modified anionic high-float rapid setting emulsion
2. [Supplier 1] – PMCRS-2H: PMCRS-2H is a polymer-modified cationic rapid setting emulsion
3. [Supplier 2] – CVRS-2P: CVRS-2P is a polymer-modified cationic very rapid setting emulsion
4. [Supplier 3] – CRS-3P: CRS-3P is a polymer-modified cationic rapid setting emulsion

9.4 CONSTRUCTION EQUIPMENT

All of the required equipment on the day of construction were ready on site. First, asphalt distributors were checked and ready for the construction crew to spray the emulsion for triple coverage at the calculated spraying rate. Second, aggregate spreader and haul trucks were ready and checked for the construction crew to apply the aggregate at the designed application rate. Third, two pneumatic-tired rollers and one steel-drum roller were ready and checked for the construction crew to utilize as soon as the emulsion and aggregate were applied. Rolling and compaction is an important process during the construction phase to embed the aggregate on the freshly placed emulsion before it sets and hardens. Finally, after completing three passes of rolling and compaction, the finished surface was broomed by two broomers to remove any loose aggregate from the surface.

Figure 9.3 illustrates the chip seal processes of emulsion spraying, aggregate spreading, rolling and compaction, and sweeping the surface before opening the road to the public.

Figure 9.3. Chip seal construction equipment

9.5 AGGREGATE CHARACTERISTICS

The aggregate utilized for this chip seal project was 100% crushed basalt from Oregon, and the gradation was uniformly graded. The aggregate was tested in the laboratory for gradation, flakiness index, AGD, unit weight, and specific gravity. Table 9.1 contains all the data collected from the laboratory prior to the construction process.

Table 9.1. Basalt Aggregate Characteristics

Testing criteria	Result
Flakiness index	11.40%
AGD	9.89 mm
Unit weight	92.02 lb/ft^3
Performance uniformity coefficient (PUC)	0.2
Bulk dry specific gravity	2.75
Absorption %	2.52%
Gradation	Uniformly graded
% passing ½ in.	100%
% passing 3/8 in.	92.65%
% passing ¼ in.	44.27%
% passing No. 4	18.86%
% passing No. 8	1.08%
% passing No. 30	0.91%
% passing No. 200	0.77%

Also, the gradation curve for the aggregate is shown in Figure 9.4.

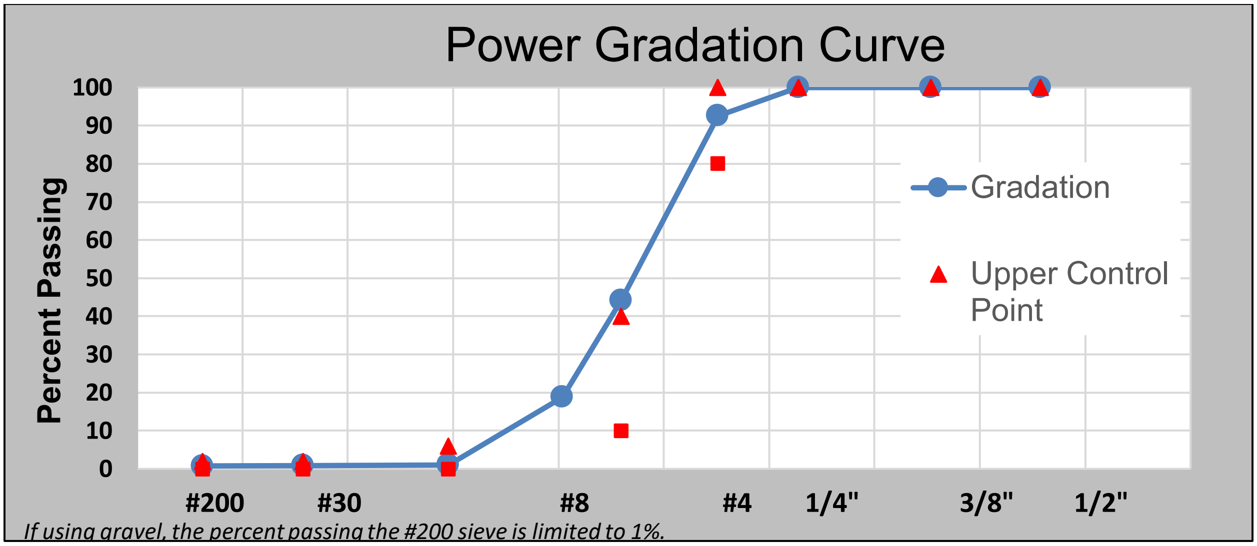


Figure 9.4. Basalt aggregate gradation

9.6 CONSTRUCTION PROCESS

The demonstration project is 7.5 mi long. The construction started by spraying the emulsion for triple coverage as shown in Figure 9.5.

Figure 9.5. Asphalt emulsion spraying for triple coverage

The emulsion was first sprayed by supplier 1, followed by spraying the emulsion provided by supplier 2, and then followed by the emulsion produced by supplier 3.

Supplier 1 tested two emulsions PMCRS-2H and HFE-100S/HFRS-2P in this demonstration project. The aggregate and emulsion application rates applied in the project by supplier 1 are presented in Table 9.2.

Table 9.2. Aggregate and Emulsion Application Rates for Supplier 1

Supplier	Emulsion	WB asphalt shot rate**	WB agg. application rate*	EB asphalt shot rate**	EB agg. application rate*
1	PMCRS-2H	0.48	22	0.48	20
1	-	0.50	22	0.48	20
1	-	0.48	22	0.48	20
1	-	0.49	22	0.48	20
1	-	0.48	20	-	-
1	HFE-100S/HFRS-2P	0.38	15	0.38	15
1	-	0.45	19	0.45	19
1	-	0.47	19	0.38	19
1	-	0.47	18	0.47	18

*Aggregate Application Rate lbs/yd^2
**Emulsion Spraying Rate Gallon/yd^2
Note: WB = westbound, EB = eastbound

Supplier 2 tested one emulsion CRS-3P in this demonstration project. The aggregate and emulsion application rates applied in the project by supplier 2 are presented in Table 9.3.

Table 9.3. Aggregate and Emulsion Application Rates for Supplier 2

Supplier	Emulsion	WB asphalt shot rate**	WB agg. application rate*	EB asphalt shot rate**	EB agg. application rate*
2	CRS-3P	0.47	21	0.50	21
2	-	0.49	21	0.5	21

*Aggregate Application Rate lbs/yd^2
**Emulsion Spraying Rate Gallon/yd^2
Note: WB = westbound, EB = eastbound

Supplier 3 tested one emulsion CVRS-2P in this demonstration project. The aggregate and emulsion application rates applied in the project by supplier 3 are presented in Table 9.4.

Table 9.4. Aggregate and Emulsion Application Rates for Supplier 3

Supplier	Emulsion	WB asphalt shot rate**	WB agg. application rate*	EB asphalt shot rate**	EB agg. application rate*
3	CVRS-2P	0.38	20	0.38	20
3	-	0.38	14.5	0.38	14.5

*Aggregate Application Rate lbs/yd^2
**Emulsion Spraying Rate Gallon/yd^2
Note: WB = westbound, EB = eastbound

Two pneumatic-tired rollers and one steel-drum roller made three passes in each direction. The steel-drum roller was utilized over the center line to level it. Lastly, two broomers cleaned the surface of any loose aggregate.

9.7 MTD RESULTS

Before construction, the MTD of the surface was measured by performing the sand circle test at three locations, as shown in Figure 9.6.

Figure 9.6. Sand circle tests prior to construction

In addition, 12 post-construction sand circle tests were performed at different locations to measure and compare the chip seal performance at different application rates. Sand circle test data collected from before and after construction are presented in Table 9.5 and Table 9.6.

Table 9.5. Sand Circle Tests Data Pre-construction

Location	WP MTD	BWP MTD
Pre-construction	1.56	1.57
Pre-construction	1.61	1.67
Pre-construction	1.88	2.44

Table 9.6. Sand Circle Tests Data One Day Post-construction

Location	Supplier	Emulsion	Asphalt shot rate	Application rate	WP MTD	BWP MTD
1	1	HFE-100S/HFRS-2P	EB - 0.45	EB - 19	2.76	3.16
2	1	HFE-100S/HFRS-2P	EB - 0.38	EB - 15	2.46	2.81
3	1	HFE-100S/HFRS-2P	EB - 0.48	EB - 20	2.60	2.83
4	2	CRS-3P	EB - 0.50	EB - 20	2.61	2.36
5	2	CRS-3P	EB-0.49	EB - 19	2.50	2.07
6	3	CVRS-2P	EB-0.38	EB - 14.5	2.90	3.69
7	3	CVRS-2P	EB - 0.38	EB - 14.5	2.70	2.38
8	2	CRS-3P	WB - 0.48	WB - 20	2.34	2.69
9	3	CVRS-2P	WB - 0.38	WB - 20	2.55	2.19
10	1	PMCRS-2H	WB - 0.48	WB - 22	3.08	3.01
11	1	HFE-100S/HFRS-2P	EB - 0.47	EB - 19	2.78	2.61
12	1	HFE-100S/HFRS-2P	EB - 0.47	EB - 18	2.40	2.65

Note: EB = eastbound, WB = westbound

It is worth noting that the post-construction data was collected the next day, six months post-construction, and one year post-construction. Further data collection is required to evaluate the application rate versus the MTD at each section at longer time intervals.

9.8 SIX MONTH FOLLOW-UP MACROTEXTURE TESTING

At six months post-construction, the ODOT conducted follow-up sand circle tests to document any declines in macrotextures. The required MTD at one year post-construction is 1.22 mm. All sections were expected to exceed the macrotexture depth requirement at one year based on the six-month post-construction performance. These sections will be further monitored to document the MTD values and the overall chip seal performance at one year post-construction. It is worth noting that the WP MTD values were less than the BWP MTD values, which was expected in this study based on the literature. A formal visual inspection was not performed, but all parties agreed that the chip seal is performing well to date. One-year post-construction macrotexture depth can be theoretically calculated by using the following equation.

$$\boldsymbol{TD1 = 0.07 \times (ALD) \times \left(Log10(Yd)\right) + 0.9} \tag{8-13}$$

Where:

TD1 = the required macrotexture one year post-construction, in mm

Yd = the design life, in years

ALD = the average least dimension of aggregate, in mm

9.9 ONE YEAR FOLLOW-UP MACROTEXTURE TESTING

The one-year post-construction field measurements of MTD revealed that all 12 sections met the one year requirement of 1.22 mm, as shown in Table 9.7 and Figure 9.7 to Figure 9.9.

Table 9.7. Chip Seal Information and Average Macrotexture Measurements over Time

Location	Supplier	Emulsion	EB/WB asphalt shot rate	EB/WB aggregate application rate	One day post-construction		Six months post-construction		One year post-construction	
					WP MTD*	BWP MTD*	WP MTD*	BWP MTD*	WP MTD*	BWP MTD*
1	Supplier 1	HFE-100S/ HFRS-2P	EB - 0.45	EB - 19	2.76	3.16	1.88	2.64	2.02	2.07
2	Supplier 1	HFE-100S/ HFRS-2P	EB - 0.38	EB - 15	2.46	2.81	2.41	2.67	1.99	2.14
3	Supplier 1	HFE-100S/ HFRS-2P	EB - 0.48	EB - 20	2.60	2.83	2.23	2.81	1.76	1.84
4	Supplier 2	CRS-3P	EB - 0.50	EB - 20	2.61	2.36	2.55	2.88	1.93	2.25
5	Supplier 2	CRS-3P	EB-0.49	EB - 19	2.50	2.07	2.42	3.06	1.87	2.17
6	Supplier 3	CVRS-2P	EB-0.38	EB - 14.5	2.90	3.69	2.42	2.73	1.79	1.96
7	Supplier 3	CVRS-2P	EB - 0.38	EB - 14.5	2.70	2.38	2.41	2.85	1.76	2.13
8	Supplier 2	CRS-3P	WB - 0.48	WB - 20	2.34	2.69	2.71	3.01	2.11	2.18
9	Supplier 3	CVRS-2P	WB - 0.38	WB - 20	2.55	2.19	2.43	2.47	1.93	1.85
10	Supplier 1	PMCRS-2H	WB - 0.48	WB - 22	3.08	3.01	2.33	2.84	1.69	2.13
11	Supplier 1	HFE-100S/ HFRS-2P	EB - 0.47	EB - 19	2.78	2.61	2.52	2.55	1.89	2.18
12	Supplier 1	HFE-100S/ HFRS-2P	EB - 0.47	EB - 18	2.40	2.65	2.26	2.48	1.76	2.02

Note: EB = eastbound, WB = westbound
MTD*: Macro Texture Depth (mm)

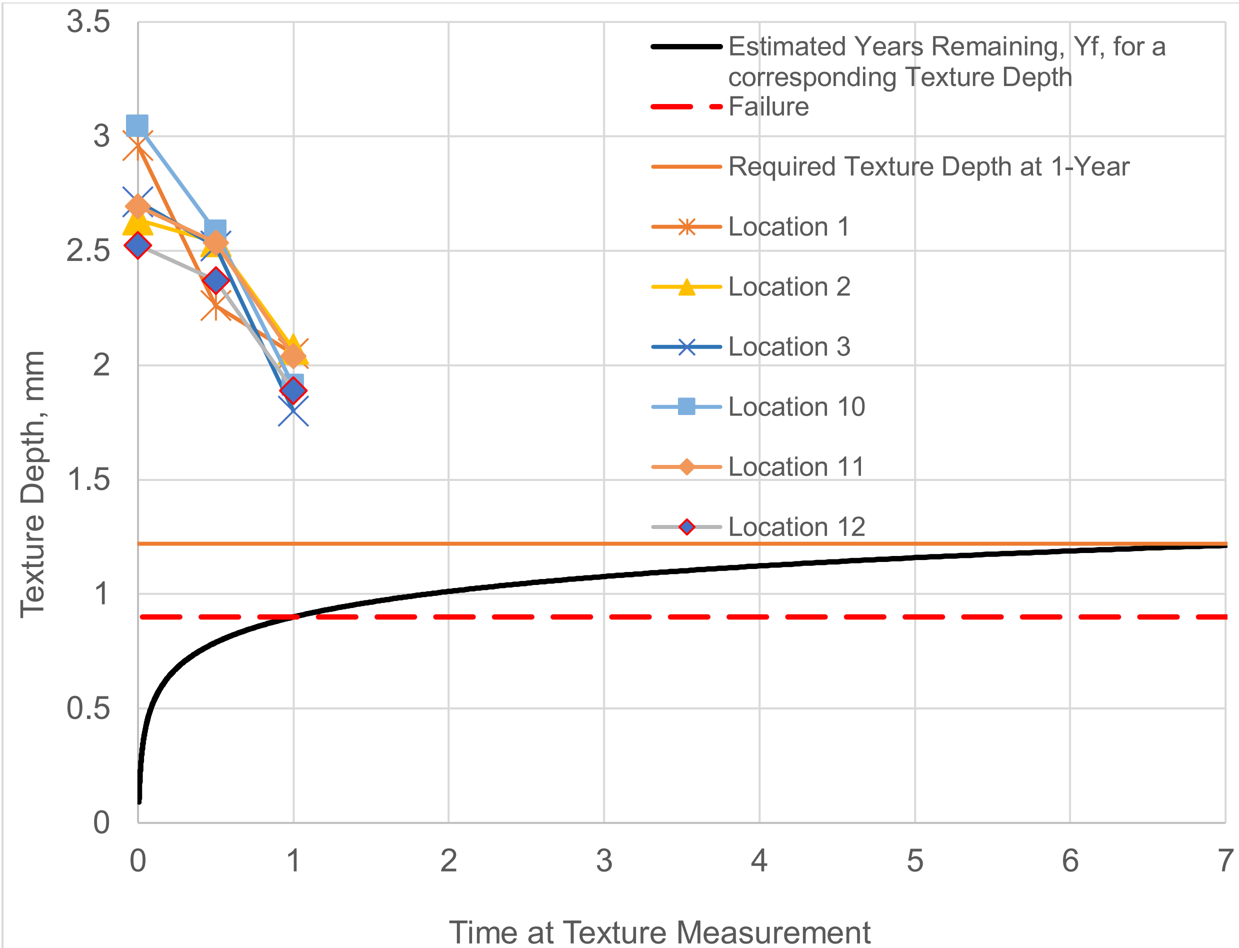


Figure 9.7. Supplier 1 macrotexture for demonstration project

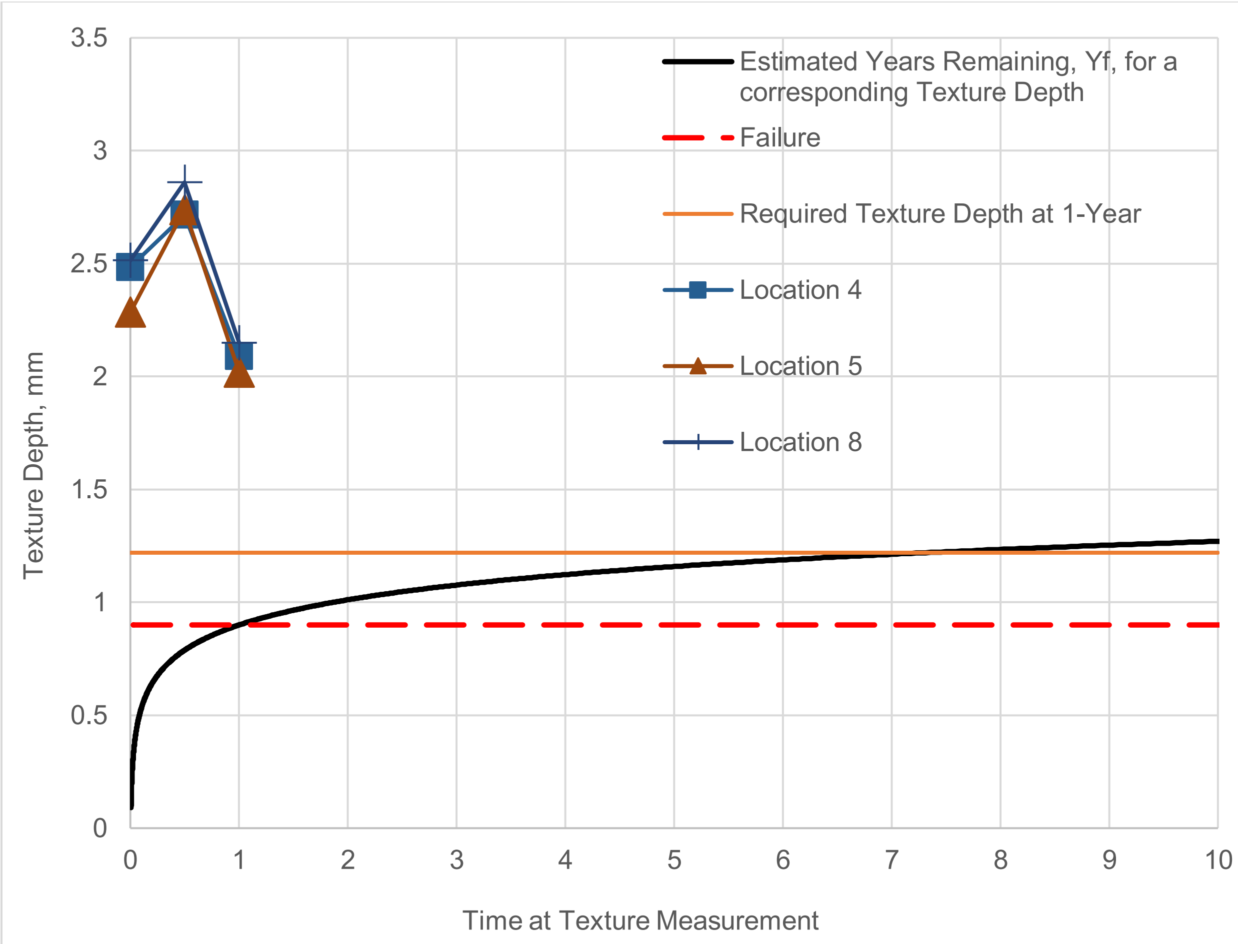


Figure 9.8. Supplier 2 macrotexture results for demonstration project

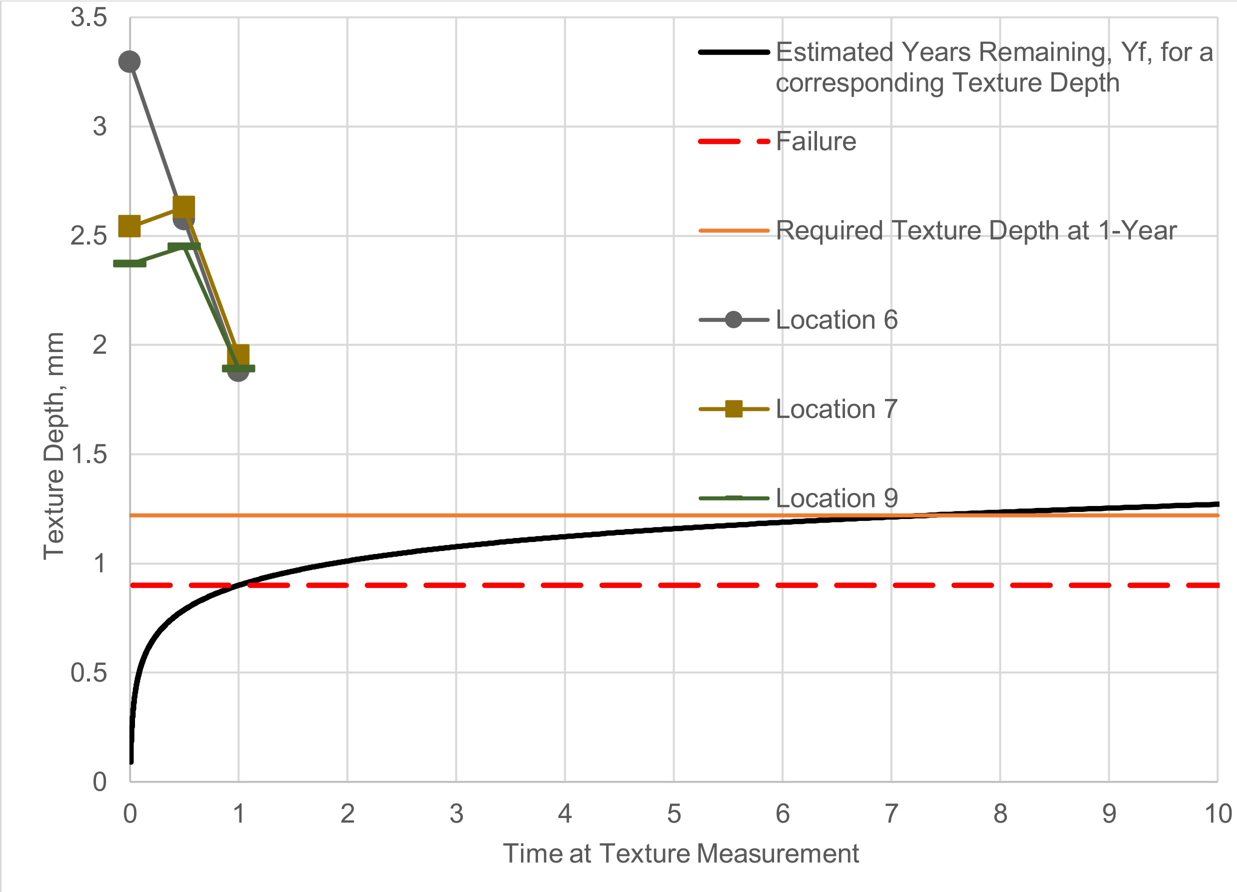


Figure 9.9. Supplier 3 macrotexture measurements on demonstration project

Furthermore, 11 out of 12 sections have an MTD value higher BWP measurement compared to the WP measurement. All 12 sections are performing well so far, and they are expected to continue to perform well until the end of their service life.

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APPENDIX A: INITIAL CHIP SEAL WORKSHOP PRESENTATIONS

Performance Specifications

R. Christopher Williams

November 2, 2017

Important Note: Figures, pictures, maps, logos, and diagrams were removed to avoid copywrite issues.

REVIEW SPECIFICATION TYPES

- Method
- End Result
- Statistical Acceptance
- Performance
- Warranty

METHOD SPECIFICATIONS

- Historically, most common specification type used in roadway construction.
- Specify………
  - Each constituent material,
  - The method of production,
  - Combined materials, and
  - In-situ material.
- The specification type is personnel intensive.
- Stifles innovation.

END RESULT SPECIFICATIONS

- Final characteristics of the product are specified.
- Typically use statistical methods to assess overall quality.
- Specifications are ranges, minimums, and/or maximums.
- Often referred to as "QC/QA Specifications"

STATISTICAL ACCEPTANCE SPECIFICATIONS

- A method of accepting or rejecting work.
- They are designed to monitor or audit a process.

PERFORMANCE SPECIFICATION

- Specifications in which the product is directly related to its actual performance.
- Contractors are held responsible for the product performance **within the context of what they have control over.**
- Contractor is given leeway in providing the product as long as it performs according to established guidelines.
- The contractor assumes risk for the level of service the product provides including maintenance and/or repair within the performance period.

WARRANTY- 2 TYPES

- Materials and Workmanship
  - Most pavement construction is covered by typically one year.
  - Agency is responsible for forensic investigation if issues arise.
  - Contractor repairs if issue is non-compliance related.
- Performance
  - Agency monitors performance during warranty period.
  - Unacceptable performance due to construction is addressed by contractor at their expense.
- Contractor is allowed to control most construction aspects.

REVIEW PERFORMANCE SPECIFICATIONS

- New Zealand
- Michigan

DEMOGRAPHICS

	Population	Size, sq. mi.
Oregon	4.1 mil.	98,466
New Zealand	4.7 mil.	103,483
Michigan	9.9 mil.	96,716

NEW ZEALAND

- Pre-eminent chip seal design and construction specifications.
- Specification: TNZ P17
- "The P17 specification is intended to apportion responsibility/risk in a more equitable manner, and to provide an environment to encourage innovation."
- Stipulate design life based upon traffic volume and chip grade for both single and multilayer seals.
- Use the sand circle test at one year and estimate expected chip seal life.
- Proportional payment which is based upon a reduced life as compared to the design life.

MICHIGAN

- Section 505.03, 12SP-505A-04 and 12SP-505B-06
- 2-year warranty period for both single and double chip seals.
- Initial acceptance after construction.
- Supply a warranty bond equal to 100% from the acceptance date of the warranted work.
- Warranty covers surface cracking, loss of cover aggregate, and bleeding/flushing.

SUMMARY

- Performance based specifications for chip seals have been working well in other places such as New Zealand and Michigan.
- We recommend performance based specifications for Oregon looking at the best offered by New Zealand and Michigan.

1

Oregon DOT Chip Seal Workshop Research-Validated Best Practices

Doug Gransberg, PhD, PE

Important Note: Figures, pictures, maps, logos, and diagrams were removed to avoid copywrite issues.

2

Outline

- Discuss research key findings
- Specifics of New Zealand performance specification
- Summary
- Questions

3

NCHRP Synthesis 342

- Chip Seal Best Practices Synthesis
- Responses from 42 US states, 12 US cities/counties, all Canadian provinces, plus Australia, New Zealand, United Kingdom, and South Africa.
- Chip seal performance results were mixed across the US.
- No regional or climatological trends

4

Excellent Responses

- 14 respondents reported "Excellent" chip seal performance from:
  - Arkansas, Colorado, Idaho, Nevada, North Carolina, Oklahoma, Texas, Washington
  - Cities of Austin and Lubbock, Texas
- All reported that chip seals used as a PM tool
- 5-year PM cycle – 6-year expected life

Important Note: Figures, pictures, maps, logos, and diagrams were removed to avoid copywrite issues.

5

Collective Statistics

- Ave 7000 miles of chip sealed surface.
- 150-2000 lane miles new seal each year -- $2.6 million
- Use both in-house and contract crews – 10 of 14 say in-house gets better overall results
  - Major distress In-house seal :
    - bleeding
  - Major distress contract seal :
    - chip loss

6

Design/Material Selection

- Maintenance engineers complete design (8 of 14)
- Formal design method (McLeod, Kearby, etc.) is used (13 of 14)
- Design method in use for an average of 21 years
- All only seal roads with:
  - Moderate or better distress level
  - Fair or better structural cross-section
  - Average rut depth < ALD of aggregate

Contracting/Construction

7

- 11 of 14 seal on ADT >5000; 3 seal roads ADT > 20,000
- Require computerized distributor controls and ½ also require on chip spreader
- Require pneumatic rollers and control by specifying:
  - Passes, speed, and/or weights

Quality Management

8

- Season runs May to October
- Temperature spec is 60° to 70° F
- Traffic Control
  - Speed limits 35 mph on newly sealed
  - Flaggers 4-6 hours after sealing
- All used in-house inspectors
- All required distributor calibration
- 10 of 14 required chip spreader calibration

Performance

9

- 11 of 14 describe ride as good or excellent after sealing
- Major short-term problems are weather-related
- Major long-term problem is bleeding;
  - can control through rigorous QA/QC efforts

Individual Statistics

10

- 2005 TRB Paper (TRR 1933) has tables with details from:
  - 3 excellent programs with low-volume roads; Colorado, Idaho, Washington; ADT < 5000
  - 3 excellent programs with high-volume roads; Colorado (different district), Nevada; Texas; ADT > 20,000
- Very little difference reported details
- Mainly just the maximum ADT on which chip seals are used

Conclusions

11

- Excellent programs use chip seal as a PM tool…not a repair technique
  - Treat technology as a science
  - Formal design adjusted by years of experience
  - Apply to roads that are in good condition to extend pavement life
- Transfer high degree of specificity from design to construction – allows them to replicate success.

Best Practices

12

- Chip seal viewed as a PM tool, applied on a regular cycle
- Only apply to roads before pavement distress is severe
- Can be successfully used on high volume roads
  - Both hot AC and emulsion binders can be used on high volume roads
  - Modify with polymers or crumb rubber

13

Best Practices

- Use in-house maintenance forces to seal those roads that require the greatest care
- Require chip seal contractors to use state-of-the-art equipment
- Aggressive QC testing combined with close inspection = chip seal success.

14

Correlating Chip Seal Performance and Construction Methods

Critical Analysis of NCHRP Synthesis 342 Findings:

2006 TRB paper published in Transportation Research Record

15

Performance Correlation Categories

- Pre-seal surface preparation.
- Ambient air and pavement temperature specifications in which chip seals can be installed
- Applying binder and aggregate
- Rolling and brooming
- Traffic control
- Post-seal measures

16

Pre-seal surface preparation

Pre-seal Procedure	Excellent	Good	Fair	Poor	Excellent	Good	Fair
	Number of responses				*Percentage within category*		
Chip seal on paved asphalt surface	2	5	2	0	6.7%	11.1%	15.4%
Crack sealing	16	20	8	0	53.3%	44.4%	61.5%
Fog coat	0	0	0	0	0.0%	0.0%	0.0%
Patching	7	15	3	1	23.3%	33.3%	23.1%
Geotextile to retard reflective cracking	1	1	0	0	3.3%	2.2%	0.0%

Emphasis on crack sealing enhances chip seal performance

17

Average Temperature Specifications

	Average Ambient Air Temperature				Average Pavement Temperature			
Category	Excellent	Good	Fair	Poor	Excellent	Good	Fair	Poor
Degrees F	57.9	57.9	55.0	50.0	61.1	58.4	81.0	50.0
No specification	3	12	0	0	7	9	0	0
Range	40-70	45-70	50-60	50	40-80	32-80	70-130	50

Increasing temperature specifications enhances chip seal performance

18

Distributor and chip spreader specifications

Require computerized controls on binder distributors					Require computerized controls on chip spreaders				
	Excellent	Good	Fair	Poor		Excellent	Good	Fair	Poor
Yes	17	23	2	0	Yes	1	0	0	0
No	5	11	6	2	No	0	1	2	0

Requiring state-of-the-art application equipment enhances chip seal performance

Roller specifications

19

	Number of responses				Percentage of category population			
Roller controls	Excellent	Good	Fair	Poor	Excellent	Good	Fair	Poor
Number of passes	12	26	6	0	40.0%	57.8%	46.2%	0.0%
Rolling patterns	10	13	1	0	33.3%	28.9%	7.7%	0.0%
Speed limits	11	15	4	0	36.7%	33.3%	30.8%	0.0%
Roller weight	8	16	4	0	26.7%	35.6%	30.8%	0.0%
Typical number pneumatic-tired rollers required	Excellent	Good	Fair	Poor	Excellent	Good	Fair	Poor
One	4	9	3	1	13.3%	20.0%	23.1%	50.0%
Two	12	21	3	0	40.0%	46.7%	23.1%	0.0%
Three	3	4	1	0	10.0%	8.9%	7.7%	0.0%
Four	1	0	1	0	3.3%	0.0%	7.7%	0.0%

Emphasis on rolling enhances chip seal performance

Brooming controls

20

Average time span between final rolling and initial brooming.				
Category	Excellent	Good	Fair	Poor
Hours	5.5	15.9	31.5	0

Requiring brooming as soon as feasible enhances chip seal performance

Traffic Control Period

21

Average time span between final rolling and opening to full speed traffic				
Typical maximum reduced speed limit				
Category	Excellent	Good	Fair	Poor
MPH	31.4	28.4	21.4	25
Time span between final rolling and opening to *reduced speed* traffic				
Minutes	48.2	68.1	43.2	60.0
Average time span between final rolling and opening to *full speed* traffic				
Hours	28.0	19.8	18.5	8.0

Maintaining traffic control as long as possible enhances chip seal performance

Traffic Control Methods

22

Required traffic control measures	Number of responses				Percentage of category population			
	Excellent	Good	Fair	Poor	Excellent	Good	Fair	Poor
Reduced speed	18	27	7	1	60.0%	60.0%	53.8%	50.0%
Interim pavement markings & devices	14	22	4	0	46.7%	48.9%	30.8%	0.0%
Pilot vehicles	16	24	8	2	53.3%	53.3%	61.5%	100.0%
Flaggers	20	25	8		66.7%	55.6%	61.5%	50.0%

Increased use traffic control measures enhances chip seal performance

Traffic Control Measures

23

- Traffic control measures keep traffic where:
  - It will do the most good
  - **Or** do the least harm
- New Zealand spec requires the cones to be moved every 3-4 hours to shift the traffic across the entire sealed surface
- Considered "final rolling" in TNZ spec
- Personal work in NZ shows excellent chip seals where policy requires ADT>25K to justify HMAC surface

Water Retexturizing

24

- New Zealand Contractor has a patented ultra-high pressure watercutter for removing excess bitumen from the road and restoring the microtexture of polished aggregates and chips in road surfacings.

Important Note: Figures, pictures, maps, logos, and diagrams were removed to avoid copywrite issues.

NZ Performance-based Chip Seal Design

25

- TNZP17 minimum binder application rate is determined by:
  - Percentage of voids to be filled,
  - Total available voids, and
  - Desired thickness of the seal
- Adjustments for aggregate and traffic levels are added to derive a design voids factor.
- Design voids factor is multiplied by the ALD of the aggregate to get the basic binder application rate

New Zealand Performance-based Chip Seal Design

26

- Adjustments then made for:
  - Underlying pavement condition:
    - Hardness, existing texture, oxidation
  - Geometric factors:
    - narrow lanes, climbing lanes, and turning locations. traffic is channeled into confined wheel paths such as on single lane bridges, tight radius curves or pavements with confined lane widths,
- Some of the allowances may be negative -> design binder application rate may be lower than the base binder application rate.

TNZ T/3 Sand Circle Test

27

- Uses 45 ml (2.75 in3) of sand of particle size of 300 µm to 600 µm (#40 to #80)
- Spread out
- Divide Volume by
  Area = Depth

Important Note: Figures, pictures, maps, logos, and diagrams were removed to avoid copywrite issues.

Transit New Zealand P/17 Performance Specification

28

$Td_1 = 0.07 \text{ ALD} \log Y_d + 0.9$

Where: Td_1 = texture depth in one year (mm)
Y_d = design life in years
ALD = average least dimension of the aggregate

Ultimate Failure Criterion = 0.9 mm

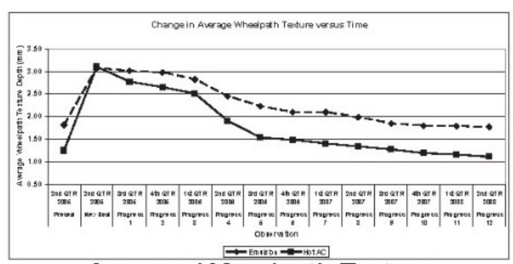
Tried ASTM E965 Sand Patch

29

- Similar protocol
- Uses half the volume of sand of particle size of #60 to #80
- Worked great in lab
- Bad reproducibility in field
- Light wind blew away significant amount of the finer material
- TNZ T/3 proved to be more robust

Change in Texture Over Time

30



Average Wheelpath Texture

Results

31

- Quantitative proof that substrate condition can adversely impact chips seal performance
- Quantitatively characterizing the existing surface, helps the engineer better understand performance failures
- TNZ T/3 sand circle is less sensitive to field testing conditions than ASTM E965 sand patch.

Results

32

- Neither qualitative nor quantitative showed poor performance in those roads that had adequate preseal texture based on TNZ P/17 regardless of binder
- Emulsion binder roads lost their texture depth at a slower rate than hot asphalt cement binder roads.
  - AC roads used precoated aggregate – EM roads did not: black vs. white surface color.
  - Perhaps color/surface temperature may affect flushing

Conclusions

33

- Emulsion roads performing as well as the AC roads using TxDOT PMIS standards.
- Using TNZ P/17 performance standard
  - All EM & 3 of 5 AC roads passed at 5 & 6 year design lives
  - All EM and 2 of 5 AC roads passed at 7 year
- Emulsion roads are more cost effective in every metric.

Conclusions

34

- US needs its own TNZ P/17 performance specification
- This approach can be used to quantitatively determine pavement preservation treatment usage
- This approach can be used to prioritize pavement preservation treatment programs

Important Note: Figures, pictures, maps, logos, and diagrams were removed to avoid copywrite issues.

Oregon Chip Seal

Design and Specifications

Ashley Buss
Doug Gransberg
Minas Guirguis
R. Christopher Williams

Project Acknowledgements

- Oregon Department of Transportation
- Jon Lazarus and Larry Ilg.
- Binder suppliers for these projects
- Chip seal contractors for their help on the construction site.
- R. Christopher Williams, Paul Ledtje, Ben Claypool, Marie Grace Mercado, Jinhua Yu, and Jesse Studer at Iowa State University

Project Introduction

- <u>Objectives</u>
  - Document methods of chip sealing
  - Report the performance of chip seals
  - Apply Chip Seal Design
  - Identify best practices for implementation

Project Introduction

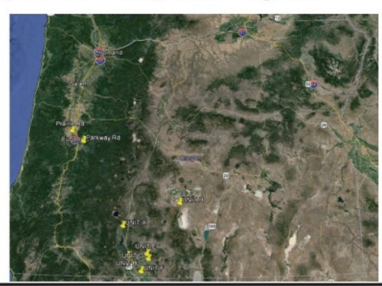
- <u>Benefits</u>
  - Improve the cost effectiveness of chip seals by increasing performance
  - Improved roadway surfaces
  - Integrate a rational method for binder and aggregate application rates

Project Introduction

- Literature Review and Best Practices
  - Design Methods
  - NCHRP Synthesis 342
  - Performance Specifications
  - Specification Review and Comparison
- Experimental Plan
  - Hot Applied and Emulsified Chip Seal
  - Various Regions in Oregon
  - Variety of ADT

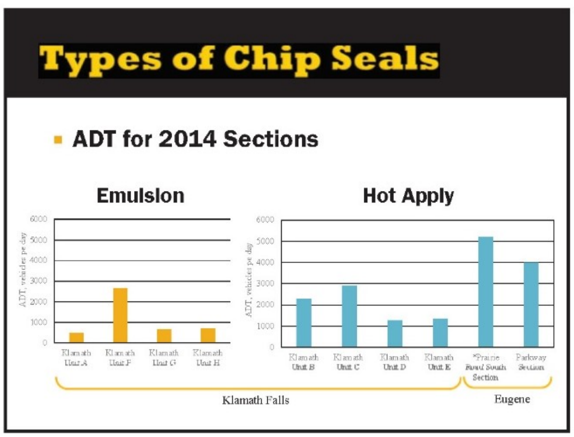
Chip Seal Locations

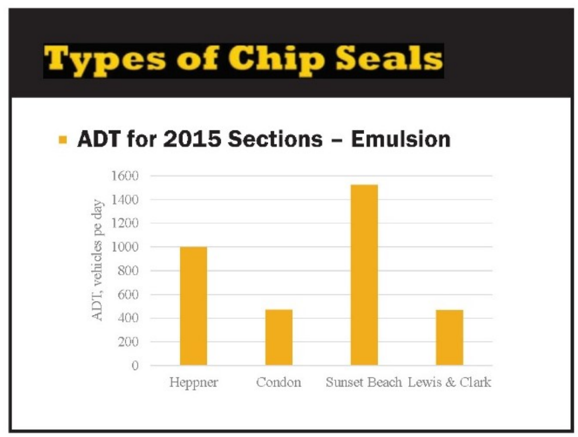
- Map of 2014 Chip Seal Projects

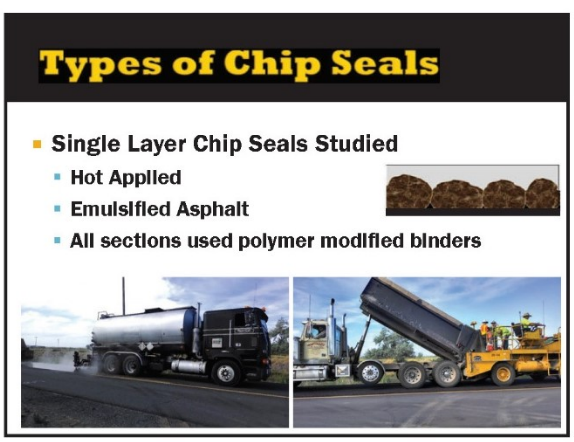


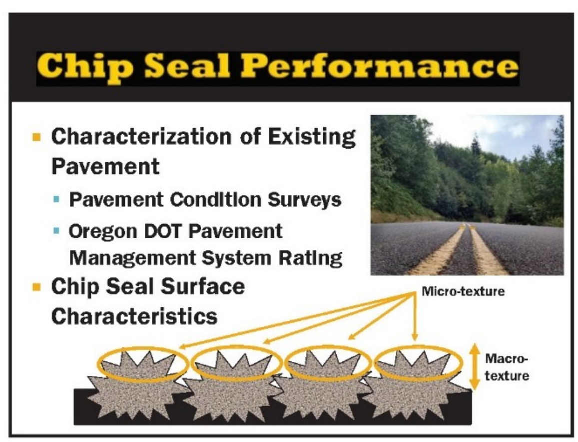

Chip Seal Locations
Map of All Project Locations
OREGON DEPARTMENT OF TRANSPORTATION
REGION MAP
Lewis & Clark Rd. (L&C)
Sunset Beach Rd. (Seaside)
Heppner
Condon
Parkway Rd.
(Jasper)
Prairie Rd.
Units A-H
1
2
3
4
5


Chip Seal Locations
Map of All Project Locations and Rainfall
Precipitation (in.)
Average Annual Precipitation (1981-2010)
Oregon
Less than 10
10 - 15
15 - 20
20 - 35
35 - 40
40 - 50
50 - 65
65 - 80
80 - 100
100 - 130
130 - 160
More than 160
Lewis & Clark Rd. (L&C)
Sunset Beach Rd. (Seaside)
Heppner
Condon
Parkway Rd.
(Jasper)
Prairie Rd.
Units A-H
OSU
Rainfall Map developed by: PRISM Climate Group, Oregon State University, 2014. http://www.prism.oregonstate.edu/gallery/view.php?state=OR


Types of Chip Seals
ADT for 2014 Sections
Emulsion
Hot Apply
ADT, vehicles pe day
6000
5000
4000
3000
2000
1000
0
Klamath Unit A
Klamath Unit F
Klamath Unit G
Klamath Unit H
Klamath Unit B
Klamath Unit C
Klamath Unit D
Klamath Unit E
*Prairie Road South Section
Parkway Section
Klamath Falls
Eugene

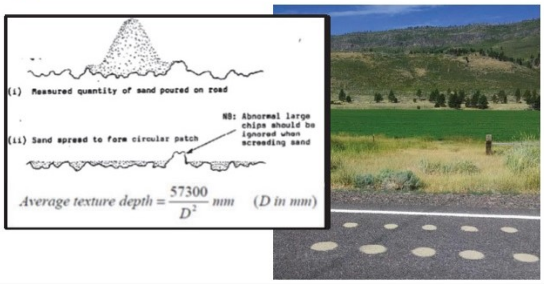

Types of Chip Seals
ADT for 2015 Sections – Emulsion
ADT, vehicles pe day
1600
1400
1200
1000
800
600
400
200
0
Heppner
Condon
Sunset Beach
Lewis & Clark


Types of Chip Seals
Single Layer Chip Seals Studied
Hot Applied
Emulsified Asphalt
All sections used polymer modified binders


Chip Seal Performance
Characterization of Existing Pavement
Pavement Condition Surveys
Oregon DOT Pavement Management System Rating
Chip Seal Surface Characteristics
Micro-texture
Macro-texture

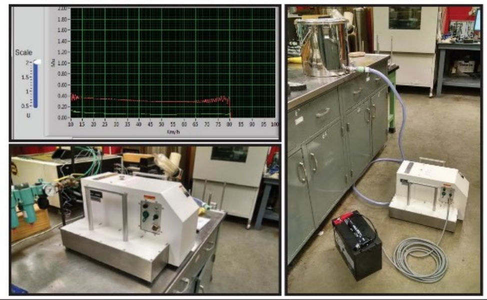
Chip Seal Performance

- Macro-texture – Sand Circles



Chip Seal Performance

- Micro-texture – Dynamic Friction Tester



Chip Seal Specifications

- Can a Macrotexture performance specification be applied in Oregon?
- New Zealand Performance Specification

New Zealand Transport Agency – P/17 Performance Specification for chip seal macrotexture deterioration

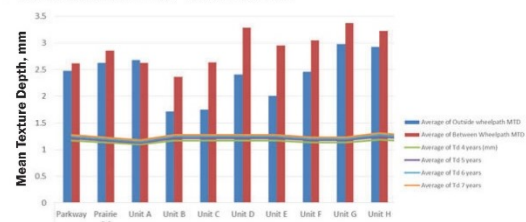
$$Td_1 = 0.07\ ALD\ \log Y_d + 0.9$$

Where:
Td_1 = texture depth in one year (mm)
Y_d = design life in years
ALD = average least dimension of the aggregate (mm)

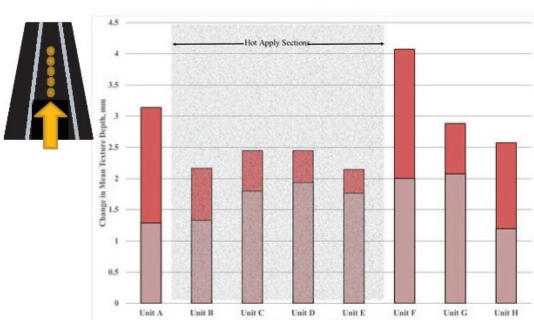
0.9 mm is considered failure

Chip Seal Specification

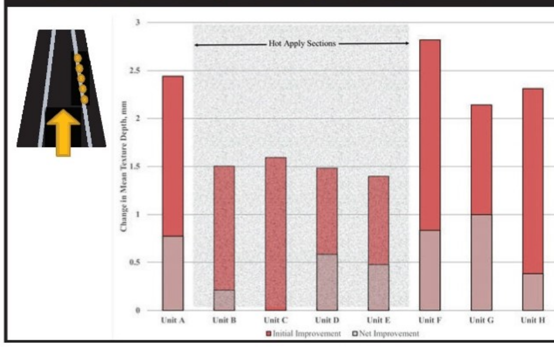
- New Zealand Performance Specification
  - Blue is the performance specification
  - Red is shown for illustration

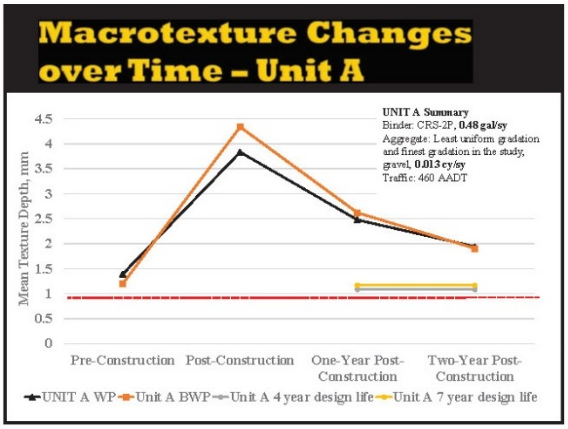


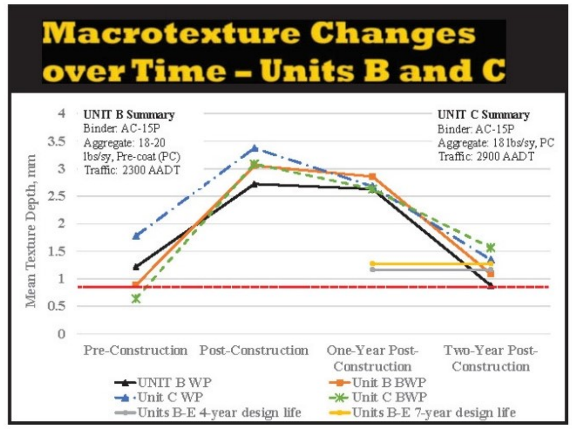
Macrotexture Changes over Time – Between WP

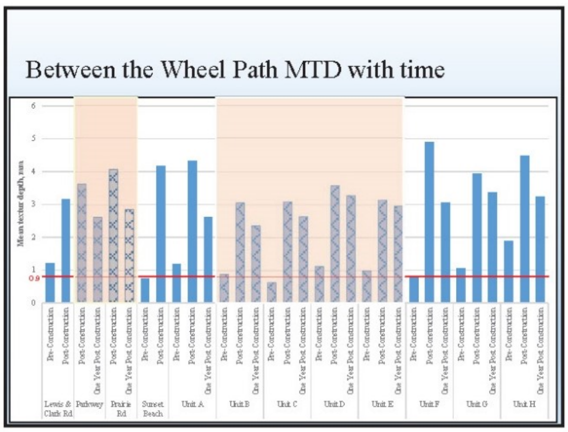


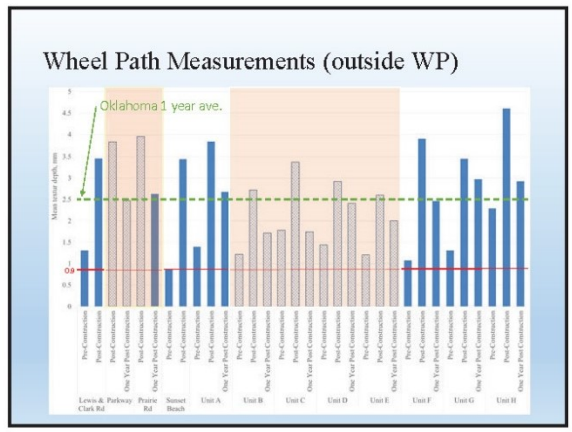
Macrotexture Changes over Time – In the WP

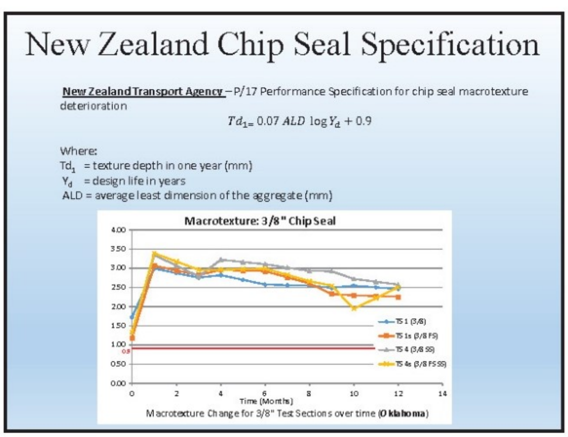


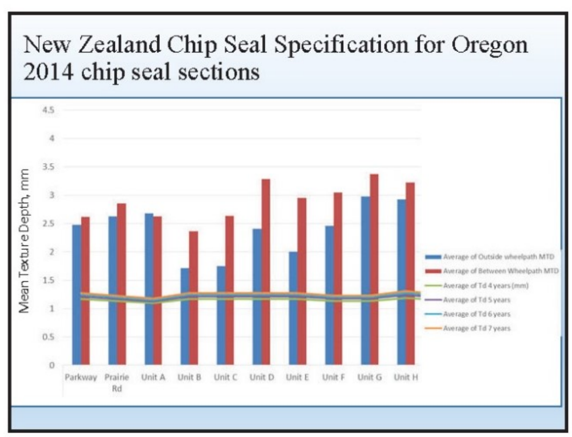

Macrotexture Changes over Time – Unit A
UNIT A Summary
Binder: CRS-2P, 0.48 gal/sy
Aggregate: Least uniform gradation and finest gradation in the study, gravel, 0.013 cy/sy
Traffic: 460 AADT
Mean Texture Depth, mm
Pre-Construction
Post-Construction
One-Year Post-Construction
Two-Year Post-Construction
UNIT A WP
Unit A BWP
Unit A 4 year design life
Unit A 7 year design life


Macrotexture Changes over Time – Units B and C
UNIT B Summary
Binder: AC-15P
Aggregate: 18-20 lbs/sy, Pre-coat (PC)
Traffic: 2300 AADT
UNIT C Summary
Binder: AC-15P
Aggregate: 18 lbs/sy, PC
Traffic: 2900 AADT
Mean Texture Depth, mm
Pre-Construction
Post-Construction
One-Year Post-Construction
Two-Year Post-Construction
UNIT B WP
Unit B BWP
Unit C WP
Unit C BWP
Units B-E 4-year design life
Units B-E 7-year design life


Between the Wheel Path MTD with time
Lewis & Clark Rd
Parkway
Prairie Rd
Sunset Beach
Unit A
Unit B
Unit C
Unit D
Unit E
Unit F
Unit G
Unit H

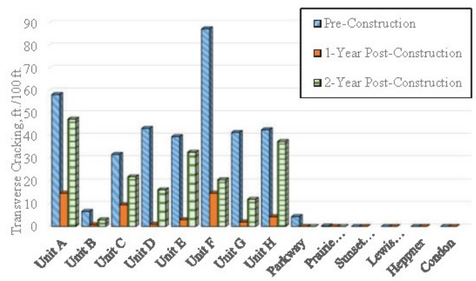

Wheel Path Measurements (outside WP)
Oklahoma 1 year ave.


New Zealand Chip Seal Specification
New Zealand Transport Agency – P/17 Performance Specification for chip seal macrotexture deterioration
$Td_{1} = 0.07\ ALD\ \log Y_d + 0.9$
Where:
Td_1 = texture depth in one year (mm)
Y_d = design life in years
ALD = average least dimension of the aggregate (mm)
Macrotexture: 3/8" Chip Seal
Time (Months)
Macrotexture Change for 3/8" Test Sections over time (Oklahoma)


New Zealand Chip Seal Specification for Oregon 2014 chip seal sections
Mean Texture Depth, mm
Parkway
Prairie Rd
Unit A
Unit B
Unit C
Unit D
Unit E
Unit F
Unit G
Unit H

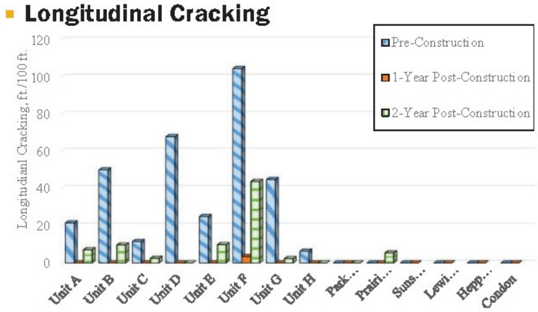
Performance Surveys

- Transverse Cracking



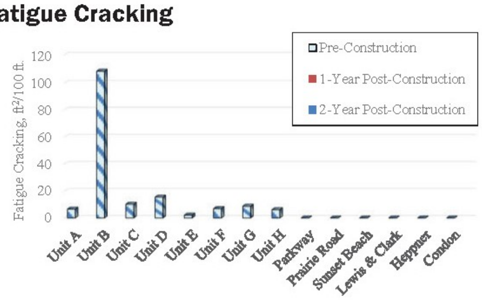
Performance Surveys

- Longitudinal Cracking



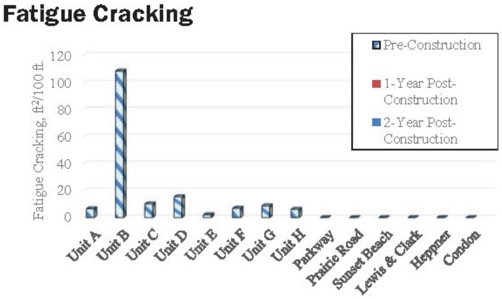
Performance Surveys

- Fatigue Cracking



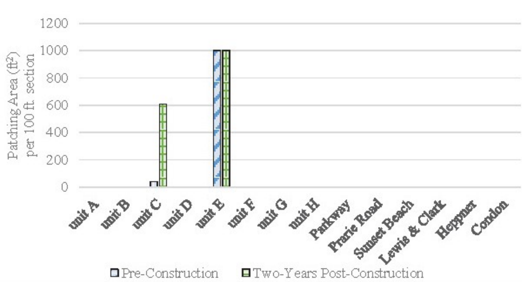
Performance Surveys

- Fatigue Cracking



Performance Surveys

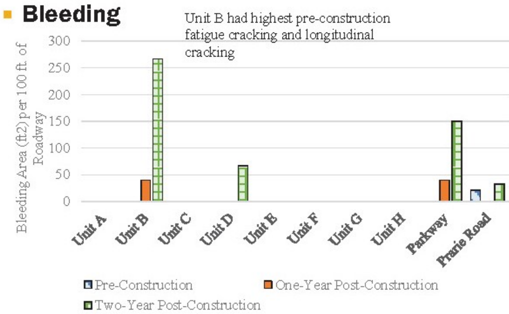
- Patching Area



Performance Surveys

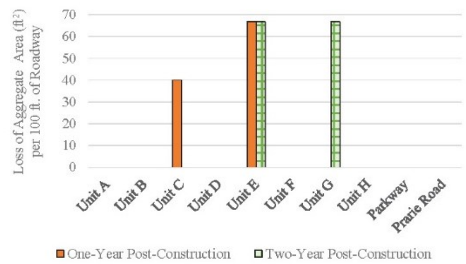
- Bleeding

Unit B had highest pre-construction fatigue cracking and longitudinal cracking



Performance Surveys

- Chip Seal - Loss of Aggregate



Chip Seal Design

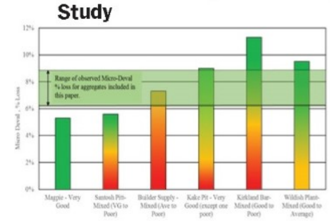
- Back calculate the chip seal design using:
  - McLeod Method (MnDOT Seal Coat Design Manual)
  - New Zealand Design Method
  - Optimal one-stone thick
- Compare with actual applied rates

Laboratory Investigation

- Aggregate Properties

Micro-Deval Testing

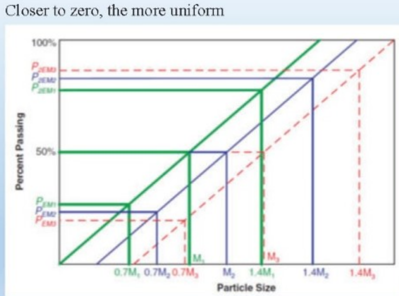
- Micro-Deval Testing
  - Similar Values for all aggregates tested
  - Compared with previous Oregon Aggregate Study



Sample ID	Percent Loss
Unit A Klamath Chips	6.09
Unit F Klamath Chips	7.45
Unit H Klamath Chips	8.60
Hot Applied Klamath Chips	7.21
Parkway Eugene Chips	6.76

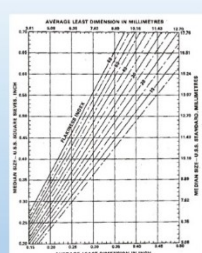
Performance-Based Uniformity Coefficient

- Closer to zero, the more uniform



(Lee and Kim, 2009)

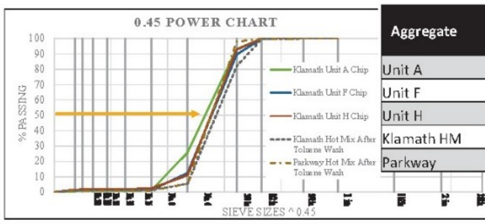
Average Least Dimension/Flakiness Index



Aggregate from Section:	Flakiness Index	ALD
Unit A Chips	13.1	0.182
Unit H Chips	12.1	0.27
Unit F Chips	6.4	0.22
Hot Applied Klamath Chips	5.2	0.25
Parkway	5.2	0.25

Aggregate Gradation and PUC

- Performance Uniformity Coefficient
  - Indicates Aggregate Size Uniformity
  - Lower PUC = More Uniform Gradation



Aggregate	PUC
Unit A	0.41
Unit F	0.12
Unit H	0.12
Klamath HM	0.20
Parkway	0.11

Aggregate Gradation and PUC

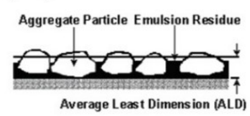
Aggregate	Aggregate contributing to bleeding (P_{EM}), %	Aggregate contributing to loss ($100-P_{2EM}$), %	PUC
Unit A	33	20	0.41
Unit F and G	11	10	0.12
Unit H	11	6	0.12
Klamath Hot Applied Sections (Units B-E)	16	18	0.20
Parkway	11	2	0.11

McLeod: Flakiness Index

Test Section	Flakiness Index	AADT
Parkway	5.2	4000
Unit A	13.1	460
Unit B	5.2	2300
Unit C	5.2	2900
Unit D	5.2	1280
Unit E	5.2	1345
Unit F	6.4	2650
Unit G	6.4	670
Unit H	12.1	690

McLeod and New Zealand Average Least Dimension

- New Zealand and Austroads measure each aggregate particle
- Flakiness index provides relationship
- The average least dimension is determined by:
  - $H = [M / 1.139285 + (0.011506)*FI]$
  - H = Average Least Dimension (ALD)
  - M = Median Particle Size
  - FI = Flakiness Index



(California Division of Maintenance 2003; FHWA 1992)

Loose Unit Weight

- A metal cylinder with a known volume of is loosely filled with aggregate until full. The weight of the aggregate was determined.
- Find Voids in Loose Aggregate

Test Section	LUW
Parkway	89.3
Unit A	86.9
Unit B	85.4
Unit C	85.4
Unit D	85.4
Unit E	85.4
Unit F	87.7
Unit G	87.7
Unit H	82.6

McLeod Traffic Considerations

- Traffic Volume
  - Factor accounts for the role that traffic volumes play in achieving the ultimate embedment of 80 percent (20 percent void space).

Test Section	AADT	McLeod Traffic Correction Factor	Traffic whip-off factor, E
Parkway	4000	0.60	1.1
Unit A	460	0.75	1.05
Unit B	2300	0.60	1.1
Unit C	2900	0.60	1.1
Unit D	1280	0.65	1.1
Unit E	1345	0.65	1.1
Unit F	2650	0.60	1.1
Unit G	670	0.70	1.1
Unit H	690	0.70	1.1

Vehicles/Day	0-100	101-500	501-1000	1001-2000	>2000
Correction Factor	0.85	0.75	0.70	0.65	0.60

(Wood et al. 2006)

Traffic Considerations

- Traffic Whip-Off (Similar to NZ)
  - Assume 5% for low volume, residential type traffic
  - Assume 10% for higher speed roads such as county roads.

McLeod Aggregate Design Equation

- Aggregate Application Rate:
- C= (1 - 0.4V) × H × G × E
  - C = Cover Aggregate (kg/m2)
  - V = Voids in Loose Agg. (%)
  - H = ALD (mm)
  - G = Bulk Specific Gravity
  - E = Wastage Factor (%)

Test Section	McLeod Cover Aggregate Rate (lbs/yd^2)	Actual Rate (lbs/yd2)	Rates given in CY/SY
Parkway	26	20	
Unit A	21	30.5**	0.013
Unit B	27	19	
Unit C	27	18	
Unit D	27	20	
Unit E	27	19	
Unit F	25	30.8**	0.013
Unit G	25	30.8**	0.013
Unit H	23	23	

- **Values based on LUW

New Zealand Chip Seal Agg. Spread Rate

- For Single Coat Seals (Chipsealing in New Zealand)
- $Rate = \frac{750}{ALD}\ m^2/m^3$

Test Section	ALD (mm)	Rate m2/m3	Chip Rate lbs/SY
Parkway	5.9	127.5	21
Unit A	5.0	149.8	17
Unit B	6.3	119.4	21
Unit C	6.3	119.4	21
Unit D	6.3	119.4	21
Unit E	6.3	119.4	21
Unit F	5.8	128.5	20
Unit G	5.8	128.5	20
Unit H	5.5	136.5	18

Aggregate Absorption

- McLeod suggests an absorption correction factor, A, of 0.02 gal/yd^2 if the aggregate absorption is around 1%.
- MnDOT Seal Coat Handbook recommends if absorption is 1.5 percent or higher.

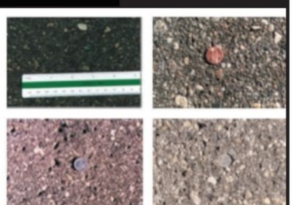
Test Section	Aggregate Absorption
Parkway	1.49
Unit A	2.01
Unit B	1.63
Unit C	1.63
Unit D	1.63
Unit E	1.63
Unit F	2.06
Unit G	2.06
Unit H	2.65

Aggregate type		Class A			Class B		Class C
		Granite	Quartzite	Trap Rock	Limestone	Red Rock	Pea Rock
Percent Absorption	Min.	0.40	0.61	0.31	1.75	no data	1.14
	Max.	0.92	0.72	0.59	5.44	no data	2.32
	Avg.	0.59	0.67	0.43	2.80	-	1.69

(Wood et al. 2006)

Surface Correction Factor, S

- New surfaces will not absorb much binder
- Older surfaces can absorb a lot of binder
- Must be included in design
- Not all roads in a project will need same amount of asphalt binder

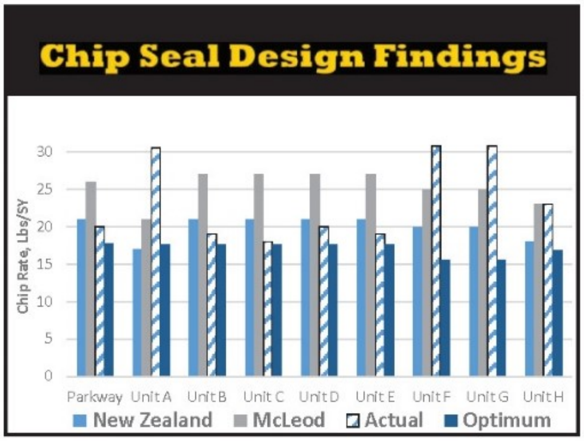


(Wood et al. 2006)

Existing Pavement Texture	Correction, S	
	S.I. Metric (L/m^2)	U. S. Customary (gal/yd^2)
Black, flushed asphalt	-0.04 to -0.27	-0.01 to -0.06
Smooth, non-porous	0.00	0.00
Slightly porous & oxidized	+0.14	+0.03
Slightly pocked, porous & oxidized	+0.27	+0.06
Badly pocked, porous & oxidized	+0.40	+0.09

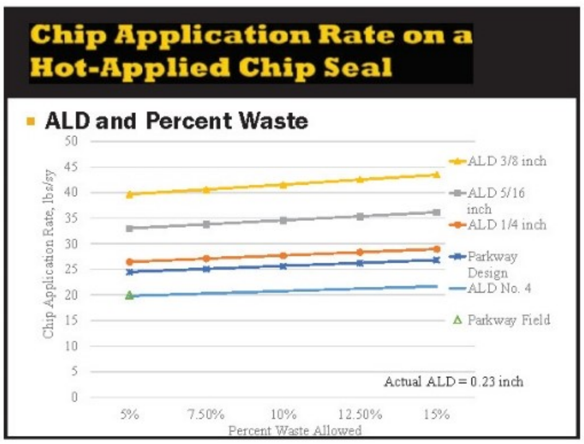
Comparison of All Chip Application Rates

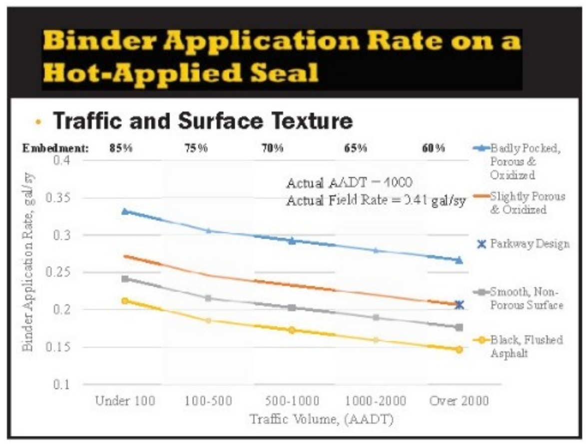
Test Section	New Zealand Chip Rate Lbs/SY	McLeod Cover Aggregate Rate (lbs/yd^2)	Actual Applied Rate (lbs/yd^2)	Rates given in CY/SY
Parkway	21	26	20	
Unit A	17	21	30.5**	0.013
Unit B	21	27	19	
Unit C	21	27	18	
Unit D	21	27	20	
Unit E	21	27	19	
Unit F	20	25	30.8**	0.013
Unit G	20	25	30.8**	0.013
Unit H	18	23	23	

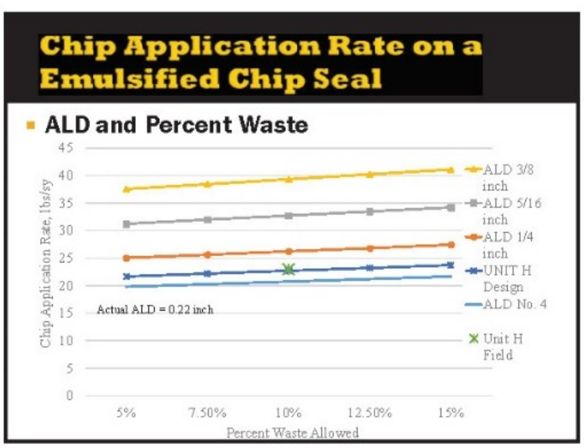


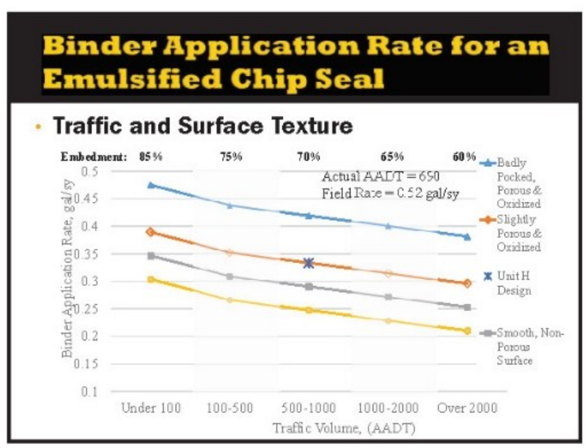
Comparison of All Binder Application Rates

Test Section	Binder Application Starting Rate in Field (gal/sy) (Different surface factors: S=0.06 / S=0.09)	New Zealand Method (gal/sy)	Actual Binder Rate (gal/sy)
Parkway	0.24/0.25	*	0.41 gallons / sy
Unit A	0.43/0.44	0.36	0.48 gallons / sy
Unit B	0.25/0.27	0.37	0.37 gallons / sy
Unit C	0.25/0.27	0.36	0.37 - 0.38 gallons / sy
Unit D	0.26/0.28	0.40	0.37 gallons / sy
Unit E	0.26/0.28	0.39	0.36 gallons / sy
Unit F	0.39/0.42	0.34	0.50 gallons / sy
Unit G	0.44/0.46	0.39	0.50 gallons / sy
Unit H	0.44/0.45	0.41	0.52 gallons / sy









Preliminary Findings

- All three chip seals with chip-seal related distresses are hot-apply
- Both chip seal types show an overall improvement in pavement condition
- Dynamic Friction Data was consistent between sections- inconsistent between years.
- All chip seals passed the New Zealand one-year performance specification
- Emulsified chip seals tended to be over-chipped whereas Hot-apply were close to the design

Recommendations

- Know the materials
- Pre-seal pavement condition plays a key role
- Projects demonstrate performance specification proof of concept
- Design methods provide engineering approach and a framework for chip seal education

Next Steps

- Finalize Design Guide
- Phase II Implementation Phase
  - Chip Seal Workshops
  - Teach Chip Seal Design Methodology
  - Design Lab-Field Validation
  - Introduce New Zealand Performance Specification

ODOT Chip Seal Practices

Iowa/ODOT Chip Seal WS
February 07, 2018

Presented by:
Larry Ilg – Pavement Quality and Materials Engineer

Presentation Outline:

- History of Chip Seals in OR
- Project Selection
- Construction Responsibility
- Recent Research
- Chip Seal Performance

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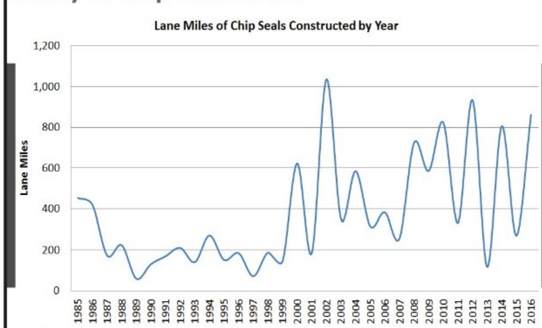
History of Chip Seals in OR

- OR has used chip seals back to 1920's over gravel road base
- Today Chips Seals are used for preventive maintenance
  - Seal fine cracks
  - Prevent water intrusion
  - Slow aging of asphalt cement

History of Chip Seals in OR

- 1984 The OTC dedicated $15 million per year for pavement preservation
- 1999 ODOT started the Low Volume Preservation
  - Moved low volume roadways to Maintenance
- During the 2000's Low Volume program increased
- 2008 High Volume Chip Seals started

History of Chip Seals in OR



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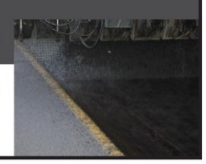
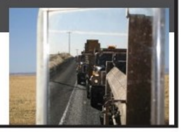
History of Chip Seals in OR

- Mid 1990 to 2012
  - $^2/_3$ Constructed by ODOT Maintenance
  - $^1/_3$ Constructed by Contract
- Starting in 2012 High Volume Preservation moved to STIP and some Low Volume used federalized dollars.
  - $^2/_3$ Constructed by Contract
  - $^1/_3$ Constructed by ODOT Maintenance



Project Selection – Low Volume

- Low Volume Funds are managed by DM's
  - Consult with Pavement Management
  - Use pavement conditions, construction history, level of importance, traffic, crew input and costs
- Adjusted every biennium to react to changing pavement conditions and funding priorities



Project Selection – Low Volume

- Region 4 and 5 typically use ¾ of Low Volume biennial funding for chip seals
- Region 2 and 3 typically use $^1/_3$ to $^2/_3$ Low Volume biennial funding for chip seals
- Very rare for Region 1 to chip seal

Project Selection – STIP Funded

- Pavement Management Engineer and Statewide Pavement Committee establish list of candidate projects
  - Funding is broken up into regional allocations
  - Project selection is planned for 12-18 months before construction
  - Goal is to balance needs and funds

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Project Selection – STIP Funded

- PME and District jointly select final project list
- Projects follow PS&E process at Region Tech Center
  - Pavement Designer is assigned to project and a stamped pavement memo is provided

Project Selection

- ODOT's Pavement Design Guide provides general criteria for chip seal projects
  - Rural roadways with low to moderate ADT
  - Minimal access, sharp curves and snow plow
  - Should be in fair to good pavement condition with localized repairs, crack sealing and rut leveling prior to chip seal project

Project Selection – Factors used by Pavement Management Engineer

- Rural Highway
- Traffic volumes less than 5,000 ADT for emulsion seals
- Traffic volumes less than 10,000 ADT for hot seals
- Pavement condition fair to good with no structural issues

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Project Selection – Factors used by Pavement Management Engineer

- Smoothness – IRI less then 140 inches/mile and minimal snow plow chatter
- Average rut depth less then ½ inch
- Apply chip seal early in pavement life
  - Studies show 2-5 years to get best life extension
  - ODOT currently is applying 8 to 10 years

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Project Selection – Factors used by Pavement Management Engineer

- Prioritize locations with lengthy warm and dry season favorable to chip seals
- Prioritize re-chip on EAC surfaces which are prone to moisture damage
- Prioritize unsealed dense ACP where first signs of raveling or fine cracking is starting
- Prioritize locations with top down cracking

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Project Selection – Factors used by Pavement Management Engineer

- Avoid placing on Open graded mixtures
- Avoid snow zones, areas with sharp turns and low temperatures
- Avoid areas with long periods of shade and low temperatures
- Avoid areas where underground springs or subsurface water flows in pavement layers

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Project Selection – Factors used by Pavement Management Engineer

- Avoid sections with obvious signs of stripping (strings of potholes or shoving)
- Avoid sections with extensive block type patterns with wide cracks (best to patch and hold for inlay or overlay)
- Avoid sections with known structural weakness
- Reduce impact on high bicycle traffic locations

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Construction Responsibility – Maintenance Forces

- Success of project is fully on Maintenance
  - Chip Seal Guru is making decisions on time of year, go/no-go weather conditions, binder types and aggregate selection
  - Experience with reading pavement condition for setting applications rates
  - Production rates and timelines not as critical

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Construction Responsibility – Maintenance Forces

- Chip Seal Guru has the experience and crews that can react to changing conditions and issues
- Many Maintenance chip seals receive little attention or compliant from traveling public

Construction Responsibility – Contract

- Responsibility is shared between ODOT and Contractor
  - ODOT sets the applications rates
  - Contractor is responsible for placing at those rates

Construction Responsibility – Contract

- Often PM offices do not have the expertise to establish applications rates
  - Team discussion between ODOT, Contractor and Supplier to establish rates
  - ODOT by spec is responsible for rates

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Construction Responsibility – Contract

- Contractor is driven by production rate
  - Creates environment to ignore equipment or other issues
- Contractor is paid by binder and aggregate quantity
  - Creates an incentive to creep up on rates

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Recognition of need

- 2013 research was initiated to look at design methodology and specifications for chip seals
- Goal to try to bring some science to the art of chip seals

Recognition of need

- Use of pre-construction testing surface testing could improve application rates established
- A performance based specification should be considered for implementation

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Recognition of need

- The TAC for the research recognized a significant effort would be needed for implementation
- ODOT received a State Transportation Innovation Council Incentive (STIC) grant to aid in the process

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Recognition of need

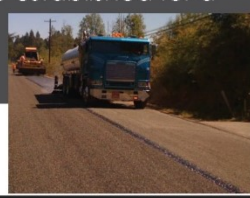
- The process for the implementation are:
  - Workshop with Agency and Industry to review findings
  - Update Specs
  - Demo chip seal best practices
  - Compare old vs new methods
  - Follow up study on lab chip seal design vs field

Recognition of need

- The process for the implementation are:
  - Final implementation workshop/conference for Agency and Industry
  - Final Report

Chip Seal Performance

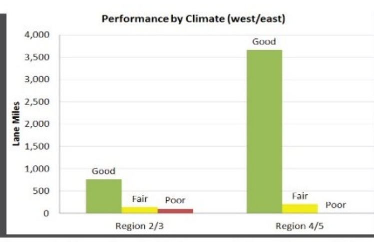
- The Pavement Management Database was used to look at Chip Seal performance for 2005 to 2015
- Three categories were established for a rating



Chip Seal Performance

- Good – Chip Seal constructed successfully and meets expected life
- Fair – most of the Chip Seal mileage constructed successfully, but there may have localized performance issues
- Poor – widespread Chip Seal performance within 1 or 2 years

Chip Seal Performance



The west side and east side have a similar mileage of fair projects, however as a percentage of overall chip seal mileage, there is a lower success rate on west side projects than on east side ones.

Chip Seal Performance

There are slightly more fair category chip seals on contracts than on in-house chip seals, and all of the poor category chip seals were contract chip seals. There are many reasons for this, but it should be mentioned that many contract chip seals are on higher volume routes which tend to magnify performance problems and cost of remediation.

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Chip Seal Summary

- Current practices provide effective preventive maintenance
  - There may be some adjustments for traffic volumes for the West side
- Training for inspection and contract administration needs to continue
  - Adjust training as research is implemented

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Chip Seal Summary

- Specifications being explored
  - Seasonal change and weather condition improvements
  - Change aggregate from a per ton basis to a per sq yd placed basis
  - Others as research is implemented

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Thank you.

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Oregon Chip Seal Performance Specification Workshop

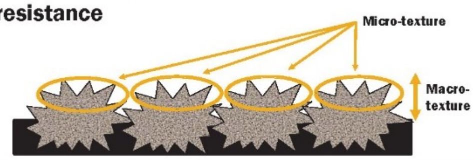
Mean Texture Depth Details

Outline

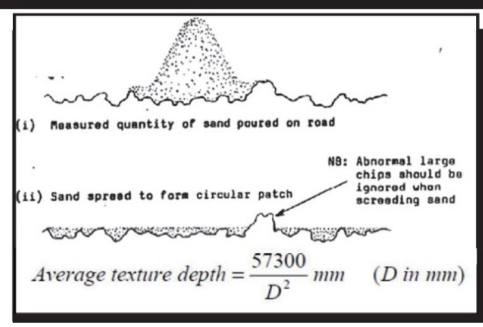
- Macrotexture and Mean Texture Depth (MTD) Definitions
- Sand Circle Test
- Findings from SPR-777
- Role MTD Plays in the Performance Specification in New Zealand

Macrotexture

- Determined by the size, shape, and spacing of the aggregate particles (Abdul-Mala et al. 1993; Gransberg and James 2005)
- Best indication of macrotexture is the mean texture depth.
- In general, higher microtexture = better skid resistance



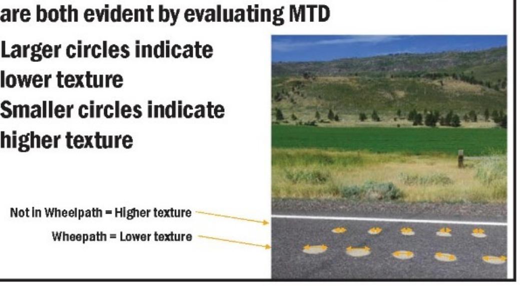
Mean Texture Depth



$$Average\ texture\ depth = \frac{57300}{D^2}\ mm \quad (D\ in\ mm)$$

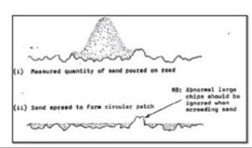
Sand Circle Test for MTD

- Aggregate retention and resistance to bleeding are both evident by evaluating MTD
- Larger circles indicate lower texture
- Smaller circles indicate higher texture



Sand Circle Test Procedure

- Provides the volume of voids.
- Fill a cylinder with sand and tap lightly until sand ceases to compact
- Pour sand in conical heap
- Spread out with straight edge
- (We use the hockey puck with a handle)



Field Data Collection Sheet For Research Project

Test Section Name	
Tester(s)	
Date of Testing	
Chip Seal Date of Construction (or Expected)	
Weather Comments**	
Ambient Temperature (F)	
Pavement Temperature (F)	
Wind Speed (mph)	
Humidity (%)	

**sunny, partly cloudy, etc.

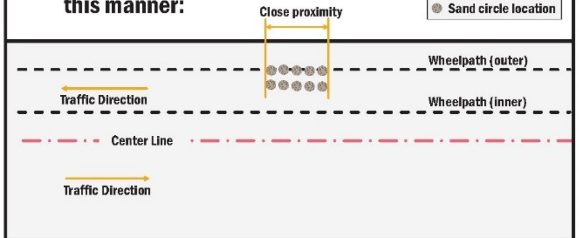
Outside Wheel Path (O.W.P)	Station	Milepost	Rut Depth (mm)	DFT	Sand Circle d1	Sand Circle d2
O.W.P. #1						
O.W.P. #2						
O.W.P. #3						
O.W.P. #4						
O.W.P. #5						

Between Wheel Path (B.W.P.)	Sand Circle d1	Sand Circle d2
B.W.P. #1		
B.W.P. #2		
B.W.P. #3		
B.W.P. #4		
B.W.P. #5		

FIELD NOTES

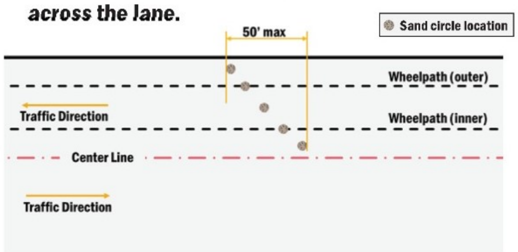
Research sand circles

- Sand patch testing in the research were tested in this manner:



Performance Specification

- Sand patch testing will be performed on 5 spots *across the lane.*



Testing location in Research

- Three 500' sections to be tested per chip seal.
- Section randomly chosen but safety of the site was considered in where the actual readings were taken.
- Measurements included:
  - Visual pavement survey
  - Microtexture – Dynamic Friction tester
  - Macrotexture – Sand circle test

Macrotexture and MTD

- Macrotexture provided clear trends of deterioration over the life of the chip seal.
- Microtexture did not provide clear trends.
- How did the studied seals perform against the new performance specification?

Assumptions

- Readings were taken a bit differently between the research and the specification recommendations
- Comparisons were made with the lowest MTD and the highest Standard Deviation for each category (BWP, WP, Both).

Texture Measured in the field = X - 0.519S

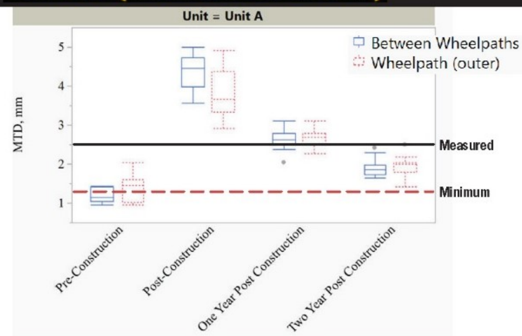
Where:

- X = average of the 5 texture depth measurements
- S = sample standard deviation calculated for the 5 tests

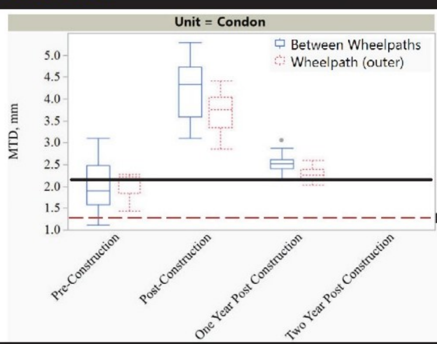
Evaluation

- Macrotexture trend over time
- Variability in the tests

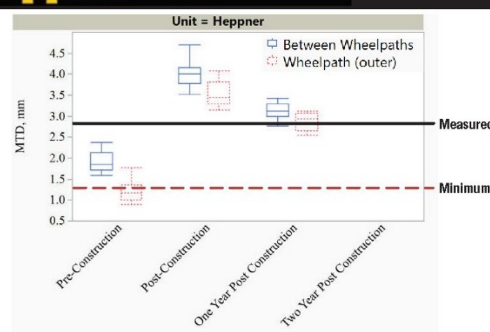
Macrotexture Trends Unit A (Klamath Falls)



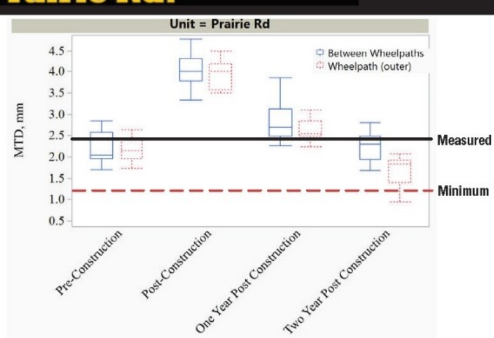
Macrotexture Trends Condon



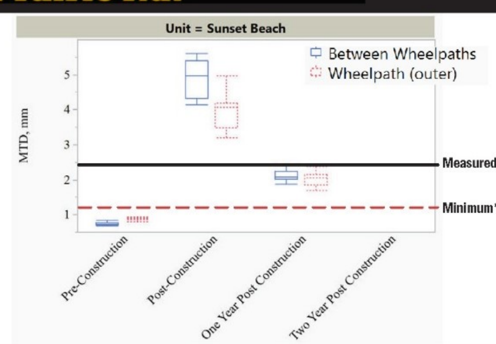
Macrotexture Trends Heppner

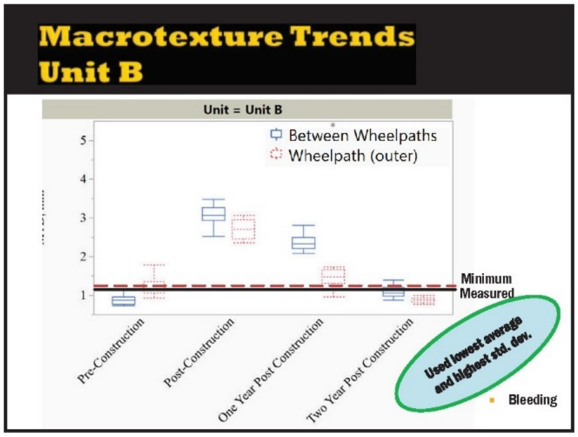


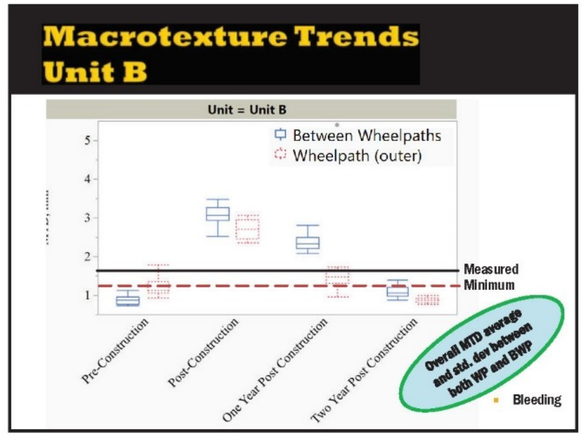
Macrotexture Trends Prairie Rd.

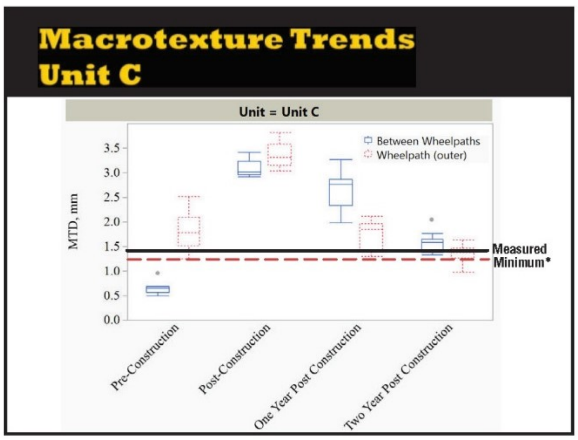


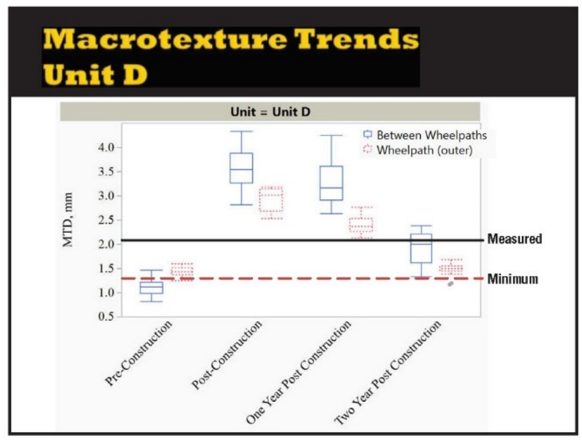
Macrotexture Trends Prairie Rd.

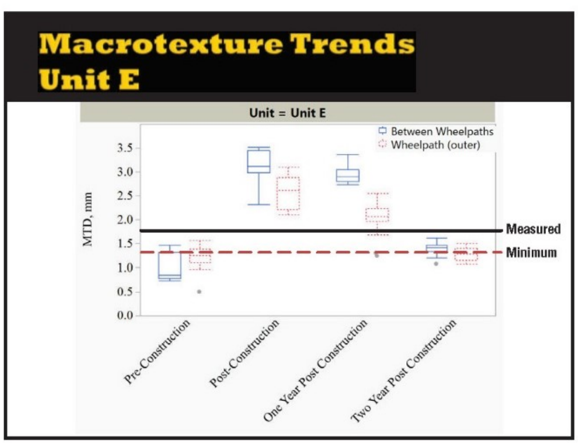


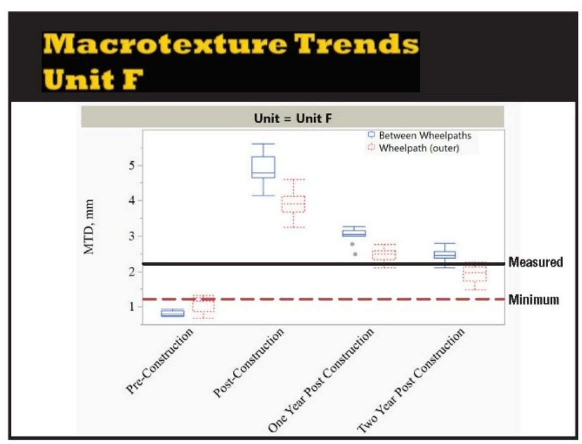

Macrotexture Trends
Unit B
Unit = Unit B
Between Wheelpaths
Wheelpath (outer)
Minimum
Measured
Pre-Construction
Post-Construction
One Year Post Construction
Two Year Post Construction
Used lowest average and highest std. dev.
Bleeding


Macrotexture Trends
Unit B
Unit = Unit B
Between Wheelpaths
Wheelpath (outer)
Measured
Minimum
Pre-Construction
Post-Construction
One Year Post Construction
Two Year Post Construction
Overall MTD average and std. dev between both WP and BWP
Bleeding

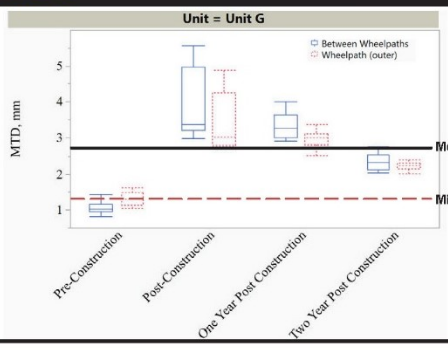

Macrotexture Trends
Unit C
Unit = Unit C
Between Wheelpaths
Wheelpath (outer)
MTD, mm
Measured
Minimum*
Pre-Construction
Post-Construction
One Year Post Construction
Two Year Post Construction


Macrotexture Trends
Unit D
Unit = Unit D
Between Wheelpaths
Wheelpath (outer)
MTD, mm
Measured
Minimum
Pre-Construction
Post-Construction
One Year Post Construction
Two Year Post Construction

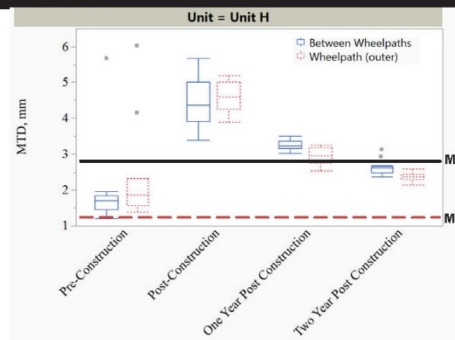

Macrotexture Trends
Unit E
Unit = Unit E
Between Wheelpaths
Wheelpath (outer)
MTD, mm
Measured
Minimum
Pre-Construction
Post-Construction
One Year Post Construction
Two Year Post Construction


Macrotexture Trends
Unit F
Unit = Unit F
Between Wheelpaths
Wheelpath (outer)
MTD, mm
Measured
Minimum
Pre-Construction
Post-Construction
One Year Post Construction
Two Year Post Construction

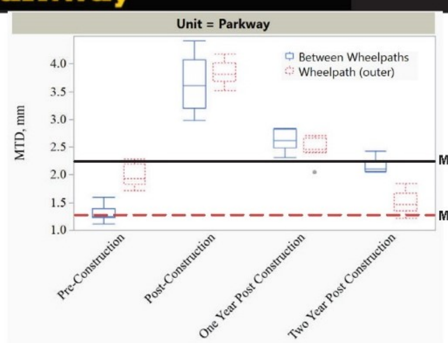
Macrotexture Trends Unit G



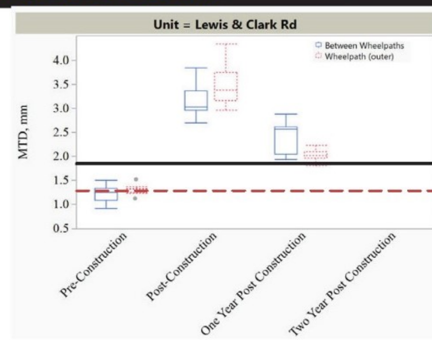
Macrotexture Trends Unit H



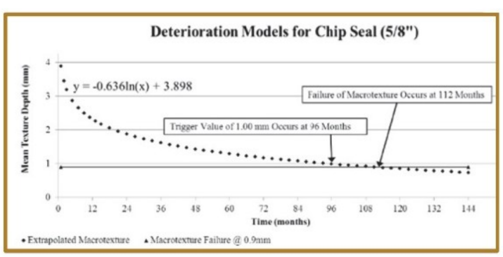
Macrotexture Trends Parkway



Macrotexture Trends Lewis & Clark

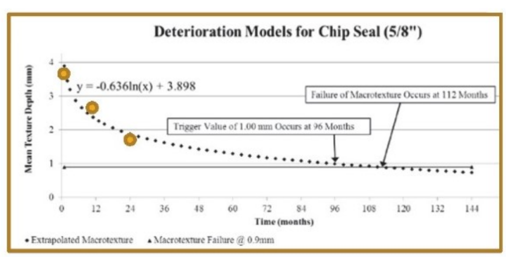


Macrotexture Deterioration model in Oklahoma



Model for Skid was also developed. Omitted in this figure to focus on MTD.

MTD Average Comparison-OK Model and OR Results



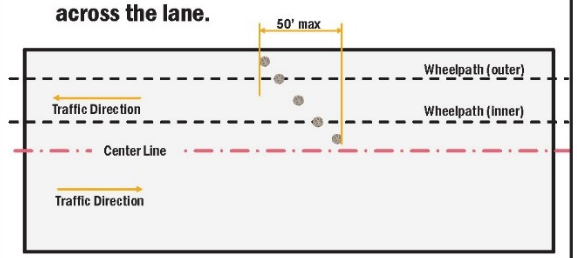
Model for Skid was also developed. Omitted in this figure to focus on MTD.

Notes on Performance and MTD trends

- Chip seals reduced crack severity in all sections.
- Transverse cracking length decreased.
- In the cases where no pre-construction transverse cracking was observed, no additional cracking has occurred.
- The MTD showed clear trends over time
- The performance metric for MTD provides an indication of indicator of performance.

Performance Specification

- Sand patch testing will be performed on 5 spots across the lane.



Performance Specification

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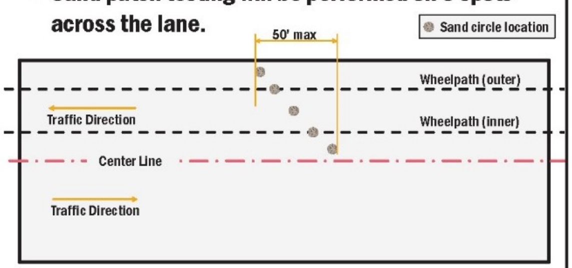


Oregon Chip Seal Performance Specification

Specification Changes and Processes

Specifications that played a role in the research

- New Zealand's P17 chip seal performance specification
  - Performance specification
  - Design guidance
- Michigan's chip seal warranty
  - Clear visual inspection expectations
- Minnesota's seal coat handbook
  - Design guidance

Performance-based specification

- Performance-based contracts:
  - Instead of specifying the materials or methods to be used, as is done for traditional maintenance contracts, the desired outcome is identified and it is then up to the contractor to achieve it.
  - Contractor accepts more responsibility for customer input
  - Maintenance contracts need clear definition of maintenance covered under the contract
- Design-build-maintain
  - Industry assumes full responsibility for comprehensive maintenance

Specifications Overview

- Challenges with pavement preservation in general

Keys to a successful pavement preservation program

- Adequate dedicated funds
- Effective marketing of preventative maintenance
- Support from management
- Legislative support
- Training and buy-in of workers
- Public awareness of the financial benefits of preventive maintenance

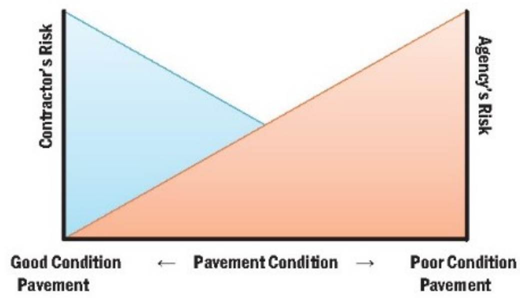
Major Specification Changes

- Removed application rates
  - Contractor provides the materials tests and designed rates of chips and binder
- Moving from prescriptive to performance
  - Changes risk profile
  - Changes the role of the inspector on the job site
  - Initial Inspection @ two weeks (visual)
  - Final Inspection @ one year (performance)

Major Specification Changes

- One-year maintenance period for the contractor
  - Anticipated to be built into the price of the bid
- Pay schedule (dependent on initial (70%) and final inspection (30%).
- Conflict Resolution Team written into specification
- Pay item change
  - Square yard

Shared Risk Profiles



Main Specification Sections

- Materials
  - Aggregate
  - Emulsified Asphalt
  - Aggregate Production Quality Control
  - Acceptance of Aggregate
- Equipment
  - Asphalt Distributor
  - Chip Spreaders
  - Rollers
  - Power Brooms

Main Specification Sections

- Labor
- Construction
  - Season and Weather Limitation
  - Rate of Progress and Scheduling
  - Preparation of Underlying Surfaces
  - Sequence of Operations
  - Application Rates
  - Applying Emulsified Asphalt
  - Hauling and Spreading Aggregate
  - Shaping and Compacting

Main Specification Sections

- Maintenance
  - Power Brooming
  - Maintenance Period
  - Removal of Loose Chip
- Measurement
- Payment
  - Pay item
- Performance Criteria at 12 months

Main Specification Sections

- Acceptance
  - Initial Acceptance
    - Visual inspection
      - Surface cracking
      - Loss of Cover Aggregate
      - Bleeding/flushing
      - Chip retention
  - Final Inspection
    - Visual Inspection
    - Macrotexture requirement
- Conflict Resolution Team

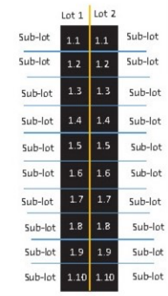
OREGON CHIP SEAL DESIGN AND SPECIFICATIONS

EXAMPLE CHIP SEAL

WORKSHOP 2
OREGON (FEB. 7, 2018)

Chip Seal Project Description

- A 10 Mile (double sided lane) chip Seal project would be constructed in Oregon
- Agency prepares chip seal bid
  - Materials types and specifications
  - design and preparation of Plans
  - Each project contains lots and sub-lots
  - each lane is named a lot → 2 lots in the project
  - Each lots is divided into 10 (1-mile sub-lots)
  - A total of 10 sub-lots per lot.



1- Bidding

- Agency Calls for bids
- Contractors study documents
- Contractor visits site and study field conditions
  - Road condition
  - Texture
  - Communicates any concerns to ODOT
  - Contractors Submit Bid

Chip Seal Process → **1-Bidding** → 2- Design → 3- Construction → 4- Initial inspection → 5- Maintenance → 6-Final Acceptance

2- Design

- Contractor performs and submits chip seal design and proposed materials
- Design is based upon pavement performance criteria
- The percentage of the air voids is to be (60-75) percent
- Design application rates depend on:
  - Aggregate properties
  - Binder properties
  - Traffic and existing surface condition

Chip Seal Process → 1-Bidding → **2- Design** → 3- Construction → 4- Initial inspection → 5- Maintenance → 6-Final Acceptance

2- Design

- Example of performance based chip seal design
  - A hot applied chip seal with the gravel aggregates of the following properties:
  - Aggregates Properties:
    - M= 0.25 inch, FI= 13.1, G= 2.615, LUW = 86.9 lb, A = 0.02
  - Binder Properties:
    - R= 1
  - Traffic and Existing pavement Condition:
    - AADT of 460, The road condition is slightly pocked, porous, and oxidized hard pavement.

Chip Seal Process → 1-Bidding → **2- Design** → 3- Construction → 4- Initial inspection → 5- Maintenance → 6-Final Acceptance

2- Design

- Step 1: Road & Traffic Correction Factors

Vehicles/day (ADT)	0-100	101-500	501-1000	1001-2000	>2000
Correction factor	0.85	0.75	0.7	0.65	0.6

Traffic Factor → 0.75

Existing Pavement	Correction (gal/yd²)
Black, flushed asphalt	-0.01 to -0.06 (depending on severity)
Smooth, non-porous surface	0
Slightly porous oxidized surface	+0.03
Slightly pocked, porous, oxidized surface	+0.06
Badly pocked, porous, and oxidized	+0.09

Whip-off Factor → + 0.03

Road Type	Whip off factor (E)
Rural & Residential	1.05
High volume	1.10
State High ways	1.15

Surface Condition Factor → 1.05

Chip Seal Process → 1-Bidding → **2- Design** → 3- Construction → 4- Initial inspection → 5- Maintenance → 6-Final Acceptance

2- Design

- Step 2: Design Calculations
- Based upon given road condition and traffic, perform calculations
  - T= 0.75, E = 1.05, S= +0.03, P= 0
    $ALD = \frac{M}{1.139285+(0.011506)(FI)} = \frac{0.25}{1.139285+(0.011506)(13.1)}$ = 0.193 inch
  - $V = 1 - \frac{LUW}{62.4\,G} = 1 - \frac{86.9}{62.4\,(2.615)}$ = 0.46 %
  - $B = \frac{(2.244)(ALD)(T)(V)+S+A+P}{R} = \frac{(2.244)(0.193)(0.75)(0.4674)+0.06+0.02}{1}$ = 0.23 gal/yd2
  - $Agg = 46.8 * (1 - 0.4V) \times ALD \times G \times E = 46.8 * (1 - (0.4 * 0.4674)) \times 0.193 \times 2.615 \times 1.05$ = 20.16 lb/yd2
- A Spread sheet could be easily developed

Chip Seal Process → 1-Bidding → 2- Design → 3- Construction → 4- Initial Inspection → 5- Maintenance → 6-Fina Acceptance

2- Materials and Application Rates

- DOT reviews chip seal design
  - (materials types and specifications)
- DOT can approve/reject submitted design
- IF materials fails requirements and/or application rates are not reasonable
  - ODOT informs contractor what/how to correct
- IF materials meet requirements are reasonable
  - contractor receives notice to proceed

Chip Seal Process → 1-Bidding → 2- Design → 3- Construction → 4- Initial Inspection → 5- Maintenance → 6-Fina Acceptance

3- Construction Process

- Contractor executes construction activities and progress of work
- ODOT conducts field inspection on the following :
  - Materials quality control compliance
  - Equipment quality control compliance
  - Labor quality control compliance
  - Construction activities quality control compliance

Chip Seal Process → 1 Bidding → 2 Design → 3- Construction → 4- Initial Inspection → 5- Maintenance → 6-Fina Acceptance

4- Initial Inspection

- ODOT arranges initial inspection two-weeks after chip seal construction.
- ODOT conducts a visual field inspection
  - Entire chip seal subject to the visual inspection
- IF 1st initial inspection is accepted,
  - ODOT Schedules 12 month final acceptance inspection
  - Contractor is paid 70 percent
  - Maintenance Period Begins

Chip Seal Process → 1-Bidding → 2- Design → 3 Construction → 4 Initial Inspection → 5 Maintenance → 6 Fina Acceptance

4- Initial Inspection

- IF 1st initial inspection is rejected,
  - ODOT provides inspection report showing which sub-lots are failing
  - Contractor get permission and coordinate with ODOT to make repairs
  - Contractor makes appropriate repairs
  - ODOT re-conducts visual field inspection
- IF 2nd initial inspection is accepted, maintenance period begins

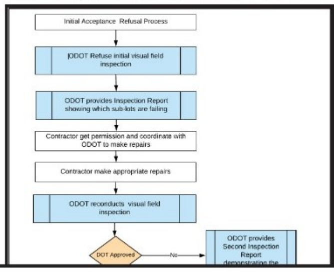
Chip Seal Process → 1-Bidding → 2- Design → 3- Construction → 4- Initial Inspection → 5- Maintenance → 6-Fina Acceptance

4- Initial Inspection

- IF 2nd initial inspection is rejected
  - ODOT provides " 2nd Inspection Report"
    - demonstrate the failure of chip seal
  - ODOT decides to either
    - Fail the job
    - Allow another round of inspection
  - Contractor can file a claim

Chip Seal Process → 1-Bidding → 2- Design → 3 Construction → 4 Initial Inspection → 5 Maintenance → 6 Fina Acceptance

4- Initial Inspection Refusal Process



5- Maintenance Period

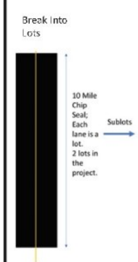
- Contractor maintains chip seal project for one year
- Contractor is responsible for the removal of excess materials
- ODOT arranges final inspection

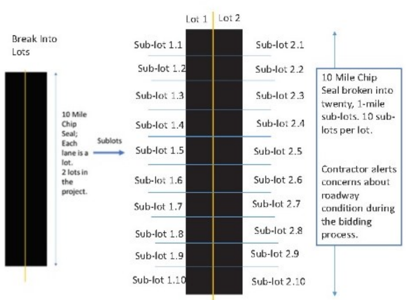
Chip Seal Process ⇨ 1-Bidding ⇨ 2- Design ⇨ 3- Construction ⇨ 4- Initial Inspection ⇨ 5- Maintenance ⇨ 6-Final Acceptance

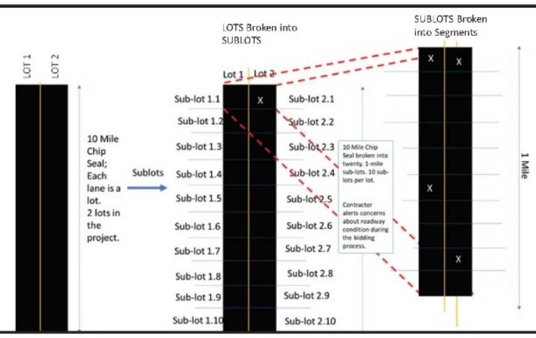
6- Final Inspection

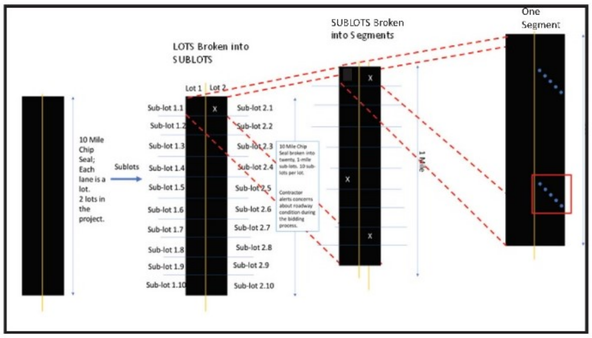
- ODOT conducts final field inspection
- Contractor performs performance testing
  - Macro texture testing at one-year post construction
  - Sand circle test

Chip Seal Process ⇨ 1-Bidding ⇨ 2- Design ⇨ 3- Construction ⇨ 4- Initial Inspection ⇨ 5- Maintenance ⇨ 6-Final Acceptance



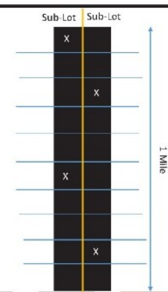






6- Final Inspection

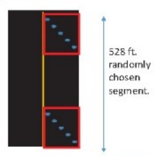
- Performance Testing Scheme:
  - Each 1-mile sub-lot is divided into ten 528 ft segments
- 1-mile sub-lot separated into ten 528 ft. Two segments are randomly selected for sand circle testing. (See "X")



Chip Seal Process → 1-Bidding → 2- Design → 3- Construction → 4- Initial inspection → 5- Maintenance → 6-Final Acceptance

6- Final Inspection

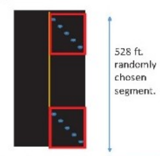
- Performance Testing Scheme:
  - Each 1-mile sub lot is divided into ten 528 ft segments
  - Two segments are randomly selected



Chip Seal Process → 1-Bidding → 2- Design → 3- Construction → 4- Initial inspection → 5- Maintenance → 6-Final Acceptance

6- Final Inspection

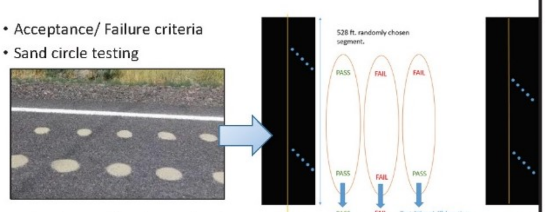
- Performance Testing Scheme:
  - Each 1-mile sub lot is divided into ten 528 ft segments
  - Two segments are randomly selected



Chip Seal Process → 1-Bidding → 2- Design → 3- Construction → 4- Initial inspection → 5- Maintenance → 6-Final Acceptance

6- Final Inspection

- Acceptance/ Failure criteria
- Sand circle testing



Chip Seal Process → 1-Bidding → 2- Design → 3- Construction → 4- Initial inspection → 5- Maintenance → 6-Final Acceptance

MTD Segment Results

$$MTD = \frac{57300}{(Sand\ Circle\ Diameter)^2}$$

Sand Circle Location	Diameter Average	MTD
Between shoulder and the WP Closest to the shoulder	149.0	
In the Wheel Path Closest to the shoulder	152.5	
Between Wheelpaths	140.5	
In the Wheel Path Closest to the Centerline	151.5	
Between centerline and the WP Closest to the centerline	136.0	

MTD Segment Results

$$MTD = \frac{57300}{(Sand\ Circle\ Diameter)^2}$$

Sand Circle Location	Diameter Average	MTD (mm)	Average MTD "X"
Between shoulder and the WP Closest to the shoulder	149.0	2.58	
In the Wheel Path Closest to the shoulder	152.5	2.46	
Between Wheelpaths	140.5	2.90	
In the Wheel Path Closest to the Centerline	151.5	2.50	
Between centerline and the WP Closest to the centerline	136.0	3.10	

MTD Segment Results

$$MTD = \frac{57300}{(Sand\ Circle\ Diameter)^2}$$

Sand Circle Location	Diameter Average	MTD (mm)	Average MTD "X"	Standard Deviation
Between shoulder and the WP Closest to the shoulder	149.0	2.58	2.71	$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2}$
In the Wheel Path Closest to the shoulder	152.5	2.46		
Between Wheelpaths	140.5	2.9		
In the Wheel Path Closest to the Centerline	151.5	2.5		
Between centerline and the WP Closest to the centerline	136.0	3.10		

MTD Segment Results

$$MTD = \frac{57300}{(Sand\ Circle\ Diameter)^2}$$

Sand Circle Location	Diameter Average	MTD (mm)	Average MTD "X"	Standard Deviation
Between shoulder and the WP Closest to the shoulder	149.0	2.58	2.71	$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2}$ 0.25
In the Wheel Path Closest to the shoulder	152.5	2.46		
Between Wheelpaths	140.5	2.9		
In the Wheel Path Closest to the Centerline	151.5	2.5		
Between centerline and the WP Closest to the centerline	136.0	3.10		

Acceptance Criteria

- Texture to be compared with Criteria is:

  X – 0.519*S =

Acceptance Criteria

- Texture to be compared with Criteria is:

  X – 0.519*S = 2.71 – (0.519 *0.25) =

Acceptance Criteria

- Texture to be compared with Criteria is:

  X – 0.519*S = 2.71 – (0.519 *0.25) = **2.58**

ALD (mm)/AADT	200	400	600	1000	1500	2000	4000	6000	10000	12000
5	1.22	1.21	1.21	1.20	1.19	1.18	1.16	1.15	1.14	1.14
6	1.31	1.30	1.29	1.28	1.27	1.26	1.24	1.23	1.22	1.21
7	1.41	1.39	1.38	1.37	1.36	1.35	1.33	1.32	1.30	1.29

6- Final Inspection

- IF final Acceptance is accepted,
  - contractor is paid remaining 30 percent

Chip Seal Process → 1-Bidding → 2- Design → 3- Construction → 4- Initial inspection → 5- Maintenance → 6-Final Acceptance

6- Final Acceptance

- IF 1st final acceptance is rejected
    - Failure of visual inspection
    - Failure of macro texture requirements
  - ODOT provides detailed final inspection report
  - Contractor coordinate with ODOT to make repairs
  - Contractor makes appropriate repairs
  - ODOT re-conducts final field inspection
- IF 2nd final acceptance is accepted,
  - contractor is paid remaining 30 percent

Chip Seal Process → 1-Bidding → 2- Design → 3- Construction → 4- Initial inspection → 5- Maintenance → 6-Final Acceptance

6- Final Acceptance

- IF 2nd final acceptance is rejected,
  - ODOT provides 2nd final inspection report
    - Demonstrates failure of chip seal
  - ODOT decides to either,
    - Fail the job
    - Allow another round of inspection
  - Contractor can file a claim

Chip Seal Process → 1-Bidding → 2- Design → 3- Construction → 4- Initial inspection → 5- Maintenance → 6-Final Acceptance