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APPROPRIATE IMPLEMENTATION OF PAVEMENT PRESERVATION TREATMENTS

Volume 2-Appendices

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16. Abstract This research conducted an extensive literature search of national, state, and industry pavement preservation and rehabilitation centers' libraries for applicable treatment (pavement preservation, rehabilitation, and reconstruction) that New Jersey DOT could use on their high volume state-maintained roads. Reports in PDF format were collected and stored in an Access database to allow easy searches by DOT staff.

A survey of all state DOTs was conducted to determine their use of these treatments. Fourteen states responded. The survey is summarized in volume 2 of this report. Our research partner, Deighton Associates conducted a survey and interviews of the state DOT contacts that use dTIMS PMS software. A review of their PMS database identified what treatments were used, the treatment's trigger, condition reset, life extension and costs. Summary tables are listed in this report.

Based on the literature search and survey results, NJDOT selected seven treatment types that could be used in NJ. These included Fog Seal, Slurry Seal, Micro-Surfacing, Chip Seal, Cold In-place Recycling-Foamed Asphalt, Cold In-place Recycling-Asphalt Emulsion, and Hot In-place Recycling.

Material and construction specifications, test methods (mix design, where applicable) and usage guides were developed. These are provided in volume 2.

This research also summarized the effect of available suppliers and contractors on implementation. Some states limit the use of certain treatments based on the availability of contractors in their state. Demonstration projects which included CIR, FDR, Asphalt Rubber Chip Seal, Slurry Seal and Microsurfacing treatments provided training opportunities for NJDOT staff.

. **Key Words** **Pavement Preservation, Crack Seal, Slurry Seal, Micro-Surfacing, Chip Seal**	**18.** Distribution Statement		
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TABLE OF CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

RESEARCH OBJECTIVES

The objectives of this research study were to:

- Develop a list of appropriate pavement preservation treatments for use on HMA, Composite and PCC pavements on the NJDOT state-maintained road network
- Develop and Implement Pavement Management System inputs for Pavement Preservation Treatments
- Develop NJDOT Specifications for each Pavement Preservation Treatment
- Document the Constraints on Pavement Preservation Treatments on Suppliers and Contractors availability
- Develop and Facilitate Pavement Preservation Treatment Training and Implementation

INTRODUCTION

The research addressed the needs of the NJDOT concerning the development and implementation of pavement preservation treatments' applicability for the state-maintained roads in NJ. The research team explored the various aspects of the pavement preservation treatment topics to summarize the state-of-the-art in the pavement preservation area for the various units within the NJDOT. The research refined the current pavement management system inputs concerning the pavement preservation treatments, developed NJDOT specifications and construction procedure for the various pavement preservation treatments, assessed the effects of constrained availability of pavement preservation treatment material suppliers and contractors on the pavement preservation program and facilitated the training and implementation within New Jersey.

This volume provides the list of reports collected under the literature search, the user manual for the Access database and search tool, the list of Pavement Preservation Centers, the survey instrument used for the National survey, the POC list developed from the survey and the summary of the survey results.

APPENDIX 1 – LIST OF REPORTS IN DIGITAL LIBRARY

The literature seach identified more than 170 reports, presentations, and industry training documents. These were entered into a database that could be searched by source, title, author, traffic volume, pavement preservation type, and keywords.

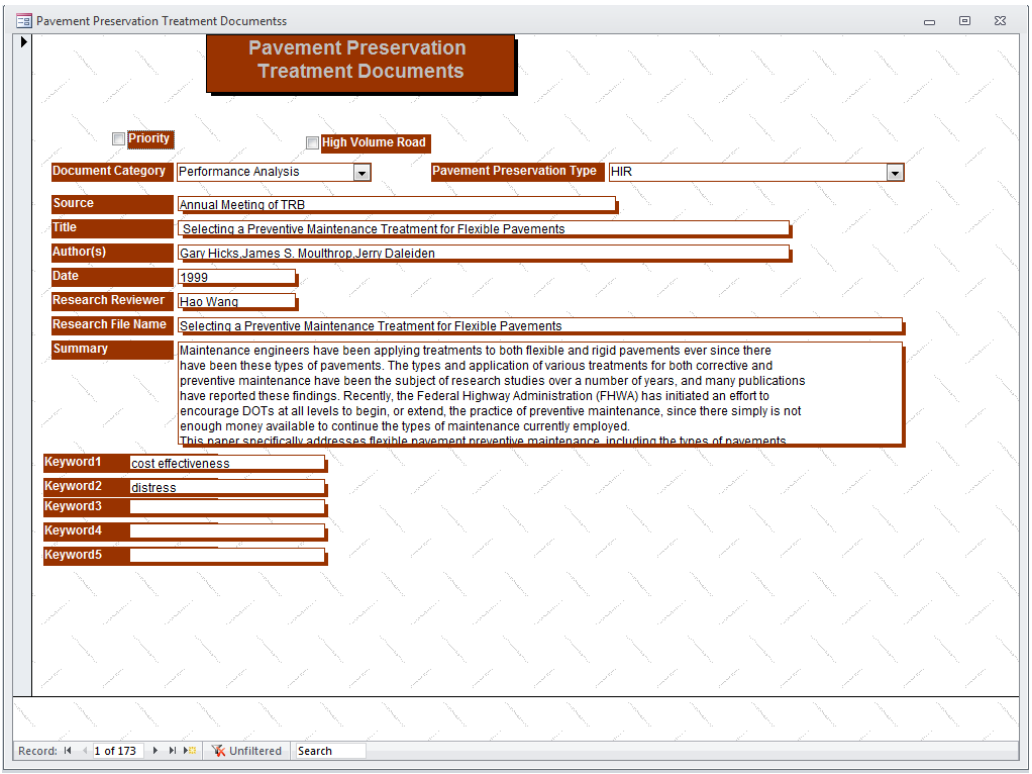


Figure 1. Input Form of Pavement Preservation Treatment Documents Database

The following is the user manual developed for data entry and search of the reports collected.

Rutgers The State University of New Jersey

Pavement Preservation Treatments Database

User Manual

Pavement Preservation Treatments –
Database

The ‘Pavement Preservation Treatment Document’ will contain the summary information from the documents that were found. The ‘Document Category Type’ table will classify the documents based on the types shown below:

Document_Category_Type
All
Construction Specification
General
Material & Construction Specification
Material Specification
Material, Construction & Mix Design
Mix Design
Performance Analysis

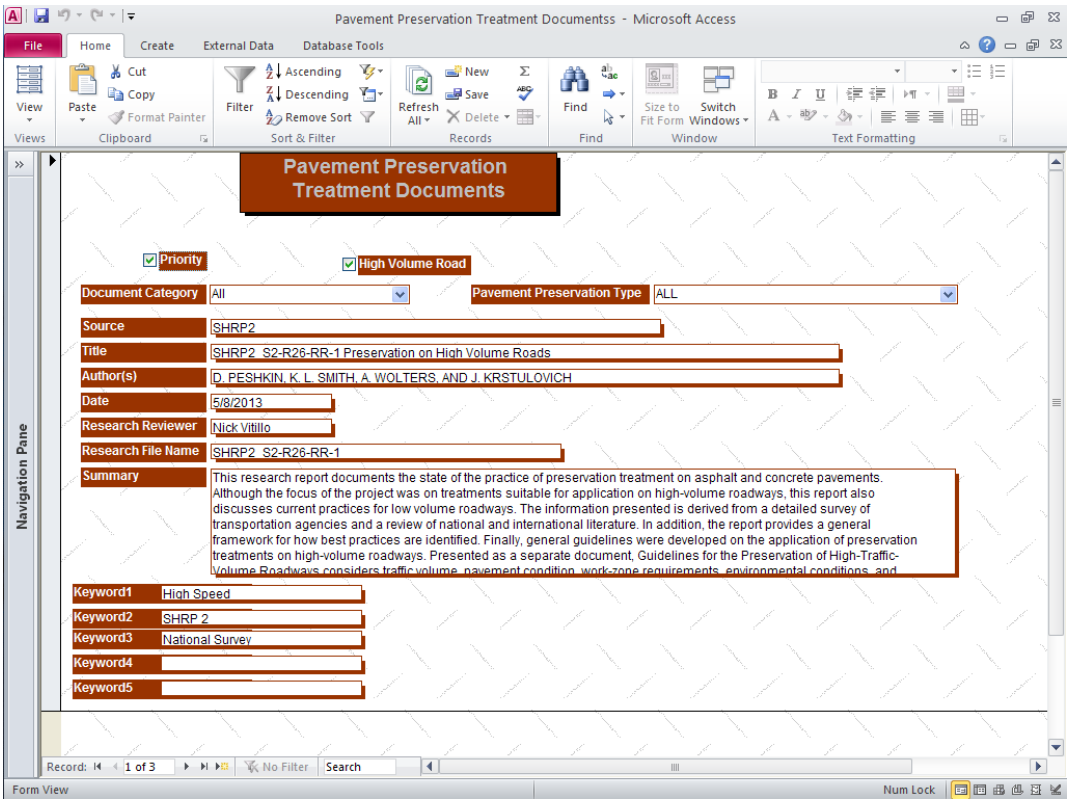
These are the basis of a pull-down list on the form which will fill-in the Document Category Type field. Additional categories can be added to the list by adding more entries in this table.

The ‘PPTreatmentTypes’ table will classify the documents based on the treatment type(s) cited in the document. The ‘PPTreatmentTypes’ are shown below:

PPTreatmentType	
ALL	Joint Sealing
Asphalt Binder	Microsurfacing
Cape Seal	Novachip
Chip Seal	Partial-Depth Repair of PCC
CIR	Profile Milling
Composite Pavement Systems	Recycling
Crack Seal	Scrub Seal
Diamond Grinding	Scrub Seal
Dowel Bar Retrofit	Slurry Seal
FDR	Thin HMA Overlay
Fog Seal	Thin Overlay
Full-Depth Repair of PCC	Ultra-thin Bonded Overlay
HIR	Ultra-thin HMA Overlay

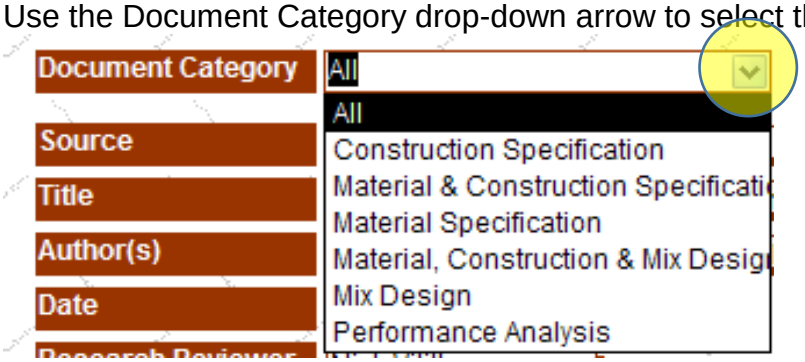
These are the basis of a pull-down list on the form which will fill-in the Pavement Preservation Type field. Additional categories can be added to the list by adding more entries in this table.

Open the Access Database. Under Forms choose ‘Pavement Preservation Treatment Documents’. The following form opens.

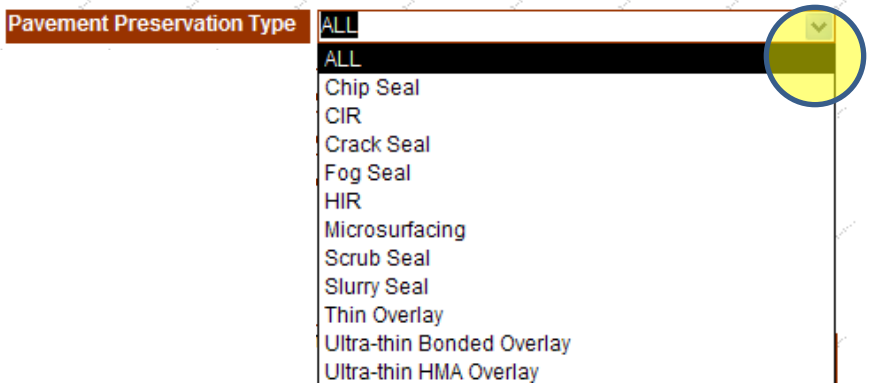


Use the ‘Priority’ field to identify reports that you feel merit immediate attention. Use the ‘High Volume Road’ field to indicate reports where treatments were used or designed for High Volume Roads.

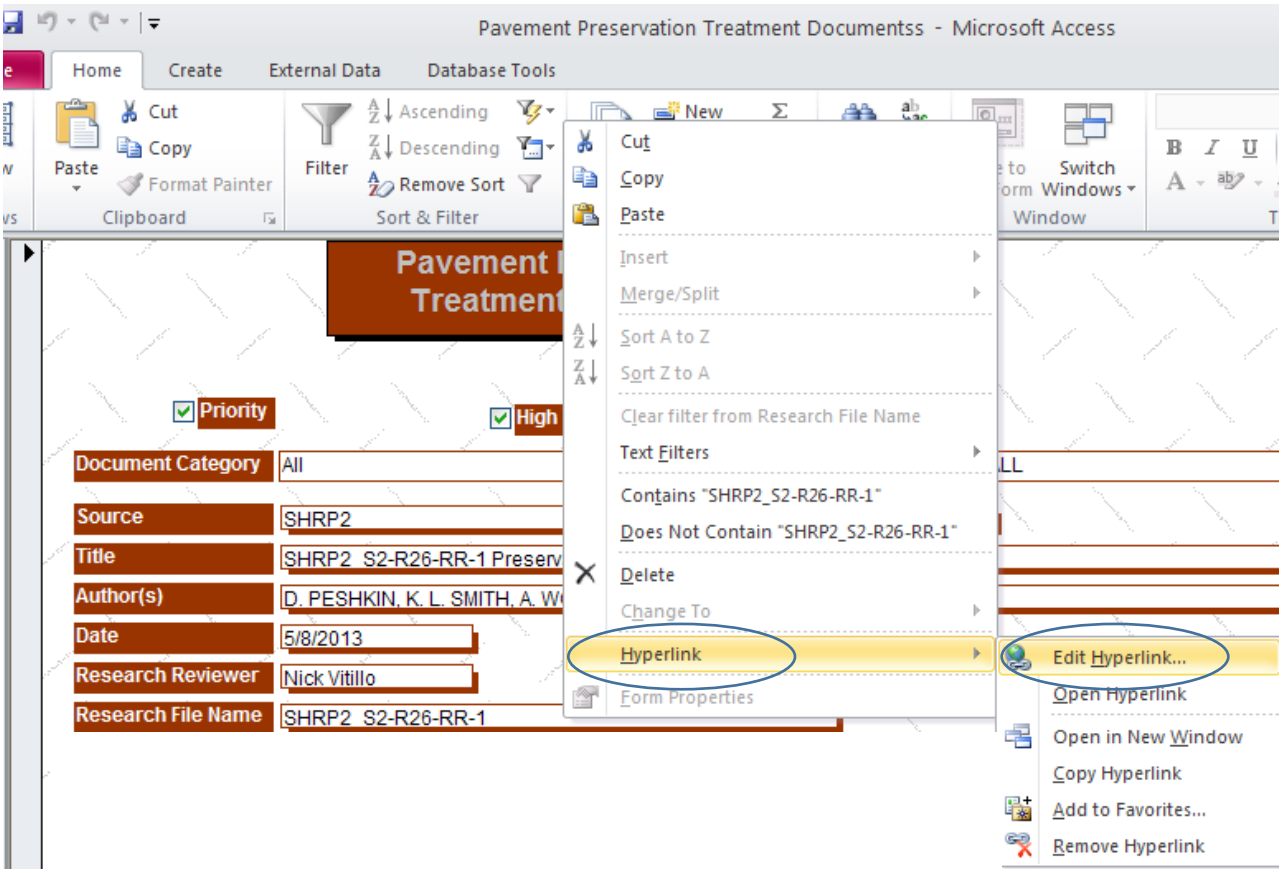
Use the Document Category drop-down arrow to select the type of document.



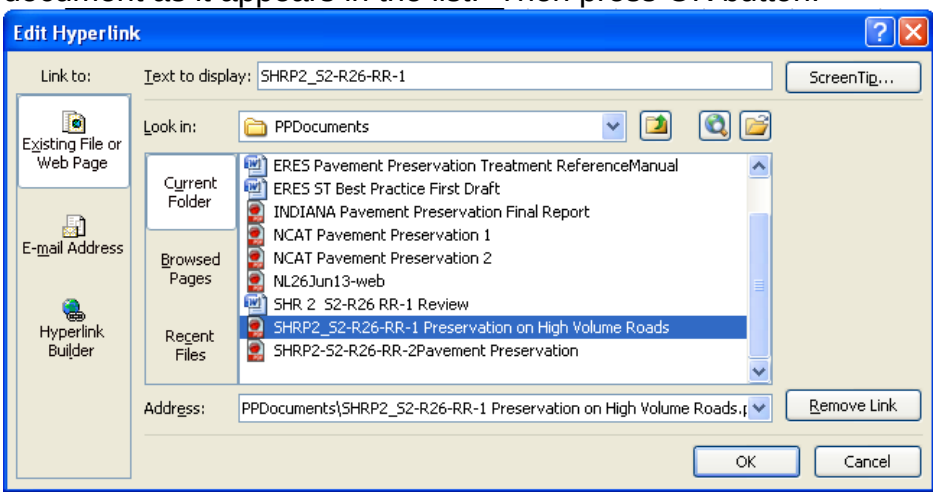
Use the Pavement Preservation drop-down arrow to select the type of pavement preservation(s) discussed in the document.



The ‘Source’ field identifies where the document was found. The ‘Title’ field is the title of the document. The ‘Authors’ field identifies who wrote the document. The ‘Date’ field identifies the year when the document was written. The ‘Research Reviewer’ field identifies which of the CAIT-Deighton staff found the document.
The ‘Research File Name’ field identifies the file name used to store the document in the PPDocument folder. All PDF files are saved in the Pavement Management unit shared drive folder:
S:\Pavetech\Pavement Preservation\Pavement Preservation Treatments\PPDoucuments
The file name MUST NOT have any spaces between the words in the file name. Use underscore characters (_) between words. This is a hyperlink field. Right click on the field box on the form and choose hyperlink – Edit Hyperlink.



In the Edit Hyperlink Box, select the PPDocuments folder and the name of the document as it appears in the list. Then press OK button.

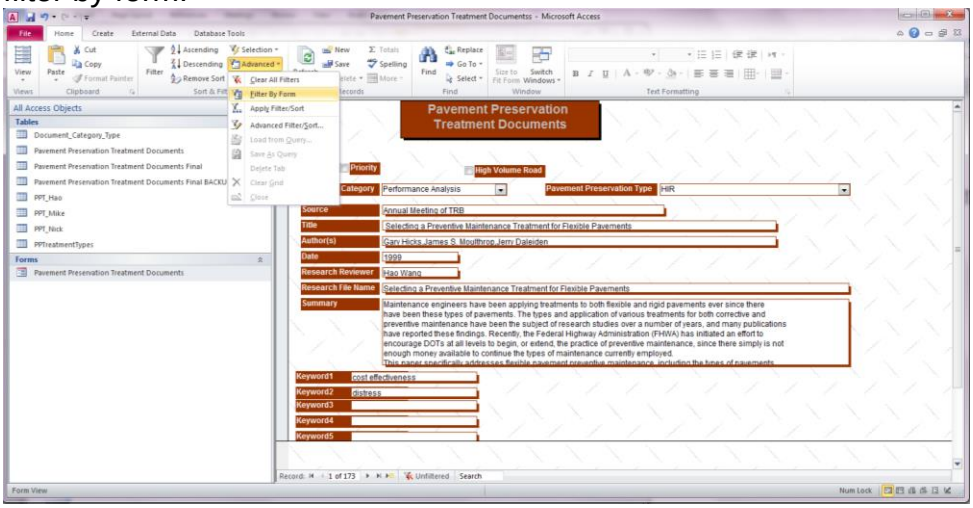


The name of the document will be copied into the Research File Name field. After you save the record, you can point to the Research File Name, the cursor will change to a pointing hand and when you click it, the document will be retrieved for review. Closing the document, will return to the database.

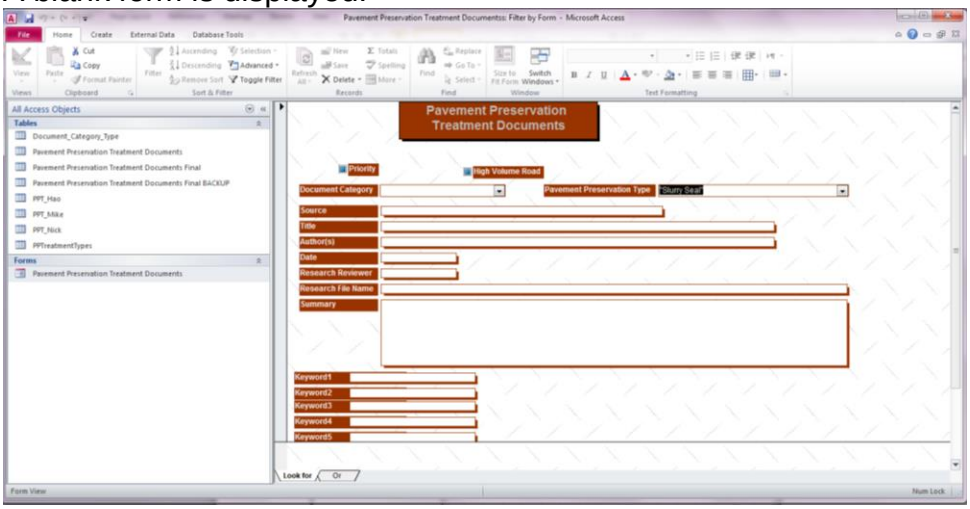
The ‘Summary’ field provides a memo field to summarize the contents of the document. The ‘Keyword’ fields provide information that can be used as search criteria when the database has hundreds of records. Many papers have keywords that can be inserted in these fields.

Searching the Database

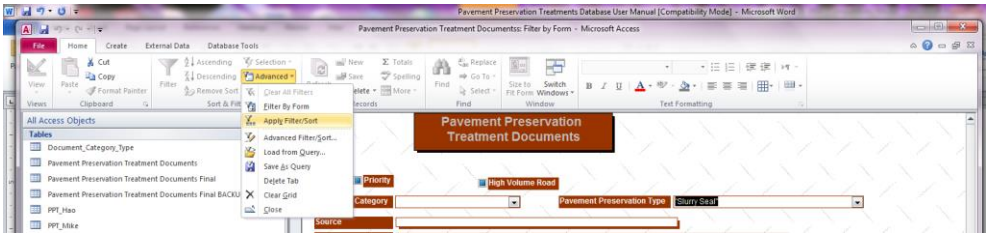
To facilitate finding documents that meet your specific interest, use the advanced filter, filter by form.

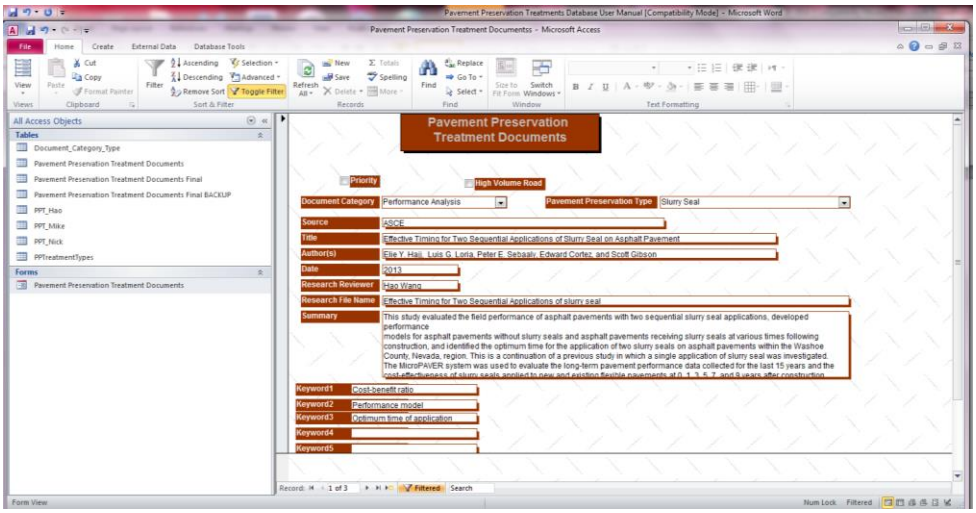


A blank form is displayed.



To find documents that refer to a particular Pavement Preservation Treatment Type, such as “Slurry Seal”, select Slurry Seal from the drop down menu and then choose “Apply Filter/Sort”





The three documents that refer to “Slurry Seals” are identified in the filtered list. Each paper can be opened, read, and printed by selecting the “Research File Name” field.
The database can be toggled between the full list and the filtered list.
The filter can be removed by selecting “Clear All Filters” from the advanced filter menu.

Table 1 List of Report collected in the Literature Search

Pavement Preservation Document List				
PPTreatmentType	Source	Title	Author(s)	Document Category
ALL	California Pavement Preservation Center	improving_Pavement Preservation Treatment Selection using expert_system_approach	Gary Hicks, DingXin Cheng	General
ALL	National Pavement Preservation Center	Indiana Pavement Preservation Program	Ghim Ping (Raymond) Ong	General
ALL	California Pavement Preservation Center	MAINTENANCE TECHNICAL ADVISORY Guide GUIDE	Caltrans	General
ALL	Texas A&M Transportation Institute	Methodology for Developing Performance-related Specs for Pavement Preservation	Litao Liu	Material & Construction Specification
ALL	AASHTO	Consideration of Pavement Preservation in Mechanistic-Empirical Design and Analysis of Pavement Structures	David G. Peshkin, P.E.,Linda M. Pierce, P.E., Ph.D. James M. Krstulovich, Jr.	Mix Design
ALL	Minnesota T2/LTAP Program	Best Practices Handbook on Asphalt Pavement Maintenance	Ann M. Johnson, P.E.	Material, Construction & Mix Design
ALL	Airfield Asphalt Pavement Technology Program	GUIDE FOR PREVENTION AND MITIGATION OF NON-LOAD-ASSOCIATED DISTRESS	1. Monte Symons 2. Gregory Cline 3. Jeffrey L. Rapol 4. John D'Angelo 5. Mike DeVoy	Material, Construction & Mix Design
ALL	TRB Annual Meeting	Cost Benefit Analysis of Thin Surface Treatments in Pavement Cost Benefit Analysis of Thin Surface Treatments in Pavement Treatment Strategies & Cycle Maintenance	DENNIS MORIAN,GUANGMING WANG,DOUG FRITH	Performance Analysis

PPTreatmentType	Source	Title	Author(s)	Document Category
ALL	TRB 2012 Annual Meeting	Estimating Optimum Timings for Maintenance Treatments to Alleviate Pavement Surface Rutting	Monther B. Dwaikat,Syed Waqar Haider	Performance Analysis
ALL	TRB 2003 Annual Meeting CD-ROM	A Pavement Management Perspective on Integrating Preventive Maintenance into A Payment Management System	Kathryn A. Zimmerman,David G. Peshkin	All
ALL	Journal of Performance of Constructed Facilities	Costs and Effectiveness of Flexible Pavement Treatments: Experience and Evidence	Yuhong Wang,George Wang,Neil Mastin	Performance Analysis
ALL	TRANSPORTATION RESEARCH RECORD	Effectiveness of Maintenance Treatments of Flexible Pavements	AHMED A. ELTAHAN, JEROME F. DALEIDEN, AND AMY L. SIMPSON	Performance Analysis
ALL	JOURNAL OF PERFORMANCE OF CONSTRUCTED FACILITIES	Effectiveness of Preventative Maintenance Treatments Using Fourteen SPS-3 Sites in Texas	Dar-Hao Chen,Deng-Fong Lin,Huan-Lin Luo	Performance Analysis
ALL	1st International Conference on Preservation	Energy Usage and Greenhouse Gas Emissions of Pavement Preservation Processes for Asphalt Concrete Pavements	Jim Chehovits,Larry Galehouse	All
ALL	Illinois Center for Transportation	EVALUATION OF HMA OVERLAYS IN ILLINOIS	Angela S. Wolters,Todd E. Hoerner,Kurt D. Smith	All
ALL	TRB 2012 Annual Meeting	Impact of Climate Conditions on the Effectiveness of Asphalt Pavement Preservation Techniques	Yuhong Wang, George Wang, Yong Han Ahn	Performance Analysis

PPTreatmentType	Source	Title	Author(s)	Document Category
ALL	FHWA	Indiana Pavement Preservation Program	Ghim Ping (Raymond) Ong, Tommy E. Nantung,Kumares C. Sinha	All
ALL	JOURNAL OF TRANSPORTATION ENGINEERING	Measures of Short-Term Effectiveness of Highway Pavement Maintenance	Samuel Labi and Kumares C. Sinha	Performance Analysis
ALL	TRB 2003 Annual Meeting CD-ROM	Life-Cycle Evaluation of Flexible Pavement Preventive Maintenance	Samuel Labi,Kumares C. Sinha	Performance Analysis
ALL	NCHRP	Resource Allocation Logic Framework to Meet Highway Asset Preservation	John Wiegmann,Balaji Yelchuru	Material, Construction & Mix Design
ALL	NCHRP	LTPP Data Analysis: Effectiveness of Maintenance and Rehabilitation Options	Kathleen T. Hall,Carlos E. Correa,Amy L. Simpson	Performance Analysis
ALL	FHWA	Impact of Design Features on Pavement Response and Performance in Rehabilitated Flexible and Rigid Pavements	R. Carvalho, M. Ayres, H. Shirazi, O. Selezneva, and M. Darter	All
ALL	FHWA	Maintaining Flexible Pavements - The Long Term Pavement Performance Experiment SPS-3 5-Year Data Analysis	D.A. Morian, S.D. Gibson, I.A. Epps	All
ALL	SHRP2	Preservation on High Volume Roads	D. PESHKIN, K. L. SMITH, A. WOLTERS, AND J. KRSTULOVICH	All
ALL	Naval Facilities Engineering Command	EVALUATION OF A CORROSION CONTROL MATERIAL FOR ASPHALT PRESERVATION OF DOD AIRFIELD PAVEMENTS	G.D. Cline	Material, Construction & Mix Design

PPTreatmentType	Source	Title	Author(s)	Document Category
ALL	FHWA	Performance Evaluation of Various Rehabilitation and Preservation Treatments	Zheng Wu, Jonathan L. Groeger, Amy L. Simpson, R. Gary Hicks	All
ALL	International Conference on Pavement Preservation	Rational Procedures for Evaluating the Effectiveness of Pavement Preservation Treatments	David K. Hein,Shreenath Rao	Performance Analysis
ALL	SHRP	SHRP-LTPP Monitoring Data: Five-Year Report	Gonzalo R. Rada	All
ALL	International Conference on Pavement Preservation	Statistical Analysis of LTPP SPS-3 Experiment on Preventive Maintenance of Flexible Pavements	Hamid Shirazi,Regis L. Carvalho,Manuel Ayres Jr,Olga Selezneva	Performance Analysis
ALL	6th International Conference on Managing Pavements	Supporting Preventive Maintenance with Pavement Management	Kathryn A. Zimmerman and David G. Peshkin	Material, Construction & Mix Design
ALL	ASCE	Analytical Framework for Optimizing Pavement Maintenance	James V. Carnahan	Material, Construction & Mix Design
ALL	ASCE	Characterizing Stability of Asphalt Emulsions Using Electrokinetic Techniques	Ambarish Banerjee, Amit Bhasin, and Jorge Prozzi	Mix Design
ALL	ASCE	Cost-Effectiveness Analyses of Maintenance Treatments for Low- and Moderate-Traffic Asphalt Pavements in Tennessee	Qiao Dong, Baoshan Huang, Stephen H. Richards and Xuedong Yan	Performance Analysis

PPTreatmentType	Source	Title	Author(s)	Document Category
ALL	JOURNAL OF COMPUTING IN CIVIL ENGINEERING	Decision-Support System for Infrastructure Preservation	Yung-Ching Shen and Dimitri A. Grivas	Material Specification
ALL	ASCE	Estimating Optimum Timings for Treatments on Flexible Pavements with Surface Rutting	Syed Waqar Haider and Monther B. Dwaikat	Performance Analysis
ALL	ASCE	Leveling Process of Annual Budgetary Requirements for Pavement Preservation	Yoojung Yoon, Hiral Shah, Makarand Hastak, Jusang Lee	Material, Construction & Mix Design
ALL	ASCE	Life-Cycle Optimization of Pavement Overlay Systems	Han Zhang, Ph.D.1; Gregory A. Keoleian2; Michael D. Lepech3; and Alissa Kendall4	All
ALL	ASCE	Mechanistic-Empirical and Life-Cycle Cost Analysis for Optimizing Flexible Pavement Maintenance and Rehabilitation	Venkata Mandapaka, Imad Basheer, Khushminder Sahasi, Per Ullidtz, John T. Harvey, and N. Sivaneswaran	All
ALL	ASCE	Multiobjective Pavement-Preservation Decision Making with Simulated Constraint Boundary Programming	Pan Lu and Denver Tolliver	All
ALL	ASCE	On Improving System Wide Sustainability in Pavement Preservation Programming	Panagiotis Ch. Anastasopoulos,John E. Haddock, Srinivas Peeta	Construction Specification

PPTreatmentType	Source	Title	Author(s)	Document Category
ALL	ASCE	Pavement Preservation Optimization Considering Multiple Objectives and Budget Variability	Zheng Wu and Gerardo W. Flintsch	All
ALL	TRB	Preservation Strategies for Flexible Pavement Network of Washington State Department of Transportation	David R. Luhr, Jianhua Li, Jeffrey S. Uhlmeyer, and Joe P. Mahoney	All
ALL	TRB	Probabilistic Approach to Life-Cycle Cost Analysis of Preventive Maintenance Strategies on Flexible Pavements	John T. Harvey, Arash Rezaei, and Charles Lee	Material, Construction & Mix Design
ALL	Delaware Center for Transportation	Thin Overlay Maintenance Treatment Application in Delaware Communities	NII ATTOH-OKINE, HONG JOON PARK	Material & Construction Specification
ALL	ASCE	Use of Knowledge Graphs to Formalize Decisions in Preserving Pavements	Yung-Ching Shen, and Dimitri A. Grivas	Construction Specification
ALL	Montana Department of Transportation	PREVENTIVE MAINTENANCE TREATMENTS OF FLEXIBLE PAVEMENTS: a SYNTHESIS OF HIGHWAY PRACTICE	Eli Cuelho Robert Mokwa Michelle Akin	Performance Analysis
ALL	WSDOT	WSDOT Pavement Preservation Guide for Local Agencies	George White	Other
ALL	NCHRP	PAVEMENT PRESERVATION: PRACTICES, RESEARCH PLANS, AND INITIATIVES	D.G. Peshkin and T.E. Hoerner	General
ALL	FHWA	Pavement Preservation Compendium II	FHWA David R. Geiger, P.E.	General

PPTreatmentType	Source	Title	Author(s)	Document Category
ALL	FHWA	Pavement Preservation Technology In France, South Africa, And Australia	Tommy L. Beatty, Dennis C. Jackson, Dan A. Dawood,	All
ALL	FHWA	Performance Evaluation of Various Rehabilitation and Preservation Treatments	Zheng Wu, Ph.D., P.E., Jonathan L. Groeger, Amy L. Simpson, Ph.D., P.E., R. Gary Hicks, Ph.D., P.E.	Performance Analysis
ALL	National Center for Pavement Preservation	Preventive Maintenance Treatment Performance at 14 Years	Larry Galehouse, Helen King, David R. Leach, Jim Moulthrop, Bill Ballou	Performance Analysis
ALL		PREVENTIVE MAINTENANCE TREATMENTS OF FLEXIBLE PAVEMENTS: a SYNTHESIS OF HIGHWAY PRACTICE	Eli Cuelho, Robert Mokwa, Michelle Akin	Performance Analysis
ALL	SHRP2	SHRP2_S2-R26-RR-1 Preservation on High Volume Roads	D. PESHKIN, K. L. SMITH, A. WOLTERS, AND J. KRSTULOVICH	General
ALL	SHRP2	Select Proven Preservation Techniques to Treat High-Volume Roads	D. PESHKIN, K. L. SMITH, A. WOLTERS, AND J. KRSTULOVICH	General
ALL	SHRP2	Preservation Approaches for High-Traffic-Volume Roadways	D. PESHKIN, K. L. SMITH, A. WOLTERS, AND J. KRSTULOVICH, J. MOULTHROP AND C. ALVARADO	General
ALL	SHRP2	Preservation Approaches for High-Traffic-Volume Roadways REPORT S2-R26-RR-1	D. PESHKIN, K. L. SMITH, A. WOLTERS, AND J. KRSTULOVICH	General

PPTreatmentType	Source	Title	Author(s)	Document Category
ALL		Guidelines for the Preservation of High-Traffic-Volume Roadways	D. PESHKIN, K. L. SMITH, A. WOLTERS, AND J. KRSTULOVICH, J. MOULTHROP AND C. ALVARADO	All
ALL	National Pavement Preservation Center	REFERENCE MANUAL OF PAVEMENT PRESERVATION TREATMENTS	Jerry Hajek, Campbell Chow, Chris Olidis, Gerard R. Pelletier, John Sansom, David K. Hein	General
ALL	FHWA	Pavement Preservationn Toolbox	Steve Mueller	All
ALL	FHWA	FHWA Resource Center Pavement and Materials Contact	FHWA	All
ALL	Airfield Asphalt Pavement Technology Program	GUIDE FOR PREVENTION AND MITIGATION OF NON-LOAD-ASSOCIATED DISTRESS GUIDE FOR PREVENTION AND MITIGATION OF NON-LOAD-ASSOCIATED DISTRESS	AMEC Earth and Environmental, Inc.	General
ALL	Asphalt Recycling and Reclaiming Association (ARRA	Basic Asphalt Recycling Manua - part 1	Asphalt Recycling and Reclaiming Association (ARRA)	All
ALL	Asphalt Recycling and Reclaiming Association (ARRA	Basic Asphalt Recycling Manua - part 2	Asphalt Recycling and Reclaiming Association (ARRA)	All

PPTreatmentType	Source	Title	Author(s)	Document Category
ALL	Asphalt Recycling and Reclaiming Association (ARRA	Basic Asphalt Recycling Manua - part 3	Asphalt Recycling and Reclaiming Association (ARRA)	All
Asphalt Binder	Minnesota DOT	SBR and Natural Rubber Latex-Modified Emulsions for Micro Surfacing	Chris Lubbers, Erland Lukanen, P.E.	Performance Analysis
Binders	Texas Department of Transportation	REVISION AND FURTHER VALIDATION OF SURFACE-PERFORMANCE GRADED SPECIFICATION FOR SURFACE TREATMENT BINDERS	Aishwarya Vijaykumar, Edith Arambula, Thomas J. Freeman	General
Cape Seal	CENTER FOR TRANSPORTATION RESEARCH	EVALUATION OF THE CAPE SEAL PROCESS AS A PAVEMENT REHABILITATION ALTERNATIVE	Mansour Solaimanian and Thomas W. Kennedy	Material, Construction & Mix Design
Cape Seal		CAPE SEAL SPECIFICATIONS		Material & Construction Specification
Chip Seal	South Dakota Department of Transportation	High Volume-High Speed Asphalt Roadway Preventive Maintenance Surface Treatments	Monty Wade, Rachel DeSombre, David Peshkin	Performance Analysis
Chip Seal	National Pavement Preservation Center	HOT CHIP SEAL SPECIFICATIONS		Material & Construction Specification
Chip Seal	Louisiana Transportation Research Center	Evaluation of Louisiana's Maintenance Chip Seal and Micro-Surfacing Program	Erat S. Joseph and Shashikant C. Shah	Performance Analysis

PPTreatmentType	Source	Title	Author(s)	Document Category
Chip Seal	Texas Department of Transportation	Seal Coat and Surface Treatment Manual	Zane L. Webb, P.E.	Material, Construction & Mix Design
Chip Seal	NCHRP	Manual for Emulsion-Based Chip Seals for Pavement Preservation	Scott Shuler,Anthony Lord,Amy Epps-Martin,Denise Hoyt	Material, Construction & Mix Design
Chip Seal	CENTER FOR TRANSPORTATION RESEARCH,Texas	Evaluation of the Cape Seal Process as a Pavement Rehabilitation Alternative	Mansour Solaimanian and Thomas W. Kennedy	Material, Construction & Mix Design
Chip Seal	TRB Maintenance Management Conference	Improvements in Asphalt Rubber Chip Seal Application with Warm-Mix Technology	Cheng, DingXin;Lane, Lerose;Hicks, R Gary	Material, Construction & Mix Design
Chip Seal	Transportation Research Record	Aggregate Retention in Chip Seal	Farhana Rahman, M. Shahidul Islam, Haritha Musty, and Mustaque Hossain	Material, Construction & Mix Design
Chip Seal	TRB	Chip Seal with Lightweight Aggregates for Low-Volume Roads	Md Shahidul Islam and Mustaque Hossain	Performance Analysis
Chip Seal	California Pavement Preservation Center	Los Angeles County Department of Public Works Asphalt Rubber Chip Seal with Warm Mix Additive Demonstration Project	Dragos Andrei, Erik Updyke, R Gary Hicks, Ding Cheng	All
Chip Seal	NCHRP	NCHRP REPORT 680 Manual for Emulsion-Based Chip Seals for Pavement Preservation	Scott Shuler, Anthony Lord	General

PPTreatmentType	Source	Title	Author(s)	Document Category
Chip Seal	NCHRP	SYNTHESIS 342 Chip Seal Best Practices	DOUGLAS GRANSBERG, DAVID M.B. JAMES	General
Chip Seal	FHWA Resource Centers	Chip Seal Application Checklist	FHWA	General
Chip Seal		CHIP SEAL SPECIFICATIONS		Material & Construction Specification
Chip Seal	California Pavement Preservation Center	SPECIFICATIONS FOR POLYMER MODIFIED ASPHALT CHIP SEAL		Material & Construction Specification
Chip Seal	Ohio Department of Transportation	EFFECTIVENESS OF CHIP SEALING AND MICRO SURFACING ON PAVEMENT SERVICEABILITY AND LIFE	Arudi Rajagopal, Ph.D.	Performance Analysis
Chip Seal	ASCE	Analysis of Emulsion and Hot Asphalt Cement Chip Seal Performance	Douglas D. Gransberg, M.ASCE,1 and Musharraf Zaman, M.ASCE2	Performance Analysis
Chip Seal	California Department of Transportation	CHAPTER 5 CHIP SEALS	California Department of Transportation	Material & Construction Specification
Chip Seal	FHWA LTAP	Chip Seal Video Part 1	FHWA LTAP	General

PPTreatmentType	Source	Title	Author(s)	Document Category
Chip Seal	FHWA LTAP	Chip Seal Video Part 2	FHWA LTAP	General
Chip Seal	FHWA LTAP	Chip Seal Video Part 3	FHWA LTAP	General
Chip Seal	CaliforniaPavementPreservationCenter	I-5 Fresno AR Chip Seal Project with Warm Mix Additives	Lerose Lane, R. Gary Hicks, and DingXin Cheng,	Performance Analysis
Chip Seal	Texas Pavement Preservation Center	DOUBLE CHIP SEAL SPECIFICATIONS	TexasDOT	Material & Construction Specification
CIR	Kansas Department of Transportation	EVALUATION OF COLD IN-PLACE RECYCLING	Stephen A. Cross and Bala M. Ramaya	Performance Analysis
CIR	Transportation Research Board	Performance-Related Tests and Specifications for Cold In-Place Recycling: Lab and Field Experience	Todd Thomas, Arlis Kadrmas	Material Specification
CIR	CaliforniaPavementPreservationCenter	I-5 Fresno AR Chip Seal Project with Warm Mix Additives	Lerose Lane, R. Gary Hicks, and DingXin Cheng	Performance Analysis
CIR		Cold In-Place Asphalt Recycling Application Checklist	FHWA	General
CIR	National Pavement Preservation Center	Evaluation of Rehabilitation Techniques for Flexible Pavements in Nevada	Peter Sebaaly	Performance Analysis

PPTreatmentType	Source	Title	Author(s)	Document Category
CIR	National Pavement Preservation Center	EVALUATION OF COLD IN-PLACE RECYCLED MIXTURES ON US-283	Stephen A. Cross	Performance Analysis
Composite Pavement Systems	SHRP2	Composite Pavement Systems HMA/PCC Composite Pavements	Shreenath Rao, Michael Darter, Derek Tompkins, Mary Vancura, and Lev Khazanovich, Jim Signore, Erdem Coleri, Rongzong Wu, and John Harvey, Julie Vandenbossche	General
Concrete Patch	ASCE	Improved Repair of Concrete Structures Using Polymer Concrete Patch and FRP Overlay	Goli Nossoni and Ronald S. Harichandran	Performance Analysis
continuously reinforced concrete	ASCE	Precast Repair of CMC Pavement	Alvin H. Meyer and B. F. McCullough	Construction Specification
Crack Seal	Canadian Journal of Civil Engineering	Field performance comparison of asphalt crackfilling materials: hot pour versus cold pour	Yetkin Yildirim	Performance Analysis
Crack Seal	Center for Transportation Research	Field Manual for Crack Sealing in Asphalt Pavements	Yetkin Yildirim, Ahmed Qatan, and Jorge Prozzi	Material, Construction & Mix Design
Crack Seal	Texas Department of Transportation	Performance Comparison of Hot Rubber Crack Sealants to Emulsified Asphalt Crack Sealants	Yetkin Yildirim, Armagan Korkmaz, and Jorge Prozzi	Performance Analysis
Crack Seal	Louisiana Department of Transportation	Cost Effective Prevention of Reflective Cracking of Composite Pavement	Mostafa Elseifi, Ph.D., and Rakesh Bandaru	Performance Analysis

PPTreatmentType	Source	Title	Author(s)	Document Category
Crack Seal	KANSAS DEPARTMENT OF TRANSPORTATION	CRACK SEALING AND REPAIR OF OLDER SERVICEABLE BRIDGES USING POLYMER SEALERS	DAVID A. MEGGERS	Performance Analysis
Crack Seal	Connecticut Transportation Institute	Evaluation of Pavement Crack Treatments Literature Review	Scott Zinke,Brian Hogge,Chris O'Brien,James Mahoney	Material & Construction Specification
Crack Seal	TRB Annual Meeting CD-ROM	Potential Benefits of Integrating Preventive Maintenance into New Jersey Pavement Management System	Khaled Helali,Hudson Jackson,Sameh Zaghloul,Wael Bekheet,Andris A. Jumikis	Material & Construction Specification
Crack Seal	Journal of Transportation Engineering	COST-EFFECTIVENESS OF JOINT AND CRACK SEALING: SYNTHESIS OF PRACTICE	Adam J. Hand,1 P.E., Khaled A. Galal,2 David R. Ward,3 P.E., and Chuanxin Fang4	Material, Construction & Mix Design
Crack Seal	FHWA Resource Centers	Crack Seal Application Checklist	FHWA	General
Crack Seal	FHWA Resource Centers	Joint Sealing Portland Cement Concrete Pavements	FHWA	General
DIAMOND GRINDING	Caltrans Division of Maintenance	CHAPTER 5 Diamond Grindingand Grooving		All
Diamond Grinding	Caltrans	THE EFFECTIVENESS OF DIAMOND GRINDING CONCRETE PAVEMENTS IN CALIFORNIA	Richard Stubstad Michael Darter Chetana Rao Tom Pyle Walid Tabet	Performance Analysis

PPTreatmentType	Source	Title	Author(s)	Document Category
Diamond Grinding	FHWA Resource Centers	Diamond Grinding of Portland Cement Concrete Pavements Checklist	FHWA	General
Diamond Grinding	Ohio Research Institute for Transportation and the	Effectiveness of Tire/Road Noise Abatement through Surface Retexturing by Diamond Grinding for Project SUM-76-15.40	Lloyd A. Herman, Jared M. Withers	Performance Analysis
Diamond Grinding	FHWA LTAP	Concrete Pavement Rehabilitation – Concrete Pavement Rehabilitation –Guide for Diamond Grinding	Angel L. Correa, (404)562-3907, Angel.Correa@fhwa.dot.gov, dot.gov Bing Wong, (202)366-2169, Bing.Wong@fhwa.dot.gov Bing Wong, (202)366-2169, Bing.Wong@fhwa.dot.gov	General
Dowel Bar Retrofit	California DOT	Dowel Bar Retrofit Evaluation	Doran Glauz	Performance Analysis
Drainage	Louisiana Transportation Research Center	Effect of Drainage in Unbound Aggregate Bases on Flexible Pavement Performance	Mingjiang Tao, Ph.D., P.E., and Murad Y. Abu-Farsakh, Ph.D., P.E.	Material, Construction & Mix Design
FDR	Texas Transportation Institute	FULL-DEPTH RECLAMATION: NEW TEST PROCEDURES AND RECOMMENDED UPDATES TO SPECIFICATIONS	Tom Scullion, Stephen Sebesta, Cindy Estakhri, Pat Harris	Performance Analysis
Fog Seal	National Pavement Preservation Center	POLYMER MODIFIED FOG SEAL		Material & Construction Specification
Fog Seal	Texas Transportation Institute	ANALYZE EXISTING FOG SEAL ASPHALTS AND ADDITIVES: LITERATURE REVIEW	Nikornpon Prapaitrakul, Tom Freeman, and Charles J. Glover	Performance Analysis

PPTreatmentType	Source	Title	Author(s)	Document Category
Fog Seal	Texas Transportation Institute	ASSESSING THE ABILITY OF FOG SEALS TO SEAL PAVEMENTS, TO REJUVENATE IN SITU BINDER, AND TO RETARD BINDER OXIDATION	Nikornpon Prapaitrakul, Thomas J. Freeman, and Charles J. Glover	Performance Analysis
Fog Seal	Texas Pavement Preservation Center	GUIDELINES ON THE USE OF FOG SEALS AND REJUVENATOR SEALS	Charles J. Glover	Material & Construction Specification
Fog Seal	FHWA Resource Centers	Fog Seal Application Checklist	FHWA	General
Fog Seal	California Pavement Preservation Center	Spray Applied Polymer Surface Seals	Jim Sorenson, Gerry Eller, Jim Moulthrop, and Bill O'Leary Moulthrop, and Bill O'Leary	General
Fog Seal	California Pavement Preservation Center	Fog Seals Guidelines	Caltrans	Material & Construction Specification
Full-Depth Repair of PCC	FHWA Resource Centers	Full-Depth Repair of Portland Cement Concrete Pavements Checklist	FHWA	General
HIR	Utah Department of Transportation	Heatwurx Asphalt Pavement Repair Demonstrations on US-89 in Region 3 and on I-84 in Region 2	Ken Berg, P.E.	Performance Analysis
HIR	California Pavement Preservation Center	Hot In-Place Recycling of Polymer Modified Hot In-Place Recycling of Polymer Modified Open Graded HMA Open Graded HMA	Brandon Fraser, Ding Cheng, R. Gary Hicks, and Joel Gasik	Performance Analysis

PPTreatmentType	Source	Title	Author(s)	Document Category
HIR	Annual Meeting of TRB	Selecting a Preventive Maintenance Treatment for Flexible Pavements	Gary Hicks,James S. Moulthrop,Jerry Daleiden	Performance Analysis
HIR	FHWA Resource Centers	Hot In-Place Asphalt Recycling Application Checklist	FHWA	General
HIR	California Pavement Preservation Center	Viability of Hot In-Place Recycling as a Pavement Preservation Strategy	Ronald L. Terrel and R. Gary Hicks	Performance Analysis
HIR	California Department of Transportation	Hot In-Place Recycling of Polymer Modified Open Graded HMA	Brandon Fraser, Ding Cheng, R. Gary Hicks, and Joel Gasik	Performance Analysis
Microsurfacing	Caltrans	Microsurfacing Mix Design	Caltrans	Mix Design
Microsurfacing	NCHRP SYNTHESIS 411	Microsurfacing A Synthesis of Highway Practice	DOUGLAS D. GRANSBERG	Material, Construction & Mix Design
Microsurfacing	International Slurry Surfacing International Slur	Microsurfacing Quality Control	International Slurry Surfacing Association	General
Microsurfacing	Texas Department of Transportation	MICROSURFACING IN TEXAS	Benjamin Broughton and Soon-Jae Lee	Material, Construction & Mix Design
Microsurfacing	JOURNAL OF TRANSPORTATION ENGINEERING	Effectiveness of Microsurfacing Treatments	Samuel Labi; Geoffrey Lamptey; and Siew-Hwee Kong	Performance Analysis
Microsurfacing	NCHRP SYNTHESIS	Microsurfacing A Synthesis of Highway Practice	DOUGLAS D. GRANSBERG	All

PPTreatmentType	Source	Title	Author(s)	Document Category
Microsurfacing	ASCE	Evaluation for Microsurfacing as Pavement Preservation Treatment Preventive Maintenance Treatment to Mitigate Pavement Roughness	Yigong Ji, Tommy Nantung, Bill Tompkins, and Dwayne Harris	Performance Analysis
Microsurfacing	Mid-America Transportation Center	Extending Pavement Life Using Thin Surfacing To Counter the Effect of Increased Truck Traffic Due to Freight Movements on Highways	Mustaque Hossain,Vikranth S. Manepalli,Shaidur Rahman,Haritha Y. Musty	Material, Construction & Mix Design
Microsurfacing	NCAT	NCAT Pavement Preservation Effectiveness Study		Performance Analysis
Microsurfacing	FHWA Resource Centers	Microsurfacing Application Checklist	FHWA	General
Microsurfacing	International Slurry Surfacing Association	Recommended Performance Guidelines For Micro-Surfacing	International Slurry Surfacing Association	Material & Construction Specification
Microsurfacing	Midwestern Pavement Preservation Partnership	Slurry/Microsurfacing Mix Design Pooled Fund Study		Mix Design
Microsurfacing	California Pavement Preservation Center	Thick Microsurfacing		Performance Analysis
Novachip	TRB	Evaluation of Reclaimed Asphalt Pavement Materials from Ultra-Thin 1 Bonded Bituminous Surface	Haritha Musty	Performance Analysis

PPTreatmentType	Source	Title	Author(s)	Document Category
Novachip	PENNSYLVANIA DEPARTMENT OF TRANSPORTATION	CONSTRUCTION AND PERFORMANCE EVALUATION OF NOVACHIP IN PENNSYLVANIA	TED KEITER, P.E.	Performance Analysis
Partial-Depth Repair of PCC	FHWA Resource Centers	Partial-Depth Repair of Portland Cement Concrete Pavements Checklist	FHWA	General
Partial-Depth Repairs	ASCE	Field Evaluations of the Patch Materials for Partial-Depth Repairs	Dar Hao Chen; Moon Won; Qisen Zhang; and Tom Scullion	Performance Analysis
PCC	SHRP	Innovative Materials Development and Testing Volume 5: Partial Depth Spall Repair in Jointed Concrete Pavements	Cynthia A. Good Mojab, Arti J. Patel, A. Russell Romine	All
PCC	ASCE	Rehabilitation of Cracked and Corroded Reinforced Concrete Beams with Fiber-Reinforced Plastic Patches	Chung-Yue Wang; Chien-Chih Shih; Shao-Chih Hong; and Wei-Chih Hwang	All
Recycling	NCHRP	Nchrp_syn_421 Recycling and Reclamation of Asphalt Pavemenets using in-place Methods	MARY STROUP-GARDINER	General
Recycling	SHRP2	Using the Existing Pavement In-Place and Achieving Long Life	Newton Jackson, Joe Mahoney, Jason Puccinelli	General
Recycling	California Department of Transportation	FEASIBILITY OF RECYCLING RUBBER-MODIFIED PAVING MATERIALS	California Department of Transportation	Performance Analysis
Recycling	California Department of Transportation	CHAPTER 13—IN-PLACE RECYCLING	California Department of Transportation	Material & Construction Specification

PPTreatmentType	Source	Title	Author(s)	Document Category
Rigid	ASCE	Behavior of Patch-Repaired Concrete Structural Elements under Increasing Static Loads to Flexural Failure	O. Río, C. Andrade, D. Izquierdo and C. Alonso	All
Slab Jacking	Oregon Department of Transportation	INJECTED POLYURETHANE SLAB JACKING	Steven Soltesz	Performance Analysis
Slurry Seal	National Pavement Preservation Center	Michigan Seal Coat Specification		Material & Construction Specification
Slurry Seal	ASCE	Effective Timing for Two Sequential Applications of Slurry Seal on Asphalt Pavement	Elie Y. Hajj, Luis G. Loria, Peter E. Sebaaly, Edward Cortez, and Scott Gibson	Performance Analysis
Slurry Seal	FHWA Resource Centers	Slurry Seal Application Checklist	FHWA	General
Thin HMA Overlay	FHWA Resource Centers	Thin Hot-Mix Asphalt Overlay Checklist	FHWA	General
Thin HMA Overlay	National Pavement Preservation Center	Preservation of Asphalt Concrete Pavements Using Thin Pavement Surfacings	Dr. Jerry Hajek	General
Thin HMA Overlay	MnROAD	Evaluation of a Polyvinyl Alcohol Fiber Reinforced Engineered Cementitious Composite for a Thin-Bonded Pavement Overlay	Alexandra Akkari	Performance Analysis
Thin HMA Overlay	Texas Pavement Preservation Center	DESIGN AND CONSTRUCTION RECOMMENDATIONS FOR THIN OVERLAYS in Texa	Bryan Wilson, Tom Scullion, and Cindy Estakhri	Material & Construction Specification

PPTreatmentType	Source	Title	Author(s)	Document Category
Thin Overlay	NAPA Education and Research Foundation	THIN HMA OVERLAYS FOR PAVEMENT PRESERVATION AND LOW VOLUME ASPHALT ROADS	E. Ray Brown Michael Heitzman	Material, Construction & Mix Design
Thin Overlay	JOURNAL OF INFRASTRUCTURE SYSTEMS © ASCE	Empirical Modeling of Pavement Overlay Crack Progression with Field Data	Samer Madanat, Ziad Nakat, and Eui-Jae Jin with Field Data	Performance Analysis
Thin Overlay	Texas Department of Transportation	MIX DESIGN, CONSTRUCTION, AND PERFORMANCE OF A THIN HMA OVERLAY ON PUMPHREY DRIVE, FORT WORTH, TX	Fujie Zhou and Tom Scullion	Material, Construction & Mix Design
Ultra-thin Bonded Overlay	Iowa Department of Transportation	ULTRA-THIN PORTLAND CEMENT CONCRETE OVERLAY EXTENDED EVALUATION	James K. Cable, L. E. Edgar, and D. R. Anderson	Performance Analysis
Ultra-thin Bonded Overlay	Minnesota Department of Transportation	Performance of Ultra-Thin Bonded Wearing Course (UTBWC) Surface Treatment on US-169 Princeton, Minnesota	Malaki Musa Ruranika , Jerry Geib	Performance Analysis
	Journal of Transportation Engineering	Lessons Learned on Jointed Concrete Pavement Rehabilitation Strategies in Texas	Dar Hao Chen1; Tom Scullion, P.E.2; and John Bilyeu, P.E.3	Performance Analysis
	Virginia Transportation Research Council	Evaluation of Hydraulic Cement Concrete Overlays Placed on Three Pavements in Virginia	Michael M. Sprinkel,Celik Ozyildirim	Material, Construction & Mix Design
	TRB	UNDERSTANDING THE EFFECTS OF AGGREGATE AND EMULSION APPLICATION RATES ON THE PERFORMANCE OF ASPHALT SURFACE TREATMENTS	Ju Sang Lee, Y. Richard Kim,	Performance Analysis

APPENDIX 2 - CURRENT PAVEMENT PRESERVATION CENTERS

The following is a list of the current pavement preservation centers:

- California Pavement Preservation Center (CPPC) – Established by CALTRANS at Chico State University, the CPPC provides regional and national outreach, training, research and technical assistance to government, industry, and academia in Pavement Preservation.
- Texas Pavement Preservation Center (TPPC) at University of Texas Austin – The TPPC represents a joint collaboration between the Center for Transportation Research (CTR) and the Texas Transportation Institute (TTI) which promotes the use of pavement preservation strategies to government, industry, and other agencies within the national highway community.
- Texas Transportation Institute (TTI) at Texas A&M – TTI focuses on a program of practical, applied research designed to address a wide range of transportation challenges, including those associated with pavements.

Some of the other pavement related academic centers include:

- California State Polytechnic University-Pomona, Pavement Recycling and Reclaiming Center – The Pavement Recycling and Reclaiming Center (PR2C) was established at CAL POLY POMONA in August 2010. The Center is a partnership between agencies, academia and industry. Seed funding for the Center was provided by the California Department of Transportation (Caltrans) through a $1million, three-year contract.

- Center for Transportation Research (CTR) at University of Texas Austin – CTR is a nationally recognized research institution focusing on transportation research, education, and public service.

- Illinois Center for Transportation – The Illinois Center for Transportation (ICT) is a premier transportation research center that builds on the experience of renowned experts in transportation and related fields at the University of Illinois, the Illinois Department of Transportation (IDOT), and other universities in Illinois and across the country by providing the appropriate tools and support required for objective research.

- Louisiana Transportation Research Center – Since its creation by the Louisiana Legislature in 1986, the Louisiana Transportation Research Center (LTRC) has grown to national prominence through its efforts to improve transportation systems in Louisiana. The center conducts short-term and long-term research and provides technology assistance, engineering training, and continuing education, technology transfer, and problem-solving services to the Louisiana Department of Transportation and Development (DOTD) and others in the transportation community.

- Midwest Regional University Transportation Center (MRUTC) – The MRUTC represents a regional consortium which focuses on research, outreach, and education in asset optimization and management techniques for transportation infrastructure.

- Minnesota Road Research Facility – MnROAD is a pavement test track using various research materials and pavements. It finds ways to make roads last longer, perform better, cost less to build and maintain, be built faster and have minimal impact on the environment.

- National Center for Asphalt Technology (NCAT) at Auburn University – NCAT works to improve hot mix asphalt performance through research, education, and information services on a national scale.

- National Concrete Pavement Technology Center (NCPTC) at Iowa State University – The Concrete Pavement Technology Center focus is on advancing concrete pavement technology through research, technology transfer, and accelerated implementation of promising technologies.

- North Central Superpave Center (NCSC) – Joint project of Purdue University and the Indiana Department of Transportation.

- University of California Berkeley Pavement Research Center – Dedicated to providing knowledge, the Pavement Research Center uses innovative research and sound engineering principles to improve pavement structures, materials, and technologies.

- USDOT University Transportation Centers (UTCs) – Thirty-three (33) UTCs have been established to advance U.S. technology and expertise in the many

disciplines comprising transportation through the mechanisms of education, research and technology transfer at university-based centers of excellence.

- Virginia Transportation Research Council – The Virginia Center for Transportation Innovation and Research (VCTIR) is one of the nation's leading transportation research centers, specializing in basic and applied research to support the Virginia Department of Transportation (VDOT), its primary customer. It also provides technical consulting and training of future transportation professionals through its work with the University of Virginia and other Virginia universities.

- Western Research Institute – Western Research Institute is a technology development center serving private clients, industry, and government with expertise in energy, environment, and highway materials.

APPENDIX 3 –SURVEY INSTRUMENT

April 15, 2013

(Interviewees)

Subject: New Jersey DOT Appropriate Implementation of Pavement Preservation Treatments Study

Dear (name):

Deighton Associates, Ltd., is participating in a research project with Rutgers University to assist the New Jersey Department of Transportation in the implementation of pavement preservation treatments and incorporating these treatments in its pavement management system analysis. As a part of this study, we are interviewing state DOT's to determine the state of the practice in the U.S. The attached questionnaire has been developed as a tool to assist in these interviews.

We are requesting that you participate in a follow-up phone interview on (date and time) to discuss your agency's responses to the questions. Once the responses have been compiled, we will share the results with the interview participants.

Thank you in advance for your time, contribution, and thoughtful input.

Sincerely,

(interviewer)

INTERVIEW GUIDE

Introductory Questions

1. Name:
2. Position/title:
3. Department/Division:
4. Address:
5. Phone:
6. Email:

Pavement Preservation Treatments

This research study will examine the pavement preservation treatments that are appropriate on NJ's State-maintained roads, the means of selecting the right time and condition to apply the treatment, the treatment effectiveness on the roads condition, the extension of the service life, and the cost of applying the treatment.

This survey is focused on determining what pavement treatments your agency uses to protect, and preserve your pavements or extend their lives, at the least cost.

1. Does your department of transportation use pavement preservation treatments in its general pavement treatments toolbox? (Y/N)
2. Does your department of transportation incorporate pavement preservation treatments in its pavement management system analysis? (Y/N)
3. If you are not currently using pavement preservation treatments in your pavement management system analysis, are there active plans to do so? (Y/N)

4. If you answered “yes” to Question #1, please indicate which treatments you currently use and approximately how many lane-miles are applied.

Flexible and Composite Pavement Treatments

	Yes/No			Mainline
	mainline	**shoulder**	**ramps**	**Lane-miles**
Crack Sealing				
Crack Filling				
Seals				
Slurry Seals				
Scrub Seals				
Fog Seals/Asphalt Rejuvenators				
Sand Seals				
Chip Seals				
Cape Seals				
Micro-surfacing				
Thin Overlays (non-structural, generally <= 1 ½ inch)				
Ultra-Thin Overlays (generally <= ¾ inch)				
Mill & Resurface (non-structural, generally <= 1 ½ inch) Bonded Wearing Course				
Profile Milling				
Hot In-Place Recycling				
Cold In-Place Recycling				
Other proprietary treatments				
Others:				

Rigid Pavement Treatments

	Yes/No			Mainline
	mainline	**shoulder**	**ramps**	
Crack Sealing				
Joint Resealing				
Spall Repair				
Dowel Bar Retrofit				
Cross Stitching (longitudinal cracks and joints)				
Partial Depth Repair				
Full Depth Repair (limited				

number of repairs)				
Undersealing/slab stabilization				
Slab Lifting				
Diamond Grooving				
Diamond Grinding				
Other CPR (concrete pavement restoration)				
Other proprietary treatments				
Thin White Topping				
Ultra-Thin White Topping				
Others:				

5. For those treatments listed in Question #3, what are the triggers or decision trees used for each of the treatments in the pavement management system?

Flexible and Composite Pavement Treatments

Treatment	**Trigger**	**Condition Reset Value***	**Life Extension**	**Cost/SY**
Crack Sealing				
Crack Filling				
Seals				
Slurry Seals				
Scrub Seals				
Fog Seals/ Asphalt Rejuvenators				
Sand Seals				
Chip Seals				
Cape Seals				
Micro-surfacing				
Thin Overlays				
Ultra-Thin Overlays				
Mill & Resurface Bonded Wearing Course				
Profile Milling				
Hot In-Place Recycling				
Cold In-Place Recycling				
Other proprietary treatments				
Others:				

* How does the pavement preservation treatment impact condition?

Does the treatment improve the pavement condition or simply extend the pavement life?

How is the pavement preservation treatment impact on condition represented in your PMS? .

Rigid Pavement Treatments

Treatment	**Trigger**	**Condition Reset Value***	**Life Extension**	**Cost/SY**
Crack Sealing				
Joint Resealing				
Spall Repair				
Dowel Bar Retrofit				
Cross Stitching				
Partial Depth Repair				

Full Depth Repair				
Undersealing/ Stabilization				
Slab Lifting				
Diamond Grooving				
Diamond Grinding				
Other CPR				
Other proprietary treatments				
Thin White Topping				
Ultra-Thin White Topping				
Others:				

* How does the pavement preservation treatment impact condition?

Does the treatment improve the pavement condition or simply extend the pavement life?

How is the pavement preservation treatment impact on condition represented in your PMS? .

If you are <u>not</u> currently using pavement preservation treatments in your pavement management system <u>analysis</u>, are they still used by the agency? (Y/N)

If so, which ones and what is the decision making process?

6. Are your technical specifications for the treatments you use available on your website or available upon request? (Y/N)

Please provide the Web URL address.

7. Are your design and construction procedures for the treatments you use available on your website or available upon request? (Y/N)

Please provide the Web URL address.

8. Are there other issues your DOT deals with when considering treatments, such as available contracting resources or traffic volume limits or climatic conditions? (Y/N) Please specify.

9. Can you estimate the number of Pavement Preservation Contractors available in your stare or surrounding states? (Y/N) How many?

10. Can you provide a listing of the contractors and the amount of confidence that you have in their abilities? We recognize that this question is subjective, but a

key element to the identification of pavement preservation techniques is the amount of qualified contractors.

11. Do you employ certain pavement preservation treatments because there are contractors in the vicinity and not employ others because there are no contractors?

12. Does your agency apply any pavement preservation treatments utilizing your DOT personnel? (Y/N)

Which ones?

Flexible and Composite Pavement Treatments (Please select all that apply)

Crack Sealing	
Crack Filling	
Seals	
Slurry Seals	
Scrub Seals	
Fog Seals/Asphalt Rejuvenators	
Sand Seals	
Chip Seals	
Cape Seals	
Micro-surfacing	
Thin Overlays (non-structural, generally <= 1 ½ inch)	
Ultra-Thin Overlays (generally <= ¾ inch)	
Mill & Resurface (non-structural, generally <= 1 ½ inch) Bonded Wearing Course	
Profile Milling	
Hot In-Place Recycling	
Cold In-Place Recycling	
Other proprietary treatments	
Others:	

Rigid Pavement Treatments

Crack Sealing	
Joint Resealing	
Spall Repair	
Dowel Bar Retrofit	
Cross Stitching (longitudinal cracks and joints)	
Partial Depth Repair	
Full Depth Repair (limited number of repairs)	
Undersealing	
Slab Lifting	
Diamond Grooving	
Diamond Grinding	

Other CPR (concrete pavement restoration)	
Other proprietary treatments	
Thin White Topping	
Ultra-Thin White Topping	
Others:	

13. What is the total cost of the pavement preservation treatments projects constructed annually?
14. What percentage of the annual pavements program is used for pavement preservation treatments?

Closing Questions

1. Is there anything else we should have asked that we didn't?

2. Are there other Comments that you have:

3. Are there any completed or active research studies on pavement preservation in your department of transportation that you can share with us?

If so, could you provide a link to the website and/or provide us with a copy of the research report?

Please identify the name of the research Principal Investigator and email address.

On behalf of the Rutgers-CAIT, Deighton, and NJDOT Research team, we thank you again for your inputs. A copy or the survey question summary will be sent to the individual identified as the point of contact in the survey.

APPENDIX 4 – POC SURVEY

STATE	NAME	DEPARTMENT/DIVISION	EMAIL
AL	STEVE SABOUNDJIAN	ALASKA DOT&PF / STATEWIDE MATERIALS	STEVE.SABOUNDJIAN@ALASKA.GOV
CA	BOB MOORE	CALTRANS/MAINTENANCE	BOB_MOORE@DOT.CA.GOV
IN	TODD SHIELDS	MAINTENANCE	TSHIELDS@INDOT.IN.GOV
KS	RICK MILLER	BUREAU OF CONSTRUCTION AND MATERIALS	RICK@KSDOT.ORG
LA	MARK CHENEVERT	PAVEMENT PRESERVATION	MARK.CHENEVERT@LA.GOV
ME	ANNE EMIDY, P.E.	ASSISTANT HIGHWAY MGT. ENGINEER	ANNE.EMIDY@MAINE.GOV
MI	ERIN CHELOTTI	CONSTRUCTION FIELD SERVICES DIVISION	CHELOTTIE@MICHIGAN.GOV
MN	JERRY GEIB	OFFICE OF MATERIALS AND ROAD RESEARCH	JERRY.GEIB@STATE.MN.US
MS	CINDY SMITH, P.E.	RESEARCH DIVISION	CJSMITH@MDOT.MS.GOV
	KEN HAUSER	MAINTENANCE DIVISION	KHAUSER@MDOT.MS.GOV
MT	DAN HILL PE	ENGINEERING DIVISION / MATERIALS BUREAU	DAHILL@MT.GOV
ND	STEPHANIE WEIGEL, P.E.	PLANNING/ASSET MANAGEMENT DIVISION	SJWEIGEL@ND.GOV
WA	JEFF UHLMEYER	STATE MATERIALS LAB	UHLMEYJ@WSDOT.WA.GOV
WI	PAULETTE HANNA	WISDOT/ BTS	PAULETTE.HANNA@DOT.WI.GOV
WY	ANDREW FREEMAN	WYDOT MATERIALS	ANDY.FREEMAN@WYO.GOV

APPENDIX 5 – SUMMARY OF SURVEY RESULTS

Question 1 - Does your department of transportation use pavement preservation treatments in its general pavement treatments toolbox?

State	Yes	No
ALASKA	Y	
CALIFORNIA	Y	
INDIANA	Y	
KANSAS	Y	
LOUISIANA	Y	
MAINE	Y	
MICHIGAN	Y	
MINNESOTA	Y	
MISSISSIPPI	Y	
MONTANA	Y	
NORTH DAKOTA	Y	
WASHINGTON State DOT	Y	
WISCONSIN	Y	
WYOMING	Y	

Question 2 - Does your department of transportation incorporate pavement preservation treatments in its pavement management system analysis? (Y/N)

State	Yes	No	
ALASKA	Y		BUT NOT ALL
CALIFORNIA	Y		
INDIANA	Y		
KANSAS	Y		
LOUISIANA	Y		
MAINE	Y		
MICHIGAN	Y		
MINNESOTA	Y		
MISSISSIPPI		N	
MONTANA	Y		
NORTH DAKOTA	Y		
WASHINGTON State DOT	Y		
WISCONSIN		N	
WYOMING	Y		

Question 3 - If you are not currently using pavement preservation treatments in your pavement management system analysis, are there active plans to do so? (Y/N)

State	Yes	No	
ALASKA	Y		
CALIFORNIA			
INDIANA			
KANSAS			
LOUISIANA			
MAINE			
MICHIGAN			
MINNESOTA			
MISSISSIPPI	Y		
MONTANA			
NORTH DAKOTA			
WASHINGTON State DOT			
WISCONSIN			Y AND N
WYOMING			

Question 4 - Please indicate which treatments you currently use and approximately how many lane-miles are applied annually.

Flexible and Composite Pavement Treatments	State 1 ALASKA			2 CALIFORNIA			3 INDIANA			4 KANSAS			5 LOUISIANA			6 MAINE			7 MICHIGAN			8 MINNESOTA			9 MISSISSIPPI			10 MONTANA			11 NORTH DAKOTA			12 WASHINGTON State DOT			13 WISCONSIN			14 WYOMING			Count			Percentage		
	M	S	R	M	S	R	M	S	R	M	S	R	M	S	R	M	S	R	M	S	R	M	S	R	M	S	R	M	S	R	M	S	R	M	S	R	M	S	R	M	S	R	M	S	R	M	S	R
Crack Sealing	1	1	1	1	1	1	1	1	1	1						1	1	1	1	1	1	1		1				1			1	1	1	1	1	1	1	1	1	1	1		12	9	9	86	64	64
Crack Filling	1	1	1	1	1	1	1	1	1	1						1			1	1	1	1	1	1	1	1	1							1	1	1	1	1	1				10	8	8	71	57	57
Seals																																											0	0	0	0	0	0
Slurry Seals				1	1	1				1																					1	1	1	1	1	1	1		1				5	3	4	36	21	29
Scrub Seals				1	1	1																			1																		2	1	1	14	7	7
Fog Seals/Asphalt Rejuvenators				1	1	1	1	1								1	1		1	1	1		1											1	1						1		5	7	2	36	50	14
Sand Seals				1	1	1																															1						2	1	1	14	7	7
Chip Seals	1			1	1	1	1	1		1						1			1	1	1	1		1	1			1	1	1	1	1	1	1	1	1	1			1			13	6	6	93	43	43
Cape Seals																			1	1	1	1																					2	1	1	14	7	7
Micro-surfacing				1			1	1	1							1			1	1	1	1						1	1		1	1	1				1			1			9	4	3	64	29	21
Thin Overlays (non-structural, generally <= 1 ½ inch)				1	1	1				1						1	1	1	1	1	1							1	1	1	1	1	1				1			1			8	5	5	57	36	36
Ultra-Thin Overlays (generally <= ¾ inch)							1	1	1							1			1	1	1	1	1	1	1																		5	3	3	36	21	21
Mill & Resurface (non-structural, generally <= 1 ½ inch) Bonded Wearing Course				1	1	1				1						1	1	1	1	1	1	1		1							1	1	1				1			1			8	4	5	57	29	36
Profile Milling	1			1	1	1	1	1	1										1	1	1	1																					5	3	3	36	21	21
Hot In-Place Recycling										1																								1	1	1							2	1	1	14	7	7
Cold In-Place Recycling				1						1																		1	1		1	1	1	1	1	1							5	3	2	36	21	14
Other proprietary treatments																															1	1	1										1	1	1	7	7	7
Others:																																											0	0	0	0	0	0
Mill and Fill (~2")	1																																										1	0	0	7	0	0
RHMA-THIN OVERLAY	1			1	1																																						2	1	0	14	7	0
WMA-THIN OVERLAY				1																																							1	0	0	7	0	0
RHMA-MILL & RESURFACE				1	1																																						1	1	0	7	7	0
Ultra-Thin Bonded Asphalt Surface (NovaChip)										1						1	1																										2	1	0	14	7	0
Paver Place Surface Seal																			1	1	1																						1	1	1	7	7	7
1.8-2.4 " OVERLAY W/CHIP SEAL																												1	1	1													1	1	1	7	7	7
1.8-2.4 " MILL/FILL W/CHIP SEAL																												1	1	1													1	1	1	7	7	7
Rigid Pavement Treatments																																																
Crack Sealing							1	1	1	1									1		1	1			1	1	1				1	1	1	1	1	1	1	1	1				8	5	6	57	36	43
Joint Resealing							1	1	1	1									1	1	1	1		1	1	1	1				1	1	1	1	1	1				1			8	5	6	57	36	43
Spall Repair							1		1										1			1		1	1	1	1				1	1	1	1	1	1	1			1			8	3	5	57	21	36
Dowel Bar Retrofit							1		1	1									1		1	1		1							1			1	1	1	1			1			8	1	4	57	7	29
Cross Stitching (longitudinal cracks and joints)							1		1	1																					1		1				1						4	0	2	29	0	14
Partial Depth Repair							1		1										1		1	1		1							1	1	1	1	1	1	1			1			7	2	5	50	14	36
Full Depth Repair (limited number of repairs)							1		1	1									1	1	1	1		1	1	1	1				1	1	1	1	1	1	1			1			9	4	6	64	29	43
Undersealing/slab stabilization							1		1	1									1	1	1				1																		4	1	2	29	7	14
Slab Lifting																															1												1	0	0	7	0	0
Diamond Grooving																			1		1	1																					2	0	1	14	0	7
Diamond Grinding							1		1	1									1		1	1		1	1		1				1			1		1	1			1			9	0	5	64	0	36
Other CPR (concrete pavement restoration)										1									1		1	1		1							1	1		1		1							5	1	3	36	7	21
Other proprietary treatments																																											0	0	0	0	0	0
Thin White Topping							1			1												1			1						1	1								1			6	1	0	43	7	0
Ultra-Thin White Topping																																											0	0	0	0	0	0
Others:																																											0	0	0	0	0	0

Flexible and Composite Pavement Treatments	ALASKA	CALIFORNIA	INDIANA	KANSAS	LOUISIANA	MAINE	MICHIGAN	MINNESOTA	MISSISSIPPI	MONTANA	NORTH DAKOTA	WASHINGTON State DOT	WISCONSIN	WYOMING
	L-M	L-M	L-M	L-M	L-M	L-M	L-M	L-M	L-M	L-M	L-M	L-M	L-M	L-M
Crack Sealing		unknown*	5000				Approx. 600			350	6136 (May include some concrete miles but the vast majority is asphalt)			50
Crack Filling		unknown*	700				Approx. 900 (some of this is pre-treatment for other fixes)		100		N/A			
Seals		unknown*		500										
Slurry Seals		90									65			
Scrub Seals		unknown*							62		N/A			
Fog Seals/Asphalt Rejuvenators		unknown*	1200	80			Used with some chip seals				Districts occasionally fog seal shoulders on interstate but no exact line mile number is available			400
Sand Seals		unknown*									N/A			
Chip Seals		310	1500				215		600	150	196			400
Cape Seals		0					18	Very limited			N/A			
Micro-surfacing		210	200	700			196			30	98			30
Thin Overlays (non-structural, generally <= 1 ½ inch)		350					128			30	54			50
Ultra-Thin Overlays (generally <= ¾ inch)		0	150				61		70		N/A			
Mill & Resurface (non-structural, generally <= 1 ½ inch) Bonded Wearing Course		460		360			672				23			20
Profile Milling		unknown*					11				N/A			
Hot In-Place Recycling		0		300							N/A			
Cold In-Place Recycling		125								15	18			
Other proprietary treatments		450		1400							404			
Others:		4		100										
Mill and Fill (~2")		250												
RHMA-THIN OVERLAY														
WMA-THIN OVERLAY														
RHMA-MILL & RESURFACE														
Paver Place Surface Seal							16							
1.8-2.4 " OVERLAY W/CHIP SEAL										150				
1.8-2.4 " MILL/FILL W/CHIP SEAL										150				

Rigid Pavement Treatments	ALASKA	CALIFORNIA	INDIANA	KANSAS	LOUISIANA	MAINE	MICHIGAN	MINNESOTA	MISSISSIPPI	MONTANA	NORTH DAKOTA	WASHINGTON State DOT	WISCONSIN	WYOMING
	L-M	L-M	L-M	L-M	L-M	L-M	L-M	L-M	L-M	L-M	L-M	L-M	L-M	L-M
Crack Sealing		unknown*		15			28000 ft		50	20	Districts do not break out concrete vs asphalt lane miles when they report their crack seal tracking			
Joint Resealing		unknown*	50	?			20		25	20	As needed – number not tracked			10
Spall Repair		unknown*					29		50-100	20	40*			10
Dowel Bar Retrofit		0		6			Not used often			10	1			15
Cross Stitching (longitudinal cracks and joints)		unknown*		?							0			
Partial Depth Repair		unknown*					Not used often			10	40*			1
Full Depth Repair (limited number of repairs)		unknown*		70			113		15		40*			1
Undersealing/slab stabilization		unknown*		20			New fix, limited use		unk		N/A			
Slab Lifting		unknown*									0			
Diamond Grooving		0					New fix limited use	*Rarely done*			N/A			
Diamond Grinding		875		30			9		60 LN MI in 2011	15	40*			5
Other CPR (concrete pavement restoration)		0		70			124				40*			
Other proprietary treatments		0									N/A			
Thin White Topping		0	50	30					Not lately		23			5
Ultra-Thin White Topping		0									N/A			
Others:														

Question 5 - What are the PMS inputs and costs used for each of the treatments in the pavement management system?

Triggers	ALASKA	CALIFORNIA	INDIANA	KANSAS	LOUISIANA	MAINE	MICHIGAN	MINNESOTA	MISSISSIPPI	MONTANA	NORTH DAKOTA	WASHINGTON State	WISCONSIN	WYOMING
Flexible and Composite Pavement Treatments	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Crack Sealing						3-5 years after new construction; 2-3 yrs after overlay				65<=MCI<98.5 Age<6	Not in PMS		severity	
Crack Filling											Not in PMS		severity	
Seals											Not in PMS			
Slurry Seals											Not in PMS		condition	
Scrub Seals											Do Not Use			
Fog Seals/Asphalt Rejuvenators											Not in PMS			
Sand Seals											Do Not Use		condition	
Chip Seals			1. IRI<130, Age 8-12, Rut < ¼"	2	**Random cracking in upper fair to good**	Rutting and cracking must be minimal				65<=MCI<98.5 Age>=6	Not in PMS		condition	
Cape Seals											Do Not Use			
Micro-surfacing			IRI<130, Age 8-12		**Rutting >0.25 in and other Distress in very good condition**	Rutting < 0.75"; PCR still >=3.8 (0-5 scale)					IRI, Transverse Cracking, Structural Index, Rutting, ESALS, PM Count, AADT, TAADT, %Design Life Used		condition	Rut
Thin Overlays (non-structural, generally <= 1 ½ inch)					**Rutting>0.375 in and Distress in good condition**	PCR still >= 3.0				57<=Ride Index<70	IRI, Transverse Cracking, Structural Index, Rutting, ESALS, PM Count, AADT, TAADT, %Design Life Used		condition	IRI, Rut
Ultra-Thin Overlays (generally <= ¾ inch)			IRI<130, Age 8-12			PCR still >= 3.4					Do Not Use			
Mill & Resurface (non-structural, generally <= 1 ½ inch) Bonded Wearing Course			IRI<130, Age 8-12			PCR usually below 3.3					IRI, Transverse Cracking, Structural Index, Rutting, ESALS, PM Count, AADT, TAADT, %Design Life Used			IRI, Rut
Profile Milling											Do Not Use			
Hot In-Place Recycling											Do Not Use			
Cold In-Place Recycling						Used when there is extensive cracking, but subbase is still OK					IRI, Transverse Cracking, Structural Index, Rutting, ESALS, PM Count, AADT, TAADT, %Design Life Used			
Other proprietary treatments														
Others:														
Nova Chip						PCR still >= 3.4, but may have significant fine cracking									
FDR-Cement						PCR 1.0-2.5. Fine content (passing #200 sieve) > 8%									
FDR-Emulsion						PCR 1.0-2.5. Fine content (passing #200 sieve) < 8%									
FDR-Foamed Asphalt						PCR 1.0-2.5. Fine content (passing #200 sieve) > 5%; Plasticity Index < 10									
1.8-2.4 " OVERLAY W/CHIP SEAL										57<=Ride Index<70				
1.8-2.4 " MILL/FILL W/CHIP SEAL										30<=Rd. Index<57				
										50<=ACI<60				

Triggers	ALASKA	CALIFORNIA	INDIANA	KANSAS	LOUISIANA	MAINE	MICHIGAN	MINNESOTA	MISSISSIPPI	MONTANA	NORTH DAKOTA	WASHINGTON State DOT	WISCONSIN	WYOMING
Rigid Pavement Treatments	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Crack Sealing					**Cracking upper fair to good condition**						Not in PMS		Condition	
Joint Resealing			Age 8-12		**Cracking upper fair to good condition**						Not in PMS			
Spall Repair											**		Condition	
Dowel Bar Retrofit			Age 8-12								IRI, Slab Cracking Index, Pavement Age			
Cross Stitching (longitudinal cracks and joints)											Not in PMS			
Partial Depth Repair											**		Condition	
Full Depth Repair (limited number of repairs)											**		Condition	
Undersealing/slab stabilization											Do Not Use			
Slab Lifting											Not in PMS			
Diamond Grooving											Do Not Use			
Diamond Grinding			IRI > 130								**		Condition	
Other CPR (concrete pavement restoration)											** IRI, Slab Cracking Index, Pavement Age			
Other proprietary treatments											Do Not Use			
Thin White Topping											IRI, Slab Cracking Index			
Ultra-Thin White Topping											Do Not Use			
Others:														
Minor Rehab					**Long, Patch, or Roughness in upper fair to good condition**									

2. KDOT uses distress state as an indicator of condition. This variable includes a roughness level, transverse cracking level, and rutting level for flexible pavements. Typically, pavement preservation treatments reset this distress state because the assumption is that they are used in the correct place to at least temporarily remove the distress. A few exceptions exist for holding actions where the distress state is only partialy modified. For instance a crack seal will not reset roughness or rutting levels, but does impact cracking.
7. Please refer to question 7 for link to this information and question 2 in the “Closing Questions” for a description of how a fix is selected
8. http://www.dot.state.mn.us/materials/pvmtmgmt.html
8. * How does the pavement preservation treatment impact condition? THE IMPACT IS BASED ON THE REASON THE TREATMENT WAS APPLIED Does the treatment improve the pavement condition or simply extend the pavement life? THE IMPROVEMENT OF THE PAVEMENT CONDITION AND /OR LIFE EXTENSION IS BASED ON THE EXISTINTG PAVEMENT CONDITION, THE TREATMENT SELECTED AND THE REASONE THE TREATMETN WAS APPLIED.
9. Hopefully it results in less cracking and distress and a higher/better pavement condition rating. Unknown, but hopefully some of each.
It is not formally, but hopefully we would see fewer distresses and a higher overall pavement condition rating.
11. ** Spall Repair, Partial Depth Repair, Full Depth Repair, and Diamond Grinding are usually done together on a project and classified as CPR. Improves IRI, Structural Cracking Index and Distress. Resets values for IRI, Structural Cracking Index and Distress that are used as triggers.

Condition Reset Value*	ALASKA	CALIFORNIA	INDIANA	KANSAS	LOUISIANA	MAINE	MICHIGAN	MINNESOTA	MISSISSIPPI	MONTANA	NORTH DAKOTA	WASHINGTON State DOT	WISCONSIN	WYOMING
Flexible and Composite Pavement Treatments	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Crack Sealing						None				+10 not > 100	Not in PMS		5-7 yrs	
Crack Filling						None					Not in PMS		5-7 yrs	
Seals											Not in PMS			
Slurry Seals											Not in PMS		7	
Scrub Seals											Do Not Use			
Fog Seals/Asphalt Rejuvenators						None					Not in PMS			
Sand Seals											Do Not Use		7-May	
Chip Seals					**Reset Rut+5 Index and Roughness +10 Index, other Distress to 100, but not age**	Add 7 to Functional Cracking Index (0-100 scale) but no higher than 99				+ 10 not > 100	Not in PMS		7-May	
Cape Seals											Do Not Use			
Micro-surfacing					**Reset all Distress to 100 but not age**	PCR re-set to 4.5					IRI=65, Trans Cracking=0, Struct Index =Existing-2, Rut=0, PM Count=Existing+1		8-Jul	PSR=80
Thin Overlays (non-structural, generally <= 1 ½ inch)					**Reset all Distress including age to 0**	PCR re-set to 4.7				+40 not > 100	IRI=65, Trans Cracking=0, Struct Index =Existing-2, Rut=0, PM Count=Existing+1		8-Jul	PSR=80
Ultra-Thin Overlays (generally <= ¾ inch)						PCR re-set to 4.5					Do Not Use			
Mill & Resurface (non-structural, generally <= 1 ½ inch) Bonded Wearing Course						PCR re-set to 4.7					IRI=60, Trans Cracking=0, Struct Index =Existing-4, Rut=0			PSR=80
Profile Milling											Do Not Use			
Hot In-Place Recycling											Do Not Use			
Cold In-Place Recycling						PCR re-set to 4.9; Age is re-set to 2 years					IRI=60, Trans Cracking=0, Struct Index =Existing-4, Rut=0			
Other proprietary treatments														
Others:														
Nova Chip						PCR re-set to 4.5								
FDR-Cement						PCR re-set to 4.9; Age is re-set to 2 years								
FDR-Emulsion						PCR re-set to 4.9; Age is re-set to 2 years								
FDR-Foamed Asphalt						PCR re-set to 4.9; Age is re-set to 2 years								
1.8-2.4 " OVERLAY W/CHIP SEAL										+40 not > 100				
1.8-2.4 " MILL/FILL W/CHIP SEAL										+50 not > 100				

Condition Reset Value*	ALASKA	CALIFORNIA	INDIANA	KANSAS	LOUISIANA	MAINE	MICHIGAN	MINNESOTA	MISSISSIPPI	MONTANA	NORTH DAKOTA	WASHINGTON State DOT	WISCONSIN	WYOMING
Rigid Pavement Treatments														
Crack Sealing					**Cracking and Patching Only to 100**					+10 not > 100	Not in PMS		5 Yr	
Joint Resealing					**Cracking and Patching Only to 100**					+10 not > 100	Not in PMS			
Spall Repair										+10 not > 100	**		7-May	
Dowel Bar Retrofit										+50 not >100	IRI=50, Slab Cracking Index=0, Distress=99			
Cross Stitching (longitudinal cracks and joints)											Not in PMS			
Partial Depth Repair										+50 not > 100	**		8-Jul	
Full Depth Repair (limited number of repairs)											**		10-Jul	
Undersealing/slab stabilization											Do Not Use			
Slab Lifting											Not in PMS			
Diamond Grooving											Do Not Use			
Diamond Grinding										+50 not > 100	**		10	
Other CPR (concrete pavement restoration)											** IRI=50, Slab Cracking Index=0, Distress=96			
Other proprietary treatments											Do Not Use			
Thin White Topping											IRI=50, Slab Cracking Index=0			
Ultra-Thin White Topping											Do Not Use			
Others:														

5. We use and Index scale from 0-100, 0 (Very Poor) and 100 (Very Good). We reset the values to 100 in most cases. The amount of life extension is determined by the Deterioration curve for that Family of Pavement after a treatment is done.

11. Improves IRI, Transverse Cracking, Structural Index and Rutting. Pavement Condition. Resets values for IRI, Transverse Cracking, Structural Index and Rutting that are used as triggers.

12. Extends estimated pavement life

14. PSR improved to less than new condition (80 vs 85) and performance curve steepened.

Life Extension	ALASKA	CALIFORNIA	INDIANA	KANSAS	LOUISIANA	MAINE	MICHIGAN	MINNESOTA	MISSISSIPPI	MONTANA	NORTH DAKOTA	WASHINGTON State DOT	WISCONSIN	WYOMING
Flexible and Composite Pavement Treatments	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Crack Sealing			3			2-3 years	Up to 3			2	Not in PMS	2-4 years		3
Crack Filling			1			2-3 years	Up to 2				Not in PMS	2-4 years		
Seals											Not in PMS			
Slurry Seals											Not in PMS			
Scrub Seals											Do Not Use			
Fog Seals/Asphalt Rejuvenators						1-4 years					Not in PMS			5
Sand Seals											Do Not Use			
Chip Seals			4		6 Years (Based on LTRC 10-4P Research Project)	5-7 years	'3-7			3	Not in PMS	6-8 years		7
Cape Seals											Do Not Use			
Micro-surfacing			8			4-6 years	'3-6				N/A			'5-8
Thin Overlays (non-structural, generally <= 1 ½ inch)					9 Years (Based on LTRC 10-4P Research Project)	8-12 years	'4-10			8	N/A			'5-8
Ultra-Thin Overlays (generally <= ¾ inch)			8			6-8 years	'3-6				Do Not Use			
Mill & Resurface (non-structural, generally <= 1 ½ inch) Bonded Wearing Course			8			10-12 years	'4-10				N/A			'5-8
Profile Milling											Do Not Use			
Hot In-Place Recycling											Do Not Use			
Cold In-Place Recycling						7-10 years					N/A			
Other proprietary treatments														
Others:														
Nova Chip						4-6 years								
FDR-Cement						8-10 years (though functional cracking may appear w/in 3-5 yr								
FDR-Emulsion						8-10 years (though functional cracking may appear w/in 3-5 years								
FDR-Foamed Asphalt						8-10 years (though functional cracking may appear w/in 3-5 years								
1.8-2.4 " OVERLAY W/CHIP SEAL										8				
1.8-2.4 " MILL/FILL W/CHIP SEAL										12				

Life Extension	ALASKA	CALIFORNIA	INDIANA	KANSAS	LOUISIANA	MAINE	MICHIGAN	MINNESOTA	MISSISSIPPI	MONTANA	NORTH DAKOTA	WASHINGTON State DOT	WISCONSIN	WYOMING
Rigid Pavement Treatments														
Crack Sealing										5	Not in PMS			
Joint Resealing			10				'3-5			5	Not in PMS			
Spall Repair							Up to 5			5	**			
Dowel Bar Retrofit							'2-3			10	N/A	15-20 years		
Cross Stitching (longitudinal cracks and joints)											Not in PMS			
Partial Depth Repair										10	**			
Full Depth Repair (limited number of repairs)							'3-10				**			
Undersealing/slab stabilization											Do Not Use			
Slab Lifting											Not in PMS			
Diamond Grooving											Do Not Use			
Diamond Grinding							'3-5			10	**	10 – 15 years		
Other CPR (concrete pavement restoration)											**N/A			
Other proprietary treatments											Do Not Use			
Thin White Topping											N/A			
Ultra-Thin White Topping											Do Not Use			
Others:														

7. Simply Extend the pavement life/Remaining Service Life (RSL) in years

10. The correlating distress index is improved and therefore extends the time before the next treatment is triggered.

Cost/SY	ALASKA	CALIFORNIA	INDIANA	KANSAS	LOUISIANA	MAINE	MICHIGAN	MINNESOTA	MISSISSIPPI	MONTANA	NORTH DAKOTA	WASHINGTON State DOT	WISCONSIN	WYOMING
Flexible and Composite Pavement Treatments	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Crack Sealing				$2.31		$0.21	$0.32		$ 15 per Gallon	$0.40	Not in PMS		$0.71	
Crack Filling						$0.35	$0.32				Not in PMS		$0.85	
Seals											Not in PMS			
Slurry Seals				$3.06							Not in PMS		$1.28	
Scrub Seals									$3.96		Do Not Use			
Fog Seals/Asphalt Rejuvenators						$0.57	$0.30				Not in PMS			
Sand Seals											Do Not Use		$1.00	
Chip Seals				$2.42	$5.26	$4.97	1.68/SINGLE 2.96/DOUBLE		$2.04	$2.28	Not in PMS	$7	$1.00	$3
Cape Seals											Do Not Use			
Micro-surfacing					$5.26		2.49 (single) 3.22(double)			$6	$66,000/Mile		$24.15	$10
Thin Overlays (non-structural, generally <= 1 ½ inch)				$5.28	$13.85	$14.91	By the ton and depends on mix type			$12	$155,000/Mile		$4.97	$10
Ultra-Thin Overlays (generally <= ¾ inch)				$3.48		$11.36	$3.10		$6.92		Do Not Use			
Mill & Resurface (non-structural, generally <= 1 ½ inch) Bonded Wearing Course				$4.40		$24.15	1.00 for milling, HMA depends on mix and is by the ton				$350,000/Mile			$10
Profile Milling											Do Not Use			
Hot In-Place Recycling				$4.65							Do Not Use			
Cold In-Place Recycling				$12.50		$34.10				$10	$195,000			
Other proprietary treatments														
Others:														
Nova Chip						$9.23								
FDR-Cement						$42.61								
FDR-Emulsion						$42.61								
FDR-Foamed Asphalt						$49.71								
PAVER PLACED SURFACE SEAL							$4.42							
1.8-2.4 " OVERLAY W/CHIP SEAL										$12				
1.8-2.4 " MILL/FILL W/CHIP SEAL										$13				

Cost/SY	ALASKA	CALIFORNIA	INDIANA	KANSAS	LOUISIANA	MAINE	MICHIGAN	MINNESOTA	MISSISSIPPI	MONTANA	NORTH DAKOTA	WASHINGTON State DOT	WISCONSIN	WYOMING
Rigid Pavement Treatments														
Crack Sealing				?	$1.63		1.99/ft		$ 15 per Gallon	$0.75/ft			$0.85	
Joint Resealing							1.10/ft		$ 15 per Gallon	$0.75/ft				
Spall Repair									$1.20	$250/sy			$2.13	
Dowel Bar Retrofit				?						$24/each		$ 90-100		
Cross Stitching (longitudinal cracks and joints)														
Partial Depth Repair										$250/sy			$2.27	
Full Depth Repair (limited number of repairs)				$8.74					$348				$3.55	
Undersealing/slab stabilization				$5.81										
Slab Lifting														
Diamond Grooving				$3.00										
Diamond Grinding				?			3.12		$21.95	$3/sy		$20	$0.42	
Other CPR (concrete pavement restoration)														
Other proprietary treatments														
Thin White Topping				?										
Ultra-Thin White Topping														
Others:														
Minor Rehab					$7.52									

Question 6 - If you are not currently using pavement preservation treatments in your pavement management system analysis, are they still used by the agency? (Y/N)				
State	Yes	No		
ALASKA	Y			
CALIFORNIA				
INDIANA				
KANSAS				
LOUISIANA				
MAINE				
MICHIGAN				
MINNESOTA				
MISSISSIPPI	Y			As for which treatments w used, we answered that in #4. As for the decision-making process, districts and central office decide based on available funds, condition, repair decision trees, and engineering judgment.
MONTANA				
NORTH DAKOTA				
WASHINGTON State DOT	Y			
WISCONSIN		N		
WYOMING				
If so, which ones and what is the decision making process?				

Question 7 - 7. Are your technical specifications for the treatments you use available on your website or available upon request? (Y/N)
State
ALASKA
CALIFORNIA
INDIANA
KANSAS
LOUISIANA
MAINE
MICHIGAN
MINNESOTA
MISSISSIPPI
MONTANA
NORTH DAKOTA
WASHINGTON State DOT
WISCONSIN
WYOMING
Please provide the Web URL address.

http://www.dot.ca.gov/hq/maint/Pavement/Offices/Pavement_Engineering/Pavement_Specifications.html
www.in.gov/dot
http://www.michigan.gov/documents/mdot/MDOT_CapitalPreventiveMaintenanceManual_322973_7.pdf
http://www.dot.state.mn.us/pre-letting/spec/index.html
http://sp.mdot.ms.gov/Construction/Pages/Standard%20Specifications.aspx
http://www.mdt.mt.gov/business/contracting.shtml
http://web.apps.state.nd.us/itd/filenet/util/file/retrievePDF?objectstore=Department%20of%20Transportation&versionseriesid=%7BCEA3DFF7-AE12-4D21-B318-A388F6649BAD%7D&type=R
http://www.wsdot.wa.gov/publications/manuals/fulltext/M41-10/SS2012.pdf

Question 8 - Are your design and construction procedures for the treatments you use available on your website or available upon request? (Y/N)				
State	Yes	No		
ALASKA				
CALIFORNIA	Y			http://www.dot.ca.gov/hq/oppd/hdm/hdmtoc.htm
INDIANA				http://www.in.gov/indot/design_manual/files/Ch52_2013.pdf
KANSAS				
LOUISIANA				
MAINE		N		See Specs
MICHIGAN	Y			http://mdotcf.state.mi.us/public/specbook/2012/
MINNESOTA	Y			PLEASE SEARCH FOR INDIVIDUAL TREATMENTS. LIMITED DESIGN AND CONSTRUCTION IS AVAILABLE.
MISSISSIPPI	Y			http://sp.mdot.ms.gov/Construction/Pages/Standard%20Specifications.aspx
MONTANA	Y			http://sp.mdot.ms.gov/Construction/Pages/Standard%20Specifications.aspx
NORTH DAKOTA	Y			2008 NDDOT Standard Specifications: http://www.dot.nd.gov/dotnet/supplspecs/standardspecs.aspx
WASHINGTON State DOT				
WISCONSIN		N		
WYOMING		N		
Please provide the Web URL address.				

Question 9 - Are there other issues your DOT deals with when considering treatments, such as available contracting resources or traffic volume limits or climatic conditions? (Y/N) Please specify.				
State	Yes	No		
ALASKA				
CALIFORNIA	Y			Traffic Management Plans, work windows, Safety analysis, Traffic volume, climate
INDIANA				
KANSAS				Traffic, proximity to other projects and other considerations are included in treatment selection. One major consideration is existing geometrics (don't raise the grade if you don't have to).
LOUISIANA				
MAINE	Y			
MICHIGAN	Y			Traffic volumes play into some treatment selections
MINNESOTA		N		
MISSISSIPPI	Y			traffic volume and rural/urban attributes are used for some low-volume/two-lane road for treatments such as chip seals.
MONTANA	Y			When specifying cold in-place recycling or microsurfacing, we normally know the bids will be high since the contractors are in different states. We wouldn't microsurface in areas where there is a lot of snowplowing.
NORTH DAKOTA		N		
WASHINGTON State DOT				
WISCONSIN		N		
WYOMING	Y			
Please specify.				

Question 10 - Can you estimate the number of Pavement Preservation Contractors available in your stare or surrounding states? (Y/N)												
State	Yes	No										
ALASKA												
CALIFORNIA												
INDIANA	Y			10								
KANSAS												
LOUISIANA												
MAINE		N										
MICHIGAN	Y			200								
MINNESOTA		N			CONTRACTORS ARE AVAILABLE FOR TO BID ON THE TREATMENTS.							
MISSISSIPPI												
MONTANA	Y			10								
NORTH DAKOTA		N										
WASHINGTON State DOT												
WISCONSIN		N										
WYOMING		N										

Question 11 - Can you provide a listing of the contractors and the amount of confidence that you have in their abilities? We recognize that this question is subjective, but a key element to the identification of pavement preservation techniques is the amount of qualified contractors.													
State	Yes	No											
ALASKA													
CALIFORNIA													
INDIANA	Y												
KANSAS													
LOUISIANA													
MAINE													
MICHIGAN		N											
MINNESOTA		N		MnDOT DOES NOT PREQUALIFY CONTRACTORS !!!									
MISSISSIPPI		N											
MONTANA		N											
NORTH DAKOTA	Y			A list of all contractors qualified to bid on NDDOT projects is at: www.dot.nd.gov/pacer/qualified.htm									
WASHINGTON State DOT													
WISCONSIN		N											
WYOMING													

Question 12 - Do you employ certain pavement preservation treatments because there are contractors in the vicinity and not employ others because there are no contractors?

Triggers	ALASKA	CALIFORNIA	INDIANA	KANSAS	LOUISIANA	MAINE	MICHIGAN	MINNESOTA	MISSISSIPPI	MONTANA	NORTH DAKOTA	WASHINGTON State DOT	WISCONSIN	WYOMING
Flexible and Composite Pavement Treatments					**N**	**Y**	**N**	**N**	**N**	**Y**	**N**		**N**	**N**

Question 13 - 13. Does your agency apply any pavement preservation treatments utilizing your DOT personnel? (Y/N)

Which ones?	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Flexible and Composite Pavement Treatments (Please select all that apply)	ALASKA	CALIFORNIA	INDIANA	KANSAS	LOUISIANA	MAINE	MICHIGAN	MINNESOTA	MISSISSIPPI	MONTANA	NORTH DAKOTA	WASHINGTON State DOT	WISCONSIN	WYOMING
	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y		N	Y
Crack Sealing	Y	Y	Y	Y			Y	Y	Y	Y	Y			X
Crack Filling	Y	Y	Y	Y			Y		Y	Y				
Seals		Y												
Slurry Seals		Y												
Scrub Seals		Y						Y						
Fog Seals/Asphalt Rejuvenators		Y	Y								Y			
Sand Seals		Y												
Chip Seals	Y	Y	Y	Y					Y	Y	Y			X
Cape Seals		Y												
Micro-surfacing		N												
Thin Overlays (non-structural, generally <= 1 ½ inch)	Y	N												
Ultra-Thin Overlays (generally <= ¾ inch)		N												
Mill & Resurface (non-structural, generally <= 1 ½ inch)		N												
Bonded Wearing Course		Y												
Profile Milling		N												
Hot In-Place Recycling		N												
Cold In-Place Recycling		N												
Other proprietary treatments														
Others:														
HIGH FLOAT ASHPHALT SURFACE TREATMENTS	Y													
MINIMAC DEPRESSED CRACK TREATMENT											Y			

Rigid Pavement Treatments	ALASKA	CALIFORNIA	INDIANA	KANSAS	LOUISIANA	MAINE	MICHIGAN	MINNESOTA	MISSISSIPPI	MONTANA	NORTH DAKOTA	WASHINGTON State DOT	WISCONSIN	WYOMING
Crack Sealing		Y	Y	Y					Y		Y			X
Joint Resealing		Y		Y				Y	Y		Y			
Spall Repair		Y		Y				Y	Y		Y			X
Dowel Bar Retrofit		N												
Cross Stitching (longitudinal cracks and joints)		Y												
Partial Depth Repair		Y									Y			X
Full Depth Repair (limited number of repairs)		Y	Y				Y	Y						
Undersealing		Y												
Slab Lifting		Y												
Diamond Grooving		N												
Diamond Grinding		N												
Other CPR (concrete pavement restoration)		N												
Other proprietary treatments		N												
Thin White Topping		N												
Ultra-Thin White Topping		N												
Others:														

Question 14 - What is the total cost of the pavement preservation treatments projects constructed annually?

State	Cost
ALASKA	
CALIFORNIA	$200m/YR MAINTAINANCE $300M/YEAR SHOPP
INDIANA	~$40M
KANSAS	$150M.
LOUISIANA	~$10M
MAINE	$60M
MICHIGAN	$80M
MINNESOTA	
MISSISSIPPI	UNKNOWN
MONTANA	$60-$65M
NORTH DAKOTA	$36.7M
WASHINGTON State DOT	
WISCONSIN	Very Small
WYOMING	$21M

Question 15 - What percentage of the annual pavements program is used for pavement preservation treatments?			
State	Percentage of the Program		
ALASKA			
CALIFORNIA	35-50%		
INDIANA	~5%		
KANSAS	44%		
LOUISIANA	~10%		
MAINE	30%		Approx.. 30%, this assumes $145m highway preservation and rehab. Plu
MICHIGAN	19.20%		
MINNESOTA			
MISSISSIPPI	UNKNOWN		
MONTANA	*35 – 40%*		
NORTH DAKOTA	35%		*Over the last approximately 5 years, ND has experienced and continues to experience an oil boom that has led to a significant increase in truck traffic. Many of our roadways affected by the truck traffic were not designed for such traffic and therefore the NDDOT has had to use larger treatment types on those roadways. Hence, a large portion of our roadways that would have received a PM treatment in the past are now requiring a larger treatment which has taken away from the PM budget.
WASHINGTON State DOT			
WISCONSIN	2%		
WYOMING	15%		

APPENDIX 6 – MATERIAL AND CONSTRUCTION SPECIFICATIONS, MIX DESIGNS, AND TREATMENT USER GUIDE

The following appendix contains draft material (900-level), construction (400-level) specifications, equipment specifications (1000-level), mix design methodologies (NJDOT Test Methods), (where appropriate), and a treatment user guide for Cold In-place Recycling.

The specifications are in NJDOT format and some references cited are contained in the NJDOT 2007 specifications. The full NJDOT 2007 specification can be found at **http://www.state.nj.us/transportation/eng/specs/2007/Division.shtml**

The Specifications included are as follows:

Fog Seal
Slurry Seal – Polymer Modified and Tire Rubber
Micro-Surfacing Polymer Modified
Chip Seal – Polymer Modified Emulsion and Asphalt Rubber
Hot In-place Recycling
Cold In-place Recycling with Foamed Asphalt
Cold In-place Recycling with Asphalt Emulsion

1. FOG SEAL

The fog seal is a bituminous surface treatment that can be used to seal pavement surfaces, centerline rumble strips, HMA longitudinal cold joints, chip seals, Cold In-place Recycling, and Full Depth Reclamation.

SECTION 422–FOG SEAL

422.01 DESCRIPTION

This section describes the requirements for furnishing and applying a fog seal surface treatment with a fine aggregate cover. This section also describes the requirements for applying fog seal over centerline rumble strips (CLRS), HMA longitudinal cold joints, Chip Seals, Cold In-place Recycling (CIR), and Full Depth Reclamation (FDR).

422.02 MATERIALS

422.02.01 Materials

Provide materials as specified:

1. **Asphalt Emulsion.** For fog seal surface treatment, fog seal of centerline rumble strips and HMA longitudinal cold joint provide emulsified asphalt of grades SS-1, SS-1h, RS-1 or RS-2 in accordance with AASHTO M 140; or provide cationic emulsified asphalt of grades CSS-1, CSS-1h, CRS-1, or CRS-2 in accordance with AASHTO M 208; and ensure all emulsified asphalts are provided as specified in 902.01.03.
2. **Polymerized Maltene Emulsion.** For fog seal of centerline rumble strips and HMA longitudinal cold joints, provide JOINTBOND® emulsion. JOINTBOND® is proprietary to Pavement Technology, Inc. of Westlake, OH, telephone number (800)333-6309. For new pavements, use JOINTBOND®. For pavements that are more than 12 months old, use JOINTBOND® PM.

Slow setting emulsified asphalts may be diluted 1 part emulsion to 1 part water. All dilution must be done at the place of manufacture.
Other emulsified asphalt designed specifically for fog sealing may be used if approved by the Bureau of Materials. Determine the application rate by the amount of residual asphalt.

Provide fine aggregate that conforms to 901.05.02 and the gradation requirements in Table 422.02.01-1:

Table 422.02.01-1 Gradation Requirements for Fine Aggregate used on Fog Seal

Sieve Size	Percent Passing
No. 8	100
No. 16	90 - 100
No. 50	70- 100
No. 200	0 - 2

422.02.02 Equipment

Provide equipment as specified:

Bituminous Material Distributor* 1003.07
Mechanical Sweeper……...1008.03

* ADD (1/8-3/16 inch nozzle set at 15-30 degrees with the bar height set to produce double coverage.)
Provide a mechanical spreader specifically designed for applying fine aggregate immediately after the fog seal emulsion application. Ensure the spreader is self propelled with positive controls capable of uniformly applying fine aggregate at the specified rate.

422.03 CONSTRUCTION

422.03.01 Fog Seal Surface Treatment

A. Fog Sealing Plan. At least 20 days before beginning placement of fog sealing, submit a detailed plan of operation to the RE for approval that includes the following:

1. Fog sealing contractor's superintendent qualifications with a list of at least 5 successful projects, including project owner contact information.
2. Size and description of crew.
3. Number, type, model of equipment and material control/metering devices along with the current calibration documentation.
4. Fog seal material type, dilution amount, manufacturer, MSDS, handling and installation guidelines, weather limitations and Quality Control plan.
5. Lighting plan for nighttime operations as specified in 108.06.
6. Schedule, hours of operation, and production rates for the Project.
7. Plant or storage locations for fog sealing emulsion, sand and additives.
8. Method of maintaining fog-sealing emulsion temperature during transportation and operation.
9. Quality control plan outlining the material testing, number and frequency planned in order to ensure compliance.
10. Method of protecting manholes, valve boxes, drop inlets and other service entrances are protected from the fog sealing.
11. Method of protecting RPMs from fog sealing

Do not begin fog sealing until the RE approves the plan. Submit an adjusted fog sealing plan to the RE for approval before making adjustments to the fog sealing operation.

B. Weather Limitations. If within the 3 hours of fog sealing, the National Weather Service locally forecasts a 40 percent chance or greater of precipitation during the scheduled placement, postpone the placement of fog seal. Do not fog seal if it is precipitating or when precipitation is imminent. The Contractor may resume fog sealing operations when the chance of precipitation is less than 40 percent, and the surface is dry.

Do not place fog sealing if the surface temperature of the underlying pavement is below 50 °F.

C. Test Strip. Construct a test strip of at least 100 feet in length on the roadway before initial placement commences. Ensure the test strip is performed during weather and sunlight conditions which will represent project production placement of the fog sealing mixture. While constructing the test strip, record the following information and submit to the RE:

1. **Ambient Temperature.** Measure the ambient temperature at the beginning and end of the fog sealing operation.

2. **Base Temperature.** Measure the surface temperature of the existing pavement at the beginning and end of the fog sealing operation.

3. **Weather Conditions.** Document the wind speed, amount of direct sunlight and humidity at the time of placement.

4. **Emulsion Temperature**. Measure the temperature of the emulsion in the distributor truck. Ensure that the emulsion is heated to the optimum application temperature as per the manufacturer prior to starting. (120-160 ^{o}F)

5. **Application Rate Verification.** With the RE present, check the application rate setting in the bituminous material distributor. With the RE present, verify the temperature of the fog sealing mixture during placement. With the RE present, verify application rate calibration using ASTM test

method D2995 except that the tiles should be 3 feet by 3 feet in dimension. After the emulsion has completely cured, weigh the tiles again to verify asphalt residual.

6. **Set Time.** Record the initial time of placement. Notify the RE when the material has completely set and is ready to be opened to traffic.

7. **Performance Under Traffic.** Do not allow traffic on the fog seal until it has completely cured. Verify that the fog sealing shows no visual signs of distress when exposed to traffic.

Upon completion of the test strip, submit test strip documentation to the RE. The RE will review the test strip documentation and visually assess the coverage of the fog seal application. Do not proceed with production fog sealing until receiving approval from the RE.

Before making adjustments to the fog sealing operations, notify the RE in writing. The RE may require a new test strip to verify the performance of the adjusted fog sealing operations.

D. Surface Preparation. Ensure all repairs and rumble strips are completed prior to beginning fog seal installation. Clean the surface of existing pavement to remove all dust debris, oil and any other materials that may prevent bonding of the fog seal. Ensure that the surface is clean and dry. Remove traffic stripes and traffic markings according to 610.03.08.

Ensure that manholes, inlets, utilities, curbs, RPM's, structures, traffic striping, and traffic markings to remain are protected from the fog seal by methods approved by the RE. Do not proceed with placement of the fog seal until the RE approves the prepared surface.

E. Fog Sealing Application. Ensure that the temperature of the CSS-1, CSS-1h, CRS-1, or CRS-2 emulsions prior to starting is at the application temperature recommended by the manufacturer (120-160^{o}F) but not exceeding 160°F.
SS-1, SS-1h, RS-1 or RS-2 emulsions are applied at ambient temperature.

Apply the fog seal uniformly at the application rate for diluted emulsion (1:1) specified in Table 422.03.01 determined during the test strip using a bituminous distributer. A 1:1 diluted emulsion is an original emulsion that has been subsequently diluted with equal parts water.

Table 422.03.01 Emulsified Binder Application Rate, gal/sy

Centerline Rumble Strip	Longitudinal Joint	Chip Seal	CIR	FDR
0.03-0.11	0.03-0.11	0.09-0.22	0.06-0.15	0.1-0.3

Ideally, one-half of the application should be sprayed in each direction to prevent build up on one side of stones only (this is particularly important in the case of chip seals) and rough surfaces. Build up on one side can result in a slippery surface and inadequate binder to fully enrich the surface or hold the stone.

Ensure that the fog seal material completely covers the pavement surface and is not streaked or ribboned. Ensure that the distribution is even with no uncoated areas or puddles of excess emulsion. Correct uncoated or lightly coated areas by applying additional fog seal emulsion. Blot areas showing an excess of fog seal with sand approved by the RE. Remove excess sand and emulsion material. In areas inaccessible to distributor spray bars, use hand spraying equipment.

The RE may reject any area where fog seal has been applied that is uncoated, ribboned, streaked or has excess emulsion material and rendered unsatisfactory. Visual inspection by the RE is considered sufficient grounds for such rejection.

F. Fine Aggregate Application. Immediately after the fog seal has been applied, apply fine aggregate at a rate of 0.25 to 0.5 pounds per square yard. Ensure sand is applied uniformly over the area where fog seal has been applied. Remove any excess material by sweeping prior to opening to traffic.

The RE may reject any area where fine aggregate has been applied that is not sufficiently covered or has excess fine aggregate material and rendered unsatisfactory. Visual inspection by the RE is considered sufficient grounds for such rejection.

G. Opening to Traffic. Allow the material sufficient curing time, as recommended by the manufacturer, before opening to traffic. Sweep to remove loose and excess aggregate by methods approved by and to the satisfaction of the RE before opening to traffic.

H. Applying Striping and Traffic Markings. Allow fog seal to cure for at least 2 weeks before applying permanent traffic striping and traffic markings. Use temporary traffic striping and markings as directed by the RE until the fog seal has cured.

I. Surface Quality Requirements. Ensure that there is no excess buildup, uncovered areas, or rough areas on the fog seal. The RE will visually inspect the fog seal for approval. The RE may reject areas of fog seal that are unsatisfactory based on visual inspection. Where fog seal has been applied that does not have sufficient aggregate cover or has excess aggregate material may be rendered unsatisfactory. Correct any areas of the fog seal that the RE rejects. Visual inspection by the RE is considered sufficient grounds for such rejection.

422.03.02 Fog Seal Strip

A. Fog Sealing Plan. At least 20 days before beginning placement of fog sealing, submit a detailed plan of operation to the RE for approval as specified in 422.03.01.A.

B. Weather Limitations. Fog seal in weather as specified in 422.03.01.B.

C. Test Strip. Construct a test strip of at least 100 feet in length on the roadway before initial placement commences as specified in 422.03.01.C.

D. Surface Preparation. Prepare the existing surface as specified in 422.03.01.D. When using polymerized maltene emulsion, the Contractor may leave the existing traffic stripes and traffic markings in place and may install new traffic stripes and markings as specified in 601.03 prior to fog seal.\

E. Fog Sealing Application. Ensure that the temperature of the asphalt emulsion prior to starting is at the application temperature recommended by the manufacturer but not exceeding 160°F. If using asphalt emulsion, apply the fog seal uniformly at the rate determined during the test strip to provide a residual asphalt of between 0.06 to 0.10 gallons per square yard using a bituminous distributer. If using polymerized maltene emulsion, apply according to manufacturer's recommendations.

Apply fog seal in a 2 feet wide strip centered over the center line rumble strip or HMA longitudinal cold joint, ensuring complete coverage of the rumble strip or HMA longitudinal cold joint. Ensure that the fog seal material completely covers the pavement surface and is not streaked or ribboned. Ensure that the distribution is even with no uncoated areas or puddles of excess emulsion. Correct uncoated or lightly coated areas by applying additional fog seal emulsion. Blot areas showing an excess of fog seal with sand approved by the RE. Remove excess sand and emulsion material. In areas inaccessible to distributor spray bars, use hand spraying equipment.

The RE may reject any area where fog seal has been applied that is uncoated, ribboned, streaked or has excess emulsion material and rendered unsatisfactory. Visual inspection by the RE is considered sufficient grounds for such rejection.

F. Applying Striping and Traffic Markings. If using asphalt emulsion, place striping as specified in 159.03.06 prior to opening to traffic. If permanent striping was not applied prior to fog sealing, allow fog seal to cure for at least 2 weeks before applying permanent traffic striping and traffic markings.

G. Opening to Traffic. Open to traffic as specified in 422.03.01.G.

H. Surface Quality Requirements. Ensure fog seal strip meets the requirements specified in 422.03.01.I.

422.04 MEASUREMENT AND PAYMENT

The Department will measure and make payment for the Items as follows:

Item	*Pay Unit*
FOG SEAL SURFACE TREATMENT	GALLON
FOG SEAL STRIP	LINEAR FOOT

The Department will make payment for REMOVAL OF TRAFFIC STRIPES and REMOVAL OF TRAFFIC MARKINGS as specified in 610.04.

The Department will make payment for TRAFFIC STRIPES LONG LIFE EPOXY RESIN, ___" as specified in 610.04.

The Department will measure FOG SEAL SURFACE TREATMENT by volume of residual asphalt by converting the quantity of emulsion to the number of gallons at 60 °F as calculated by the temperature-volume correction factors specified in 902.01 and then multiplying by the % residual asphalt in the emulsion from the certificate of compliance from the manufacturer.

2. MICRO-SURFACING AND SLURRY SEAL – POLYMER MODIFIED AND TIRE RUBBER

The micro-surfacing and slurry seal treatments are a bituminous surface treatment that can be used to seal pavement surfaces, improve pavement ride quality and skid resistance and fill wheelpath ruts.

SECTION 421 – MICRO-SURFACING AND SLURRY SEAL

421.01 DESCRIPTION

This section describes the requirements for furnishing and placing a polymer modified asphalt emulsion micro-surfacing or slurry seal. The following specification applies to both micro-surfacing and slurry seal construction unless otherwise stated.

421.02 MATERIALS

421.02.01 Materials

Provide materials as specified:

Tack Coat:
Emulsified Asphalt, Grade SS-1, SS-1h, Grade CSS-1, CSS-1h, ... 902.01.03
CQS-1h(Slurry), CSS-1hP(Micro-Surfacing), CQS-1h TR*
Micro-Surfacing 902.09
Slurry Seal 902.10

* contains 2.5% latex solids based on mass asphalt (asphalt residual) within the emulsion.

902.01.03 Emulsified Asphalts

Use emulsified asphalts of the rapid-setting (RS), medium-setting (MS), and slow-setting (SS) types conforming to AASHTO M 140. Use cationic emulsified asphalts of the rapid-setting (CRS), medium-setting (CMS), and slow-setting (CSS) types conforming to AASHTO M 208. Add CQS-1h, CQS-1h TR (contains 2.5% latex solids based on mass asphalt [asphalt residual) within the emulsion)

The emulsified asphalt producer shall provide the emulsified asphalt quality control plan annually to the ME for approval.

Submit to the ME a certification of compliance, as specified in 106.07, for the asphalt binder. The ME will perform quality assurance sampling and testing of each emulsified asphalt lot as defined in the approved quality control plan.

421.02.02 Equipment

Provide equipment as specified:
Bituminous Material Distributor 1003.07
Pneumatic-Tired Compactor 1002.01

Provide equipment that is specifically designed for mixing and spreading slurry seal or micro-surfacing. Perform calibration in the presence of the ME. Ensure that the documentation includes an individual calibration of each material at various settings that can be related to the machine metering devices. Any component replacement affecting material proportioning requires that the machine be recalibrated. Do not use a machine on the project until the calibration has been completed and accepted. Provide equipment as follows:

A. Mixing Equipment. Ensure that the machine is specifically designed and manufactured to mix micro-surfacing or slurry seal materials. Mix the material in an automatic-sequenced, self-propelled, micro-surfacing or slurry seal mixing machine. Ensure that it is a continuous-flow mixing unit that accurately delivers and proportions the mix components through a revolving multi-blade, double-shafted mixer. Sufficient storage capacity for all mix components is required to maintain an adequate supply to the proportioning controls.

Ensure that the machine is capable of loading materials while continuing to apply micro-surfacing or slurry seal. Ensure that the continuous-run machine is equipped to provide the operator with full control of the forward and reverse speeds during application and is equipped with opposite-side driver stations to assist in alignment. Ensure that the self-loading device, opposite-side driver stations, and forward and reverse speed controls are of original-equipment-manufacturer design.

Provide material control devices, readily accessible and so placed that the inspector may determine the amount of each material used at any time.

Provide machine with a water pressure system and nozzle type spray bar to provide a water spray ahead of and outside the spreader box.

Locate mineral filler feed so the proper amount of mineral filler is dropped on the aggregate before discharge into mixer.

B. Spreading Equipment. Provide spreading equipment that agitates and spreads the mixture uniformly in the surfacing box by means of twin shafted paddles or spiral augers fixed in the spreader box. Ensure that a front seal is provided such that there is no loss of the mixture at the road contact point. Ensure that there is an adjustable rear seal which will act as a final strike-off. Ensure that the spreader box and rear strike-off is designed and operated so that a uniform consistency is achieved and a free flow of material is provided to the rear strike-off. Ensure that the spreader box has suitable means provided to side shift the box to compensate for variations in the pavement geometry.

Ensure that a secondary strike-off is provided to improve surface texture. Ensure that the secondary strike-off is adjustable to match the width of the spreader box and allows for varying pressures to control the surface texture.

C. Rut, Longitudinal Joint or Rumble Strip Filling Equipment. Provide rut filling equipment with a steel V-configuration screed rut box commercially designed and manufactured to fill ruts, longitudinal joints, and rumble strips, as required. Ensure that the rut box will achieve a mixture spread width of between 2 and 6 feet and have a moveable steel strike-off to control crown.

D. Small Tools. Provide hand squeegees, shovels, and other equipment necessary to perform the work.

E. Cleaning Equipment. Provide cleaning equipment such as power brooms, air compressors, water flushing equipment, and hand brooms adequate for surface preparation.

421.03 CONSTRUCTION

421.03.01 Installing Micro-Surfacing or Slurry Seal Treatment

J. Micro-surfacing/Slurry Seal Plan. At least 20 days before beginning placement of micro-surfacing or slurry seal, submit a detailed plan of operation to the RE for approval that includes the following:

12. Micro-surfacing/slurry seal contractors' superintendent qualifications with a list of at least 5 successful projects, including project owner contact information.

13. Size and description of crew.

14. Number, type, model of equipment and material control/metering devices along with the current calibration documentation.

15. Lighting plan for nighttime operations as specified in 108.06.
16. Method of locating, protecting and maintaining manholes, inlets, other utilities and RPM's.
17. Paving procedures for maintaining continuous operation as specified.
18. Paving sequence. Ensure that the micro-surfacing or slurry seal is constructed for the full lane width as a single paving operation as required in the plans and specifications.
19. Schedule, hours of operation, and production rates for the Project.
20. Plant or stockpile locations for aggregate, micro-surfacing emulsion, mineral filler and any additives.
21. Method of maintaining micro-surfacing or slurry seal modified emulsion temperature during transportation.
22. Method of constructing joints.
23. Quality control plan outlining the material testing, number and frequency planned in order to ensure compliance.
24. Mix design of the micro-surfacing mixture, the AASHTO accredited laboratory used and the test results of the mixture.

Do not begin micro-surfacing or slurry seal until the RE approves this plan. Submit an adjusted micro-surfacing or slurry seal plan before making adjustments to the micro-surfacing operation.

K. Weather Limitations. If within the 3 hours of micro-surfacing or slurry seal, the National Weather Service locally forecasts a 50 percent chance or greater of precipitation during the scheduled placement, postpone the placement of micro-surfacing or slurry seal. Do not place micro-surfacing or slurry seal if it is precipitating and when precipitation is imminent. The Contractor may resume micro-surfacing or slurry seal operations when the chance of precipitation is less than 50 percent, and the surface is dry.

Do not place micro-surfacing or slurry seal if the surface temperature of the underlying pavement is below 50 F or if there is a possibility of freezing temperatures within 24 hours after application.

L. Test Strip. Construct a test strip of at least 500 feet in length on the roadway before initial placement commences. Ensure that the tack coat has been placed as specified in 401.03.02. Ensure the test strip is performed during weather and sunlight conditions which will represent project production placement of the micro-surfacing or slurry seal mixture. While constructing the test strip, record the following information and submit to the RE:

8. Ambient Temperature. Measure the ambient temperature at the beginning and end of each day's micro-surfacing or slurry seal operation.
9. **Base Temperature.** Measure the surface temperature of the existing pavement at the beginning and end of each day's operation.
10. **Weather Conditions.** Document the wind speed, amount of direct sunlight and humidity at the time of placement.
11. **Tack Coat**. Measure to verify the proper application rate, coverage and temperature of tack coat for compliance.
12. Micro-surfacing or Slurry Seal Mixture. Measure to verify the proper proportions of emulsion, cement, aggregate, additives (if any) and temperature of the micro-surfacing or slurry seal mixture during placement. Measure to verify the proper application rate of the micro-surfacing or slurry seal mixture for compliance.
13. **Roller Pattern.** Provide details on the number of rollers, type, and number of passes used on the test strip.
14. **Initial Set Time.** Record the initial time of placement. Verify that the micro-surfacing or slurry seal mixture has achieved initial set within 30 minutes of placement.
15. Performance Under Traffic. Verify that the micro-surfacing shows no visual signs of distress when exposed to traffic after curing for 1 hour.

Submit test strip results to the RE. The RE will analyze the test strip results in conjunction with the ME's results to approve the test strip. Do not proceed with production placement of the micro-surfacing or slurry seal until receiving written permission from the RE.

If the test strip does not meet requirements, make adjustments and construct a second test strip. If the second test strip does not meet requirements, suspend operations until written approval to proceed is received.

Before making adjustments to the operations, notify the RE in writing. The RE may require a new test strip to verify the performance of the adjusted operations.

M. Surface Preparation. Ensure that the surface where the micro-surfacing or slurry seal is placed is clean of foreign and loose material. Remove traffic tape and thermoplastic traffic markings according to 610.03.08. Clean the surface of existing pavement using a self-propelled power broom equipped with a vacuum collection system before placing the micro-surfacing. Ensure that the surface is dry when the micro-surfacing operations are about to start. If water is used, allow cracks to dry thoroughly before applying the micro-surfacing.

Ensure that manholes, valve boxes, drop inlets and other service entrances are protected from the micro-surfacing by methods approved by the RE. Protect the RPM's by methods approved by the RE.

If directed by the RE, apply water to dry areas, Apply tack coat prior to application of the micro-surfacing mixture in accordance with 401.03.02. If necessary, dampen the pavement surface with water or apply a tack coat emulsion to the pavement surface before applying **quick-set slurry**. The tack coat may consist of one part emulsified asphalt/three parts water and should be applied with a standard distributor. The distributor shall be capable of applying the dilution evenly at a rate of 0.05-0.15 gal/sy.

N. Application Rates.

Micro-surfacing Application Apply the micro-surfacing mixture over the full lane width in accordance with table 421.03.01-1.

Table 421.03.01-1 Job Mix Types and Application

Aggregate Type (See Table 902.09.03-1)	Location	Application Rate (lbs/yd^2)
Type II	Surface Course – All Highways	18 – 22
	Leveling Course	As required
Type III	Surface Course – Highways with Heavy Trucks	20 – 30
	Wheel Ruts	As required (See ISSA[1] A143)

1. International Slurry Seal Association (ISSA)

Slurry Seal Application. Apply the slurry seal mixture in accordance with table 421.03.02-2.

Table 421.03.02-2 Job Mix Types and Application

Aggregate Type (See Table 902.10.03-1)	Location	Application Rate (lbs/yd^2)
Type I	Surface Course – Low ESAL Roads Scratch Course – Low to Moderate Cracking	10 - 14
Type II	Surface Course – All Highways	16 – 20

1. International Slurry Seal Association (ISSA)

Operate spreading equipment to prevent the loss of the mixture on super-elevated curves. Spread the mixture to fill cracks and minor surface irregularities and leave a uniform high-skid resistant application of aggregate and asphalt on the surface. Operate spreader box so a uniform consistency is achieved without causing skips, lumps or tears in the finished surface. The maximum speed of the slurry machine shall not exceed 270 feet per minute.

Spread the mixture to fill ruts and shallow potholes and leave a uniform surface. Take care when filling ruts to restore the designed profile of the pavement cross section. Ruts which are 1/2" or less can be filled with a single full lane micro-surfacing operation. Ruts which are greater than 1/2" in depth require filling with a separate rut-filling operation in each wheelpath, as needed. Ruts which are greater than 1 1/2" in depth may require multiple applications with the rut-filling spreader box. Avoid excess crowning (over filling) of rut areas. All rut-filling and level-up material should cure under traffic for at least twenty-four (24) hours before additional material is placed.

Carry a sufficient amount of material, at all times, in all parts of the spreader box, so complete coverage is obtained. Water may be sprayed into spreader box to facilitate spreading without harming the mix. No lumping, balling or unmixed aggregate is permitted in the finished surface.

Adjustments to the additive may be required for slow setting where hand spreading is needed. Use squeegees and lutes to spread the mixture in areas inaccessible to the spreader box and areas requiring hand spreading. When hand spreading, pour the mixture in a small winnow along one edge of the surface to be covered and then spread uniformly by a hand squeegee or lute. Make a neat appearing seam where two passes join. The maximum overlap of longitudinal lane line joints is 3 inches. Remove excess material from ends of each run immediately.

Do not leave streaks, such as those caused by oversized aggregate, in the finished surface. If excess streaking develops, stop the job and propose a solution to the RE. Do not resume placing the micro-surfacing until approved by the RE.

O. Compaction. Rolling of micro-surfacing is required. Do not roll until the micro-surfacing has cured sufficiently to avoid damage by the roller. Use a 10-ton (maximum) pneumatic-tired compactor as specified in 1002.01, except ensure the roller is equipped with a water-spray system. Roll micro-surfacing with a minimum of at least 2 passes of the pneumatic-tired compactor. The RE may direct additional passes to eliminate roller marks or facilitate compaction of rut-filled areas.

P. Opening to Traffic. Allow the material sufficient curing time before opening to traffic. Remove loose material from the traveled way before opening to traffic. If the material becomes damaged by allowing vehicles to ride on it before it has cured, or it becomes damaged, replace the damaged area.

Ensure all rut-filling and leveling material cures under traffic for at least twenty-four (24) hours before placing additional material.

Q. Surface Quality Requirements. Ensure that there is no excess buildup, uncovered areas, or rough areas on the micro-surfacing including the longitudinal or transverse joints. The RE may use a 10 foot straightedge to verify transverse profiles of all finished surfaces. Correct areas that have more than 1/4 inch deviation between any 2 contact points of the straightedge in a manner approved by the RE. Following correction, retest the area to verify conformance with this requirement.

R. Ride Quality Requirements. The Department will evaluate the final surface placed in the traveled way as specified in 401.03.03.J.

421.04 MEASUREMENT AND PAYMENT

The Department will measure and make payment for the Items as follows:

Item	*Pay Unit*
MICRO-SURFACING AGGREGATE, TYPE II	TON
MICRO-SURFACING AGGREGATE, TYPE III	TON
MICRO-SURFACING AGGREGATE, TYPE III RUT-FILLING	TON
MICRO-SURFACING EMULSION	GALLON
SLURRY SEAL AGGREGATE, TYPE II	TON
SLURRY SEAL AGGREGATE, TYPE I	TON
SLURRY SEAL EMULSION	GALLON

The Department will make payment for TACK COAT as specified in 401.04.

The Department will make payment for REMOVAL OF TRAFFIC STRIPES and REMOVAL OF TRAFFIC MARKINGS as specified in 610.04.

The Department will measure MICRO-SURFACING EMULSION and SLURRY SEAL EMULSION by the volume delivered, converted to the number of gallons at 60 °F as calculated by the temperature-volume correction factors specified in 902.01.

MICRO-SURFACING AGGREGATE TYPE II, MICRO-SURFACING AGGREGATE TYPE III, MICRO-SURFACING AGGREGATE TYPE III RUT-FILLING and SLURRY SEAL AGGREGATE, TYPE II will be measured by the ton as indicated on the certified weigh tickets, excluding unused material.

902.09 MICRO-SURFACING

902.09 MICRO-SURFACING

902.09.01 Composition of the Mixture

Ensure that the micro-surfacing mixture components conform to the following:

1. **Micro-surfacing Emulsion.** Use polymer modified emulsified asphalt or a tire rubber modified emulsion asphalt. Ensure that the emulsified asphalt and emulsified asphalt residue is a quick set polymer modified asphalt emulsion conforming to the requirements of AASHTO M 208 for a CQS-1hP emulsion or CQS-1h TR and the following:
    a. Use a minimum of 3 percent polymer material or 2.5 percent tire rubber, by weight of asphalt.
    b. Ensure that the polymer material is milled or blended into the asphalt prior to the emulsification process by an emulsion manufacturer approved by the ME.
    c. Ensure that the polymer modifier and any additives enable the micro-surfacing material to receive normal traffic within one hour without causing damage to the surface. The cement mixing test is waived for this emulsion. .
    d. Ensure that the emulsified asphalt and the emulsified asphalt residue meet all of the quality test criteria in section 4.1.2 of the International Slurry Surfacing Association (ISSA) "Recommended Performance Guideline for Micro-surfacing"; A 143.
    e. Ensure that the emulsified asphalt and the emulsified asphalt residue meet all of the quality test criteria in Table 902.09.01-1 and Table 902.09.01-2

Table 902.09.01-1– updated for QUICK SET EMULSION CQS-1h TR *

TESTS	**Test Method**	**REQUIREMENTS**	
		Min.	**Max.**
Furol Viscosity at 25°C (77°F), sec.	AASHTO T59	20	100
Residue from distillation, % by weight	AASHTO T59	62.	
Sieve Test (% retained on 850 µm [No. 20])	AASHTO T 59		0.30
Particle Charge Test (Cationic)	AASHTO T 59	Positive	
Storage Stability; 1-Day Settlement	AASHTO T 59		1%
Residue from Evaporation	California Test 331	57	
Penetration 0.1 mm	AASHTO T49	40	90
Solubility in TCE*,%	AASHTO T44	97.5	
Recycled Tire Rubber %	Certificate	5	
Ductility, 25°C (77°F), 5cm/min, cm	AASHTO T 51	400	
Softening point, ^{o}F	AASHTO T 53	130	

* The base asphalt shall contain a minimum of 5% recycled tire rubber. The finished asphalt binder composition shall be smooth and homogeneous. The tire rubber material shall be totally incorporated into the asphalt cement yielding a finished product of singular composition.
* The solubility to be run on the base asphalt of the emulsion containing the tire rubber.

902.09.01-2 Emulsified Asphalt and Residue Requirements

Tests	Test Method	Specification
Tests on Emulsified Asphalt		
Storage Stability, 24 hours, percent	AASHTO T 59	1 % maximum
Residue by Distillation*, percent	AASHTO T 59	62 % minimum
Tests on Asphalt Residue		
Softening Point by Ring and Ball	AASHTO T 53	135°F minimum

* Test temperature held at 350°F for 20 minutes

2. **Aggregate.** Use only manufactured stone sand and crushed stone that conform to 901.05. Ensure that the fine aggregate has a Sand Equivalent value of 65 percent minimum when tested according to AASHTO T 176.
3. **Mineral Filler.** Use mineral filler that conforms to ASTM D 242 and is free of lumps.
4. **Water.** Use water that conforms to 919.08.
5. **Other Additives.** The Contractor may use other additives to provide control of the break/set time in the field. Ensure that the type of additive is specified in the mix design.

902.09.02 Mix Design of Micro-surfacing Mixture

A. Mix Design Requirements. Ensure that an AASHTO accredited lab, with at least five successfully completed micro-surfacing projects greater than 5,000 square yards each, performs the mix design. Submit the mix design and certified test results of the micro-surfacing mixture for approval in accordance with the provisions of ASTM D 6372, Standard Practice for Design, Testing, and Construction of Micro-surfacing and the following:

1. Ensure that the aggregate used in the job mix formula is from the same source and representative of the material proposed for use on the project.
2. Ensure that the compatibility of the aggregate, micro-surfacing emulsion, water, mineral filler, and other additives is evaluated in the mix design. Perform the mix design using materials consistent with those supplied by the contractor for the project. Ensure the micro-surfacing mix conforms to the requirements as specified in Table 902.09.02-1.

902.09.02-1 Micro-surfacing Mixture Requirements

Tests	ISSA Test Method	Specification
Mix Time @ 77°F Mix Time @ 100°F	TB 113	Controllable to 120 seconds minimum Controllable to 35 seconds minimum
Wet Cohesion @ 30 minutes minimum (set) @ 60 minutes minimum (traffic)	TB 139	12 kg-cm minimum 20 kg-cm or near spin minimum
Wet Stripping	TB 114	90 % minimum
Wet-Track Abrasion Loss One-hour soak Six-day soak	TB 100	 50 g/ft^2 (538 g/m^2) maximum 75 g/ft^2 (807 g/m^2) maximum
Lateral Displacement	TB 147	5% maximum
Specific Gravity after 1,000 cycles of 125 pounds (56.71 kg)	TB 147	2.10 maximum
Excess Asphalt by LWT Sand Adhesion	TB 109	50 g/ft^2 (538 g/m^2) maximum
Classification Compatibility	TB 144	11 grade points minimum (AAA, BAA)

3. Ensure proportioning of the mix design is within the limits in Table 902.09.02-2:

Table 902.09.02-2 Mix Design Proportion Requirements

Component Materials	Limits
Residual asphalt	5.5 to 11.5% by dry weight of aggregates
Mineral filler	0.0 to 3% by dry weight of aggregates
Polymer-based modifier	min. of 3% polymer solids based on bitumen weight content
Additives	as needed
Water	as required to ensure proper mix consistency

4. Ensure that the proportions of aggregate and mineral filler are provided and within the limits of Table 902.09.03-1.

B. Mix Design Report. Submit the final mix design in the following format:

1. Source of each individual material.
2. Aggregate:
   a. Gradation
   b. Sand Equivalent
   c. Abrasion Resistance
   d. Soundness
3. Field Simulation Tests:
   a. Wet Stripping Test
   b. Wet Track Abrasion Loss
   c. Classification Compatibility
   d. Trial Mix Time @ 77°F and 100°F
4. Interpretation of Results and the Determination of a Job Mix Formula (JMF):
   a. Percentage of Mineral Filler (minimum and maximum)
   b. Percentage of Water, including aggregate moisture (minimum and maximum)
   c. Percentage of Mix Set Additive (if required)
   d. Percentage of Modified Emulsion
   e. Residual Content of Modified Emulsion
   f. Percentage of Residual Asphalt
   g. Combined Aggregate Gradation (JMF)
5. Signature and date

902.09.03 Sampling and Testing

The ME will perform sampling and testing of the aggregate at least 10 days prior to the start of work. The ME will sample aggregate from stockpiles designated and constructed for each mixture type on the project. The ME will sample the aggregate according to AASHTO T 2 and test according to AASHTO T 11 and T 27 using the following sampling frequency:

1. When the project quantity for the specified mixture type is less than 500 tons, designate the entire quantity as one lot and divide into three equal sublots for sampling. Obtain one sample from each sublot and submit to the ME for testing. The ME will randomly select only one of the three samples and test for compliance with Table 902.09.03-1. If the sample tested meets the specification, the entire lot is acceptable for use on the project. If the sample fails, the ME will test the remaining two samples. If the two samples both meet specification, the entire lot is acceptable for use on the project. If either of the two additional samples fails to meet the specification, the entire lot is rejected.
2. When the project quantity for the specified mixture type is 500 tons or greater, divide the aggregate into equal lots at the discretion of the ME, but in no case is the lot size to exceed 1,000 tons. Divide each lot into three equal sublots and obtain one sample for each sublot. The ME will randomly select only one of the three samples and test for compliance with Table 902.09.03-1. If the sample tested meets the specification, the entire lot is acceptable for use on the project. If the sample fails, the ME will test the

remaining two samples. If the two samples both meet specification, the entire lot is acceptable for use on the project. If either of the two additional samples fails to meet the specification, the entire lot is rejected.

Take precautions to ensure that approved stockpiles of aggregate do not become contaminated at the jobsite. Screen oversize aggregate or foreign materials from the aggregate prior to delivery to the mixer.

During the micro-surfacing application, in the presence of the inspector, sample the mixture twice daily or as directed from the pug mill discharge chute. Use a rectangular non-absorptive container, such as a loaf pan, of sufficient size to obtain a sample from the entire cross section of the mixture being discharged. Ensure that an AASHTO accredited lab, with at least five successfully completed micro-surfacing projects greater than 5,000 square yards each, analyzes the mix for binder content and compliance with specifications. Submit certified results to the ME. To ensure mix compliance, the ME may perform independent testing.

Ensure that the asphalt content is within ± 0.40 of the JMF. If the asphalt content is outside of the allowable tolerance, recalibrate or adjust the mixing machine. The RE may stop the micro-surfacing operation if two or more samples fail to conform to the tolerance. Take corrective action or re-design the micro-surfacing mixture. Resume operations only after RE has approved the corrective action.

Use aggregate, including mineral filler, which conforms to the gradation in Table 902.09.03-2.

Table 902.09.03-2 Gradation Requirements for Aggregate and Mineral Filler

Sieve Size	Type II Percent Passing	Type III Percent Passing	Stockpile Tolerances from JMF
3/8”	100	100	-
No. 4	90-100	70-90	±5%
No. 8	65-90	45-70	±5%
No. 16	45-70	28-50	±5%
No. 30	30-50	19-34	±5%
No.50	18-30	12-25	±4%
No. 100	10-21	7-18	±3%
No. 200	5-15	5-15	±2%

902.10 SLURRY SEAL

902.10.01 Composition of the Mixture

Ensure that the slurry seal mixture components conform to the following:

1. **Slurry Seal Emulsion.** Use polymer modified emulsified asphalt or a tire rubber modified emulsion asphalt. Ensure that the emulsified asphalt and emulsified asphalt residue is a quick set polymer modified asphalt emulsion conforming to the requirements of AASHTO M 208 for a CQS-1hP emulsion or CQS-1h TR and the following:
    a. Use a minimum of 3 percent polymer material or 2.5 percent tire rubber, by weight of asphalt.
    b. Ensure that the polymer material is milled or blended into the asphalt prior to the emulsification process by an emulsion manufacturer approved by the ME.
    c. Ensure that the polymer modifier and any additives enable the slurry seal material to receive normal traffic within one hour without causing damage to the surface.
    d. Ensure that the emulsified asphalt and the emulsified asphalt residue material conform to the requirements in table 902.10.01-1.
    e. Ensure that the emulsified asphalt and the emulsified asphalt residue meet all of the quality test criteria in Table 902.10.01-1

Table 902.10.01-1– updated for QUICK SET EMULSION CQS-1h TR *

TESTS	Test Method	REQUIREMENTS

		Min.	**Max.**
Furol Viscosity at 25°C (77°F), sec.	AASHTO T59	20	100
Residue from distillation, % by weight	AASHTO T59	62.	
Sieve Test (% retained on 850 µm [No. 20])	AASHTO T 59		0.30
Particle Charge Test (Cationic)	AASHTO T 59	Positive	
Storage Stability; 1-Day Settlement	AASHTO T 59		1%
Residue from Evaporation	California Test 331	57	
Penetration 0.1 mm	AASHTO T49	40	90
Solubility in TCE*,%	AASHTO T44	97.5	
Recycled Tire Rubber %	Certificate	5	
Ductility, 25°C (77°F), 5cm/min, cm	AASHTO T 51	400	
Softening point, °F	AASHTO T 53	130	

* The base asphalt shall contain a minimum of 5% recycled tire rubber. The finished asphalt binder composition shall be smooth and homogeneous. The tire rubber material shall be totally incorporated into the asphalt cement yielding a finished product of singular composition.
* The solubility to be run on the base asphalt of the emulsion containing the tire rubber.

902.10.01-2 Emulsified Asphalt and Residue Requirements

Tests	**Test Method**	**Specification**
Tests on Emulsified Asphalt		
Storage Stability, 24 hours, percent	AASHTO T 59	1 % maximum
Residue by Distillation*, percent	AASHTO T 59	62 % minimum
Tests on Asphalt Residue		
Softening Point by Ring and Ball	AASHTO T 53	135°F minimum
* Test temperature held at 350°F for 20 minutes.		

2. **Aggregate.** Use only manufactured stone sand and crushed stone that conform to 901.05. Ensure that the fine aggregate has a Sand Equivalent value of 45 percent minimum when tested according to AASHTO T 176.
3. **Mineral Filler.** Use mineral filler that conforms to ASTM D 242 and is free of lumps.
4. **Water.** Use water that conforms to 919.08.
5. **Other Additives.** The Contractor may use other additives to provide control of the break/set time in the field. Ensure that the type of additive is specified in the mix design.

902.10.02 Mix Design of Slurry Seal Mixture

C. Mix Design Requirements. Ensure that an AASHTO accredited lab, with at least five successfully completed slurry seal projects greater than 5,000 square yards each, performs the mix design. Submit the mix design and certified test results of the slurry seal mixture for approval in accordance with the provisions of ASTM D 3910, Standard Practice for Design, Testing, and Construction of Slurry Seal and the following:

1. Ensure that the aggregate used in the job mix formula is from the same source and representative of the material proposed for use on the project.
2. Ensure that the compatibility of the aggregate, slurry seal emulsion, water, mineral filler, and other additives is evaluated in the mix design. Perform the mix design using materials consistent with those supplied by the contractor for the project. Ensure the slurry seal mix conforms to the requirements as specified in Table 902.10.02-1.

902.10.02-1 Slurry Seal Mixture Requirements		
Tests	**ISSA Test Method**	**Specification**
Mix Time @ 77°F Mix Time @ 100°F	TB 113	Controllable to 120 seconds minimum Controllable to 35 seconds minimum
Slurry Seal Consistency	TB 106	0.79 to 1.18 inches
Wet Cohesion @ 30 minutes minimum (set) @ 60 minutes minimum (traffic)	TB 139	12 kg-cm minimum 20 kg-cm or near spin minimum
Wet Stripping	TB 114	90 % minimum
Wet-Track Abrasion Loss One-hour soak Six-day soak	TB 100	50 g/ft^2 (538 g/m^2) maximum 75 g/ft^2 (807 g/m^2) maximum
Lateral Displacement	TB 147	5% maximum
Specific Gravity after 1,000 cycles of 125 pounds (56.71 kg)	TB 147	2.10 maximum
Excess Asphalt by LWT Sand Adhesion	TB 109	50 g/ft^2 (538 g/m^2) maximum
Classification Compatibility	TB 144	11 grade points minimum (AAA, BAA)

3. Ensure proportioning of the mix design is within the limits in Table 902.10.02-2:

Table 902.10.02-2 Mix Design Proportion Requirements	
Component Materials	**Limits**
Residual asphalt	7.5 to 13.5% by dry weight of aggregates
Mineral filler	0.0 to 3% by dry weight of aggregates
Polymer-based modifier	min. of 3% polymer solids based on bitumen weight content
Additives	as needed
Water	as required to ensure proper mix consistency

4. Ensure that the proportions of aggregate and mineral filler are provided and within the limits of Table 902.10.03-1.

D. Mix Design Report. Submit the final mix design in the following format:

1. Source of each individual material.
2. Aggregate:
   a. Gradation
   b. Sand Equivalent
   c. Abrasion Resistance
   d. Soundness
3. Field Simulation Tests:
   a. Wet Stripping Test
   b. Wet Track Abrasion Loss
   c. Classification Compatibility
   d. Trial Mix Time @ 77°F and 100°F
4. Interpretation of Results and the Determination of a Job Mix Formula (JMF):
   a. Percentage of Mineral Filler (minimum and maximum)
   b. Percentage of Water, including aggregate moisture (minimum and maximum)
   c. Percentage of Mix Set Additive (if required)
   d. Percentage of Modified Emulsion
   e. Residual Content of Modified Emulsion
   f. Percentage of Residual Asphalt
   g. Combined Aggregate Gradation (JMF)
5. Signature and date

902.10.03 Sampling and Testing

The ME will perform sampling and testing of the aggregate at least 10 days prior to the start of work. The ME will sample aggregate from stockpiles designated and constructed for each mixture type on the project. The ME will sample the aggregate according to AASHTO T 2 and test according to AASHTO T 11 and T 27 using the following sampling frequency:

1. When the project quantity for the specified mixture type is less than 500 tons, designate the entire quantity as one lot and divide into three equal sublots for sampling. Obtain one sample from each sublot and submit to the ME for testing. The ME will randomly select only one of the three samples and test for compliance with Table 902.10.03-1. If the sample tested meets the specification, the entire lot is acceptable for use on the project. If the sample fails, the ME will test the remaining two samples. If the two samples both meet specification, the entire lot is acceptable for use on the project. If either of the two additional samples fails to meet the specification, the entire lot is rejected.
2. When the project quantity for the specified mixture type is 500 tons or greater, divide the aggregate into equal lots at the discretion of the ME, but in no case is the lot size to exceed 1,000 tons. Divide each lot into three equal sublots and obtain one sample for each sublot. The ME will randomly select only one of the three samples and test for compliance with Table 902.10.03-1. If the sample tested meets the specification, the entire lot is acceptable for use on the project. If the sample fails, the ME will test the remaining two samples. If the two samples both meet specification, the entire lot is acceptable for use on the project. If either of the two additional samples fails to meet the specification, the entire lot is rejected.

Take precautions to ensure that approved stockpiles of aggregate do not become contaminated at the jobsite. Screen oversize aggregate or foreign materials from the aggregate prior to delivery to the mixer.

During the slurry seal application, in the presence of the inspector, sample the mixture twice daily or as directed from the pug mill discharge chute. Use a rectangular non-absorptive container, such as a loaf pan, of sufficient size to obtain a sample from the entire cross section of the mixture being discharged. Ensure that an AASHTO accredited lab, with at least five successfully completed slurry seal projects greater than 5,000 square yards each, analyzes the mix for binder content and compliance with specifications. Submit certified results to the ME. To ensure mix compliance, the ME may perform independent testing.

Ensure that the asphalt content is within ± 0.40 of the JMF. If the asphalt content is outside of the allowable tolerance, recalibrate or adjust the mixing machine. The RE may stop the slurry seal operation if two or more samples fail to conform to the tolerance. Take corrective action or re-design the slurry seal mixture. Resume operations only after RE has approved the corrective action.

Use aggregate, including mineral filler, which conforms to the gradation in Table 902.10.03-1.

Table 902.10.03-1 Gradation Requirements for Aggregate and Mineral Filler

Sieve Size	Type I Percent Passing	Type II Percent Passing	Type III Percent Passing	Stockpile Tolerances from JMF
3/8”	100	100	100	-
No. 4	100	90-100	70-90	±5%
No. 8	90-100	65-90	45-70	±5%
No. 16	65-90	45-70	28-50	±5%
No. 30	40-65	30-50	19-34	±5%
No.50	25-42	18-30	12-25	±4%
No. 100	15-30	10-21	7-18	±3%
No. 200	10-20	5-15	5-15	±2%

DIVISION 1000 – EQUIPMENT

THE FOLLOWING SECTION IS ADDED:

SECTION 1012 – PAVEMENT PRESERVATION EQUIPMENT

1012.01 Micro-surfacing and Slurry Seal Paver

Provide fully automated self-propelled continuous flow type equipment that is specifically designed, equipped, calibrated, and operated for mixing and spreading slurry seal and micro-surfacing conforming to the approved mix design and application rate. Immediately correct defects that adversely affect the functioning of the equipment or quality of the mixture. Perform calibration in the presence of the ME. Ensure that the documentation includes an individual calibration of each material at various settings that can be related to the machine metering devices. Any component replacement affecting material proportioning requires that the machine be recalibrated. Do not use a machine on the project until the calibration has been completed and accepted. Ensure the paver is equipped with the following:

1. **Mixing Equipment.** Ensure that the machine is specifically designed and manufactured to mix micro-surfacing or slurry seal materials. Mix the material in an automatic-sequenced, self-propelled, micro-surfacing or slurry seal mixing machine. Ensure that it is a continuous-flow mixing unit that accurately proportions and delivers the mix components, within 2 % of the required amount as per the mix design, into a revolving multi-blade double-shafted mixer. Sufficient storage capacity for all mix components is required to maintain an adequate supply to the proportioning controls.

   Ensure that the machine is capable of loading materials while continuing to apply micro-surfacing or slurry seal. Ensure that the continuous-run machine is equipped to provide the operator with full control of the forward and reverse speeds during application and is equipped with opposite-side driver stations to assist in alignment. Ensure that the self-loading device, opposite-side driver stations, and forward and reverse speed controls are of original-equipment-manufacturer design.

   Provide material control devices, readily accessible and so placed that the inspector may determine the amount of each material used at any time.

   Provide machine with a water pressure system and nozzle type spray bar to provide a water spray ahead of and outside the spreader box.

   Locate mineral filler feed so the proper amount of mineral filler is dropped on the aggregate before discharge into mixer.

2. **Spreading Equipment.** Provide spreading equipment that agitates and spreads the mixture uniformly in the surfacing box by means of twin shafted paddles or spiral augers fixed in the spreader box. Ensure that a front seal is provided such that there is no loss of the mixture at the road contact point. Ensure that there is an adjustable rear seal which will act as a final strike-off. Ensure that the spreader box and rear strike-off is designed and operated so that a uniform consistency is achieved and a free flow of material is provided to the rear strike-off. Ensure that the spreader box has suitable means provided to side shift the box to compensate for variations in the pavement geometry.

   Ensure that a secondary strike-off is provided to improve surface texture. Ensure that the secondary strike-off is adjustable to match the width of the spreader box and allows for varying pressures to control the surface texture.

3. **Electronic Mix Control and Diagnostic (EMCAD) System.** Ensure the paver is equipped with a computer mix control and diagnostic system that records, displays, and prints the following:

   1. Individual sensor counts for emulsion, aggregate, mineral filler, water, and additive.

   2. Aggregate, emulsion and mineral filler output in pounds per minute.

   3. Spread rate in pounds per square yard.

   4. Percentages of emulsion, mineral filler, water, and additive.

   5. Cumulative total quantities of aggregate. Emulsion, mineral filler, water, and additive.

   6. Scale factor for all materials.

   Ensure the computer system is functional and capable of printing reports.

4. **Rut, Longitudinal Joint or Rumble Strip Filling Equipment.** Provide rut filling equipment with a steel V-configuration screed rut box commercially designed and manufactured to fill ruts as required. Ensure that the rut box can be adjusted to provide a mixture spread width of between 2 feet to 6 feet and have a moveable steel strike-off to control crown.

1012.02 Mechanical Fine Aggregate Spreader

Provide fully automated self-propelled fine aggregate spreading equipment with positive controls that is specifically designed, equipped, calibrated, and operated for spreading fine aggregate uniformly at the required width and application rate. Immediately correct defects that adversely affect the functioning of the equipment or quality of the fine aggregate application. Perform calibration in the presence of the ME. Ensure that the calibration documentation includes the fine aggregate at various application rate settings that can be related to the machine metering devices. Any component replacement affecting application rate requires that the machine be recalibrated. Do not use a machine on the project until the calibration has been completed and accepted.

3. CHIP SEAL

The chip seal treatments are a bituminous surface treatment that can be used to seal pavement surfaces, improve pavement ride quality and skid resistance. NJDOT chose to use a polymer modified bituminous emulsion binder. An asphalt rubber chip seal specification was also developed.

SECTION 40X – ASPHALT RUBBER/POLYMER MODIFIED BINDER CHIP SEAL

40X.01 DESCRIPTION

This Section describes the requirements for applying Asphalt Rubber or Polymer Modified Binder Chip Seal.

40X.02 MATERIALS

40X.02.01 MATERIALS AND EQUIPMENT

Provide materials as specified:	
Asphalt Rubber Binder	902.XX
Polymer Modified Binder	902.XX
Aggregates	902.XX
Polymer Modified Tack Coat	902.01.04
Water	919.08
Fog Seal	422.03.01

40X.02.02 EQUIPMENT

Provide equipment as specified:	
Pneumatic-Tired Compactor	1002.01
HMA Compactor	1003.05
Vibratory Drum Compactor	1003.06
Bituminous Material Distributor	1003.07*
Sealer Application System	1003.08
Mechanical Sweeper**	1008.03
Aggregate Chip Spreader	**1003.0X**

***** addition to the requirements in 1003.7 – Equip the distributor with an internal heating device capable of heating the material evenly up to 218°C, (425° F); an internal mixing unit capable of maintaining a proper mixture of asphalt cement and granulated rubber; have adequate pump

capacity to maintain a high rate of circulation in the tank and to spray the asphalt-rubber at a viscosity of 1,500 to 5,000 centipoise; have adequate pressure devices and suitable manifolds to provide constant positive cut-off to prevent dripping from the nozzles. Equip the Distributor with an electronically controlled computerized compensation unit for controlling application rates at various width and speed changes. Equip the distributer with electronic controls and a digital read out installed and operated from the inside of the cab of the distributor. Ensure that the distribution bar on the distributor is fully circulating. Promptly repair or remove any distributor that produces a streaked or irregular distribution of the material. Ensure that the distributors are capable of providing a uniform application rate of emulsion varying from .05-1.00 gallons per square yard over a variable width up to twenty feet in a single pass. Equip the distributor with a tachometer, pressure gauges, volume measuring devices, and a thermometer for reading temperature of tank contents. Ensure controls for spray bar are located in cab of truck, for controlling width and rate of spray of product. Ensure the uniformity of the distributors does not vary by more than plus or minus 0.05 gallons per square yard. Ensure that the nozzle angle and bar height is set to provide one hundred percent of double coverage in a single pass.

A "bootman" shall accompany the distributor and ride in a position so that all spray bar nozzles are in his full view and readily accessible for unplugging.

****** Equip the rotary sweepers with adjustable down pressure on the sweeper heads and are capable of temporarily storing the picked up material from the surface of the pavement for disposal offsite.

40X.03 CONSTRUCTION

43X.03.01 PREPARING EXISTING PAVEMENT

Prepare the existing pavement surface as specified in Section 401.3.01.
Repair potholes, other areas of pavement failure, and major depressions in the existing pavement surface. Place a leveling course on planed, milled or existing surface, if required.

Immediately prior to application of the asphalt binder sealer, sweep the surface thoroughly. Cover all utility irons just prior to application and uncovering after aggregate is spread.

40X.03.02 Chip Seal Application

A. Chip Seal Application Plan. At least 20 days before constructing the chip seal course, submit a detailed plan of operation to the RE for approval that includes the following:

1. Submit the name and experience of the chip seal operations supervising representative to the RE. Ensure that experience includes a minimum of 5 federal or state agency projects, with references, on which chip seal operations were successfully completed. Ensure that the supervising representative is at the work site during all chip Seal operations. Do not begin the work until the RE approves the chip seal operations supervising representative.
2. Size and description of crew.
3. Number, type, and model of all equipment for the chip seal operation.
4. Lighting plan for nighttime operations as specified in 108.06.
5. Chip seal procedures for maintaining continuous operation.

6. Chip seal sequence. Ensure that the chip seal is constructed for the full width of shoulder, and ramps as a single operation.
7. Schedule, hours of operation, and production rates for the Project.

B. Weather Limitations. Do not perform chip seal if the pavement temperature in the shade is below 55°F and falling, but may be applied when both pavement and air temperatures are above 50°F and rising. Do not perform chip seal if precipitating or pavement surface is wet.

C. Application of Bituminous Materials. Apply the binder material by means of the approved bituminous material distributor in a manner to achieve a uniform and continuous spread over the asphalt surface. Apply the binder in accordance with **Table 40X.0X.03-1 Material Application Rates (Binder Application Rate / Aggregate Application Rate).**

The distributor shall be moving forward at proper application speed at the time the spray bar is opened. Immediately halt the operation a nozzle becomes clogged or not spraying a proper pattern until repairs are made. Repairs all deficiencies prior to spreading the aggregate. Ensure that the width of the spread is no greater than the width of the aggregate spreader except where additional passes are required. Where adjacent passes are required, spread the emulsion 4 to 6 inches beyond the aggregate spread at fifty percent application rate. Do not allow the binder to chill, setup, harden, or otherwise impair the aggregate retention before the aggregate has been properly applied and rolled.

1. **Asphalt Rubber.** Apply the asphalt rubber binder between 340 and 400^{o}F.

2. **Polymer Modified Emulsion**. Apply the polymer modified emulsion between 130^{o}F and 180 ^{o}F.

D. Application of Pre-Coated Aggregates. Apply the pre-coated aggregate immediately following the binder using the approved aggregate spreader. Spread the pre-coated aggregates in such a manner that the tires of the trucks and aggregate spreader never contact the newly applied bituminous material. Cover any deficient areas with additional material.

E. Application Rates. Apply the binder and aggregates in accordance with **Table 40X.0X.03-1 Material Application Rates (Binder Application Rate / Aggregate Application Rate).**

Table 40X.0X.03-1. Material Application Rates (Binder Application Rate / Aggregate Application

Material	3/8" Chip Seal
Asphalt Rubber Binder	0.50 to 0.65 gal/sy 30-40lb/sy
Polymer Modified Emulsion	0.30-0.35 gal/sy 20-30lb/sy

The application rate may be altered at any time during the course of the construction upon approval by the RE.

F. **Rolling.** Begin initial rolling with the pneumatic tire rollers immediately after the application of pre-coated aggregate chips. Work rollers in tandem and complete a minimum of three passes with a sufficient overlap. Apply finish rolling with an 8-10 ton steel wheel roller in static mode to smooth and reorient the chips. Should the rolling operation be delayed, halt the operation so the proper sequencing and timing can be achieved.

G. Sweeping. After the chip seal has cooled, sweep excess aggregate from the roadway and adjacent areas. Excess aggregate that is clean may be stockpiled and re-used in subsequent locations at the discretion of the RE.

H. **Fog Seal.** After the initial sweeping, apply a Fog Seal in accordance with Section 422.03.01 at an approximate rate between 0.06 and 0.13 gallon per sy using a 1:1 CSS-h emulsion at a Residual rate of 0.2-0.3 gal/SY or CRS-2P, diluted 40 percent with water at an approximate rate between 0.10 and 0.13 gallons per square yard. Do not apply fog seals when the air temperature is below 60°F.

I. **Surface Tolerance.** The final surface of the chip seal will not deviate in excess of ½ inch from the testing edge with a 10-foot straightedge resting on any two points. Correct any deviations.

J. **Opening to Traffic.** Remove loose material from the traveled way, shoulder, ramps, and auxiliary lanes before opening to traffic. Open chip seal layer to traffic two hours after application of fog seal.

40X.03.04. MEASUREMENT AND PAYMENT

The Department will measure and make payment for Items as follows:

Item	Pay Unit
ASPHALT RUBBER/POLYMER MODIFIED BINDER CHIP SEAL	SQUARE YARD
BINDER MATERIAL (BY METER)	GALLON
AGGREGATES	TON
FOG SEAL	SQUARE YARD

OR

ASPHALT RUBBER/POLYMER MODIFIED BINDER CHIP SEAL	SQUARE YARD

Which includes the application of the binder seal, and aggregate chips, the binder material and the pre-coated aggregates in one item.

The Department will make payment for TACK COAT as specified in 401.04.

The Department will make payment for REMOVAL OF TRAFFIC STRIPES and REMOVAL OF TRAFFIC MARKINGS as specified in 610.04.

The Department will measure binder material by the volume delivered, converted to the number of gallons at 60°F as calculated by the temperature-volume correction factors specified in 902.01. or By meter

Aggregates will be measured by the ton as indicated on the certified weigh tickets, excluding unused material.

Equipment

1003.0X Aggregate Chip Spreader

Ensure that the unit is hydrostatically driven and self-propelled, and equipped with a hydraulically controlled variable adjustable head that is capable of spreading stone in widths from 4.5 to 18 feet. Ensure the spreader is mounted on pneumatic tires, and capable of applying the stone on the road surface in a manner that the tires do not contact the road surface until after the stone has been applied. Equip the unit with an electronic radar type sensor used to measure ground speed and will automatically adjust the stone application rate depending on width of application and the speed of chip spreader. Ensure that the unit is able to apply stone on any grade from 0 - 6%. Equip the unit with an integral hopper with a minimum capacity of 5 tons of stone filled by trucks in a manner which ensures that the truck tires never come in contact with asphalt treated road surfaces until the stone has been properly applied. To maintain constant stone application, a self-locking truck hitch will permit towing of aggregate trucks without stopping the chip spreader and capable of maintaining positive engagement over irregular terrain.

902.XX ASPHALT RUBBER/POLYMER MODIFIED BINDER CHIP SEAL

902.XX.01 Composition of Mixture

Composition of the mixture of Asphalt Rubber or Polymer Modified Binder Chip Seal is a bituminous surface seal and single size or limited multi-size coated stone chip cover aggregates. Ensure that the material conforms to the following requirements:

1. Use aggregates that conform to **901.03.01 Table 901.03.01-1 Requirements for Broken Stone.**
2. Do not use RAP, CRCG, GBSM, or RPCSA
3. Use asphalt-rubber binder that conforms to **902.07.02**.

902.XX.02 Binders

Asphalt-Rubber Binder

A. **Materials.** Use the following materials:

1. **Asphalt Binder.** Use asphalt binder that conforms to AASHTO M 320, Table 1; PG 58-28, PG 64-22 or an approved blend of both grades needed to meet the requirements of ASTM D 6114 (type II). The asphalt binder producer is required to provide the asphalt binder quality control plan annually to the ME for approval. Ensure that the quality control plan conforms to AASHTO R 26. Submit to the ME a certification of compliance, as specified in 106.07, for the asphalt binder. The ME will perform quality assurance sampling and testing of each asphalt binder lot as defined in the approved quality control plan.

2. **Ground Crumb Rubber.** Ensure that the ground crumb rubber has a specific gravity of 1.15 ± 0.05, is free of wire or other contaminating materials, and

contains not more than 0.5 percent fabric. Use crumb rubber that is ambient ground and conforms to the gradation requirements specified in Table 902.07.02-1. Ensure that the moisture content is less than 0.75 percent. Add up to four percent calcium carbonate by weight of the granulated rubber, to prevent the particles from sticking together.

Table 902.07.02-1 Ground Crumb Rubber Gradation

Sieve Size	Percent Passing1, 2
No. 8	100
No. 16	65 – 100
No. 30	20 – 100
No. 50	0 – 45
No. 200	0 – 5

1. Perform gradation according to AASHTO T27 using a minimum 50 gram sample
2. Ensure that the gradation is performed as specified in NJDOT B-11.

Submit to the ME a certification of compliance, as specified in 106.07, for the ground crumb rubber. In addition, ensure that the certification confirms that the rubber is a crumb rubber, derived from processing whole scrap tires or shredded tire materials; and the tires from which the crumb rubber is produced are taken from automobiles, trucks, or other equipment owned and operated in the United States. Include with the certifications verifications that the processing did not produce, as a waste product, casings, or other round tire material that can hold water when stored or disposed of above ground.

B. **Mixing.** Using the asphalt-rubber binder blending equipment in 1009.03, produce the asphalt-rubber binder to contain at least 15-17 percent ground rubber by the weight of total asphalt binder (asphalt + crumb rubber). Ensure that the temperature of the asphalt cement is between 350 and 400 °F at the time of addition of the ground rubber. Ensure that there are no agglomerations of rubber particles in excess of two inches in the least dimension in the mixing chamber.

Document that the proportions are accurate and that the rubber has been uniformly incorporated into the mixture. Report as directed by the ME. Ensure that the crumb rubber and asphalt-cement are thoroughly mixed before beginning the one-hour reaction period. Rubber floating on the surface or agglomerations of rubber particles is evidence of insufficient mixing. Maintain the temperature of the asphalt-rubber binder immediately after mixing between 325 and 375 °F. Maintain the temperature of the asphalt-rubber binder for at least one hour before using.

C. **Properties.** Prepare asphalt-rubber binder using the "wet process." Physical properties are required to comply with the requirements of ASTM D 6114, Type II, except for the properties specified in Table 902.07.02-2.

Table 902.07.02-2 Asphalt-Rubber Binder Properties

Property	Test Procedure	Requirement
Resilience: 77 °F; %, minimum	ASTM D 5329	25
Rotational Viscosity[1] 350 °F; cP	NJDOT B-12	2000 – 4000

1. The viscotester used must be correlated to a Rion (formerly Haake) Model VT-04 viscotester using the No. 1 Rotor. The Rion viscotester rotor, while in the off

position, is required to be completely immersed in the binder at a temperature from 350 ± 3 °F for a minimum heat equilibrium period of 60 seconds, and the average viscosity determined from three separate constant readings (± 500 cP) taken within a 30 second time frame with the viscotester level during testing and turned off between readings. Continuous rotation of the rotor may cause thinning of the material immediately in contact with the rotor, resulting in erroneous results.

D. **Handling and Testing.** Once the asphalt-rubber binder has been mixed, thoroughly agitate during periods of use to prevent settling of the rubber particles. During production, maintain asphalt-rubber binder between 325 and 375 °F. Ensure that asphalt-rubber binder is not held at 325 °F or higher for more than 16 hours. Allow asphalt-rubber binder held for more than 16 hours to cool. To reuse, gradually reheat to between 325 and 375 °F.

For each load or batch of asphalt-rubber binder, provide the RE with the following:

1. The source, grade, amount, and temperature of the asphalt cement before the addition of rubber.
2. The source and amount of rubber and the rubber content expressed as percent by the weight of the asphalt cement.
3. Times and dates of the rubber additions and resultant viscosity test.
4. A record of the temperature, with time and date reference for each load or batch. The record begins at the time of the addition of rubber and continue until the load or batch is completely used. Take readings and record every temperature change in excess of 20 °F, and as needed to document other events that are significant to batch use and quality.

Polymer Modified Binder

A. **Materials.** Use the following materials:

1. **Asphalt Binder.** Use **Polymer Modified Emulsion** binder that conforms to **902.01.03 Emulsified Asphalts,** and **Table 902.XX.XX-1**. Use a Cationic rapid set emulsified asphalt (CRS-2P) containing an emulsified blend of asphalt, water, emulsifiers, and polymer. The emulsion shall contain a minimum of three percent (3.0%) styrene butadiene rubber (SBR) solids by weight of asphalt cement. The SBR polymer dispersion shall be co-milled during the emulsification process such that a bituminous polymer-asphalt network is formed upon curing of the finished emulsion.

   The asphalt binder producer is required to provide the asphalt binder quality control plan annually to the ME for approval. Ensure that the quality control

plan conforms to AASHTO R 26. Submit to the ME a certification of compliance, as specified in 106.07, for the asphalt binder. The ME will perform quality assurance sampling and testing of each asphalt binder lot as defined in the approved quality control plan.

The polymer modified emulsified asphalt binder shall conform to the following requirements:

Table 902.XX.SS-1 Binder Requirements			
Test on Emulsion	**Test Method**	**Minimum**	**Maximum**
Elastic Recovery on Residue @10 °C, **%**	AASHTO T 301[1]	**50**	
Total Residue by Distillation, %	AASHTO T 591	70	
Penetration, 25 °C, 100g , 5s, dmm	ASTM D5	60	110
Particle Charge	AASHTO T 59	Positive	
Storage Stability Test, 1 day, %	AASHTO T 59		1
Sieve Test, % mass (850 mm)	AASHTO T 59		0.01
Demulsibility, 35 ml, 0.8% Dioctyl	AASHTO T 592	40	
Softening Point, Ring & Ball, °C	ASTM D36	57	
Ductility, 25 °C, 5 cm/min, cm	ASTM D113	100	
Ductility, 4 °C, 5 cm/min, cm	ASTM D113	45	

[1] AASHTO T 59 modified to maintain a temperature of 177 ± 5 °C for 15 minutes. Use an ASTM 16C thermometer to monitor the temperature of the emulsion during distillation.

[2] For demulsibilty testing, use 35 mL of 0.8 percent dioctyl sodium sulfosuccinate solution.

902.XX.03 Aggregates

A. **Materials.** Use the following materials:

1. **Cover Aggregate.** Use aggregate for AR Chip Seal that conforms to **901.05** to meet the requirements in Table **902.XX.03-1 and 902.XX.03-2,** use a blend of coarse aggregates (argillite, gneiss, granite, quartzite, or trap rock) conforming to 901.05.01. Ensure that the cover aggregate is washed, hard, durable, clean rock and free from coatings or deleterious material with 100% fractured faces. Use one type of aggregate that conforms to the gradation in **Table 902.X.2.**

Table 902.XX.03-1 Aggregate Requirements		
Additional Aggregate Criteria		
Property	*Method*	*Limit*
Los Angeles abrasion value, % loss	AASHTO T96	25% maximum
Sand Equivalent,%	ASTM D2419	60% minimum
Flat and Elongated	ASTM D4791 (3:1)	12% maximum
Water absorption %	AASHTO T 85	5% maximum

Table 902.XX.03-2 Chip Gradation

Sieve Size	Polymer Modified Emulsion 3/8" Cover Coat Material	Asphalt Rubber Binder[1] 3/8" Cover Coat Material
5/8”	100%	100%
3/8"	90-100 %	85-100%-
No. 4	--	0-8 %
No. 8	0-3 %	0-4 %
No. 200	0-2.5 %	0-2 %

1. For the 3/8” Asphalt Rubber gradation requirements. The Flakiness Index shall be less than 20% (NFP 18-561 Test).

2. Aggregate Coating. Pre-heat the aggregate to a temperature between 200°F and 300°F. Pre-coat the aggregate with 0.4% to 0.8% (by weight of aggregate) of PG 58-28, PG 64-28 or PG 64-22 asphalt binder prior to application.

4. HOT IN-PLACE RECYCLING

Hot In-place Recycling is a rehabilitation treatment used to eliminate cracking, rutting, and other distresses in the top two inches of the pavement surface.

SECTION 431 – HOT IN-PLACE RECYCLING (HIR) OF ASPHALT PAVEMENT

431.01 DESCRIPTION

This Section describes the requirements for recycling asphalt pavement using the hot in-place recycling (HIR) method and equipment.

431.02 MATERIALS

431.02.01 Materials

Provide materials as specified:

A. Asphalt Rejuvenating Agent. Furnish an asphalt rejuvenating agent as required by the mix design in 431.02.01.B. Ensure that any bituminous materials required are meeting the requirements of 902.01 or otherwise approved by the Bureau of Materials. Ensure that the asphalt rejuvenating agent contains no polynuclear aromatic compounds.

B. HIR Mixture Design. At least 45 days prior to the start of production, provide a mix design and job mix formula that meets the criteria of Table 431.02.01.B-1. Submit the completed mix design to the RE for approval prior to the start of the project. Perform additional mix designs based on road variability, as directed by the RE.

Table 431.02.01.B-1 HIR Mix Design Requirements

Mixture Property	**Test Method**	**Requirement**
Density	AASHTO T 166	Report
Tensile Strength, 77°F	AASHTO T 283	75 psi Min.
Boil Test	NJDOT X-1	Report
Asphalt Pavement Analyzer	AASHTO TP 63	7 mm Max.
Overlay Tester	NJDOT B-10	Report
Combined Asphalt Property	**Test Method**	**Requirement**
Penetration, 77°F, 100 g, 5 sec.	AASHTO T 49	40 Min., 80 Max.

Sampling. Obtain cores at intervals throughout the project to determine the existing condition of the roadway and account for variability within the project limits. Obtain an adequate quantity of material to perform the mixture design. Evaluate cores and note any evidence of material (rubber seal, fabric underseal, etc.) that could be detrimental to the process. A minimum of 2 in. of the existing pavement structure must remain in place following milling. Note any base or uncoated material that falls within the layer to be recycled. Notify the RE of any of these conditions before proceeding with the mix design.

Job-Mix Formula Approval. The job-mix formula (JMF) is the combined aggregate gradation and target asphalt rejuvenating agent percentage established from the laboratory mixture design used for hot in-place production.

Other Additives. If necessary, use additives to meet the requirements in **Table 431.02.01.B-1 HIR Mix Design Requirements.** In the case that an additive is used, describe the type and allowable usage percentage in the submitted design recommendation.

431.02.02 Equipment

Provide equipment as specified:

A. Sweeping and Compacting Equipment.

HMA Compactor 1003.05
Vibratory Drum Compactor 1003.06
Mechanical Sweeper 1008.03
Milling Machine 1008.01

Provide a thin-lift nuclear density gauge according to ASTM D 2950.

B. HIR Processing Equipment. Provide equipment that is capable of a continuous single pass, multi-step operation, including heating; milling; introducing rejuvenating agent; mixing the reclaimed material; redistributing the recycled material; placing the mix and leveling it; and compacting the mixture, that meets the following requirements:

1. **Heating Units.** Supply a minimum of 2 pavement heating units capable of uniformly heating the existing pavement to a temperature high enough to remove excess moisture and allow loosening of the asphalt pavement material to the specified depth. Ensure heating units are operated in a manner such that they do not produce undesirable pollutants and do not cause fracturing of aggregate particles. Ensure that the heaters are equipped with an enclosed or shielded hood to prevent damage to adjacent property or vegetation. Ensure that the heaters are capable of providing overlap of the completed adjacent lane by a minimum of 4 to 6 inches to create a hot bond at the longitudinal joint.

2. **Milling/Scarifying.** Provide milling and scarifying equipment for pavement recycling capable of uniformly loosening the entire pavement lane width to the depth specified in the plans. Utilize equipment that is equipped with height controls and is capable of recycling the material around manholes and other utilities in the pavement surface. Operate the equipment in such a manner to minimize aggregate degradation.

3. **Gathering, Adding Materials, Mixing, Distributing, Spreading, and Finishing.** Provide equipment capable of:

   · gathering heated, milled/scarified hot-mix asphalt materials;

   · adding rejuvenating agent at the required rate; Ensure that a controlled system for adding and uniformly blending a rejuvenating agent at a predetermined rate with the reclaimed mix during the remixing and leveling operation. Ensure that the application rate for the added material is synchronized with the machine speed to provide uniform application..

   Calibration. Calibrate the measuring system in the presence of the RE. A minimum 2-week notice is required when scheduling this calibration. Approved calibrations are required for each project. If the calibration date exceeds 90 days, then the bituminous meters will need to be recalibrated. Work shall not progress until the calibration has been completed and verified. The equipment shall be calibrated in accordance with ASTM D2995 Standard Practice for Estimating Application Rate of Bituminous Distributors. Other calibration methods may be used with the approval of the RE.

   · uniformly mixing all ingredients;

   · distributing the blended mixture over the width being processed; and

   · spreading and finishing to produce a smooth surface meeting the requirements of the typical cross section.

431.03 CONSTRUCTION

431.03.01 HIR

A. HIR Plan. At least 20 days before beginning HIR operation, submit a detailed plan of operation as follows:

1. Submit the name and experience of the HIR operations supervising representative to the RE. Ensure that experience includes a minimum of 5 federal or state agency projects, with references, on which HIR operations were successfully completed. Ensure that the supervising representative is at the work site during all HIR operations. The Contractor may not begin the work until the RE approves the HIR operations supervising representative.
2. Size and description of crew.
3. Number, type, and model of all equipment for the HIR operation.
4. Lighting plan for nighttime operations as specified in 108.06.
5. HIR procedures for maintaining continuous operation.
6. Recommended temperature range for compaction of the HIR material.
7. HIR sequence. Ensure that the HIR is constructed for the full width of the traveled way, shoulder, and auxiliary lanes as a single operation.
8. Submit the material Certification of Compliance, as specified in 106.07, for the asphalt rejuvenating agent (ARA) to be used for the HIR.
10. Schedule, hours of operation, and production rates for the Project.
11. Storage location(s) for the ARA to be used.
12. Method of constructing and compacting joints as specified in 401.03.03.E.
13. Quality control plan outlining the use of the thin lift nuclear density gauge, quality control cores, and the control of the compaction process.

Do not begin HIR operations until the RE approves the HIR plan. Submit an adjusted HIR plan before making adjustments to the HIR operation. Include in the HIR plan a proposed location for the test strip.

B. Weather Limitations. Do not perform HIR if it is precipitating. The Contractor may resume operations when the precipitation has stopped and the surface is free of water.

Do not perform HIR if the pavement temperature is below 50 F.

C. Test Strip. Construct a test strip for the HIR mixture. Heat, mill/scarify, mix, spread, grade and compact HIR mixture as specified in 401.03.03.F, respectively, and according to the approved HIR plan. Construct a test strip for the first 700 to 1200 square yards recycled for each job mix formula. While constructing the test strip, record the following information and submit to the RE:

1. Ambient Temperature. Measure ambient temperature at the beginning and end of each day's paving operation.

2. Base Temperature. Measure the surface temperature of the existing base before heating.

3. HIR Mixture Temperature. Measure the temperature of the HIR mixture immediately behind the screed.

4. Roller Pattern. Provide details on the number of rollers, type, and number of passes used on the test strip.

5. Nuclear Density Gauge Readings. Obtain the maximum density from the mix design, and input it into the nuclear density gauge. Use the nuclear density gauge to read the bulk density and percent air voids.

6. Quality Control Core Density Test Results. Take 5 randomly selected quality control cores to test for the bulk specific gravity and the maximum specific gravity.

Use drilling equipment with a water-cooled, diamond-tipped, masonry drill bit that shall produce 6-inch nominal diameter cores for the full depth of the pavement. Remove the core from the pavement without damaging it. After removing the core, remove all water from the hole. Fill the hole with HMA or cold patching material, and compact the material so that it is 1/4 inch above the surrounding pavement surface.

Compare the nuclear density gauge readings and the core test results to establish a correlation. Use this correlation as a guide for the continued use of the nuclear density gauge for density control.

7. **Field Verification of Mix Design.** Use the 5 randomly selected cores to confirm mix design requirements as specified in Table 431.02.01.B-1

Upon completion of the test strip, the Contractor may continue paving. If the Contractor does not continue paving, the Department will accept the test strip as 1 lot regardless of size.

If the test strip does not meet requirements, make adjustments and construct a second test strip. If the second test strip does not meet requirements, suspend paving operations until written approval to proceed is received.

Before making adjustments to the paving operations, notify the RE in writing.

D. Spreading and Grading. Protect from heat damage all trees, shrubs, and other landscaping that is adjacent to the pavement. Before beginning heating and scarifying/milling, remove all dirt and other debris from the pavement surface by blading, brooming, or other approved methods. Heat, scarify, and rework pavement surface to the widths and depths shown on the plans. Control heating to ensure uniform heat penetration to a maximum of 375°F and to prevent differential softening of the pavement. Do not char the asphalt or break aggregate particles. Keep the temperature of material immediately behind the screed between 225°F and 325°F. Gather the scarified material and uniformly add asphalt, rejuvenating agent, to the scarified material as specified in 431.02.01B, "Mixture Design." Mix all ingredients uniformly. Distribute the homogenous mixture over the width being processed. Spread and finish the surface to produce a smooth surface according to the typical cross section. Record the temperature immediately behind the paving screed at least once per hour during paving. Submit the temperatures to the RE.

When making a pass adjacent to a previously placed mat, locate the longitudinal joint at least 2 in. horizontally into the previously placed mat.

E. Compacting. Compact HIR MIXTURE as specified in 401.03.03.F.

F. Opening to Traffic. Follow the requirements of 401.03.03.G for opening HIR MIXTURE to traffic. Any damage will be fixed. Do not allow traffic or construction equipment on the HIR course until the surface temperature is less than 140 °F.

G. Verification of Mix Design (Penetration Requirements). Drill cores as specified in 401.03.05. Mainline lots are defined as the area covered by a day's paving production of the HIR between 5,000 and 10,000 square yards for the traveled way and auxiliary lanes. The RE will combine daily production areas less than 5,000 square yards with previous or subsequent production areas to meet the minimum lot requirements. When the maximum lot requirement is exceeded in a day's production, the RE will divide the area of HIR recycled into 2 lots with approximately equal areas.

Ramp pavement lots are defined as approximately 10,000 square yards of pavement in ramps. The RE may combine ramps with less than the minimum area into a single lot. If 2 or more ramps are included in a single lot, the RE will require additional cores to ensure that at least 1 core is taken from each ramp.

Other pavement lots are defined as approximately 10,000 square yards of pavement in shoulders and other undefined areas. If areas of existing shoulders are found to be insufficient to support the proposed HIR pavement and the required compaction cannot be achieved, notify the RE immediately. The RE may waive coring in such shoulder areas.

Prior to construction of the surface course the RE will drill 5 cores from each lot in random locations. The RE will remove the top portion of the HIR depth specified in the plans. The RE will extract and recover the residual binders according to ASTM D1856 for each core separately. The RE will determine the average penetration value for the lot based on the penetration values from the 5 cores taken according to AASHTO T 49.

The RE will calculate pay adjustments based on the following:

$$\%\ Payment = (PI_{avg} - PI_i)/(\frac{PI_f - PI_i}{100})$$

Where:

% Payment = Percent payment for cost of rejuvenating agent and square yards of HIR. Maximum of 100

PI_{avg} = Average penetration value from the 5 random cores

PI_i = Penetration value of existing HMA

PI_f = Minimum acceptable penetration value according to Table 431.02.01.B-1

G. Air Void Requirements. Drill cores as specified in 401.03.05. Mainline lots are defined as the area covered by a day's paving production of the HIR between 5,000 and 10,000 square yards for the traveled way and auxiliary lanes. The RE will combine daily production areas less than 5,000 square yards with previous or subsequent production areas to meet the minimum lot requirements. When the maximum lot requirement is exceeded in a day's production, the RE will divide the area of HMA placed into 2 lots with approximately equal areas.

Ramp pavement lots are defined as approximately 10,000 square yards of pavement in ramps. The RE may combine ramps with less than the minimum area into a single lot. If 2 or more ramps are included in a single lot, the RE will require additional cores to ensure that at least 1 core is taken from each ramp.

Other pavement lots are defined as approximately 10,000 square yards of pavement in shoulders and other undefined areas. If areas of existing shoulders are found to be insufficient to support the proposed HIR pavement and the required compaction cannot be achieved, notify the RE immediately. The RE may waive coring and air void requirements in such shoulder areas.

The ME will calculate the percent defective (PD) as the percentage of the lot outside the acceptable range of 2 percent air voids to 8 percent air voids. The acceptable quality limit is 10 percent defective. For lots in which PD < 10, the Department will award a positive pay adjustment. For lots in which PD > 10, the Department will assess a negative pay adjustment.

The ME will determine air voids from 5 cores taken from each lot in random locations. The ME will determine air voids of cores from the values for the maximum specific gravity of the mix and the bulk specific gravity of the core. The ME will determine the maximum specific gravity of the mix according to NJDOT B-3 and AASHTO T 209, except that minimum sample size may be waived in order to use a 6-inch diameter core sample. The ME will determine the bulk specific gravity of the compacted mixture by testing each core according to AASHTO T 166.

The ME will calculate pay adjustments based on the following:

1. **Sample Mean ($\overline{X}$) and Standard Deviation (S) of the N Test Results (X_1, X_2,..., X_N).**

$$\overline{X} = \frac{(X_1 + X_2 + ... + X_N)}{N}$$

$$S = \sqrt{\frac{(X_1 - \overline{X})^2 + (X_2 - \overline{X})^2 + ... + (X_N - \overline{X})^2}{N - 1}}$$

2. **Quality Index (Q).**

$$Q_L = \frac{(\bar{X} - 2.0)}{S}$$

$$Q_U = \frac{(8.0 - \bar{X})}{S}$$

3. **Percent Defective (PD).** Using NJDOT ST for the appropriate sample size, the Department will determine PD_L and PD_U associated with Q_L and Q_U, respectively. $PD = PD_L + PD_U$

4. **Percent Pay Adjustment (PPA).** Calculate the PPA for traveled way and ramp lots as specified in Table 401.03.03-3.

Table 401.03.03-3 PPA for Mainline Lots and Ramp Lots

	Quality	PPA
HIR	PD < 30	PPA = 1 − (0.1 PD)
	PD ≥ 30	PPA = 40 − (1.4 PD)

Calculate the PPA for other pavement lots as specified in Table 401.03.03-4.

Table 401.03.03-4 PPA for Other Pavement Lots

	Quality	PPA
HIR	PD < 50	PPA = 1 − (0.1 PD)
	PD ≥ 50	PPA = 92 − (1.92 PD)

5. **Outlier Detection.** The ME will screen all acceptance cores for outliers using a statistically valid procedure. If an outlier is detected, replace that core by taking an additional core at the same offset and within 5 feet of the original station. The following procedure applies only for a sample size of 5.

    1. The ME will arrange the 5 core results in ascending order, in which X_1 represents the smallest value and X_5 represents the largest value.
    2. If X_5 is suspected of being an outlier, the ME will calculate:

$$R = \frac{X_5 - X_4}{X_5 5 - X_1}$$

    3. If X_1 is suspected of being an outlier, the ME will calculate:

$$R = \frac{X_2 - X_1}{X_5 - X_1}$$

4. If R > 0.642, the value is judged to be statistically significant and the core is excluded.

6. **Retest.** If the initial series of 5 cores produces a percent defective value of PD ≥ 30 for mainline or ramp lots, or PD ≥ 50 for other pavement lots, the Contractor may elect to take an additional set of 5 cores at random locations chosen by the ME. Take the additional cores within 15 days of receipt of the initial core results. If the additional cores are not taken within the 15 days, the ME will use the initial core results to determine the PPA. If the additional cores are taken, the ME will recalculate the PPA using the combined results from the 10 cores.

7. **Removal and Replacement.** If the final lot PD ≥ 75 (based on the combined set of 10 cores or 5 cores if the Contractor does not take additional cores), remove and replace the lot and all overlying work. The replacement work is subject to the same requirements as the initial work.

H. Thickness Requirements. Thickness requirements will apply for the compacted HIR material. The size and the assigned number of thickness lots will match those of the HIR air void lots.

The ME will test for thickness using the HIR cores taken for surface course air voids, evaluated according to NJDOT B-4. The ME will base acceptance on total thickness and thickness of the surface course.

The ME will calculate the percent defective (PD) as the percentage of the lot that is less than the design thickness. The ME will consider 10 percent defective as the acceptable quality limit. For lots where PD < 10, the Department will award a positive pay adjustment. For lots where PD > 10, the Department will assess a negative pay adjustment. The ME will base HIR thickness acceptance on the percentage of the lot estimated to fall below the allowable thickness as follows:

a. Sample Mean ($\overline{X}$) and Standard Deviation (S) of the N Test Results (X_1, X_2,..., X_N). Calculate using the formula as specified in 401.03.03.H.1.

b. Quality Index (Q).

$Q_L = (\overline{X} - T_{all})/S$, where T_{all} is the minimum allowable thickness.

Table 401.03.03-6 Surface Course Thickness Requirements

HIR Design Thickness	Minimum Allowable Compacted Lift Thickness (T_{all})
1.00 inch	0.75 inch
1.50 inch	1.25 inches
2.00 inches	1.50 inches

c. Percent Defective. Using NJDOT ST for the appropriate sample size, determine the percentage of material (PD) falling below the allowable thickness associated with Q_L (lower limit).

d. Retest. If the initial series of 5 cores produces a percent defective value of PD > 10, the Contractor may take an additional 5 cores at random locations determined by the ME. Take the additional cores within 15 days of receipt of the initial core results. If the additional cores are not taken within the 15 days, the ME will use the initial core results to determine the PPA. When the additional cores are taken, the ME will recalculate the PPA using the combined results from the 10 cores to obtain the total PD.

e. Removal and Replacement. If the surface course fails to meet the acceptance requirement, the Department will require removal and replacement of the lot. The replacement work is subject to the same requirements as the initial work.

431.04 MEASUREMENT AND PAYMENT

The Department will measure and make payment for Items as follows:

Item	*Pay Unit*
HOT IN-PLACE RECYCLING	SQUARE YARD
REJUVENATING AGENT	GALLON

The Department will make payment for CORE SAMPLES, HOT MIX ASPHALT as specified in 401.04.

5. COLD IN-PLACE RECYCLING

COLD IN-PLACE RECYCLING IS A REHABILITATION TREATMENT USED TO ELIMINATE CRACKING, RUTTING, AND OTHER DISTRESSES IN THE TOP TWO TO SEVEN INCHES OF THE PAVEMENT SURFACE.

COLD IN-PLACE RECYCLING WITH FOAMED ASPHALT

Section 432 – COLD IN-PLACE RECYCLING OF ASPHALT PAVEMENT FOAMED ASPHALT (CIR-FA)

432.01 DESCRIPTION

This Section describes the requirements for recycling asphalt pavement using cold in-place recycling (CIR) with foamed asphalt method and equipment.

432.02 MATERIALS

432.02.01 MATERIALS

Provide materials as specified.

Asphalt Stabilizing Agent PG 64-22 (Foamed Asphalt)	902.01.01
Cement, type I	903.01
Aggregates	901.05
Water	919.08
Fog Seal	422.02.01

432.02.02 EQUIPMENT

Provide equipment as specified:	
Pneumatic-Tired Compactor	1002.01
HMA Compactor	1003.05
Vibratory Drum Compactor	1003.06
Bituminous Material Distributor	1003.07
Sealer Application System	1003.08
Milling Machine	1008.01
Mechanical Sweeper	1008.03
Cold In-Place Recycler/Reclaimer Machinery	**1012.xx**
Cement Distributor	**1012.xx**
Rotomiller	**1012.xx**
Portable Storage Tanks	**1012.xx**

432.03 CONSTRUCTION

432.03.01 CIR

A. CIR Plan. At least 20 days before constructing the CIR base course, submit a detailed plan of operation to the RE for approval that includes the following:

1. Submit the name and experience of the CIR operations supervising representative to the RE. Ensure that experience includes a minimum of 5 federal or state agency projects, with references, on which CIR operations were successfully completed. Ensure that the supervising representative is at the work site during all CIR operations. The Contractor may not begin the work until the RE approves the CIR operations supervising representative.
2. Size and description of crew.
3. Number, type, and model of all equipment for the CIR operation.
4. Lighting plan for nighttime operations as specified in 108.06.
5. CIR procedures for maintaining continuous operation.
6. CIR sequence. Ensure that the CIR is constructed for the full lane width as a single operation.
7. Schedule, hours of operation, and production rates for the Project.
8. Method of constructing and compacting joints as specified in 432.03.01.G.
9. Quality control plan outlining the use of the thin lift nuclear density gauge, quality control cores, and the control of the compaction process.

F. Weather Limitations. Do not perform CIR if it is precipitating. The Contractor may resume operations when the precipitation has stopped and the surface is free of water. Do not perform CIR if the pavement temperature is below 50 F.

G. Density Control Strip. Construct a Density Control Strip in accordance with Section 302.03.01.B except perform AASHTO T 180, Method C, including replacement option instead of AASHTO T 99 to ensure that the moisture content and maximum dry density for the density control strip material are within 2 percent of its optimum moisture content and equal to or greater than 95 percent of its maximum dry density.

D. Cement Application. Place the cement accelerator uniformly on the HMA surface immediately prior to pulverization in accordance with mix design. Every 500 feet, verify the amount of cement applied by weight.

E. Pulverization. Pulverize the HMA surface with the CIR recycler/reclaimer to meet the gradation as specified in Table 902.10.02-1. Check the gradation at the start of each day's production and as directed by the RE..

F. Binder Application. During the pulverizing operations, apply foamed-asphalt to the pulverized material at the rate determined from the mix design. Maintain an allowable tolerance of plus or minus 0.2 percent of the initial design rate at all times. Test the foaming characteristics of the asphalt for each new tanker within 2 minutes. Collect 1 quart sample of asphalt stabilizing agent from each tanker load and retain in a sealed container for later testing.

Maintain the temperature of the asphalt delivered to site at 340 ^{o}F (+/- 20 ^{o}F). If the asphalt is below 320 ^{o}F test at the recycler's test nozzle to ensure it meets the requirements as specified in **Table 902.10.01-1**. Do not use asphalt that has been heated above the maximum specified temperature and remove it from the project site.

The Contractor may add water to the pulverized material for the purpose of cooling the cutting teeth on the mill or pulverizing equipment or to facilitate uniform mixing with the foamed asphalt.

G. Spreading and Grading. Ensure grade and profile are maintained. Spread and grade CIR material uniformly across the mat. If segregation occurs behind the paver, stop the operation and submit a corrective action plan to the RE.

When making a pass adjacent to a previously placed mat, locate the longitudinal joint at least 6 in. horizontally into the previously placed mat. For transverse joints, trim all transverse joints to provide a vertical face. Moisten the face of the joint if necessary. Begin the stabilization a minimum of 5 feet into the previous day's construction.

H. Compacting. Immediately after spreading and strike-off, compact CIR material with vibratory steel wheel and pneumatic tire rollers until the density reaches 96% of the maximum density from the density control strip. The ME will verify compaction levels every 5000 square yards based upon compaction levels of density control strip using a nuclear density gauge.

Perform additional passes to eliminate roller marks. Remove and replace CIR material that becomes loose, broken, or otherwise defective. Do not start or stop rollers on uncompacted recycled material.

If cracking, movement, or other types of pavement distress occur, discontinue rolling until such time as the problem can be resolved.

I. Curing. Apply a Fog Seal in accordance with Section 422.02.01 at an approximate rate of 0.05 to 0.1 gallon per square yard to seal the surface of the CIR layer to control surface raveling.

J. Surface Tolerance. Ensure the final surface of CIR does not deviate in excess of ½ inch from the testing edge with a 10-foot straightedge resting on any two points. Correct any deviations.

K. Opening CIR Layer to Traffic.

Remove loose material from the traveled way, shoulder, and auxiliary lanes before opening to traffic. Open CIR layer to traffic as specified in 422.03.01.

L. Placement of Surface Course.

Do not Pave surface course less than 3 days or more than 14 days after constructing the CIR.

M. Acceptance Testing and Strength Verification.

Ensure that the CIR materials meets the requirements specified in **Table 902.10.03-5**

432.04. MEASUREMENT AND PAYMENT

The Department will measure and make payment for Items as follows:

Item	Pay Unit
COLD IN-PLACE RECYCLING-FOAMED ASPHALT	SQUARE YARD
ASPHALT STABILIZING AGENT PG64-22	GALLON
CEMENT	TON

The Department will make payment for FOG SEAL SURFACE TREATMENT as specified in 422.04.

The Department will measure ASPHALT STABILIZING AGENT by the volume delivered, converted to the number of gallons at 60°F as calculated by the temperature-volume correction factors specified in 902.01 or by meter.

Equipment

1012.xx COLD IN-PLACE RECYLCER/RECLAIMER MACHINERY.

A. Provide a self-propelled machine equipped with automatic depth control to maintain the cutting depth to within ± ¼ inch and a positive means for controlling cross slope elevations.

B. Ensure that the recycler/reclaimer is capable of:

1. Pulverizing to the size specified, mix and recycle material to a depth as determined in the design documents in one pass

2. Maintaining a constant cutting depth and width, uniform grade, and uniform slope

C. Ensure that the recycler/reclaimer includes:

1. Two microprocessor controlled systems, complete with two independent pumping systems and spray bars, to regulate the application of foamed asphalt, separate from water that is used to increase the moisture content of the mixed material for compaction. Both systems will perform in relation to the forward speed of the recycler/reclaimer and the mass of the material being processed.

2. Individual expansion chambers to produce the foamed asphalt at the spray bar into which hot asphalt stabilizing agent, water, and air are injected under pressure through individual and small orifices that promote atomization. The rate of addition of water into the hot asphalt stabilizing agent kept at a constant percentage by mass of asphalt by the same microprocessor.

3. An inspection or test nozzle fitted at one end of the spray bar that produces a representative sample of foamed asphalt.

4. An electrical heating system capable of maintaining the temperature of asphalt flow components above 240 ^{o}F

5. A single bitumen (asphalt cement) feed pipe installed between the recycler/reclaimer and the supply tanker. Do not use circulating systems that incorporate a return pipe to the supply tanker.

D. Ensure that the recycler/reclaimer has a centrally divided spreading auger with scraper, capable of rotating clock wise and counter clockwise to distribute the recycled mix evenly across the entire working width. Ensure that the recycler/reclaimer is capable of moving recycled material from the spreading auger to the paving screed installed on the recycler/reclaimer or be able to transfer the recycled material to the HMA paver for laydown. Ensure that the screed mounted on the recycler/reclaimer meets the requirements of HMA Paver in section 1003.03 except the screed heater is not required.

1012.xx CEMENT DISTRIBUTOR

Provide calibrated spreaders or distributors for applying dry powder cement that are shrouded and non-pressurized mechanical vane-feed, cyclone or screw type that provide consistent, accurate and uniform distribution of material while minimizing dust during placement.

1012.xx ROTOMILLER

Provide to the RE the rotomiller manufacturer's technical data sheets.

Ensure that the rotomiller will mill to a minimum depth of 4" longitudinally along all curbs and gutters, and around all manholes, inlets, and any other structure not accessible by either a single processing unit or a multi-unit train.

Cover Inlets/manholes during the rotomilling and recycling operation to prevent recycled material from entering the inlet area where it could contaminate and/or block the storm water system.

1012.xx PORTABLE STORAGE TANKS

Provide an insulated tanker(s) equipped with push bar hitches. Ensure that the tanker is equipped with a built-in thermometer and heating facility to ensure that the asphalt is maintained within 5 ^{o}F of the specified application temperature.

902.10 COLD INPLACE RECYCLING WITH FOAMED ASPHALT (CIR-FA)

902.10.01 Composition of Mixture

Mix **CIR-FA** in-place using the 1012.xx Cold In-place Recycler/Reclaimer. The composition of the mixture for **CIR-FA** includes the in-place HMA surface material, and virgin aggregates, where necessary, to meet the gradation in Table **902.10.02-1**.

Use asphalt binder and aggregates that meet the following requirements:

1. **Asphalt Stabilizing Agent**. Use PG 64-22 as specified in 902.01.01.
2. **Aggregates.** Use aggregate for CIR with foamed asphalt that conform to **901.05** to modify gradation of the pulverized HMA material to meet the requirements in Table **902.10.02-1,** use a blend of coarse aggregates (argillite, gneiss, granite, quartzite, or trap rock), fine aggregate, rap or mineral filler as specified in 901.05
3. **Water**. Use water that conforms to 919.08.
4. **Cement**. Use cement type I (up to 1%) as specified in 903.01.

902.10.02 Mix Design

At least 45 days prior to the start of production, submit a mix design and job mix formula that meets the criteria of mix design procedure NJDOT B-14 – Mix Design Procedure of CIR with Foamed Asphalt Including a statement naming the source of each component and a report showing the results meet the criteria specified in Tables 902.10.02-1, 902.10.02-2 902.10.02-3, and 902.10.03-4. The NJDOT RE will verify the mix design based on IDT performance requirement in the mix design.

Ensure that the job mix formula is within the master range specified in, Table 902.10.02-1.

Ensure that the job mix formula provides a mixture that meets a minimum tensile strength as specified in Table 902.10.03-4 when prepared according to AASTHO T 312, except the material, molds, and other equipment is not heated.

For each mix design, submit six gyratory specimens and one loose sample of the pulverized material including the design asphalt content. The ME will use these samples for verification of the properties of the job mix formula. Compact the specimens to 30 gyrations. To be acceptable the loose material sample comply with the gradation requirements in Table 902.10.02-2. The ME reserves the right to be present at the time of molding the gyratory specimens.

Prior to the start of any Recycling work, a test report including a job mix formula (JMF) must be submitted to the ME for approval. After the JMF is established, ensure that all mixtures furnished for the project conform to the JMF unless adjusted by the ME.

Table 902.10.02-1 CIR Mix Design Requirements		
Mixture Property	**Test Method**	**Requirement**
Density	AASHTO T 166	Report
Tensile Strength, 77°F	ASTM D6931	45 psi minimum
Expansion Ratio	Current Wirtgen Cold Recycling Technology manual	8 Times minimum
Half-life	Current Wirtgen Cold Recycling Technology manual	6 Seconds minimum

Characterization of the RAP Material

Sieve Analysis

The pulverized RAP material must be subjected to sieve analysis using AASHTO T 27 Sieve Analysis of Fine and Coarse Aggregates carried out on representative samples, taken from the recycling layer in the existing road. **Table 902.10.02-2** provides requirements for pulverized material use with Foamed Asphalt recycling operations.

Table 902.10.02-2 CIR-FA Grading of Total Aggregate	
Sieve Size	Gradation Requirements – CIR-FA Percent Passing by Mass
2 inch	100
# 200	4-15

Addition of Crushed Reclaimed Asphalt Pavement (RAP) or Virgin Aggregate Material

RAP or Virgin Aggregate material, conforming to **901.05** may be added to meet the requirements of Table 902.10.02-2.

Active Binder in RAP

Use the following table to determine the state of the binder in the RAP material before recycling operations.

	Inactive	**Active**
Visual Appearance	RAP is dull grey color with no black shining surfaces	RAP has shiny black surfaces
Brittleness	RAP breaks cleanly into pieces	RAP separates with strings of asphalt binder connecting the surfaces
Adhesion	RAP (at ambient temperature) do not stick to the hand when a sample is firmly squeezed	RAP (at ambient temperature) sticks to the hand when a sample is firmly squeezed

If there is doubt, heat a sample of the RAP to 70 ^{o}C and manufacture 100 mm diameter specimens ITS test samples. Soak the specimens for 24 hours before performing ITS test. If the soaked ITS value is greater than 15 psi, regard the RAP as active. RAP material classified as active is blended with up to 15% (by volume) mineral filler.

Foamed Asphalt Characteristics
Two properties form the basis of a asphalt's suitability for use, namely the:

• The expansion ratio is a measure of the viscosity of the foam and determines how well the asphalt will disperse in the mix. It is calculated as the ratio of the maximum volume of foam relative to the original volume of asphalt.

• The half-life is a measure of the stability of the foam and provides an indication of the rate of collapse of the foam. It is calculated as the time taken in seconds for the foam to collapse to half of its maximum volume.
Table 902.10.02-3 provides the minimum requirements for verifying the Expansion Ratio (ER) and Half-life ($t_{1/2}$) foaming characteristics of each binder material.

Table 902.10.02-3 CIR-FA Expansion Ratio and Half-Life Requirements		
Foamed Asphalt Characteristics (Minimum Limits)		
RAP Temperature	50°F to 60 °F	Greater than 60 °F
Expansion Ratio, ER (times)	10	8
Half-life, $t_{1/2}$ (seconds)	8	6

Cement

Use Cement type I (up to 1%) as active filler to improve adhesion of the asphalt to the aggregate, and improve dispersion of the asphalt in the mix.

902.10.03 Sampling and Testing

Sampling. The ME will collect loose material immediately behind the recycler/reclaimer for each 5000 SY lot or day's production. Compact 6 each 150mm gyratory specimens 75 mm high with 30 gyrations within 4 hours. Supply these to the ME for acceptance testing.

or

The ME will take 6 random 6 inch diameter cores for each day's production. Remove the surface layer material. Trim the cores to 3 inches thick using the upper portion of the CIR layer for testing. Supply these to the RE for acceptance testing.

Performance Testing. Compact the additional gyratory specimens according to AASHTO T 312 except the material is tested at 25 °C. Ensure that the 6 gyratory specimens are 75 millimeters high. The ME will perform testing for strength in accordance with **AASHTO T283, 150mm gyratory samples, except no freeze cycle.** If the CIR-FA mix fails to meet the performance requirement in Table the ME may stop production until corrective action is taken.

Table 902.10.03-4 CIR-FA Strength Requirements	
Test Results	Heavy Traffic Pavements
ITS_{Dry} (150 mm specimens)	>45 psi
ITS_{Wet}	>30 psi

NEW JERSEY
DEPARTMENT OF TRANSPORTATION
STANDARD SPECIFICATIONS
FOR ROAD AND BRIDGE CONSTRUCTION
2007

NJDOT B-X – MIX DESIGN PROCEDURE OF CIR WITH FOAMED ASPHALT

A. **Scope**. This test method is used to develop a mix design for CIR with Foamed Asphalt.

B. **Apparatus**. Use the following apparatus:

1. Wirtgen Laboratory foamer plant - foamed asphalt mixer and foamed asphalt dispenser approved by ME.

2. Gyratory Compactor as specified in AASHTO M 323.
3. ITS breaking head for 6 inch diameter specimens as specified in AASHTO T 283

4. Calibrated steel bucket and dipstick provided by Wirtgen
5. Scoop and spatulas.
6. Stopwatch
7. Equipment for AASHTO T180

C. **Procedure**. Perform the following steps:

Background

Cold recycling is the term used for recovering and re-using material from an existing pavement, without the addition of heat. The NJDOT CIR Mix Design Procedure is based on 100% reclaimed asphalt pavement (RAP) material recycling where the depth of recycling encounters only asphalt.

PRECONSTRUCTION SAMPLING AND MIX DESIGN

The Department's Pavement Evaluation Consultant will extract random cores in each lane over the length of the project to estimate the thickness of the HMA layers and depth of cracks. These results will be provided in the project documents prior to bidding. The summary of the evaluation is for preliminary information only and not considered complete to develop full mix designs.

Ensure that AASHTO accredited laboratory will be equipped with a foamed asphalt laboratory plant capable of testing the foaming characteristics of the liquid asphalt and producing foamed asphalt mixtures for use in the design testing. Ensure the foamed asphalt laboratory is capable of dispensing the

exact quantity of asphalt and water required for the optimum expansion ratio and half-life of the foam and is calibrated and verified relative to the expansion ratio and half-life of the foamed asphalt.

Sample Quantities

Use the following table to estimate the quantity of material required for respective tests:

Table B-X-1 Sample Weights	
Test	Mass of sample in lbs
Moisture/Density Relationship Modified (AASHTO T180)	100
Optimum bitumen addition indication (150 mm dia. samples)	200
Sieve analysis to determine gradation, fine washing procedure ASTM D 422	20

Characterization of the RAP Material

Sieve Analysis

Perform sieve analysis of pulverized HMA material taken to the specified depth using AASHTO T 27 using air dry the material samples. **Table B-X-2** provides gradation sieves for testing. Add stone dust, if minus 200 material is deficient.

Table B-X-2 CIR-FA Grading of Total Aggregate	
Sieve size (inch)	Gradation Requirements – Foamed Asphalt
2	100
No. 200	4-15

Active Binder in RAP

If the binder material in the pulverized RAP is active ("sticky") according to Table B-X-3, blend with crushed dust (0 to 10mm) up to 15% (by volume).

The following table provides a means of determining the state of the bitumen in the RAP material.

Table B-X-3 Characteristics of RAP		
	Inactive	Active
Visual Appearance	RAP is dull grey color with no black shining surfaces	RAP has shiny black surfaces
Brittleness	RAP breaks cleanly into pieces	RAP separates with strings of asphalt binder connecting the surfaces
Adhesion	RAP (at ambient temperature) do not stick to the hand when a sample is firmly squeezed	RAP (at ambient temperature) sticks to the hand when a sample is firmly squeezed

If there is doubt whether the binder in the RAP is active or inactive, heat a sample of the RAP to 25 ^{o}F and manufacture 4 inch diameter Indirect Tensile Strength (ITS) test samples. Soak the specimens for 24 hours before performing ITS test. If the soaked ITS value is > 14 psi, regard the RAP as active.

Foamed Bitumen

Asphalt binder to be used for producing foamed asphalt shall meet the requirements of AASHTO M 320, Table 1.

Foamed Bitumen Characteristics

Test the foaming characteristics of each asphalt binder considered for CIR treatment. Two properties form the basis of a bitumen's suitability for use, namely the Expansion Ratio (ER) and Half-life ($t_{1/2}$):

- The expansion ratio is a measure of the viscosity of the foam and determines how well the bitumen will disperse in the mix. It is calculated as the ratio of the maximum volume of foam relative to the original volume of bitumen.

- The half-life is a measure of the stability of the foam and provides an indication of the rate of collapse of the foam. It is calculated as the time taken in seconds for the foam to collapse to half of its maximum volume.

One of the dominant factors influencing foam characteristics is the amount of water that is injected into the expansion chamber to create the foam, the foamant water. Increasing the application rate of water creates greater expansion (higher ER) but leads to more rapid subsidence or decay, a shorter half-life ($t_{1/2}$), as illustrated in Figure B-X-1 below.

Table B-X-4 Foamed Bitumen Characteristics (Minimum Limits)	
Expansion Ratio, ER (times)	8
Half-life, $t_{1/2}$ (seconds)	6

Filler (active) selection

Use **1% active filler (Cement type I) in all foamed asphalt mixes.**

Laboratory Mix Design

Prepare samples as closely as possible to simulate the material that will be produced on site during the actual treatment process.

Mix Design Procedures for CIR (Cold In-place Recycling) Material

1. Determine the Optimum Foaming Characteristics of the Asphalt Binder

The objective is to determine the temperature and percentage of water addition that is required to produce the best foam properties (maximum expansion ratio and half-life) for a particular source of bitumen. This is achieved as follows:

Step 1. Heat the bitumen in the kettle of the laboratory foaming unit with the pump circulating the bitumen through the system until the required temperature is achieved (normally starting with 160°C).

After sufficient temperature is achieved make sure the binder in the kettle is completely liquid and free of clumps. Maintain the required temperature for at least 5 minutes prior to commencing with testing.

Step 2. Calibrate the discharge rate of the bitumen and set to discharge 500g of bitumen.

Step 3. Set the water flow-meter to achieve the required water injection rate (normally starting with 2% by mass of the bitumen).

Step 4. Discharge foamed bitumen into a preheated (± 75°C) calibrated steel bucket for a calculated spray time for 500g of bitumen, generally 5 seconds. Immediately after the foam discharge stops, start a stopwatch.

Step 5. Using a dipstick (which is calibrated using the calibrated steel bucket diameter and 500g of bitumen as a unit height) measure the maximum height the foamed bitumen achieves in the drum. This is the maximum volume and recorded as the number of times it exceeds the unit height

Step 6. Use the stopwatch to measure the time in seconds that the foam takes to dissipate to half of its maximum volume. This is recorded as the foamed bitumen's half-life.

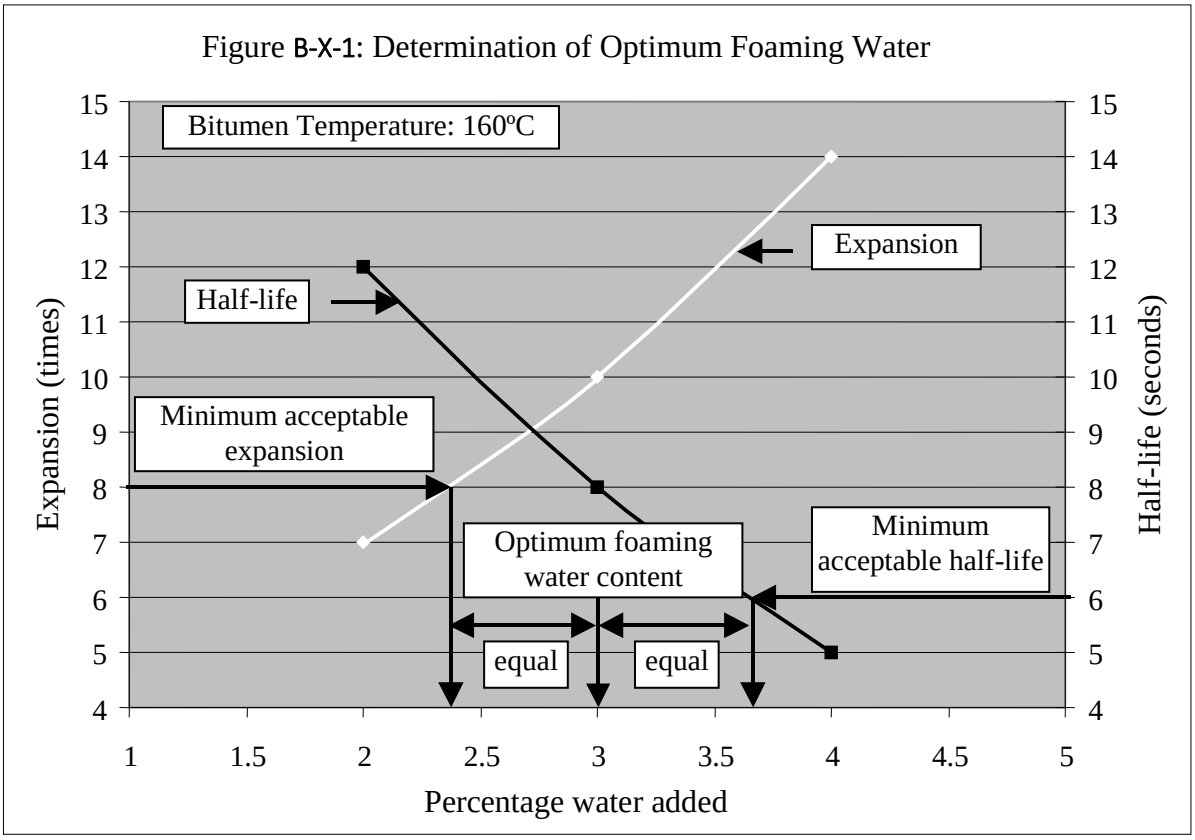
Step 7. Repeat the above procedure three times and use the average value for half-life and expansion ratio.

Step 8. Repeat steps 3 to 7 for a range of at least three water injection rates. Typically, values of 2%, 3% and 4% by mass of bitumen are used.

Step 9. Plot a graph of the expansion ratio versus half-life at the different water injection rates on the same set of axes. The optimum water addition is chosen as an average of the two water contents required to meet these minimum criteria.

If the foaming characteristics are not met at 160°C then repeat Step 1 to 9 for two other bitumen temperatures (normally 170°C and 180°C).

Figure B-X-1: Determination of Optimum Foaming Water



Use the temperature and optimum water addition that produces the best foam in the mix design procedure.

The absolute minimum foaming properties that are acceptable for effective Foamed Asphalt stabilization material are found in Table B-X-4.

If these minimum requirements cannot be met, the asphalt binder is unsuitable for foaming. Test a new asphalt binder for the mix design.

2. Determine the optimum compaction moisture content

The pulverized HMA material is compacted to a maximum density through the lubricating effect of the free moisture in the mixture. Determine the optimum compaction moisture of the pulverized HMA material compacted with four different moisture contents in accordance with AASHTO T180, method D. Plot the results to determine the optimum moisture required for compaction.

3. Sample preparation for foamed asphalt material

Step 1. Determine the dry mass of the sample.
Step 2. Place the required quantity (15 to 20kg) of representative sample into the pug-mill mixer of the Wirtgen Laboratory foamer plant.
Step 3. Determine the mass of cement (1% of dry mass of sample) required and add to sample.
Step 4. Determine the quantity of mixing water (60% of OMC) and add to material.
Step 5. Mix the material, active filler and water in the mixer until uniform.

Note: Inspect the sample after mixing to ensure that the mixed material is not packed against the sides of the mixer. If this situation occurs, mix a new sample at a lower moisture content. Check to see that the material mixes easily and remains in a “fluffy” state. If any dust is observed at the end of the mixing process, add small amounts of water and remix until a "fluffy" state is achieved with no dust.

Step 6. Determine the foamed bitumen to be added, set the timer in the laboratory unit.
Step 7. Position the mechanical mixer adjacent to the foaming unit so that the foamed bitumen can be discharged directly into the mixer.
Step 8. Start the mixer and allow it to mix for at least 10 seconds before discharging the required mass of foamed bitumen into the mixer. Continue mixing for a further 30 seconds after the foamed bitumen has discharged into the mixer.
Step 9. Add compaction water. The additional compaction water increases the moisture content from 60% (mixing moisture) to between 80 to 100% of OMC for gyratory compaction. Mix until uniform or 60 seconds.
Step 10. Transfer the foamed bitumen treated material into a container and immediately seal the container to retain moisture. To minimize moisture loss from the prepared sample, manufacture briquette specimens as soon as possible.

Repeat the above steps for at least four different foamed bitumen contents.

4. Gyratory Compaction

Step 1. Prepare the gyratory equipment by cleaning the mold, base-plate and face of the compaction foot. Note: the compaction equipment must not be heated but kept at ambient temperature.
Step 2. Weigh sufficient material to achieve a compacted height of 2½" ± 0.06". Poke the mixture with a spatula 15 times around the perimeter leaving the surface slightly rounded. This is required mainly for coarse materials to allow for fine materials to fill the voids at the sides of the specimen.
Step 3. Compact the mixture by gyrating for 30 gyrations.
Step 4. Take ±2.2 lb representative samples after compaction of the third briquette and dry to a constant mass to determine the moisture content of the mix.
Step 5 After compaction, remove the mold from compactor and extrude the briquette by means of an extrusion jack. Carefully remove paper disks.

5. Curing procedure

Place the briquettes on a steel mesh and cure in a forced-draft oven for at least 72 hours at 40°C. Remove from oven and allow to cool to ambient temperature

6. Determination of bulk density

After cooling to ambient temperature, for each briquette:

Step 1. Determine the mass.
Step 2. Measure the height at four evenly-spaced places around the circumference and calculate the average height or use the height shown by the gyratory compactor after preparation of the relevant specimen.
Step 3. Measure the diameter.
Step 4. Calculate the bulk specific gravity (G_{mb}) using AASHTO T 166.

Exclude from further testing any briquette whose Bulk Specific Gravity (G_{mb}) differs from the mean bulk specific gravity of the batch by more than 0.050.

7. Determine the Optimum Foamed Asphalt Content for the CIR Mixture through Indirect Tensile Tests

The ITS test described below is used to test the briquettes under dry and wet conditions.

The dry specimens are cooled to 70 – 77 ^{O}F prior to testing.

Place the wet specimens in water at 70 – 77 ^{O}F for a period of 24 hours. Remove the briquettes from the water, surfaced dried and then tested immediately.

Use **AASHTO T 283, except that 150mm gyratory samples** to determine the Indirect Tensile Strength (ITS).

8. Interpretation of the ITS test results

Plot the average ITS wet and dry strength for each foamed asphalt content. The added foamed bitumen content that meets the minimum ITS strength value for the required material classification is selected as the minimum amount of bitumen to be added. For heavy traffic pavements rehabilitated with foamed asphalt stabilized RAP, select the amount of foamed bitumen that meets the requirements in Table B-X-5.

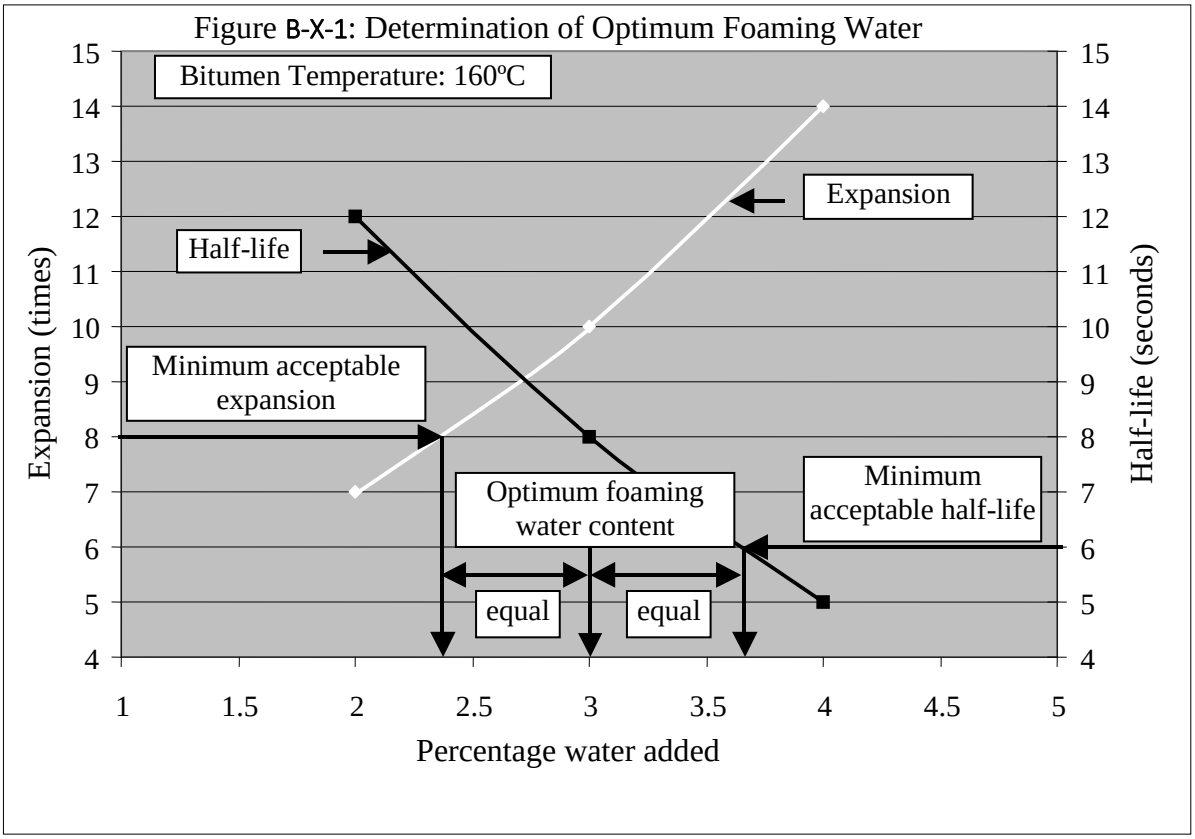
Table B-X-5 Test Requirements	
Test Results	Class 1 Heavy Traffic Pavements
ITS_{Dry} (150 mm specimens)	>45 psi
ITS_{Wet}	>30 psi

10. Mix Design Report

The report shall contain the following minimum information:

- Gradation of the pulverized HMA materials.
- Optimum moisture content and the maximum dry density of the pulverized HMA material.
- Type and source of the asphalt binder.
- Percentage of foaming water.
- The dry and soaked ITS strengths together with the retained ITS value.
- Asphalt binder temperature for foaming (ºF).
- Percent injection water for foaming (% of asphalt by weight).
- Bulk Specific Gravity of existing bound layers from cores.
- Optimum asphalt foam content (% of dry RAP by weight).
- Expansion and Half-Life of the asphalt binder
- Graph as shown in B-X-1
- Interpretation of the foamed asphalt percentage or testing procedure.

Figure B-X-1: Determination of Optimum Foaming Water



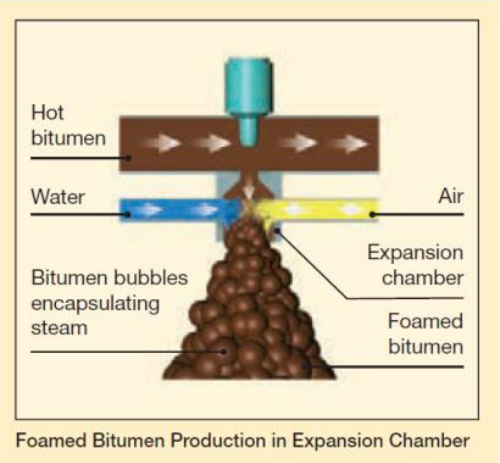
GUIDANCE FOR CIR WITH FOAMED ASPHALT

C. Introduction/Overview

Cold In-place recycling is the term used for recovering and re-using material from an existing HMA pavement layer, without the addition of heat. The NJDOT CIR Mix Design Procedure is based on 100% reclaimed asphalt pavement (RAP) material recycling where the depth of recycling encounters only asphalt.

Foamed Bitumen

Foamed Bitumen is produced by injecting water into hot bitumen, resulting in spontaneous foaming. The physical properties of the bitumen are temporarily altered when the injected water, on contact with the hot bitumen, is explosively transformed into vapor, which is trapped in thousands of tiny bitumen bubbles. The foaming process occurs in an expansion chamber into which bitumen and water (plus air on some systems) are injected at high pressure.



Foamed Bitumen Production in Expansion Chamber

Foamed bitumen collapses in less than a minute. Foamed bitumen is produced at the mixing chamber and incorporated into the aggregate while still in its "unstable" foamed state. The greater the volume of the foam, the better the distribution of the bitumen in the RAP during recycling. During mixing, the bitumen bubbles burst, producing tiny bitumen splinters that disperse throughout the aggregate by adhering to the finer particles (fine sand and smaller) to form a mastic. The moisture in the mix prior to mixing plays an important role in dispersing the bitumen. On compaction, the bitumen particles in the mastic are physically pressed against the larger aggregate particles resulting in localized non-continuous bonds ("spot welding").

The temperature of the material has a significant influence on the degree of dispersion and the properties of the mix. Higher material temperatures increase the size of the pulverized particles that can be coated. Consider the effects of Temperature measurements of the laboratory or field production materials.

The liquid asphalt cement (bitumen) to be used for producing foamed asphalt shall meet the requirements of AASHTO M320 – Standard Specification for Performance Graded Asphalt Binder.

Note: 2% foamed asphalt content by weight of milled bituminous material shall be used for bidding purposes, if an asphalt content is not specified by the Plans or mix design. The actual foamed asphalt content shall be adjusted based on the project Job Mix Formula/Mix Design.

Foamed Bitumen Characteristics

The foaming characteristics of each bitumen type needs to be tested. Two properties form the basis of a bitumen's suitability for use, namely the Expansion Ratio (ER) and Half-life ($t_{1/2}$):

- The expansion ratio is a measure of the viscosity of the foam and determines how well the bitumen will disperse in the mix. It is calculated as the ratio of the maximum volume of foam relative to the original volume of bitumen.

- The half-life is a measure of the stability of the foam and provides an indication of the rate of collapse of the foam. It is calculated as the time taken in seconds for the foam to collapse to half of its maximum volume.

One of the dominant factors influencing foam characteristics is the amount of water that is injected into the expansion chamber to create the foam, the foamant water. Increasing the application rate of water creates greater expansion (higher ER) but leads to more rapid subsidence or decay, a shorter half-life ($t_{1/2}$), as illustrated in the graph below.

As a rule: The larger the expansion and the longer the half-life, the better the quality of the foamed bitumen.

The water application rate and bitumen temperature are the most important factors influencing foam quality. A higher bitumen temperature usually creates better foam. Bitumen's generally foam well at 320^{o}F and foaming characteristics are generally carried out at this temperature. Testing of foamed bitumen stabilization at increased temperatures should only occur if the bitumen being tested does not meet the foaming characteristics requirement of 8 times expansion and 6 seconds half-life. To prevent damage to the bitumen, the bitumen should not be heated to above 380^{o}F. To obtain an acceptable level of statistical reliability, at least three tests are recommended for each set of conditions.

Table B-X-4 Foamed Bitumen Characteristics (Minimum Limits)	
RAP Temperature	Greater than 60^{o}F
Expansion Ratio, ER (times)	8
Half-life, $t_{1/2}$ (seconds)	6

Filler (active) selection

Only Cement type I (up to 1%) will be used as active filler. **1% active filler (cement) will be used in all foamed asphalt mixes.**

The purpose of incorporating active filler in Bituminous Stabilized Mixes is to improve adhesion of the foamed asphalt to the aggregate, and improve dispersion of the bitumen in the mix.

The cement application rate must be limited to a maximum of 1% by mass of dry material. Where active fillers are applied, the time delay between mixing the active filler with the material and application of the foamed bitumen or bitumen emulsion should be reduced to a minimum (both in the laboratory and the field). The active filler reaction begins immediately upon contact with moist material, promoting adhesion between the fine particles. The longer the delay between premixing with active filler and applying the foamed bitumen, the lower the percentage of fines available for dispersion of the asphalt in the CIR mix.

Safety aspects for Bituminous Stabilized Mixture-foam

Bitumen temperatures need to be high (typically >320°F) for the water reaction to produce an acceptable foam. At such high temperatures, bitumen must be treated with respect and adequate safety procedures established, similar to those adopted for hot mixed asphalt production.

D. Field Sampling

The Department will task the Pavement Evaluation Consultant with extracting random (4 inch dia.) cores in each lane over the length of the project to estimate the thickness of the HMA layers and depth of cracks. These results will be used to establish uniform CIR treatment section and treatment depths for pavement design. Sections with different HMA materials or thicknesses, would require a separate mix design. These section limits should be identified in typical sections on the plans. The summary of the evaluation is for preliminary information only and not considered complete to develop full mix designs.

Prior to the start of the CIR process, the contractor will extract cores (4 inch dia.) in each lane within each 0.1 mile pavement section over the length of the project to determine the depth of pavement layers and cracks, presence of fabric material, evidence of delamination between bound layers and gradation of the HMA materials.

The contractor shall obtain RAP material samples within each uniform section with a miller capable of producing RAP material with similar gradation to the recycler used for production. The rate of sampling will be a minimum of 2 samples per uniform section (approximately 350 lbs). The samples will be taken in alternate lanes that will receive the CIR treatment to the depth of cracks identified from the 4 inch cores.

E. Laboratory Testing: Test in accordance with NJDOT B-X – Mix Design

Apparatus. Use the following apparatus:

3. Laboratory foamer plant - foamed asphalt mixer and foamed asphalt dispenser.
4. Gyratory Compactor

Laboratory plant WLB 10 S with WLM 30

4. ITS breaking head for 6 inch diameter specimens

.

4. Calibrated steel bucket and dipstick

5. Scoop and spatulas.
6. Stopwatch
7. AASHTO T180 equipment

The contractor's AASHTO accredited laboratory will be equipped with a foamed asphalt laboratory. The foamed asphalt laboratory shall be capable of testing the foaming characteristics of the liquid asphalt and producing foamed asphalt mixtures for use in the design testing. The foamed asphalt laboratory shall be capable of dispensing the exact quantity of asphalt and water required for the optimum expansion ratio and half-life of

the foam. The laboratory must be appropriately calibrated and verified relative to the expansion ratio and half-life of the foamed asphalt.

Prior to the start of any Recycling work, a test report including a job mix formula (JMF) must be submitted to the RE for approval.

After the JMF is established, all mixtures furnished for the project will conform to the JMF unless adjusted by the ME.

D. **Test Procedures**. Perform the following steps:

Sample Quantities

Use the following table to estimate the quantity of material required for respective tests:

Table B-X-1 Sample Weights	
Test	**Mass of sample in lbs**
Moisture/Density Relationship Modified AASHTO T180)	100
Optimum bitumen addition indication (150 mm dia. samples)	200
Sieve analysis to determine gradation, fine washing procedure ASTM D 422	20

Characterization of the RAP Material

Sieve Analysis

The milled RAP material must be subjected to sieve analysis using AASHTO T 27 Sieve Analysis of Fine and Coarse Aggregates or ASTM D 422. Sieve analyses carried out on representative samples, taken from the HMA layer(s), depending on the CIR treatment depth in the existing road. **Table B-X-2** provides suggested gradation limits for RAP used in Foamed Asphalt recycling operations. A deficiency in fines should always be addressed by adding additional fine material (e.g. crusher dust), **never by increasing the amount of active filler (cement) to more than 1%.**

Table B-X-2 CIR-FA Grading of Total Aggregate	
Sieve size (inch)	Gradation Requirements – Foamed Asphalt
2	100
No. 200	4-15

Active Binder in RAP

It is important to know whether the asphalt binder in the RAP material is “active or inactive”. In other words, is the RAP a “black rock” (inactive) with properties similar to those of graded crushed stone or is it “sticky” (active) with inherent cohesive properties due to the existing liquid asphalt (bitumen) in the RAP material?

The following table provides a means of determining the state of the bitumen in the RAP material.

Table B-X-4 Characteristics of RAP		
	Inactive	**Active**
Visual Appearance	RAP is dull grey color with no black shining surfaces	RAP has shiny black surfaces
Brittleness	RAP breaks cleanly into pieces	RAP separates with strings of asphalt binder connecting the surfaces
Adhesion	RAP (at ambient temperature) do not stick to the hand when a sample is firmly squeezed	RAP (at ambient temperature) sticks to the hand when a sample is firmly squeezed

If there is doubt whether the binder in the RAP is active or inactive, heat a sample of the RAP to 70°C and manufacture 4 inch diameter Indirect Tensile Strength (ITS) test samples. Soak the specimens for 24 hours before performing ITS test. If the soaked ITS value is > 14 psi, regard the RAP as active.

RAP material classified as active should be blended with up to 15% (by volume) crushed dust (0 to 10mm).

Laboratory Mix Design

Samples should be prepared to simulate as closely as possible the material that will be produced on site during the actual CIR with Foamed Asphalt treatment process.

For heavy traffic pavements treated with CIR with foamed asphalt RAP, the following are recommended ITS test levels based on Indirect Tensile Strength (IDT) test results:

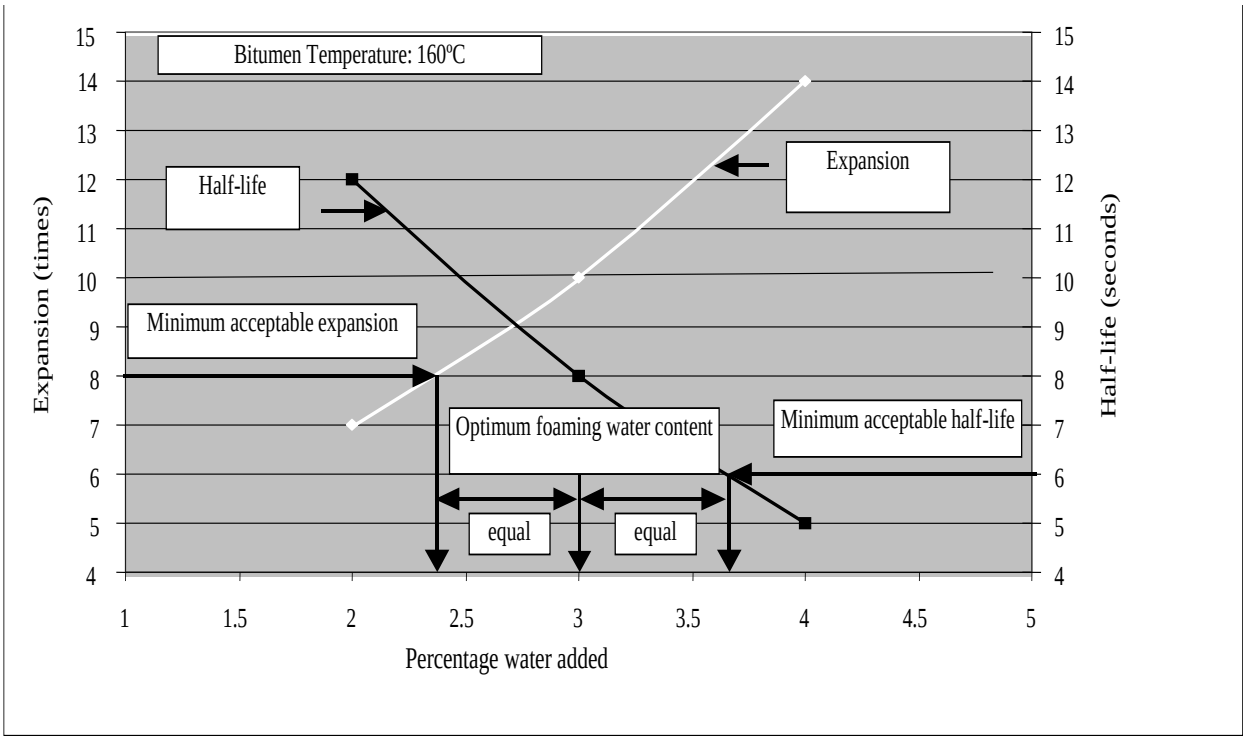
Table B-X-4 ITS Test Requirements	
Test Results	Class 1 Heavy Traffic Pavements
ITS_{Dry} (150 mm specimens)	>45 psi
ITS_{Wet}	>30 psi

Mix Design Procedures for CIR (Cold In-place Recycling) Material

1. Determine the Optimum Foaming Characteristics of the Asphalt Binder

The objective is to determine the temperature and percentage of water addition that is required to produce the best foam properties (maximum expansion ratio and half-life) for a particular source of binder. This is achieved as follows:

Step 1. Heat the bitumen in the kettle of the laboratory foaming unit with the pump circulating the bitumen through the system until the required temperature is achieved (normally starting with 160°C). After sufficient temperature is achieved make sure the binder in the kettle is completely liquid and free of clumps. Maintain the required temperature for at least 5 minutes prior to commencing with testing.
Step 2. Calibrate the discharge rate of the bitumen and set to discharge 500g of bitumen.
Step 3. Set the water flow-meter to achieve the required water injection rate (normally starting with 2% by mass of the bitumen).
Step 4. Discharge foamed bitumen into a preheated (± 75°C) calibrated steel bucket for a calculated spray time for 500g of bitumen, generally 5 seconds. Immediately after the foam discharge stops, start a stopwatch.
Step 5. Using a dipstick (which is calibrated using the calibrated steel bucket diameter and 500g of bitumen as a unit height) measure the maximum expansion the foamed bitumen achieves in the drum. This is the maximum volume and recorded as the number of times it exceeds the unit height
Step 6. Use the stopwatch to measure the time in seconds that the foam takes to dissipate to half of its maximum volume. This is recorded as the foamed bitumen's half-life.
Step 7. Repeat the above procedure three times and use the average value for half-life and expansion ratio.
Step 8. Repeat steps 3 to 7 for a range of at least three water injection rates. Typically, values of 2%, 3% and 4% by mass of bitumen are used.
Step 9. Plot a graph of the expansion ratio versus half-life at the different water injection rates on the same set of axes. The optimum water addition is chosen as an average of the two water contents required to meet these minimum criteria.
If the foaming characteristics are not met at 160°C then repeat Step 1 to 9 for two other bitumen temperatures (normally 170°C and 180°C).



The temperature and optimum water addition that produces the best foam is then used in the mix design procedure described below.

The absolute minimum foaming properties that are acceptable for effective CIR with foamed asphalt shown in Table B-X-4.:

If these minimum requirements cannot be met, the binder should be rejected as unsuitable for foaming.

2. Determine the optimum compaction moisture content

CIR mixture is compacted to a maximum density through the lubricating effect of the free moisture in the mixture. The compaction moisture is not the same as the moisture injected into the asphalt binder to create foam. Determine the optimum compaction moisture of the RAP material in accordance with AASHTO T180, method D. Plot the results to determine the optimum moisture required for compaction. Mix designs prepared over the last several years indicate that the moisture required to achieve maximum RAP density is approximately 5 percent.

3. Sample preparation for foamed bitumen treatment

Step 1. Determine the dry mass of the sample.
Step 2. Place the required quantity of representative sample into pug-mill mixer (15 to 20kg)
Step 3. Determine the mass of cement (1% of dry mass of sample) required and add to sample.
Step 4. Determine the quantity of mixing water (60% of OMC) and add to material.
Step 5. Mix the material, active filler and water in the mixer until uniform.

Laboratory twin shaft mixer WLM 30

Note: Inspect the sample after mixing to ensure that the mixed material is not packed against the sides of the mixer. If this situation occurs, mix a new sample at a lower moisture content. Check to see that the material mixes easily and remains in a “fluffy” state. If any dust is observed at the end of the mixing process, add small amounts of water and remix until a "fluffy" state is achieved with no dust.

Step 6. Determine the foamed bitumen to be added, set the timer in the laboratory unit.
Step 7. Position the mechanical mixer adjacent to the foaming unit so that the foamed bitumen can be discharged directly into the mixer.

Laboratory plant WLB 10 S with WLM 30

Step 8. Start the mixer and allow it to mix for at least 10 seconds before discharging the required mass of foamed bitumen into the mixer. Continue mixing for a further 30 seconds after the foamed bitumen has discharged into the mixer.
Step 9. Add compaction water. The additional compaction water would increase the moisture content from 60% (mixing moisture) to between 80 to 100% of OMC for gyratory compaction. Mix until uniform or 60 seconds.
Step 10. Transfer the foamed bitumen treated material into a container and immediately seal the container to retain moisture. To minimize moisture loss from the prepared sample, manufacture briquette specimens as soon as possible.

Repeat the above steps for at least four different foamed bitumen contents.

4. Gyratory Compaction

Step 1. Prepare the gyratory equipment by cleaning the mold, base-plate and face of the compaction foot. **Note: the compaction equipment must not be heated but kept at ambient temperature**.
Step 2. Weigh sufficient material to achieve a compacted height of 2½" ± 0.06". Poke the mixture with a spatula 15 times around the perimeter leaving the surface slightly rounded. This is required mainly for coarse materials to allow for fine materials to fill the voids at the sides of the specimen.
Step 3. Compact the mixture using 30 gyrations.
Step 4. Take ±1kg representative samples after compaction of the third briquette and dry to a constant mass to determine the moisture content of the mix.
Step 5 After compaction, remove the mold from compactor and extrude the briquette by means of an extrusion jack. Carefully remove paper disks.

5. Curing procedure

Place the briquettes on a steel mesh and cure in a forced-draft oven for at least 72 hours at 40°C. Remove from oven and allow to cool to ambient temperature

6. Determination of bulk specific Gravity (Gmb)

After cooling to ambient temperature, for each briquette:

Step 1. Determine the mass.
Step 2. Measure the height at four evenly-spaced places around the circumference and calculate the average height or use the height shown by the gyratory compactor after preparation of the relevant specimen.
Step 3. Measure the diameter.
Step 4. Calculate the bulk specific gravity (G_{mb}) using AASHTO T 166.

Exclude from further testing any briquette whose Bulk Specific Gravity (G_{mb}) differs from the mean bulk specific gravity of the batch by more than 0.050.

7. Determine the Optimum Foamed Asphalt Content for the CIR Mixture through Indirect Tensile Tests

Determination of Indirect Tensile Strength (ITS) ASTM D 6931-12 Standard Test Method for Indirect Tensile (ITS) Strength of Bituminous Mixtures, except that 150mm gyratory samples are used.

The ITS test described below is used to test the briquettes under dry and wet conditions.

The dry specimens are cooled to 70 – 77 ^{O}F prior to testing.

The wet specimens are placed in water at 70 – 77 ^{O}F for a period of 24 hours. The briquettes are then removed from the water, surfaced dried and then tested immediately.

The Indirect Tensile Strength is determined by measuring the ultimate load to failure of a briquette that is subjected to a constant deformation rate of 50.8 mm/minute on its diametrical axis. The procedure is as follows:

Step 1 Place the briquette onto the ITS jig;

Step 2 Position the sample such that the loading strips are parallel and centered on the vertical diametrical plane;

Step 3 Place the transfer plate on the top bearing strip and position the jig assembly centrally under the loading ram of the compression testing device;

Step 4 Apply the load to the briquette, without shock, at a rate of advance of 50.8 mm per minute until the maximum load is reached;

Step 5 Record the maximum load P (in psi), accurate to 1 psi.

Step 6 Calculate the ITS for each briquette to the nearest 1 psi using equation 1:

$$ITS = \frac{2*P}{\pi*h*d} \quad \text{[equation 1]}$$

where	ITS	=	Indirect Tensile Strength		[psi]
	P	=	maximum applied load	[psi]	
	h	=	average height of the specimen	[in]	
	d	=	diameter of the specimen		[in]

Calculate the Tensile Strength Retained (TSR) value as

$$TSR = \frac{avg\ ITS_{Wet}}{avg\ ITS_{Dry}} * 100$$

8. Interpretation of the ITS test results

Plot the average ITS wet and dry strength for each foamed asphalt content. **The added foamed bitumen content that meets the minimum ITS strength value for the required material classification is selected as the minimum amount of bitumen to be added**. Engineering judgment is used to determine the amount of foamed bitumen that needs to be added.

Refer to **Table B-X-6 Test Requirements** for testing requirements.

D. **Report**. **Mix Design Report.**

The report shall contain the following minimum information: Gradation of all materials used in the blend, including existing pavement materials and virgin aggregate. The optimum moisture content and the maximum dry density of the blended material. The type and source of the binder used for testing and the recommended percentage of foaming water. The dry and soaked ITS strengths together with the retained ITS value. Specific report values include:

- Asphalt binder temperature for foaming (ºF).
- Percent injection water for foaming (% of asphalt by weight).
- Bulk Density of existing bound layers from cores (pcf).
- Optimum asphalt foam content (% of dry RAP by weight).

E. Construction [Specification 4XX CIR with Foamed Asphalt]

EQUIPMENT

Provide equipment as specified:	
Pneumatic-Tired Compactor	1002.01
HMA Compactor	1003.05
Vibratory Drum Compactor	1003.06
Bituminous Material Distributor	1003.07

Sealer Application System	1003.08
Milling Machine	1008.01
Mechanical Sweeper	1008.03
Cold In-Place Recycler/Reclaimer Machinery	**1012.xx**
Cement Distributor	**1012.xx**
Rotomiller	**1012.xx**
Portable Storage Tanks	**1012.xx**

1012.xx COLD IN-PLACE RECYLCER/RECLAIMER MACHINERY.

A. Provide a self-propelled machine equipped with automatic depth control to maintain the cutting depth to within ± ¼ inch and a positive means for controlling cross slope elevations.

Ensure that the recycler/reclaimer is capable of:

6. Pulverizing to the size specified, mix and recycle material to a depth as determined in the design documents in one pass

7. Maintaining a constant cutting depth and width, uniform grade, and uniform slope

Ensure that the recycler/reclaimer includes:

8. Two microprocessor controlled systems, complete with two independent pumping systems and spray bars, to regulate the application of foamed asphalt, separate from water that is used to increase the moisture content of the mixed material for compaction. Both systems will perform in relation to the forward speed of the recycler/reclaimer and the mass of the material being processed.

9. Individual expansion chambers to produce the foamed asphalt at the spray bar into which hot asphalt stabilizing agent, water, and air are injected under pressure through individual and small orifices that promote atomization. The rate of addition of water into the hot asphalt stabilizing agent will be kept at a constant percentage by mass of asphalt by the same microprocessor.

10. An inspection or test nozzle will be fitted at one end of the spray bar that produces a representative sample of foamed asphalt.

11. An electrical heating system capable of maintaining the temperature of asphalt flow components above 240 degrees Fahrenheit.

12. A single bitumen (asphalt cement) feed pipe installed between the recycler/reclaimer and the supply tanker. Do not use circulating systems that incorporate a return pipe to the supply tanker.

2. The recycler/reclaimer will have a centrally divided spreading auger with scraper, capable of rotating clock wise and counter clockwise to distribute the recycled mix evenly across the entire working width. The recycled material will move directly from the spreading auger to the paving screed installed on the recycler/reclaimer or be transferred to an HMA paver for laydown. The screed mounted on the recycler/reclaimer will meet the requirements of HMA Paver in section 1003.03 except the screed heater is not required.

1012.xx CEMENT DISTRIBUTOR

Provide calibrated spreaders or distributors for applying dry powder cement that are shrouded and non-pressurized mechanical vane-feed, cyclone or screw type that provide consistent, accurate and uniform distribution of material while minimizing dust during placement.

1012.xx ROTOMILLER

Provide to the RE the rotomiller manufacturer's technical data sheets.

Ensure that the rotomiller will mill to a minimum depth of 4" longitudinally along all curbs and gutters, and around all manholes, inlets, and any other structure not accessible by either a single processing unit or a multi-unit train.

Inlets/manholes will be covered during the rotomilling and recycling operation to prevent recycled material from entering the inlet area where it could contaminate and/or block the storm water system.

1012.xx PORTABLE STORAGE TANKS

Provide an insulated tanker(s) equipped with push bar hitches. The tanker will be equipped with a built-in thermometer and heating facility to ensure that the asphalt is maintained within 5 ^{o}F of the specified application temperature.

A. CIR Plan. At least 20 days before constructing the CIR base course, the contractor will submit a detailed plan of operation to the RE.

H. Weather Limitations. Do not perform CIR if it is precipitating. The Contractor may resume operations when the precipitation has stopped and the surface is free of water. Do not perform CIR if the pavement temperature is below 50 F.

I. Density Control Strip. Construct a Density Control Strip in accordance with Section 302.03.01.B except perform AASHTO T 180, Method C, including replacement option instead of AASHTO T 99 to ensure that the moisture content and maximum dry density for the density control strip material are within 2 percent of its optimum moisture content and equal to or greater than 95 percent of its maximum dry density.

D. Cement Accelerator Application. Place the cement accelerator uniformly on the HMA surface immediately prior to pulverization in accordance with mix design. Verify the amount of cement accelerator applied every 500 feet.

E. Pulverization. Pulverize the HMA surface with the CIR recycler/reclaimer as specified.

F. Binder Application. During the pulverizing operations, foamed-asphalt will be applied to the pulverized material at the rate determined from the mix design. An allowable tolerance of plus or minus 0.2 percent of the initial design rate will be maintained at all times. Test the foaming characteristics of the asphalt for each new tanker within 2 minutes. Collect 1 quart sample of asphalt stabilizing agent will be taken from each tanker load and retained in a sealed container as a provision of later testing.

The temperature of the asphalt delivered to site will be 340 ^{o}F (+/- 20 ^{o}F). Asphalt below 320 ^{o}F will be tested at the recycler's test nozzle to ensure it meets the requirements as specified in Table 432.02.01.B-1. Any asphalt that has been heated above the maximum specified temperature will not be used and will be removed from the project site.

The Contractor may add water to the pulverized material for the purpose of cooling the cutting teeth on the mill or pulverizing equipment or to facilitate uniform mixing with the foamed asphalt.

G. Spreading and Grading. Ensure grade and profile are maintained. Spread and grade CIR material uniformly across the mat. If segregation occurs behind the paver, stop the operation and corrective action plan to the RE.

When making a pass adjacent to a previously placed mat, locate the longitudinal joint at least 6 in. horizontally into the previously placed mat. For transverse joints, trim all transverse joints to provide a vertical face. Moisten the face of the joint if necessary. Begin the stabilization a minimum of 5 feet into the previous day's construction.

H. Compacting. Immediately after spreading and strike-off, compact CIR material with vibratory steel wheel and pneumatic tire rollers until the density reaches 96% of the maximum density from the density control strip. The engineer may direct additional passes to eliminate roller marks. Remove and replace CIR material that becomes loose, broken, or otherwise defective. Rollers will not be started or stopped on uncompacted recycled material. Rolling will be established so that starting and stopping will be on previously compacted recycled material.

Rolling which results in cracking, movement, or other types of pavement distress will be discontinued until such time as the problem can be resolved. Discontinuation and commencement of rolling operations will be at the sole discretion of RE.

The RE will verify compaction levels every 5000 square yards based upon compaction levels of density control strip using a nuclear density gauge.

I. Curing. Apply a Fog Seal in accordance with Section 422.03.01 at an approximate rate of 0.05 or 0.1 gallon per square yard to seal the surface of the CIR layer to control surface raveling.

J. Surface Tolerance. The final surface of recycled asphalt base will not deviate in excess of ½ inch from the testing edge with a 10-foot straightedge resting on any two points. Correct any deviations.

K. Opening CIR Layer to Traffic.

Remove loose material from the traveled way, shoulder, and auxiliary lanes before opening to traffic. Open CIR layer to traffic two hours after application of fog seal.

L. Placement of Surface Course.

Do not Pave surface course less than 3 days or more than 14 days after constructing the CIR.

M. Acceptance Testing and Strength Verification.

A. **Sampling. Sampling.** Collect loose material immediately behind the recycler/reclaimer for each 5000 SY lot or day's production. Compact 6 each 150mm gyratory specimens with 30 gyrations within 4 hours. Supply these to the RE for acceptance testing.

or

B. Take 6 random 6 inch diameter cores for each day's production. Remove the surface layer material. Trim the cores to 3 inches thick using the upper portion of the CIR layer for testing. Supply these to the RE for acceptance testing.

C. **Performance Testing.** Compact the additional gyratory specimens according to AASHTO T 312 except the material is tested at 25 ^{o}C. Ensure that the 6 gyratory specimens are 75 millimeters high. The ME will perform testing for strength in accordance with **AASHTO T283, 150mm gyratory samples, except no freeze cycle.** If the CIR-FA mix fails to meet the performance requirement in Table the ME may stop production until corrective action is taken.

Table 902.10.03-4 CIR-FA Strength Requirements	
Test Results	Heavy Traffic Pavements
ITS_{Dry} (150 mm specimens)	>45 psi
ITS_{Wet}	>30 psi

The RE will perform indirect tensile strength testing in accordance with ASTM D6931 Standard Test Method for Indirect Tensile (IDT) Strength of Bituminous Material to verify requirements specified in Table 432.02.01.B-1.

432.04.. MEASUREMENT AND PAYMENT

The Department will measure and make payment for Items as follows:

Item	Pay Unit
COLD IN-PLACE RECYCLING-FOAMED ASPHALT	SQUARE YARD
ASPHALT STABILIZING AGENT PG64-22	GALLON
CEMENT	TON

The Department will make payment for FOG SEAL SURFACE TREATMENT as specified in 422.04.

The Department will measure ASPHALT STABILIZING AGENT by the volume delivered, converted to the number of gallons at 60°F as calculated by the temperature-volume correction factors specified in 902.01 or by meter.

Section 432 **Cold In-Place Recycling (CIR) Asphalt Pavement Asphalt Emulsion (CIR-AE)**

4XX.XX DESCRIPTION

This Section describes the requirements for recycling asphalt pavement using cold in-place recycling (CIR) with asphalt emulsion method and equipment.

4XX.XX MATERIALS

4XX.XX.01 MATERIALS

Provide materials as specified:

Asphalt Stabilizing Agents *	
Emulsified Asphalt, Grade Grade CSS-1 or CSS-1h	902.01.03
Emulsified Asphalt (HFMS-2s)	
Cement	903.01
Aggregates	901.05
Water	919.08
Fog Seal	422.03.01

4XX.02.02 EQUIPMENT

Provide equipment as specified:	
Pneumatic-Tired Compactor	1002.01
HMA Compactor	1003.05
HMA Paver with Averaging or Leveling Ski	1003.03
Vibratory Drum Compactor	1003.06
Bituminous Material Distributor	1003.07
Sealer Application System	1003.08
Milling Machine	1008.01
Mechanical Sweeper	1008.03
Cold In-Place Recycler/Reclaimer Machinery	**1012.xx**
Cement Distributor	**1012.xx**
Rotomiller	**112.xx**

4XX.03 CONSTRUCTION

432.0X.01 CIR

A. CIR Plan. At least 20 days before constructing the CIR base course, submit a detailed plan of operation to the RE for approval that includes the following:

1. Submit the name and experience of the CIR operations supervising representative to the RE. Ensure that experience includes a minimum of 5 federal or state agency projects, with references, on which CIR operations were successfully completed. Ensure that the supervising representative is at the work site during all CIR operations. The Contractor may not begin the work until the RE approves the CIR operations supervising representative.
2. Size and description of crew.
3. Number, type, and model of all equipment for the CIR operation.
4. Lighting plan for nighttime operations as specified in 108.06.
5. CIR procedures for maintaining continuous operation.
6. CIR sequence. Ensure that the CIR is constructed for the full width of the traveled way, shoulder, and auxiliary lanes as a single operation.
7. Schedule, hours of operation, and production rates for the Project.
8. Method of constructing and compacting joints as specified in 432.03.01G.
9. Quality control plan outlining the use of the thin lift nuclear density gauge, quality control cores, and the control of the compaction process.

B. **Weather Limitations**. Do not perform CIR if it is precipitating. The Contractor may resume operations when the precipitation has stopped and the surface is free of water. Do not perform CIR if the pavement temperature is below 50 F.

A. **Density Control Strip.** Construct a Density Control Strip in accordance with Section 302.03.01.B except perform AASHTO T 180, Method C, including replacement option instead of AASHTO T 99 to ensure that the moisture content and maximum dry density for the density control strip material are within 2 percent of its optimum moisture content and equal to or greater than 95 percent of its maximum dry density.

B. **Cement Accelerator Application.** Place the cement accelerator uniformly on the HMA surface immediately prior to pulverization in accordance with mix design. Every 500 feet, verify the amount of cement applied by weight.

E. **Pulverization.** Pulverize the HMA surface with the CIR recycler/reclaimer to meet the gradation as specified in Table 902.10.02-1. Check the gradation at the start of each day's production and as directed by the RE.
.

F. **Binder Application.** During the pulverizing operations, asphalt emulsion will be applied to the pulverized material at the rate determined from the mix design. An allowable tolerance of plus or minus 0.2 percent of the initial design rate will be maintained at all times.

G. **Spreading and Grading.** Ensure grade and profile are maintained. Spread and grade CIR material uniformly across the mat. If segregation occurs behind the paver, stop the operation and corrective action plan to the RE.

When making a pass adjacent to a previously placed mat, locate the longitudinal joint at least 6 in. horizontally into the previously placed mat. For transverse joints, trim all transverse joints to provide a vertical face. Moisten the face of the joint if necessary. Begin the stabilization a minimum of 5 feet into the previous day's construction.

H. Compacting. . Immediately after spreading and strike-off, compact CIR material with vibratory steel wheel and pneumatic tire rollers until the density reaches 96% of the maximum density from the density control strip. The ME will verify compaction levels every 5000 square yards based upon compaction levels of density control strip using a nuclear density gauge.

Perform additional passes to eliminate roller marks. Remove and replace CIR material that becomes loose, broken, or otherwise defective. Do not start or stop rollers on uncompacted recycled material.

If cracking, movement, or other types of pavement distress occur, discontinue rolling until such time as the problem can be resolved.

I. Curing. Apply a Fog Seal in accordance with Section 422.03.01 at an approximate rate of 0.05 or 0.1 gallon per square yard to seal the surface of the CIR layer to control surface raveling.

J. Surface Tolerance. The final surface of recycled asphalt base will not deviate in excess of ½ inch from the testing edge with a 10-foot straightedge resting on any two points. Correct any deviations.

K. Opening CIR Layer to Traffic.

Remove loose material from the traveled way, shoulder, and auxiliary lanes before opening to traffic. Open CIR layer to traffic as specified in 422.03.01.

L. Placement of Surface Course.

Cure the CIR material until the upper 4 inch of the CIR layer reaches 50% of the corresponding Optimum Moisture Content (or three days) prior to the application of the surfacing. Curing period should not exceed 14 days, before applying the surfacing.

M. Acceptance Testing and Strength Verification.

Ensure that the CIR materials meets the requirements specified in **Table 902.10.03-5**

432.04.. MEASUREMENT AND PAYMENT

The Department will measure and make payment for Items as follows:

Item	Pay Unit
COLD IN-PLACE RECYCLED ASPHALT PAVEMENT	SQUARE YARDS
EMULSIFIED ASPHALT	GALLON
CEMENT	TON
CORRECTIVE AGGREGATES OR MILLINGS	TON

The Department will measure ASPHALT STABILIZING AGENT by the volume delivered, converted to the number of gallons at 60°F as calculated by the temperature-volume correction factors specified in 902.01 or by meter.

The Department will make payment for FOG SEAL SURFACE TREATMENT as specified in 422.04.

Equipment

1012.xx COLD IN-PLACE RECYLCER/RECLAIMER MACHINERY.

D. Provide a self-propelled machine equipped with automatic depth control to maintain the cutting depth to within ± ¼ inch and a positive means for controlling cross slope elevations.

E. Ensure that the recycler/reclaimer is capable of:

3. Pulverizing to the size specified, mix and recycle material to a depth as determined in the design documents in one pass

4. Maintaining a constant cutting depth and width, uniform grade, and uniform slope

E. Ensure that the recycler/reclaimer has a centrally divided spreading auger with scraper, capable of rotating clock wise and counter clockwise to distribute the recycled mix evenly across the entire working width. Ensure that the recycler/reclaimer is capable of moving recycled material from the spreading auger to the paving screed installed on the recycler/reclaimer or able to transfer the recycled material to the HMA paver for laydown. Ensure that the screed mounted on the recycler/reclaimer meets the requirements of HMA Paver in section 1003.03 except the screed heater is not required.

1012.xx CEMENT DISTRIBUTOR

Provide calibrated spreaders or distributors for applying dry powder cement that are shrouded and non-pressurized mechanical vane-feed, cyclone or screw type that provide consistent, accurate and uniform distribution of material while minimizing dust during placement.

1012.xx ROTOMILLER

Provide to the RE the rotomiller manufacturer's technical data sheets.

Ensure that the rotomiller will mill to a minimum depth of 4" longitudinally along all curbs and gutters, and around all manholes, inlets, and any other structure not accessible by either a single processing unit or a multi-unit train.

Cover Inlets/manholes during the rotomilling and recycling operation to prevent recycled material from entering the inlet area where it could contaminate and/or block the storm water system.

1012.xx PORTABLE STORAGE TANKS

Provide an insulated tanker(s) equipped with push bar hitches. Ensure that the tanker is equipped with a built-in thermometer and heating facility to ensure that the asphalt is maintained within 5 ^{o}F of the specified application temperature.

902.10 COLD INPLACE RECYCLING WITH ASPHALT EMULSION (CIR-AE)

902.10.01 Composition of Mixture

Mix **CIR-AE** in-place using the 10xx.xx Cold In-place Recycler/Reclaimer. The composition of the mixture for **CIR-AE** includes the in-place HMA surface material, and virgin aggregates, where necessary, to meet the gradation in Table **902.10.03-1**.

Use asphalt binder and aggregates that meet the following requirements:

5. **Asphalt Stabilizing Agent**. Ensure that any bituminous materials required are meeting the requirements of 902.01.03.
6. **Corrective Aggregates.** Use aggregate for CIR with asphalt emulsion that conform to **901.05** to modify gradation of the pulverized HMA material to meet the requirements in Table **902.09.02-1,** use a blend of coarse aggregates (argillite, gneiss, granite, quartzite, or trap rock) conforming to 901.05.01 and fine aggregate conforming to 901.05.02.
7. If necessary, use mineral filler conforming to ASTM D242 and is free of lumps.
8. **Water**. Use water that conforms to 919.08.
9. **Active Filler**. Use cement type I (up to 1%) as specified in 903.01.

902.10.02 Mix Design

At least 45 days prior to the start of production, submit a mix design to the RE in accordance with NJDOT X-X – Mix Design Procedure of CIR with asphalt emulsion test method and submit a job mix formula for the **CIR-AE**. Include a statement naming the source of each component and a report showing the results meet the criteria specified in Tables 902.10.02-1, 902.10.02-2 902.10.02-3 and 902.10.03-4.

Ensure that the job mix formula is within the master range specified in, Table 902.10.02-1.

Ensure that the job mix formula provides a mixture that meets a minimum tensile strength as specified in Table 902.10.03-4 when prepared according to AASTHO T 312, except the material, molds, and other equipment is not heated.

For each mix design, submit three gyratory specimens and one loose sample corresponding to the composition of the job mix formula, including the design asphalt content. The ME will use these samples for verification of the properties of the job mix formula. Compact the specimens to 30 gyrations. To be acceptable all three gyratory specimens must comply with the gradation and asphalt content requirements in Table 902.10.02-1 and with the control requirements in Table 902.10.03-4. The ME reserves the right to be present at the time of molding the gyratory specimens.

Prior to the start of any Recycling work, a test report including a job mix formula (JMF) must be submitted to the ME for approval. After the JMF is established, ensure that all mixtures furnished for the project conform to the JMF unless adjusted by the ME.

Characterization of the RAP Material

Sieve Analysis

The milled RAP material must be subjected to sieve analysis using AASHTO T 27 Sieve Analysis of Fine and Coarse Aggregates carried out on representative samples, taken from the proposed recycling depth in the existing road. **Table 902.10.02-1** provides guide lines for gradation requirement of RAP for use with CIR operations.

Table 902.10.02-1 CIR-FA Grading of Total Aggregate

Sieve Size	Ideal Gradation Requirements – Foamed Asphalt Percent Passing by Mass
2	100
# 200	4-15

Addition of Crushed Reclaimed Asphalt Pavement (RAP) or Virgin Aggregate Material

RAP or Virgin Aggregate material, conforming to **901.05** and **Table 902.10.02-2** may be added at the discretion of the ME to adjust the RAP mix gradation to meet the requirement in **Table 902.10.02-1** .

Table 902.10.02-2 CIR-FA Corrective Aggregate Requirements

Additional Aggregate Criteria		
Property	***Method***	***Limit***
Los Angeles abrasion value, % loss	AASHTO T96	40% maximum
Sand Equivalent,%	ASTM D2419	60% minimum
Water absorption %	AASHTO T 85	5% maximum

Active Binder in RAP

Use the following table to determine the state of the binder in the RAP material before recycling operations.

	Inactive	**Active**
Visual Appearance	RAP is dull grey color with no black shining surfaces	RAP has shiny black surfaces
Brittleness	RAP breaks cleanly into pieces	RAP separates with strings of asphalt binder connecting the surfaces
Adhesion	RAP (at ambient temperature) do not stick to the hand when a sample is firmly squeezed	RAP (at ambient temperature) sticks to the hand when a sample is firmly squeezed

If there is doubt, heat a sample of the RAP to 70 ^{o}C and manufacture 100 mm diameter specimens ITS test samples. Soak the specimens for 24 hours before performing ITS test. If the soaked ITS value is > 14.5 psi, regard the RAP as active. RAP material classified as active is blended with up to 15% (by volume) crushed dust (0 to 10mm).

Filler (active) selection

Use Cement type I (up to 1%) as active filler to improve adhesion of the asphalt to the aggregate, and improve dispersion of the asphalt in the mix.

902.10.03 Sampling and Testing

A. **Sampling.** Collect loose material immediately behind the recycler/reclaimer for each 5000 SY lot or day's production. Compact 6 samples each 150mm gyratory specimens with 30 gyrations within 4 hours. Supply these to the ME for acceptance testing.

or

The ME will take 6 random 6 inch diameter cores for each day's production. Remove the surface layer material. Trim the cores to 3 inches thick using the upper portion of the CIR layer for testing. Supply these to the RE for acceptance testing.

C. **Performance Testing.** Compact the additional gyratory specimens according to AASHTO T 312 except the material is tested at 25 ^{o}C. Ensure that the 6 gyratory specimens are 75 millimeters high. The ME will perform testing for strength in accordance with **ASTM D 6931-12 Standard Test Method for Indirect Tensile (ITS) Strength of Bituminous Mixtures, except that 150mm gyratory samples are used.** If the CIR-AE mix fails to meet the performance requirement in Table 902.10.03-4 the ME may stop production until corrective action is taken.

Table 902.10.03-4 CIR-AE Strength Requirements

Test Results	Heavy Traffic Pavements
ITS_{Dry} (150 mm specimens)	>45 psi
ITS_{Wet}	>30 psi

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STANDARD SPECIFICATIONS
FOR ROAD AND BRIDGE CONSTRUCTION
2007

NJDOT B-X – MIX DESIGN PROCEDURE OF CIR WITH ASPHALT EMULSION

F. **Scope**. This test method is used to develop a mix design for CIR with Asphalt Emulsion.

G. **Apparatus**. Use the following apparatus:

1. Gyratory Compactor as specified in AASHTO M 323.
2. ITS breaking head for 6 inch diameter specimens as specified in Equipment for AASHTO T 283
3. Scoop and spatulas.
4. Equipment for AASHTO T180

E. **Procedure**. Perform the following steps:

Background

Cold recycling is the term used for recovering and re-using material from an existing pavement, without the addition of heat. The NJDOT CIR Mix Design Procedure is based on 100% reclaimed asphalt pavement (RAP) material recycling where the depth of recycling encounters only asphalt.

1.1 PRECONSTRUCTION SAMPLING AND MIX DESIGN

The Department's Pavement Evaluation Consultant will extract random cores in each lane over the length of the project to estimate the thickness of the HMA layers and depth of cracks. These results will be provided in the project documents prior to bidding. The summary of the evaluation is for preliminary information only and not considered complete to develop full mix designs.

1.2 Sample and Processing Quantities

Obtain cores from the areas to be recycled. Perform separate mix designs if cores show significant differences in various areas, such as different type or thickness of layers between cores. It is recommended to take, at a minimum, one core for every 1.2 miles of lane and where visual differences in the pavement are noticed. Cut and crush cores in the laboratory to the depth specified for the CIR project.

1.3 Characterization of the RAP Material

Sieve Analysis

Perform sieve analysis of pulverized HMA material taken to the specified depth using AASHTO T 27 using air dry the material samples. Table B-X-1 provides gradation sieves for testing. Add stone dust, if minus 200 material is deficient.

Perform a mix design using the medium gradation and a minimum of one of the fine or coarse gradations using the following recycled asphalt pavement millings criteria.

Table B-X-1			
	Fine	Medium	Coarse
1 ¼ in (31.5 mm)	0	0	0
1 in (25 mm)	0	0	0-15
¾ in (19 mm)	0-5	4-15	8-25
#4 (4.75 mm)	25-45	45-60	55-70
#30 (600 µm)	65-85	86-96	93-99
#200 (75 µm)	93-99	97-99.4	97-99.9

Perform the mix design on these crushed millings. Determine the gradation of the millings after crushing by dry, screen, and recombine millings in the laboratory to target gradation. Suggested screens are ½ in (12.5 mm), ⅜ in (9.5 mm), #4 (4.75 mm), #8 (2.36 mm), #30 (600 µm), and pan. Scalp oversize material with a 1 in (25 mm) screen when using 6 in (150 mm) diameter compaction molds.

Use the following table to estimate the quantity of material required for respective tests:

Table B-X-2 Sample Weights	
Test	Mass of sample in lbs
Moisture/Density Relationship Modified (AASHTO T180)	100
Optimum bitumen addition indication (150 mm dia. samples)	200
Sieve analysis to determine gradation, fine washing procedure ASTM D 422	20

1.4 Active Binder in RAP

If the binder material in the pulverized RAP is active (“sticky”) according to Table B-X-3, blend with crushed dust (0 to 10mm) up to 15% (by volume).

The following table provides a means of determining the state of the bitumen in the RAP material.

Table B-X-3 Characteristics of RAP		
	Inactive	Active
Visual Appearance	RAP is dull grey color with no black shining surfaces	RAP has shiny black surfaces
Brittleness	RAP breaks cleanly into pieces	RAP separates with strings of asphalt binder connecting the surfaces
Adhesion	RAP (at ambient temperature) do not stick to the hand when a sample is firmly squeezed	RAP (at ambient temperature) sticks to the hand when a sample is firmly squeezed

If there is doubt whether the binder in the RAP is active or inactive, heat a sample of the RAP to 25 °F and manufacture 4 inch diameter Indirect Tensile Strength (ITS) test samples. Soak the specimens for 24 hours before performing ITS test. If the soaked ITS value is > 14.5 psi, regard the RAP as active.

1.5 Asphalt Emulsion (CSS)

Table B-X-4			
Test		Minimum	Maximum
Residue from distillation, %	ASTM D244[1]	64.0	66.0
Oil distillate by distillation, %	ASTM D244[1]		0.5
Sieve Test, %	ASTM D244[1]		0.1
Penetration (TBD[2]), 25° C, dmm	ASTM D5	-25%	+25%

1 Modified **ASTM D 244** procedure – distillation temperature of 350o F (177o C) with a 20 minute hold. The **ASTM D 244** vacuum distillation procedure may be substituted once the maximum oil distillate is satisfied.

2 TBD – to be determined by the CIR design prior to emulsion manufacture for the project. Penetration range will be determined on the design requirements for the project and will be submitted to the ME for approval prior to project start.

The penetration is expressed in units of 0.1 mm (dmm)

1.6 Mixing

Specimen size: the amount that will produce a 2.40 to 2.60 in (61 mm to 66.0 mm) tall specimen;

Number of specimens: 4 samples per emulsion content for a total of 6 sets for long-term stability, and 6 plugs for moisture testing at 3 emulsion contents. Two specimens are required for Rice specific gravity; test at the highest emulsion content in the design and back calculate for the lower emulsion contents. Recommended emulsion contents: 1.5%, 2.0%, 2.5%, 3.0%, 3.5%, and 4.0%. Choose three emulsion contents that bracket the estimated recommended emulsion content.

Add moisture that is expected to be added at the milling head, typically 1.5 to 2.5 %.

If any lime is in the mixture, introduce the lime in a similar manner as during field production.

Mix test specimens with a mechanical bucket mixer. Mix the CIR RAP millings thoroughly with water first, then mix with emulsion. Mix One specimen at a time at ambient temperature. Do not exceed a mix time of 60 seconds.

1.7. Compaction

Compact specimens immediately after mixing. Place paper disks on the top and bottom of the specimen before compacting. Compact specimens with a gyratory compactor (GC) in a 6 in (150 mm) mold for 30 gyrations. Use molds at ambient temperature.

1.8. Curing after compaction

Extrude specimens from molds immediately after compaction. Carefully remove paper disks.

Place specimens in 140°F (60°C) forced draft oven with ventilation on sides and top. Place each specimen in a small container to account for material loss from specimens.

Dry specimens for Rice specific gravity to constant mass (less than 0.05% mass loss in 2 hours). Care should be taken not to over-dry the specimens.

Cure compacted specimens to constant mass but no more than 48 hours and no less than 16 hours. Constant mass is defined as no more than 0.05% change in mass in 2 hours. After curing, cool specimens at ambient temperature for 18 ± 6 hours.

1.9. Measurements

Determine bulk specific gravity (density) of each compacted (cured and cooled) specimen. Record the mass of the specimen in water (measurement C) after one minute submersion. Determine specimen heights from the GC printed copy, at 30 gyrations.

Determine Rice (maximum theoretical) specific gravity, and do not break any agglomerates which will not easily reduce with a flexible spatula. If necessary, perform the supplemental dry-back procedure outlined in **AASHTO T 209** to adjust for uncoated particles.

Determine air voids at each emulsion content.

Determine corrected Marshall stability at 104o F (40 °C) after 2 hour temperature conditioning in a forced draft oven. Perform this testing at the same time that the moisture conditioned specimens are tested.

1.10. Moisture Susceptibility

Perform same conditioning and volumetric measurements on moisture-conditioned specimens as on other specimens. Vacuum saturate to 55 to 75 percent, soak in a 77o F (25o C) water bath for 23 hours, followed by a one hour soak at 104o F (40o C). Determine corrected Marshall stability. The average moisture conditioned specimen strength divided by the average dry specimen strength is referred to as retained stability.

1.11. Emulsion Content Selection

Ensure the properties of the specimens at design emulsion content meet the properties in Table B-X-4.

1.12 Report

Submit a report to the RE that contains the following information: Gradation of RAP; percent lime, recommended water content range as a percentage of dry RAP; optimum emulsion content as a percentage of dry RAP and corresponding density, air void level, and absorbed water; Marshall stability and retained stability at recommended moisture and emulsion contents. Include the emulsion designation, company name, plant location, and residue content.

1.13 Mixture Design Criteria

Submit a mix design to the RE based on cores taken before the project, more than one mix may be required. Ensure the job mix formula meets the criteria of Table B-X-5 and approved by the ME.

Table B-X-5 Mix Design Criteria	
6 in (150 mm) specimens shall be prepared in a Gyratory compactor. The mixture should meet the following criteria at the selected design asphalt emulsion content:	
Property	**Criteria**
Compaction effort, Gyratory Compactor	30 gyrations
Density,	
Gradation for Design Millings,	
Marshall stability *, 104^{o}F (40^{o}C)	1100 lbs, min.
Retained stability based on cured stability **	70 % min.
Indirect Tensile Test, **AASHTO T 322**	> 45 psi

* Cured stability tested on compacted specimens after 1400 F (600 C) curing to constant mass.
** Vacuum sat. of 55 to 75 percent, water bath 770 F (25o C) @ 23 hours, last hour at 1040 F (400 C) water bath.